Operating Instruction

U103 Fuel Cell Monitor Pro 3.0

U104 Fuel Cell Monitor 3.0

Contents

1 General

1.0 Purpose / Introduction

The claimed climate change in combination with the increasing global energy requirements and the declining resources of coal, oil and gas make the development of new sources of energy one of the main tasks of the 21st century. Hydrogen technology has particular importance. Electricity can be generated directly from hydrogen and oxygen using fuel cells. The only waste product: water. Using electricity which can be obtained for example from solar cells, the required hydrogen can be produced directly from water by decomposition into hydrogen and oxygen. The underlying principle is called electrolysis. Both methods form the solar hydrogen circuit jointly.

The h-tec team wishes you fascinating experiments and interesting insights into the energy supply of the future

h-tec
Hydrogen energy Systems

1.1 Product Description

The Fuel Cell Monitor (FCM) is a didactic product consisting of a measuring transformer card and evaluation software. It is tailored to the requirements for the measurement of h-tec products and must only be used for this. The FCM is available in two versions: As Standard Version U104 Fuel Cell Monitor 3.0 and as extended Version U103 Fuel Cell Monitor Pro 3.0. Both versions provide you with the possibility of measuring, storing and evaluating various measured values and characteristic curves of h-tec fuel cell education models. The external measuring transformer card 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 measuring transformer card 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 educational fuel cells can also be measured with the FCM.

The extended Version U103 Fuel Cell Monitor Pro 3.0 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 educational electrolysers.

1.2　　Menu Languages

- English, German, French and Spanish.

1.3　　System Requirements

Minimum computer requirements: Pentium 200 Mhz or comparable processor (we recommend a Pentium III, a Celeron with 600 Mhz or a 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 2000 at least Service Pack 3, XP or Vista, RAM: minimum 128 MB (recommended 256 MB), USB connection.

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

- U103 Fuel Cell Monitor Pro 3.0

Transport case, measuring transformer card, USB cable, software, individual voltage measurement cable, cable set, power supply and detailed operating manual

- U104 Fuel Cell Monitor 3.0

Measuring transformer card, USB cable, software, cable set and detailed operating manual

1.5　　Appropriate Use

Measurements of h-tec products in the following areas can be performed and evaluated using the external measuring transformer card of the Fuel Cell Monitor and the associated software:

Fuel cell mode

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

Electrolysis mode: (only for extended Version U103 Fuel Cell Monitor Pro 3.0)

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 General Safety Instructions

- The device is only intended for commercial use (schools, universities, institutions, companies).
- The device must only be put into operation and operated by a competent person.
- ATTENTION! Not suitable for children under 12!
- The operating manual must be read before operation, observed and kept ready to hand for reference. This also applies to the operating instructions of the fuel cells and electrolysers used.
- Wear safety goggles when handling fuel cells and electrolysers.
- The device is not a toy.
- The device and gases must be kept and operated out of reach of small children.
- Disconnect the device from all connection cables before cleaning with liquids.
- Never clean measuring transformer card of Fuel Cell Monitor by using liquids!
- Unless otherwise stated, connection terminals must not be connected with reverse polarity or short-circuited.
- Remove flammable gases, fumes or liquids from the vicinity of fuel cells and electrolysers. The catalytic substances contained can trigger self-ignition.
- Hydrogen and oxygen can discharge from fuel cells and electrolysers. Prevent the gases accumulating and forming potentially explosive mixtures by only using the device in well ventilated rooms.
- Fuel cells and electrolysers must only be operated in glass cabinets if sufficient ventilation of the latter under all circumstances is ensured. The operator must prove this by means of corresponding measurements.
- Remove all substances which can trigger an ignition of the hydrogen (open flames, substances with possible electrostatic charge, catalytic substances) from the vicinity of fuel cells and electrolysers.
- Do not smoke.
- Only use the gas tanks included with the equipment for the gas storage. Never connect other gas tanks.
- In the case of non-compliance with these safety instructions, h-tec Hydrogen Energy Systems accepts no responsibility for resulting damage.

1.7 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.

1.8   Liability

It is not possible with today's technology to rule out every error in a software application. Accordingly, the „Fuel Cell Monitor 3" program 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.

1.9   Support

The program has been carefully tested by h-tec 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 FCM in the case of questions or suggestions. You can display this using „Help" → „about FCM". Current versions of the program are available for download at any time from www.h-tec.

2 External Measuring Transformer Card and Software
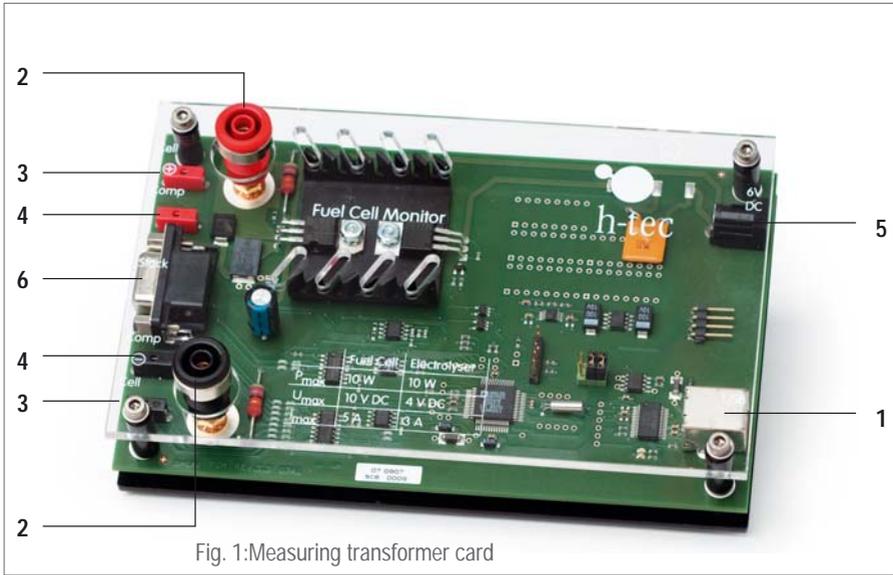
Fig. 1:Measuring transformer card

2.1 Connections

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 electrolyser 4 mm connection sockets: connections for the cell to be measured (fuel cell or electrolyser). Also suitable for 4 mm safety measuring cables. 4 mm red and black cables are included in the standard delivery (Fuel Cell Monitor Pro 3.0).

3) Fuel cell and electrolyser 2mm connection sockets: connections for the cell to be measured (fuel cell or electrolyser). 2mm 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 electrolyser measurements. The power supply is included in the standard delivery (Fuel Cell Monitor Pro 3.0).

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 (Fuel Cell Monitor Pro 3.0).

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 measuring transformer card

2. Installation of the drivers

3. Installation of the FCM software

The computer must be restarted after completion of the software installation.

Do not use the FCM until after the restart,

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 2000 / Windows XP / Windows Vista.

2. You need at least local power user rights to use the FCM software for Windows 2000 / Windows XP / Windows Vista.

2.2 Installation of the Drivers for the External Measuring Transformer Card

Two drivers must be installed for the measuring transformer card of the FCM. On the one hand, a driver for the USB connection to the measuring transformer card and on the other hand a driver for the virtual COM port. The measuring transformer card of the FCM is indeed connected to the computer via a USB port, however it is necessary to treat this as a virtual COM port.

First connect the USB data carrier (USB stick) to a USB port of your PC. Then connect the measuring transformer card to a USB port of your PC using the supplied USB cable. The „New hardware found" wizard should now start automatically.

If this is not the case, select „Start" → „Control Panel" → „Add new hardware".

Now proceed as follows:

1. On the „Install hardware driver" screen, activate the field „Search for suitable driver for the device" and confirm with „next".

2. On the next screen, activate the „Specify other source" checkbox and confirm again with „next".

3. Select „browse", navigate to the installation data carrier and open the „USB-driver" directory.

4. Confirm with „OK" and afterwards with „next". The drivers will now be installed. Exit from the wizard with „finish".

After completion of the installation of the first driver, the New Hardware Found wizard opens again in order to install the second driver. Repeat steps 1-4 for this.

2.3   Fuel Cell Monitor Installation

Run the setup program „Setup.exe" on the supplied installation data carrier and follow the instructions on the screen. If necessary, change the installation directory according to your requirements. After successful installation, FCM can be started from the START->All Programs menu or from the desktop shortcut.

Important:

The system must be restarted after the installation of the drivers and the software. Do not use FCM until after the restart.

2.4   First Run

Only for U103 Fuel Cell Monitor Pro 3.0: The first start of Fuel Cell Monitor Pro 3.0 must be done with the power supply plugged in.

1. If you have disconnected the USB connection after the installation, connect your computer and the measuring transformer card using the supplied USB cable.

2. Start the program.

During the first run of the program, a dialogue window is displayed which requests you to connect the measuring transformer card to the computer. Click on „System Settings". Another window opens in which the COM port which the card is connected to can be selected on the top right under „Port for the measuring transformer card". Click on „OK" after making the selection. The setting is thus 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 electrolysers from the measuring transformer card. The program performs a zero compensation. The Fuel Cell Monitor is ready for operation afterwards. This is indicated by green and red flashing diodes on the measuring transformer card. The program interface is now displayed on your screen (see Figure 2) which consists of the following components:
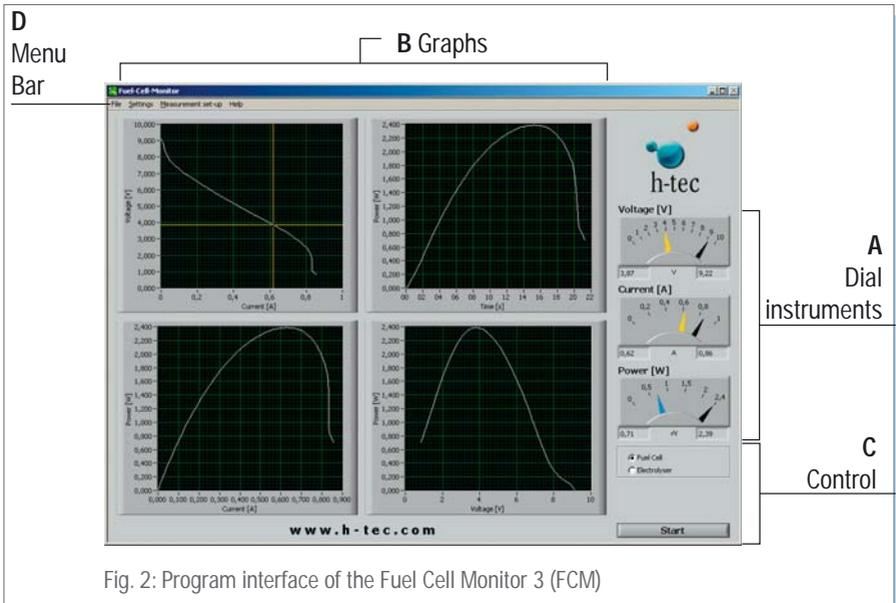

Fig. 2: Program interface of the Fuel Cell Monitor 3 (FCM)

A. Dial instruments

The three dial instruments clearly show the current and maximum measured values. The pointers can have three colours: 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 the chapter „Measured value recording") and a progress bar is displayed for measurements where a measurement duration can be specified.

D. Menu bar

Im Menü des FCM werden u.a. die verschiedenen Messoptionen und Systemeinstellungen vorgenommen sowie Daten gespeichert. (Näheres im folgenden Kapitel „Menüpunkte")

2.5   Menu Items

This section briefly shows the menu items of the FCM. Please refer to the corresponding subitems in the chapter „Measured value recording" for details about the individual measurement options.

File

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 program is restarted.

Measurement Options

The fuel cell type (or electrolyser type for the extended Version U103 Fuel Cell Monitor Pro 3.0) and the type of the measurement are specified in the „Measurement Options" menu item.

System Settings

Here you can select between the menu languages English, German, French and Spanish, set the port for the measuring transformer card, 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 complete help for FCM in the Help menu.
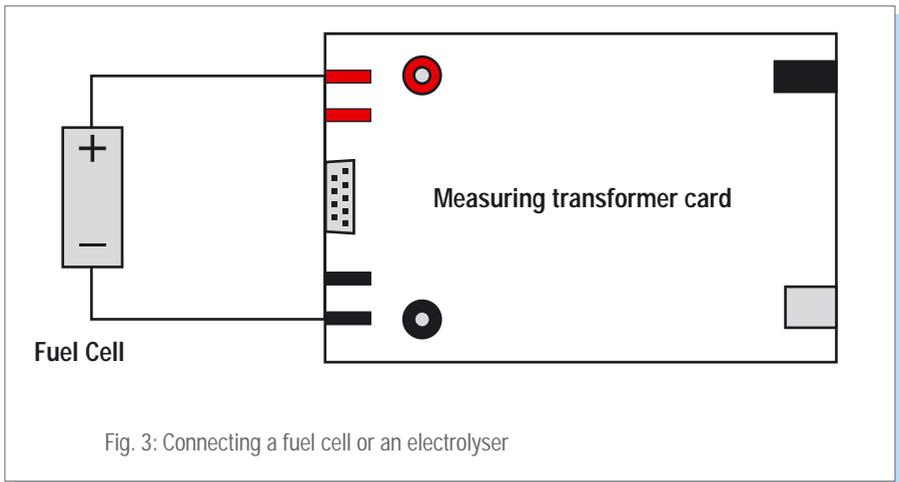
3 Measured Value Recording

3.1 General

When the program is started, a window is displayed with the instruction to disconnect any possibly connected fuel cells or electrolysers from the measuring transformer card. This is used for the zero compensation of the FCM. Confirm with „OK". The FCM is now ready for operation.

The FCM has automatic scaling during he 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 with „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 electrolyser is connected to the measuring transformer card as shown in Figure 3.

Measuring transformer card

Fuel Cell

Fig. 3: Connecting a fuel cell or an electrolyser

3.2 Characteristic Curve Recording

3.2.1 Automatic Characteristic Curve Recording 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 course 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 measuring transformer card (see Figure 3). Pay attention here to the correct polarity (red: plus and black: minus).
- 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.
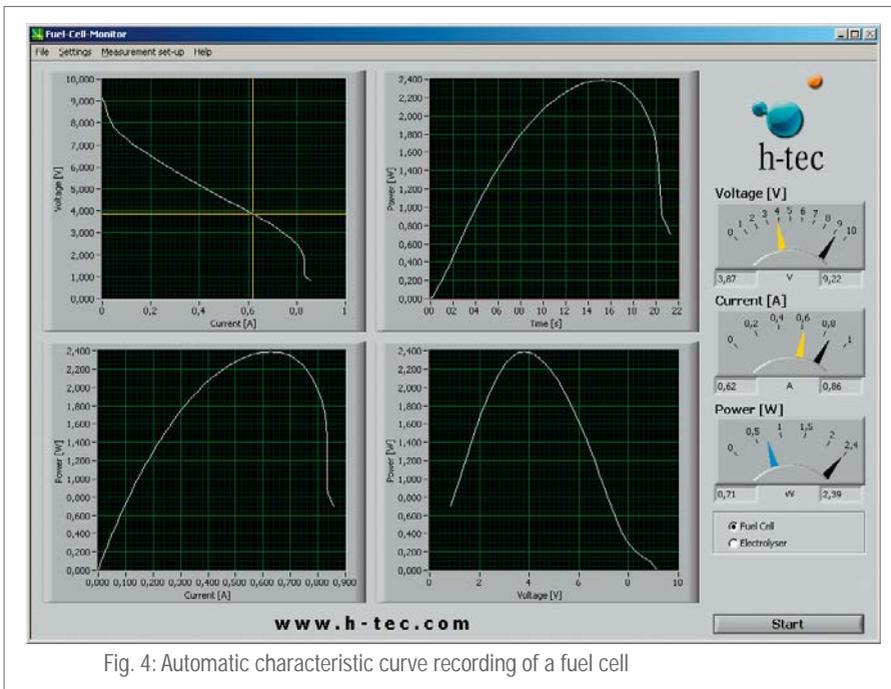- Click on the Start button.

Fig. 4: Automatic characteristic curve recording of a fuel cell

- 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 afterwards **(see Figure 4)**.

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

<u>Note:</u>

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 Options" R „Fuel Cell" R „Automatic".

<u>Note:</u>

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).

3.2.2 Voltage-regulated Characteristic Curve Recording 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, he 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.

<u>Procedure:</u>

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

- Select the „Measurement Options" 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 afterwards with „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:

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).

3.2.3 Current-regulated Characteristic Curve Recording 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, he 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 Options" 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 afterwards with „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 cancelled 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 current-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.

3.2.4 Manual Characteristic Curve Recording 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 here to the correct polarity (red="+" and black="-").

- Select the „Measurement Options" menu item. Then select „Fuel Cell" ➔ „Manual". Click on „OK" afterwards.

- 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 on „OK" if the characteristic curve meets your expectations otherwise select „Cancel". You can then restart the automatic characteristic curve recording.

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 cancelled 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).

3.3 Recording of Individual Stack Voltages

Procedure
- Select „Measurement Options" ➜ „Stack Individual Voltages" from the menu and input how many cells your stack has (2 to 10).
- Connect the individual voltage measurement cable to the „COM" connection of the measuring transformer card 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)**.

Fig. 5: Connecting a stack to the individual voltage measurement cable
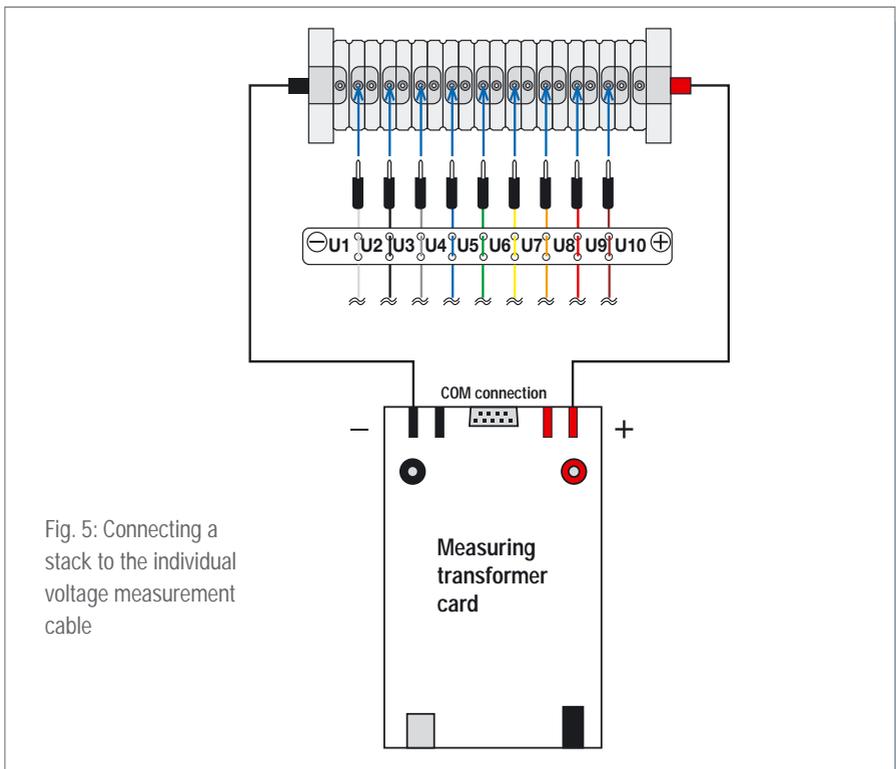
Note:

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").

■ 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 otherwise 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)**.
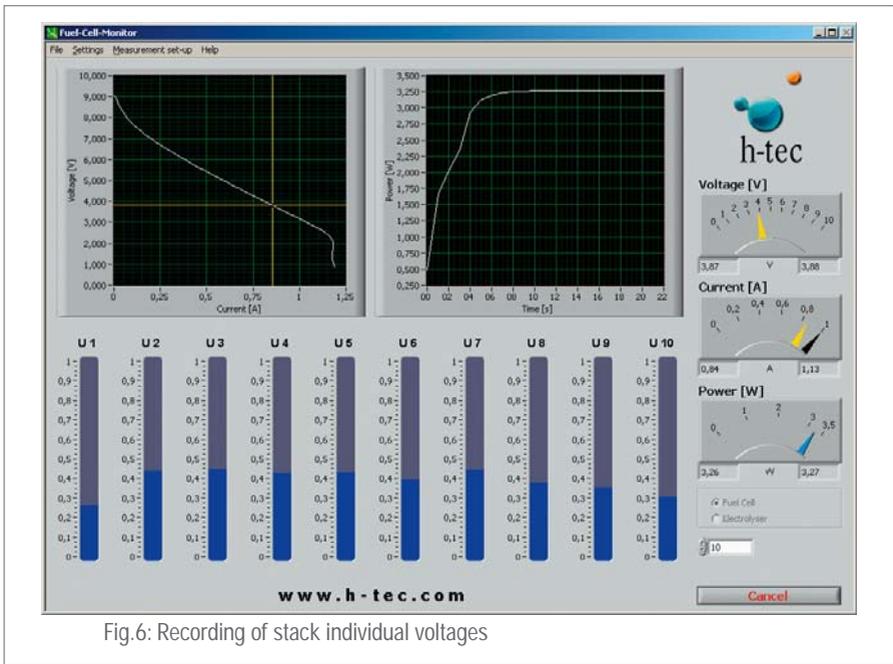

Fig.6: Recording of stack individual voltages

Note:

The working point cab 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.

Note:

If the measurement bar changes colour 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 drop is in in the cell which prevents the supply of hydrogen. Remedy: check hydrogen supply; blow through the stack with compressed air; let the stack warm up for some time.

Note:

If the individual voltages seem implausible to you, check whether the connector between „U1" and „U2" is on the negative side of the stack **(see Figure 5)**.

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.

3.4 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 Wasserstoff-Energie-Systeme GmbH.

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 measuring transformer card **(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.

- Select the „Measurement Options" 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 cancelled 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).

3.5 Recording of Electrolyser Characteristic Curves

Note:

The recording of electrolyser characteristic curves is only possible with the extended Version U103 Fuel Cell Monitor Pro 3.0.

Important:

- **Absolutely ensure that an electrolyser 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.**

- **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 Electrolyser65. Other electrolysers or RFCs with higher power cannot be measured.**

- **Only use the power supply included in the standard delivery. If a different power supply is used, the measurement result can be falsified or the measuring transformer card can be damaged.**

Procedure:

- Select „Measurement Options" ➔ „Electrolyser" ➔ „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 measuring transformer card using the measurement cables **(see Figure 3)**.

- Connect the supplied power supply to the measuring transformer card.

- Click on the Start button. A dialogue window is displayed. **Check whether you have connected a single-cell or double-cell electrolyser as a single-cell electrolyser would be destroyed in the case of an accidentally started double-cell measurement.** The h-tec Electrolyser65 is a double cell. 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 7)**.

Fig. 7: Electrolyser characteristic curve of a double cell

Important information:

As each electrolyser is in principle also a fuel cell although with extremely low power, it can happen that a no-load voltage is set after the electrolyser has already been measured. Due to this, another measurement at this electrolyser 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 electrolyser 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 electrolyser measurement using the control section.

Note:

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

3.6 Recording of Efficiency Characteristic Curves of an Electrolyser

Note:

The recording of efficiency characteristic curves of an electrolyser is only possible with the extended Version U103 Fuel Cell Monitor Pro 3.0.

Important:

- **Absolutely ensure that an electrolyser 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.**

- **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 Electrolyser65. Electrolysers or RFCs with higher power cannot be measured.**

- **Only use the power supply included in the standard delivery. If a different power supply is used, the measurement result can be falsified or the measuring transformer card can be damaged.**

<u>Note:</u>

The measurement of the efficiency is based on a simplified formula for the benefit of good usability. It refers exclusively to electrolysers from the company h-tec Hydrogen Energy Systems.

- Select „Measurement Options" ➔ „Electrolyser" ➔ „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 measuring transformer card using the measurement cables **(see Figure 3)**.
- Connect the supplied power supply to the measuring transformer card.
- Click on the Start button. A dialogue window is displayed. **Check whether you have connected a single-cell or double-cell electrolyser as a single-cell electrolyser would be destroyed in the case of an accidentally started double-cell measurement.** The h-tec Electrolyser65 is a double cell. 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. Thereby, three efficiency characteristic curves are also displayed. The output efficiency refers to the fuel value of hydrogen.

Important information:

As each electrolyser is in principle also a fuel cell although with extremely low power, it can happen that a no-load voltage is set after the electrolyser has already been measured.

Due to this, another measurement at this electrolyser 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 electrolyser 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 electrolyser measurement using the control section.

3.7 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 generally common text file format for saving data or lists which can easily be imported by spreadsheet programs (such as, e.g. 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 2009 on August 25 at 13:46 and 29 seconds would have the file name „090825_13-46-29.txt".

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

3.8   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 grey 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.

3.9   Four-terminal Sensing

The measuring transformer card of the FCM provides the possibility to perform all measurements as four-terminal sensing. First connect the cell to be measured to the compensation cables – i.e.: connect the cell with the connection sockets for the four-terminal sensing (comp) to the measuring transformer card. Then plug the „plus" and „minus" measurement cables into the compensation cables on the 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.

Fig. 8: Connecting the measuring transformer card for four-terminal sensing
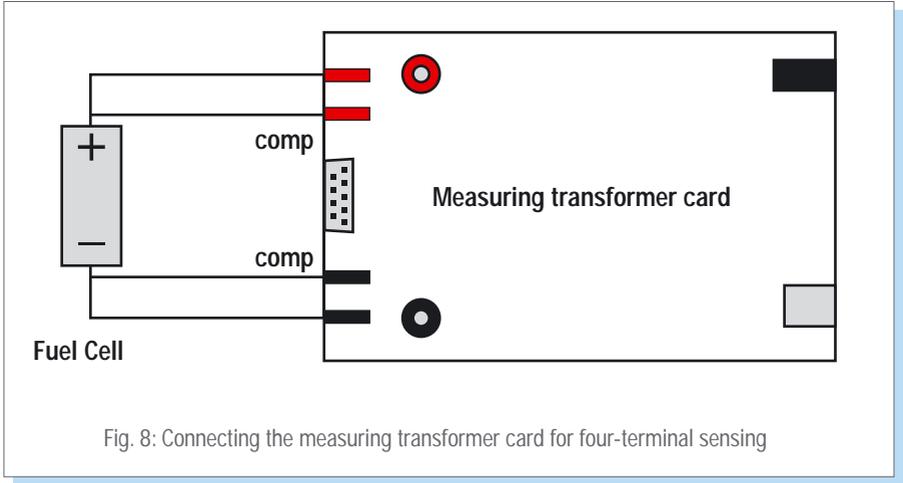
4   Maintenance

The measuring transformer card does not need any maintenance.

5   Troubleshooting

Fuel cell measurement:

First ensure whether there is a gas supply and whether the fuel cell is correctly connected to the measuring transformer card.

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

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

Solution: if the membrane of a fuel cell is too dry:

Moisten the fuel cell with a drop of distilled water.

Solution: if the membrane of a fuel cell is too moist:

Disconnect the cell from the gas supply. Blow once vigorously 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.

Cause: The fuel cell is not sufficiently supplied with gas.

Solution: Possibly, an electrolyser with more power is needed.

Electrolyser measurement:

First ensure that no fuel cell is connected and whether the power supply and the electrolyser are connected to the measuring transformer card correctly.

The electrolyser does not have the stated power.

Cause: The electrolyser is not sufficiently supplied with water.

Solution: Flood the electrolyser again and/or fill the water tank of the electrolyser.

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

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

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

possible causes:
- 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.
- The fuel cell is not sufficiently supplied with gas.

Solution: Check the connection of the cell to the measuring transformer card.

Possibly, an electrolyser with more power is needed.

6   Technical Data

Fuel Cell Monitor Pro 3.0

U103

Measuring transformer card:

Item. No:	U103
HxWxD:	40 x 160 x 100 mm
Weight:	1,4 kg
Connections:	2 and 4 mm

Fuel cell mode:

Permitted voltage:	0 - 10 V DC
Permitted current:	0 - 5 A
Power:	0 - 10 W

Electrolysis mode:

Permitted voltage:	0 - 4 V DC
Permitted current:	0 - 3 A
Power:	0 - 10 W

Power supply:

Output:	6 V
	3.33 A

Cable set:

2 x 4 mm measurement cables, red
2 x 4 mm measurement cables, black
2 x 2 mm measurement cables, red
2 x 2 mm measurement cables, black
2 x adapter
Individual voltage measurement cable
USB cable: Length 180 cm

Fuel Cell Monitor 3.0

U104

Measuring transformer card:

Item. No:	U104
HxWxD:	40 x 160 x 100 mm
Weight:	245 g
Connections:	2 and 4 mm

Fuel cell mode:

Permitted voltage:	0 - 10 V DC
Permitted current:	0 - 5 A
Power:	0 - 10 W

Cable set:

2 x 2 mm measurement cables, red
2 x 2 mm measurement cables, black
2 x adapter
USB cable: Length 180 cm

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