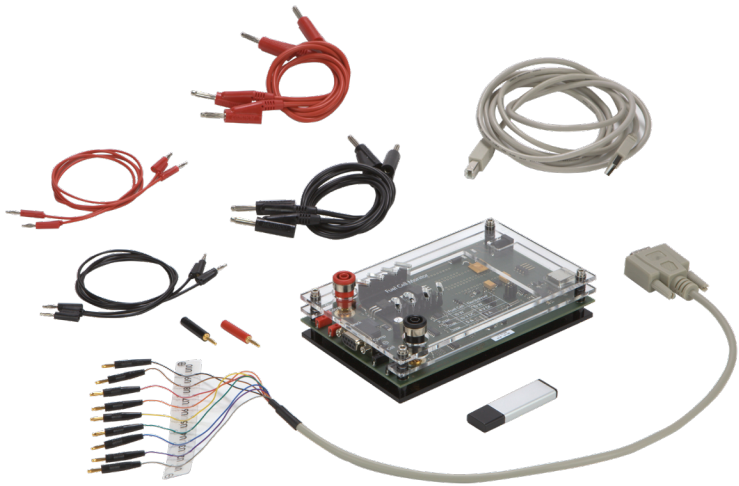# Operation Manual

U104 - Fuel Cell Monitor Pro 4.0

H-TEC EDUCATION

1   General

1.1   Product Description

The Fuel Cell Monitor Pro 4.0 (FCM) is a didactic product consisting of a measurement board and evaluation software "Fuel Cell Monitor 4.0". It is tailored to the requirements for the measurement of H-TEC EDUCATION products and must only be used for this. The FCM provides you with the possibility of measuring, storing and evaluating various measured values and characteristic curves of H-TEC EDUCATION fuel cell education models. The measurement board is connected to the PC using a USB cable. The supplied software gives you the possibility to record and display the following graphs:

- ■   Voltage against current
- ■   Power over time
- ■   Power against current
- ■   Power against voltage

The measurement board also provides the possibility of four conductor measurement for the compensation of measurement errors. The measured value recording can be performed automatically, voltage-regulated, current-regulated or manually. The efficiency of H-TEC EDUCATION educational fuel cells can also be measured with the FCM.

The FCM can also display up to ten individual voltages of a fuel cell stack in real-time and record and display characteristic curves and efficiency of H-TEC EDUCATION educational electrolyzers.

1.2   Menu Languages

The FCM can be operated in the following languages:

- ■   English
- ■   German
- ■   French
- ■   Spanish

1.3   System Requirements

Minimum computer requirements: Pentium 200 MHz or comparable processor. The FCM needs at least 80 MB free disc space (for the installation of the standard drivers, however at least 580 MB is recommended). Operating system: Windows XP, Windows 7, or Windows 10, RAM: minimum 128 MB (recommended 256 MB), USB connection.

The software for the FCM is designed for operation with Windows XP, Windows 7, and Windows 10. We therefore accept guarantee for functionality only if the FCM is operated with one of these systems.

The screen resolution should be set to at least 1024 x 768. A spreadsheet program (such as, e.g. MS Excel or Open Office) is also recommended for the further processing of the stored measured data.

1.4   Standard Delivery

Measurement Board, USB cable, software, individual voltage measurement cable, cable set, power supply for the FCM and detailed operation manual.

1.5   Appropriate Use

Measurements of H-TEC EDUCATION products in the following areas can be performed and evaluated using the external measurement board of the FCM and the associated software:

Fuel Cell Mode
- Voltage: 0 - 10 V DC
- Current: 0 - 5 A
- Power: 0 - 10 W

Electrolyzer Mode
- Voltage: 0 - 4 V DC
- Current: 0 - 3 A
- Power: 0 - 10 W

The hardware and software have been exclusively developed for educational and demonstration purposes. The output measured values and graphs must be assessed qualitatively.

Any other use is not permitted.

In order to prevent dangers, strictly observe the general safety instructions for your measurements with the FCM and fuel cells.

1.6   Usage Conditions

Read through the following paragraphs carefully before you use this software. If you do not agree with the following, do not use the software and delete it from your data carriers.

You are not entitled to reverse engineer, decompile or disassemble the software product whether in whole or in part.

1.7   Liability

It is not possible with today's technology to rule out every error in a software application.

Accordingly, the software "Fuel Cell Monitor 4.0" can contain errors. For this reason, the manufacturer makes no guarantee of any kind for this software and is not liable for any kind of damage which has been caused directly or indirectly by the software. The exception to this is gross negligence.

1.8   Support

The software has been carefully tested by H-TEC EDUCATION in order to provide you with as reliable a product as possible. Nevertheless, should you notice undiscovered error sources, please contact us. Please state the version of your "Fuel Cell Monitor 4.0" in the case of questions or suggestions. You can display this using "Help" > "about FCM".

2 Measurement Board and Software

2.1 Connections

Fig. 1
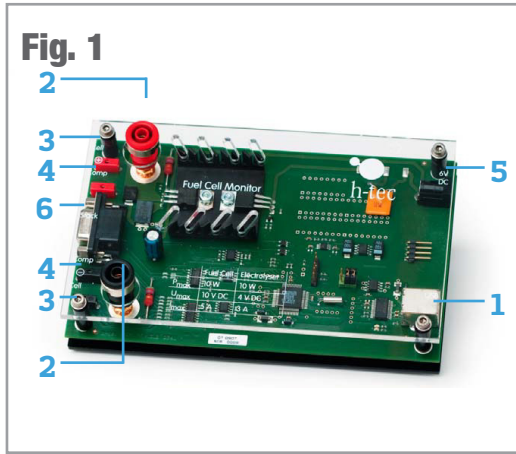
1. USB connection: for connecting the measuring transformer card to the PC. The connection cable is included in the standard delivery.

2. Fuel cell and electrolyzer 4 mm connection sockets: connections for the cell to be measured (fuel cell or electrolyzer). Also suitable for 4 mm safety measuring cables. 4 mm red and black cables are included in the standard delivery.

3. Fuel cell and electrolyzer 2 mm connection sockets: connections for the cell to be measured (fuel cell or electrolyzer). 2 mm red and black cables are included in the standard delivery.

4. Connection sockets for four-wire measurement: 2 mm connections for the compensation of measurement errors during the fuel cell and electrolyser measurement. 2 mm red and black cables and adapter for the use of 4 mm cables are included in the standard delivery.

5. Power supply connection: Connection of the power supply for electrolyzer measurements. The power supply is included in the standard delivery.

6. Connection for stack individual voltage measurements: for connecting the individual voltage measurement cable to a fuel cell stack for the measurement of the individual cell voltages. The individual voltage measurement cable is included in the standard delivery.

It is recommended to setup the hardware and software in the following order in order to ensure smooth progress of the installation.

1. Connect the measurement board
2. Install the drivers
3. Install the FCM software

## Important information before the installation:

1. You need at least local administrator rights for the installation of the drivers and the FCM software for Windows Vista / Windows 7 / Windows 10.
2. You need at least local power user rights to use the FCM software for Windows Vista / Windows 7 / Windows 10.

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2.2   Installation of the FCM Software

After unzipping the "Fuel Cell Monitor Pro Installer" Folder from the H-TEC EDUCATION Flash Drive you received, navigate through the folders to find the "Setup" Application File. Run the application to install the FCM Software on your computer.

When the application is installed, a shortcut should be created on your desktop. Connect the Measurement Board to your computer using the provided USB cable and open the FCM software. You will then need to select the correct COM port in the System Settings dialogue box. Using the process of elimination, choose the first option in the "FCM circuit board interface" and select Okay. The setting is now saved. If the dialogue window is displayed again, select a different COM port and/or check the USB connection. If the dialogue window is not displayed again, the FCM has a connection to the measuring transformer card.

Now you will be requested to disconnect any possibly connected fuel cells or electrolyzers from the measurement board. The program performs a zero compensation. The FCM is ready for operation afterwards. This is indicated by green and red fl ashing diodes on the measuring transformer card. The program interface is now displayed on your screen (see Figure 2) which consists of the following components:

Fig. 2
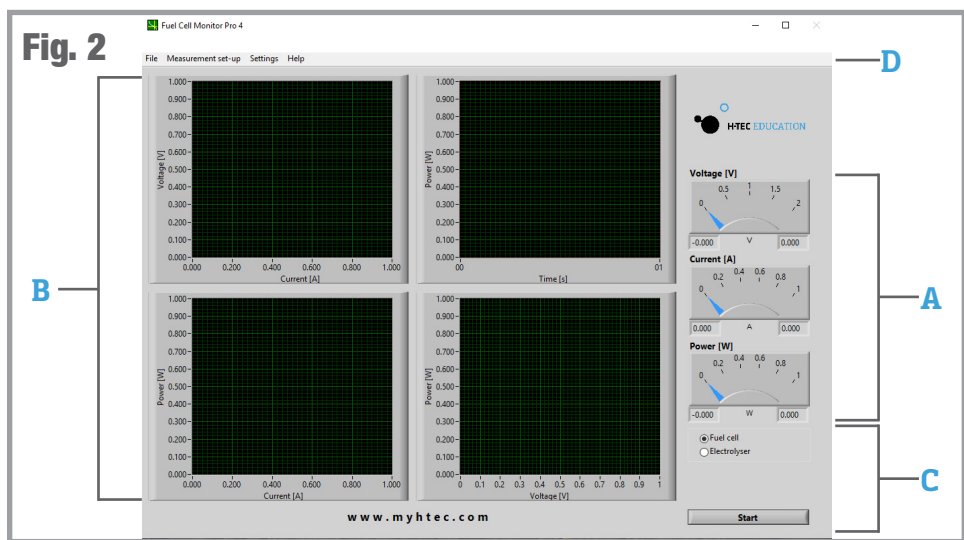
A. Dial Instruments - The three dial instruments clearly show the current and maximum measured values. The pointers can have three colors: The maximum value for voltage, current and power is displayed using a black pointer. A blue pointer displays the current value. This pointer is yellow after completion of the measurement. The yellow pointer displays the so-called MPP ("Maximum Power Point") - the point of the characteristic curve at which the cell has its maximum power output. The values are also displayed again in the form of numeric values under the dial instruments whereby the current value (blue - or in MPP yellow - pointer) is displayed on the left and the maximum value on the right.

B. Graphs - The recorded measured values and their course are displayed in the four graphs in the form of function graphs. A yellow cursor is displayed in the voltage/current graph after completion of the measurement. This shows the MPP of your cell. By clicking on the cursor and keeping the mouse button pressed, you can drag it along the characteristic curve and thus let different measured values on the characteristic curve be displayed.

C. Control - The type of the cell to be measured is specified here and measurements are started or stopped. Furthermore, you also have the possibility for certain measurements to input values (further information in Section 3.3) and a progress bar is displayed for measurements where a measurement duration can be specified.

D. Menu Bar - Among other things, the various measurement options and system settings are made and data are saved using the menu of the FCM (further information in the next section).

2.3   Menu Items

This section briefly shows the menu items of the FCM. Please refer to the corresponding sub-items in Section 3 for details about the individual measurement options.

<u>File</u>
Here, you can save the recorded measured data, display the screen as an HTML document or print it under "Report" and end the program. The "Exit" option using the cross on the top right in the program window is deactivated in order to ensure the proper shutdown of the software otherwise problems with the port recognition can occur when the software is restarted.

Measurement Set-Up

In the Measurement Set-Up menu, you can choose Fuel Cell or Electrolyzer, and choose your measurement options, such as: Automatic, Voltage Controlled, Current Controlled, Efficiency, etc.

Settings

Here you can select between the menu languages, set the port for the measurement board, specify the file path and the file format for the measured data to be saved, and select the axis assignment for current and voltage for the electrolysis measurement.

Help

You will find the version number and the producer of the software.

3 Measured Value Recording

3.1 General

Fig. 3

Measurement Board
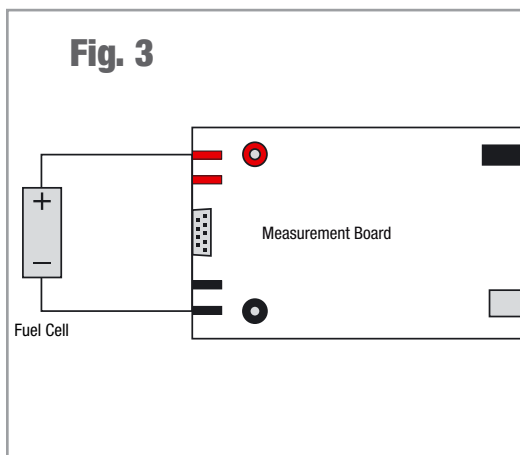
Fuel Cell

When the program is started, a window is displayed with the instruction to disconnect any possibly connected fuel cells or electrolyzers from the measurement board. This is used for the zero compensation of the FCM. Confirm the by pressing "OK". The FCM is now ready for operation.

The FCM has automatic scaling during the characteristic curve recording. This means the axes of the graphs are automatically optimally adapted to the measured values.

After the measurement has ended, you can also change the minimum and maximum values on the axes of the graphs manually in order, for example, to display specified areas of the characteristic curve magnified. Click on any scale value on the respective axis with the left mouse button and then input the desired value using the keyboard. Confirm your input afterwards by pressing Enter. The scaling changes in accordance with your input.

The menu is disabled after starting measurements. If you want to make changes in the menu after starting measurements, you must cancel the measurement or wait until the measurement is completed.

Before starting measurements, ensure that the fuel cell or the electrolyzer is connected to the measurement board as shown in Figure 3.3.

3.2   Recording the Automatic Characteristic Curve of a Fuel Cell

The measured values are recorded at system-controlled intervals for the automatic characteristic curve recording. A resistance is automatically changed from large to small values for this. The typical characteristic curve for fuel cells is thus produced.
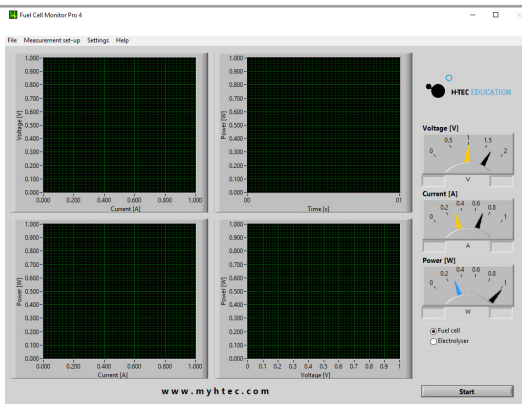
Note:
The automatic characteristic curve recording is particularly suitable for a fast and simple display.
Procedure:

- Connect a fuel cell to the connection sockets of the measurement board (see Figure 3). Pay attention here to the correct polarity (red="+" and black="-").

- The value of the no-load voltage is now displayed in black by the top dial instrument and as a numeric value on the right under the dial instruments. The FCM is now in standby mode.

- Click on the Start button.

- The FCM now automatically records the characteristic curve of the fuel cell from the no-load voltage to the short-circuit current, graphically displays the values and is again in standby mode afterward (see Figure 4).

The measurement can be canceled at any time using the "Cancel" button.

Fig. 4

Note:

When you start the FCM, it is automatically in the "automatic characteristic curve recording of a fuel cell" mode. If you have performed a different measurement in the meantime, you can find the automatic measurement again under the menu item "Measurement Set-Up" > "Fuel Cell" > "Automatic".

Note:

After the measurement is completed, you can move the cursor in the voltage/current graph by clicking on the working point with the left mouse button and keeping the button pressed. The values are taken over by the dial instruments and can be read there.

> **Black pointer:** maximum value
> **Blue pointer:** value at the cursor position
> **Yellow pointer:** value at the cursor position in the Maximum Power Point (MPP).

3.3   Recording the Voltage-regulated Characteristic Curve of a Fuel Cell

In the case of voltage-regulated characteristic curve recording, the FCM regulates the measurement so that a previously specified voltage value is started and maintained. In the ideal case, the power output of the fuel cell remains constant; a characteristic curve running in parallel to the time axis is produced in the power/time graph. However, in practice non-constant operating parameters (temperature, humidity etc.) result in the fact that the power can change in the course of a measurement.

Procedure:

■   Connect a fuel cell to the connection sockets of the measuring transformer card (see Figure 3). Pay attention here to the correct polarity (red="+" and black="-").

■   Select the "Measurement Set-Up" menu item. Then select "Fuel Cell" > "Voltage-regulated" and input the desired voltage in Volts and measurement duration and sampling rate in seconds. The sampling rate specifies at which time interval (minimum 0.5 s) measured values are recorded by the FCM.

■   For example, a sampling rate of 0.5 s means that a measured value is recorded every half a second. You can enter the desired values manually in the corresponding fields or adjust them using the arrow keys. Confirm your input afterward by pressing "OK".

■   The value of the no-load voltage is now displayed in black by the top dial instrument and as a numeric value on the right under the dial instruments. The FCM is now in standby mode.

- It is also possible to input the voltage value directly using the control.

- Click on the Start button.

- The FCM now starts the specified voltage value, keeps it as constant as possible for the specified measurement duration and is again in standby mode after the measurement.

- The measurement can be stopped at any time using the "Cancel" button.

Note:

After the measurement is completed, you can move the cursor in the voltage/current graph by clicking on the working point with the left mouse button and keeping the button pressed. The values are taken over by the dial instruments and can be read there.

> **Black pointer:** maximum value
> **Blue pointer:** value at the cursor position
> **Yellow pointer:** value at the cursor position in the Maximum Power Point (MPP).

Note:

The voltage-regulated characteristic curve recording is particularly suitable for long-term measurements. When setting a long measurement duration, the sampling rate can be set lower to reduce the measured data.

3.4 Recording the Current-regulated Characteristic Curve of a Fuel Cell

In the case of current-regulated characteristic curve recording, the FCM regulates the measurement so that a previously specified current value is started and maintained. In the ideal case, the power output of the fuel cell remains constant; a characteristic curve running in parallel to the time axis is produced in the power/time graph. However, in practice non-constant operating parameters (temperature, humidity etc.) result in the fact that the power can change in the course of a measurement.

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Procedure:

- Connect a fuel cell to the connection sockets of the measuring transformer card (see Figure 3). Pay attention here to the correct polarity (red= "+" and black= "-").

- Select the "Measurement Set-Up" menu item. Then select "Fuel Cell" > "Current-regulated" and input the desired current value in amperes and measurement duration and sampling rate in seconds. The sampling rate specifies at which time interval (minimum 0.5 s) measured values are recorded by the FCM.

- For example, a sampling rate of 0.5 s means that a measured value is recorded every half a second. You can enter the desired values manually in the corresponding fields or adjust them using the arrow keys. Confirm your input afterward by pressing "OK".

- The value of the no-load voltage is now displayed in black by the top dial instrument and as a numeric value on the right   under the dial instruments. The FCM is now in standby mode.It is also possible to input the current value directly using the control.

- Click on the Start button.

- The FCM now starts the specified current value, keeps it as constant as possible for the specified measurement duration and is again in standby mode after the measurement.

The measurement can be canceled at any time using the "Cancel" button.
Note:
After the measurement is completed, you can move the cursor in the voltage/current graph by clicking on the working point with the left mouse button and keeping the button pressed. The values are taken over by the dial instruments and can be read there.
Black pointer: maximum value
Blue pointer: value at the cursor position
Yellow pointer: value at the cursor position in the Maximum Power Point (MPP).

Note:
The voltage-regulated characteristic curve recording is particularly suitable for long-term measurements. When setting a long measurement duration, the sampling rate can be set lower to reduce the measured data.

3.5 Recording the Manual Characteristic Curve of a Fuel Cell

You can select a point on the characteristic curve of the fuel cell for the manual characteristic curve recording. It adapts to the associated voltage and current value; the load resistance belonging to this point is also displayed.

Procedure:

- Connect a fuel cell to the connection sockets of the measuring transformer card

  (see Figure 3). Pay attention to the correct polarity (red= "+" and black= "-").

- Select the "Measurement Set-Up" menu item. Then select "Fuel Cell" > "Manual". Then select "OK".

- The value of the no-load voltage is now displayed in black by the top dial instrument and as a numeric value on the right under the dial instruments. The FCM is now in standby mode.

- Now click on the Start button. The characteristic curve of the fuel cell is first determined automatically; a dialogue window is displayed afterwards. Click "OK" if the characteristic curve meets your expectations. If not, select "Cancel". You can then restart the automatic characteristic curve recording.

Note:
The menu is disabled as the FCM is performing the measurement.

Now select a working point on the characteristic curve in the voltage/current graph at which you would like to measure the fuel cell (default MPP - yellow cursor). Click on the working point with the left mouse button and keep it pressed to move the point. Click on Start again. The FCM now starts this point of the characteristic curve and maintains it.

You also have the possibility to move the cursor on the characteristic curve during the running measurement by clicking on the working point with the left mouse button and keeping it pressed. The FCM then starts the new point whereby the new current and voltage values are adjusted. In doing so, the resistance value is displayed as the quotient of voltage and current.

The measurement can be canceled at any time using the "Cancel" button.

Note:

During a longer measurement, it can happen that the power of the cell increases if the cursor is moved from the MPP. This initially seems illogical, however can be explained as follows: As this is a case of a current-regulated measurement in the background, the FCM takes over the current value of the characteristic curve and multiplies this by the current voltage value. However, as the parameters (temperature, humidity etc.) of the fuel cell change over longer operation, its power also changes, i.e. current and voltage and thus also the characteristic curve. The voltage value of the characteristic curve therefore no longer matches the current voltage.

Remedy:

Restart the measurement and let the fuel cell operate under load for a few minutes until it has reached its operating temperature before you start measurements. The power output is then more constant.

Note:

After the measurement is completed, you can move the cursor in the voltage/current graph by clicking on the working point with the left mouse button and keeping the button pressed. The values are taken over by the dial instruments and can be read there.

> **Black pointer:** maximum value
> **Blue pointer:** value at the cursor position
> **Yellow pointer:** value at the cursor position in the Maximum Power Point (MPP).

3.6 Recording the Manual Characteristic Curve of a Fuel Cell

Procedure:

- Select "Measurement Set-Up" > "Single Stack Voltages" from the menu and input the number of cells in your stack has (2 to 10).

- Connect the individual voltage measurement cable to the "COM" connection of the measurement board and connect the measurement cables to the positive and negative poles of the stack. Afterwards, connect the connectors of the individual voltage measurement cable to the individual stack cells. Start at "U1" on the negative side of the stack (see Figure 5).

Note:

If you connect a stack with less than ten cells, start at "U1" and connect the required number of measurement cables to the cells. Leave those not required disconnected (for example, in the case of a 5-cell stack, you would need the first four measurement cables between "U1" and "U5").

Fig. 5
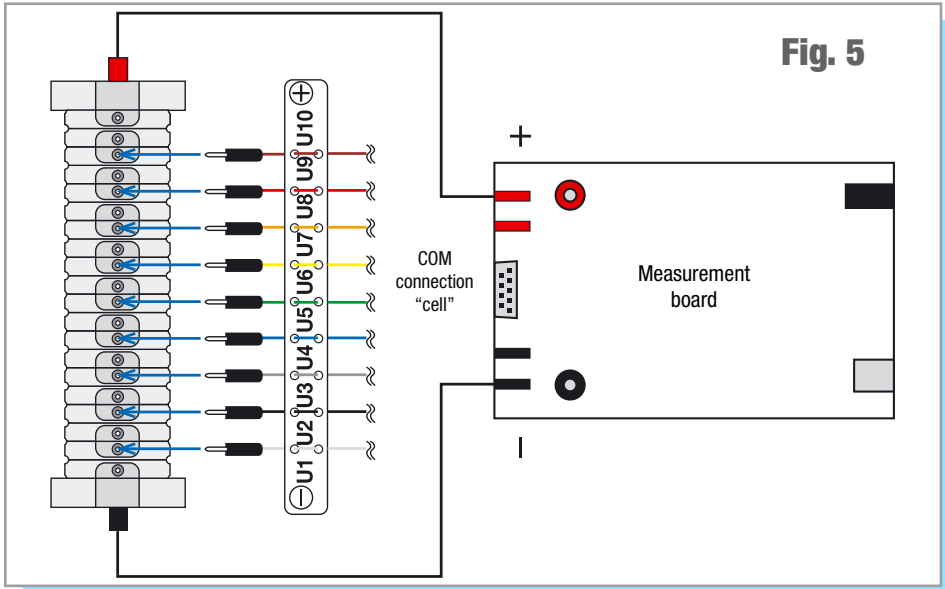
Now click on the Start button. The characteristic curve of the fuel cell stack is first determined automatically. A dialogue window is displayed after this has been completed. Click on "OK" if the characteristic curve meets your expectations. If not, select "Cancel". You can then restart the automatic characteristic curve recording.
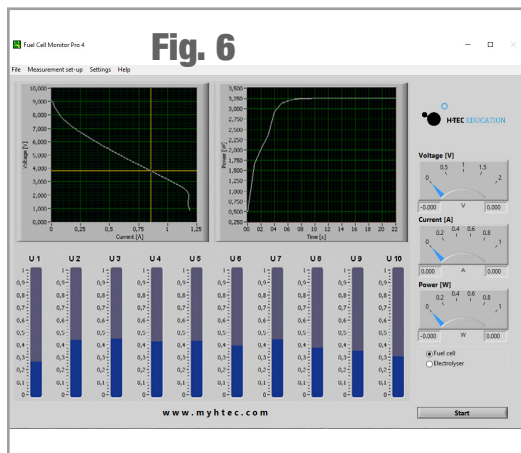
Note:
The menu is disabled as the FCM is performing the measurement.

Now select a working point on the characteristic curve in the voltage/current graph at which you would like to measure the stack (default MPP - yellow cursor). Click on the cursor with the left mouse button and keep it pressed to move the cursor. Click on Start again. The individual voltage of the stack cells is now displayed and the total power of the fuel cell stack in the power/time graph (see Figure 6).

Note:
The working point can also be changed during the running measurement by moving the cursor by clicking on the working point with the left mouse button and keeping it pressed.

Fig. 6

Note:
If the measurement bar changes color from blue to red during the measurement, this cell has no power. Among other things, this can be due to insufficient supply of hydrogen or that a water droplet is in the cell which prevents the supply of hydrogen. **Remedy:** check hydrogen supply; blow carefully through the stack; let the stack warm up for some time.

Note:
If the individual voltages seem implausible to you, check whether the connector between "U1" & "U2" is on the negative side of the stack.

Note:
During a longer measurement, it can happen that the power increases if the cursor is moved from the MPP. This initially seems illogical and wrong, however can be explained as follows: As this is a case of a current-regulated measurement in the background, the FCM takes over the current value of the characteristic curve and multiplies this by the current voltage value. However, as the parameters (temperature, humidity etc.) of the fuel cell change over longer operation, its power also changes, i.e. current and voltage and thus also the characteristic curve. The voltage value of the characteristic curve therefore no longer matches the current voltage value.

Remedy: Restart the measurement and let the fuel cell operate for a few minutes until it has reached its operating temperature before you start measurements. The power output is then more constant.

3.7 Efficiency of a Fuel Cell

Note:
The measurement of the efficiency is based on a simplified formula for the benefit of good usability. It refers exclusively to hydrogen powered fuel cells from the company H-TEC EDUCATION. The measured values are recorded at system-controlled intervals for the recording of the efficiency. A resistance is automatically changed from large to small values for this. The typical characteristic curve course for fuel cells is thus produced. Thereby, the red characteristic curve with the heat value and the white characteristic curve with the fuel value are measured.

Procedure:

- Connect a fuel cell to the connection sockets of the measurement board (see Figure 3). Pay attention to the correct polarity (red= "+" and black= "-").

- The value of the no-load voltage is now displayed in black by the top dial instrument and as a numeric value on the right under the dial instruments. The FCM is now in standby mode.

- Select the "Measurement Set-Up" menu item. Then select "Fuel Cell" > "Efficiency" and input the number of cells of the connected fuel cell.

- Click on the Start button.

- The FCM now automatically records the characteristic curve of the fuel cell from the no-load voltage to the short-circuit current, graphically displays the efficiency and is again in standby mode afterwards.

The measurement can be canceled at any time using the "Cancel" button.

Note:
After the measurement is completed, you can move the cursor in the voltage/current graph by clicking on the working point with the left mouse button and keeping the button pressed. The values are taken over by the dial instruments and can be read there.

Black pointer: maximum value
Blue pointer: value at the cursor position
Yellow pointer: value at the cursor position in the Maximum Power Point (MPP).

3.8 Recording an Electrolyzer Characteristic Curve

CAUTION!
Absolutely ensure that an electrolyzer or reversible fuel cell (RFC) has been connected. A fuel cell would be destroyed during the measurement as a voltage is applied to the cell.

CAUTION!
The electrolysis mode of the FCM is only designed for single and double cells of the JUNIOR and TUTORIAL product groups and for the H-TEC EDUCATION Electrolyzer 65. Other electrolyzers or RFCs with higher power cannot be measured.
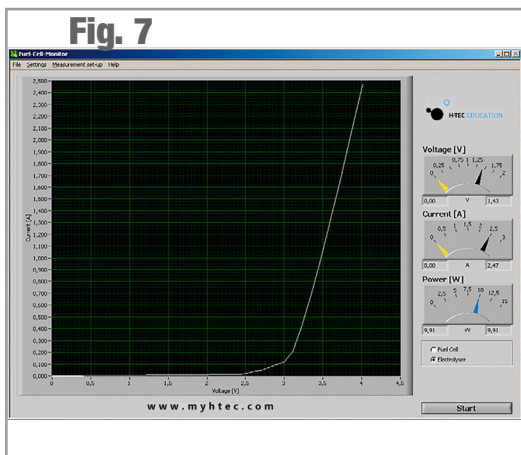
CAUTION!
Only use the power supply included in this package. If a different power supply is used, the measurement result can be falsified or the measurement board can be damaged.

Procedure:

- Select "Measurement Set-Up" > "Electrolyzer" > "Automatic" from the menu. If you have previously performed an automatic fuel cell measurement, you can also select the mode on the screen using the Start button.

- Connect a single or double cell to the measurement board using the measurement cables (see Figure 3).

- Connect the power supply to the measurement board.

- Click on the Start button. A dialogue window is displayed. Check whether you have connected a single-cell or double-cell electrolyzer as a single-cell electrolyzer would be destroyed if a double-cell measurement were accidentally started instead.

- Now input the number of cells.

The FCM records the characteristic curve by increasing the voltage at the cell of 0-2 Volts for single cells or 0-4 Volts for double cells (see Figure 5).

Fig. 7

Important information:

As each electrolyzer is in principle also a fuel cell although with extremely low power, it can happen that a no-load voltage is set after the electrolyzer has already been measured. Due to this, another measurement at this electrolyzer would not start at 0-0.1 Volts but under certain circumstances at significantly higher values whereby the measurement result would be falsified and no correct characteristic curve course would be produced.

Remedy:

Flood the electrolyzer with water again and then click on "Fuel Cell" in the control section and start an automatic "measurement". Check the no-load voltage after the automatic characteristic curve recording; this should be less than 0.1 V. If this is not the case, repeat the process. Afterwards, you can return to the electrolyzer measurement using the control section.

Note:

The axes assignment for the electrolyzer measurement can be defined under the "System Settings" menu item. You can select a current over voltage or a voltage over current display.

3.9   Recording the Efficiency Characteristic Curve of an Electrolyzer

CAUTION!

Absolutely ensure that an electrolyzer or reversible fuel cell (RFC) has been connected. A fuel cell would be destroyed during the measurement as a voltage is applied to the cell.

CAUTION!

The electrolysis mode of the FCM is only designed for single and double cells of the JUNIOR and TUTORIAL product groups and for the H-TEC EDUCATION Electrolyzer 65. Other electrolyzers or RFCs with higher power cannot be measured.

CAUTION!

Only use the power supply included in this package. If a different power supply is used, the measurement result can be falsified or the measurement board can be damaged.

Note:

The measurement of the efficiency is based on a simplified formula for the benefit of good usability. It refers exclusively to electrolyzers from the company H-TEC EDUCATION.

Procedure:

■   Select "Measurement Set-Up" > "Electrolyzer" > "Efficiency" from the menu. If you have previously performed an automatic fuel cell measurement, you can also select the mode on the screen using the Start button.

■   Connect a single or double cell to the measurement board using the measurement cables (see Figure 3).

■   Connect the power supply to the measurement board.

■   Click on the Start button. A dialogue window is displayed. Check whether you have connected a single-cell or double-cell electrolyzer as a single-cell electrolyzer would be destroyed if a double-cell measurement were accidentally started instead.

■   Now input the number of cells.

The FCM records the characteristic curve by increasing the voltage at the cell of 0-2 Volts for single cells or 0-4 Volts for double cells. Therefore, three efficiency characteristic curves are also displayed. The output efficiency refers to the fuel value of hydrogen.

Important information:

As each electrolyzer is in principle also a fuel cell although with extremely low power, it can happen that a no-load voltage is set after the electrolyzer has already been measured. Due to this, another measurement at this electrolyzer would not start at 0-0.1 Volts but under certain circumstances at significantly higher values whereby the measurement result would be falsified and no correct characteristic curve course would be produced.

Remedy:

Flood the electrolyzer with water again and then click on "Fuel Cell" in the control section and start an automatic "measurement". Check the no-load voltage after the automatic characteristic curve recording; this should be less than 0.1 V. If this is not the case, repeat the process. Afterwards, you can return to the electrolyzer measurement using the control section.

3.10 Saving of Measured Data

The FCM provides the option to save recorded measured data (except stack individual voltages). The path and the file type in which the data should be stored must be specified in the menu under System Settings before saving measured data. Measurements can be saved either as standard text as .txt files or as comma separated values in .csv files (.csv is a common text file format for saving data or lists which can easily be imported by spreadsheet programs, such as, MS Excel or Open Office).

Now you can save the last recorded measurement using "File" > "Save measured data".
A file is created in the specified directory which contains the values for time, voltage, current and power as well as the time and the type of the measurement.

The file name is formed from the date and time as follows: YearMonthDay_Hour-Minute-

Seconds.txt (the same applies for the CSV file format). Thus a recorded measurement in the year 2020 on August 25 at 13:46 and 29 seconds would have the file name "200825_13-46-29.txt".

This type of naming convention guarantees a precise and unmistakable assignment of different measurements.

3.11   Report

The saving or the printout of the graphical display of the characteristic curves can be found under "File" > "Report". You have the options "Print report" and "Open as HTML file". If you select "Print", the current screen of the FCM is printed out in gray scale. If you open the report with your web browser, the current screen of the FCM is generated as an HTML file which you can save or otherwise process with your web browser according to your requirements.

3.12   Four-Terminal Sensing

The measurement board of the FCM provides the possibility to perform all fuel cell measurements as four-terminal sensing. For a four-terminal sensing, connect the fuel cell to the measurement board as follows:

Fig. 8

comp

Measurement Board
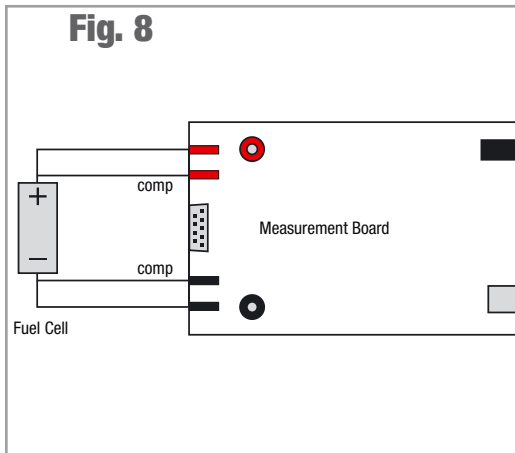
comp

Fuel Cell

Note:

First connect the fuel cell to be measured to the compensation cables. Then plug the "positive" and "negative" measurement cables into the compensation cables on the fuel cell. Pay attention here to the correct polarity (red= "+" and black= "-").

The special feature of the four-terminal

sensing is that the voltage measurement is performed with a lower (caused by the current) voltage drop and with a smaller influence of transition resistance.

The current and the voltage here are tapped using different measurement lines. Ideally considered, it can be said (assuming an ideal voltmeter) that no current flows over the measurement lines to the voltmeter and thus no voltage drop also occurs. The interfering influence is thus compensated for and the measurement is more precise.

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4 Technical Data

Measurement Board

H x W x D:.............................. 40 x 160 x 100 mm
Weight:................................... approx. 360g
Connections:.......................... 2 and 4 mm

Fuel Cell Mode

Permitted Voltage:................. 0 - 10 VDC
Permitted Current:................. 0 - 5 A
Power:................................... 0 - 10 W

Electrolyzer Mode:

Permitted Voltage:................. 0 - 4 V DC
Permitted Current:................. 0 - 3 A
Power:................................... 0 - 10 W

Power Supply

Output:.................................. 6 V / 4 A

Cable Set

2 X .... 4 mm Red Cables
2 X .... 4 mm Black Cables
2 X .... 2 mm Red Cables
2 X .... 2 mm Black Cables
2 X .... 4 mm to 2 mm Adapter
1 X .... Wiring Harness for individual cell voltage measurement
1 X .... USB Cable

5 Troubleshooting

General:

The screen display of the FCM does not show the desired homogeneous characteristic curve course.

Possible Cause:
- There is no fuel cell connected.
- The cell has been connected with the polarity reversed.
- The cell is only connected to the connection sockets for the four-wire measurement.

Solution:
- Check the connection of the cell to the measurement board.

Fuel Cell Measurement:
First ensure whether there is a gas supply and whether the fuel cell is correctly connected to the measurement board.

The fuel cell does not achieve the stated power in the MPP.

Possible Cause:
- The membrane of the fuel cell is too dry or too moist.

Solution, if the fuel cell is too dry:
- Moisten the fuel cell with a drop of distilled water ($\sigma < 2$ µS/cm).

Solution, if the fuel cell is too moist:
- Disconnect the cell from the gas supply. Blow once carefully through the connection hoses of the cell so that the water in the cell is pressed out. Reconnect the cell to the gas supply. Afterwards, let some gas flow through the cell so that there is no longer any air in the cell.

Electrolyzer Measurement:
First ensure that no fuel cell is connected and whether the power supply and the electrolyzer are correctly connected to the measurement board.

The electrolyzer does not have the stated power.

Possible Cause:
- The electrolyzer does not have enough water

Solution:
- Flood the electrolyzer again and/or fill the water tank of the electrolyzer with distilled water ($\sigma < 2$ µS/cm).

Possible Cause:
- You have clicked on single-cell for the start of the measurement, but you have connected a double cell.

Solution:
- Ascertain which type of cell you have connected and start the measurement again.

6   Maintenance

The components do not require maintenance.

7   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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