Application note #31

Fuel Cell Testing.
Part I: Overview and I/E characterizations

I-Introduction

Fuel cell is defined as a device which produces electricity from fuel and oxidant. Fuel is provided at the anode and oxidant at the cathode. Unlike batteries, fuel cell can work continuously as long as it is provided with fuel and oxidant (no electrical charge is required after discharge). There are several types of fuel cell such as alkaline fuel cell, direct methanol fuel cell, phosphoric acid fuel cell, and proton exchange membrane fuel cell (PEMFC) [1,2]. PEMFC exhibits better performance at low temperature than the others, so lots of research are carried out on this kind of fuel cell. PEMFC is constituted as follows:

- anode (hydrogen oxidation, Fig. 1 eq 1),
- cathode (oxygen reduction, Fig. 1 eq 2),
- membrane allowing proton exchange between both sides.

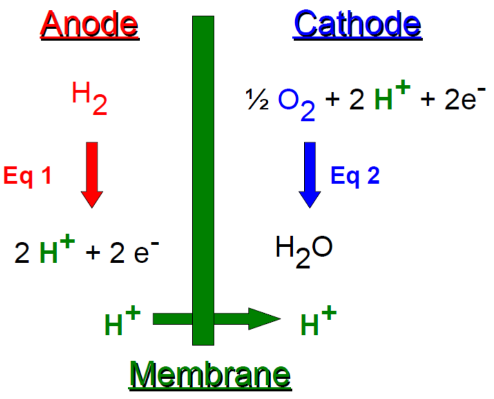


Fig. 1: PEMFC principle.

Regarding fuel cell testing, a key issue is gas (specially gas temperature and humidity) and water management. These parameters are critical for reaching the optimal fuel cell performance.

The aim of this application note is to present the capabilities of the FCT series monitored by FC-Lab® software. This association allows user to control gas, temperature, water and load box with high current ability (up to 150 A). Electrochemical Impedance Spectroscopy (EIS) will be discussed in an other application note [3].

II-Set-up description

For this application note, FCT-150S with automatic humidifier water filling and condenser purging option was used. FCT-150S was monitored by FC-Lab® software. FCT-150S was connected to fuel cell according to the two-electrode connection (blue and white leads on the anode; red lead on the cathode).

Surface area of the fuel cell is 25 (if no indication) or 50 cm^2 (Fig. 2).

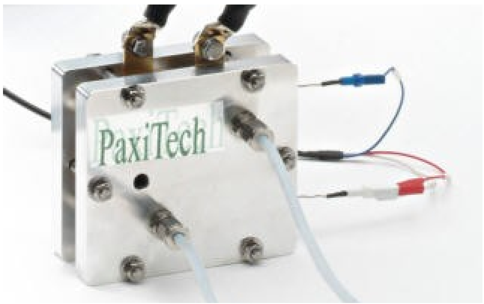


Fig. 2: Fuel cell.

III-Gas and water management

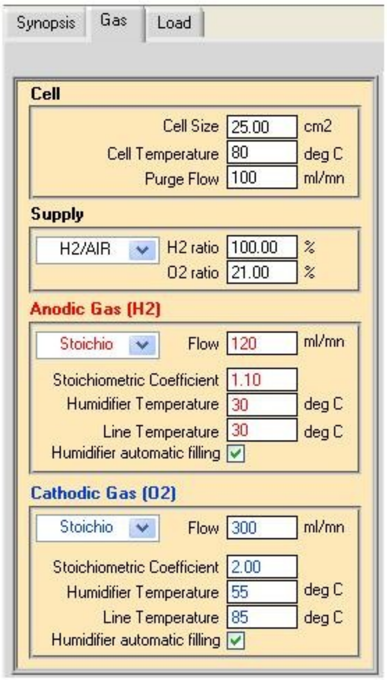
III.1 Presentation

As previously stated, a key issue for fuel cell testing is the gas and water parameters such as gas flow, gas & water temperature, gas humidity, humidifier filling and condenser purge. These parameters are defined in the **"Gas"** tab (Fig. 3). In the block named "Cell", cell size, cell temperature and purge flow are set. The following three blocks deal with the supplied gas. Fuel cell can be feed by several gas combination such as H_2 and O_2, H_2 and Air or any other anodic gas (AG) and cathodic gas (CG). In the latter combination, user can adjust H_2 and O_2 *ratio*. Flow, humidifier temperature, line temperature of anodic or cathodic gas have to be set in its respective block.

Note that stoichiometric ("stoichio") mode can be selected *via* a combo box. If "stoichio" mode is chosen, user can adjust the stoichiometric coefficient for each gas.

Note the box “Humidifier automatic filling” has to be checked to activate this feature (Fig. 3).

Gas and water management data are stored in the “*.log” format file.



Cell

Cell Size 25.00 cm2
Cell Temperature 80 deg C
Purge Flow 100 ml/mn

Supply

H2/AIR
H2 ratio 100.00 %
O2 ratio 21.00 %

Anodic Gas (H2)

Stoichio
Flow 120 ml/mn
Stoichiometric Coefficient 1.10
Humidifier Temperature 30 deg C
Line Temperature 30 deg C
Humidifier automatic filling ☑

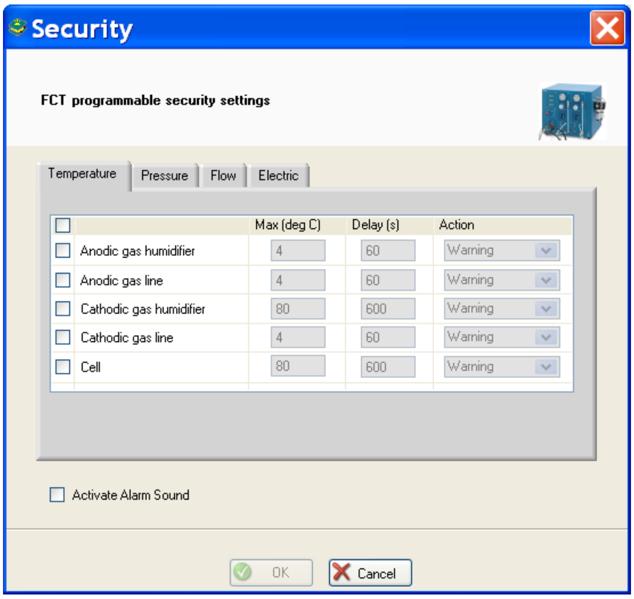
Cathodic Gas (O2)

Stoichio
Flow 300 ml/mn
Stoichiometric Coefficient 2.00
Humidifier Temperature 55 deg C
Line Temperature 85 deg C
Humidifier automatic filling ☑

A global view of the gas and water management parameters is summarized in the **“Synopsis”** tab (Fig. 4).

III.2 Safety parameters

To ensure safe investigations, temperature, pressure, flow, current or potential can be used as safety parameters in the “**Security**” window (Fig. 5).



☐		Max (deg C)	Delay (s)	Action
☐	Anodic gas humidifier	4	60	Warning
☐	Anodic gas line	4	60	Warning
☐	Cathodic gas humidifier	80	600	Warning
☐	Cathodic gas line	4	60	Warning
☐	Cell	80	600	Warning

☐ Activate Alarm Sound

Fig. 5: Security window (example is given with Temperature tab).

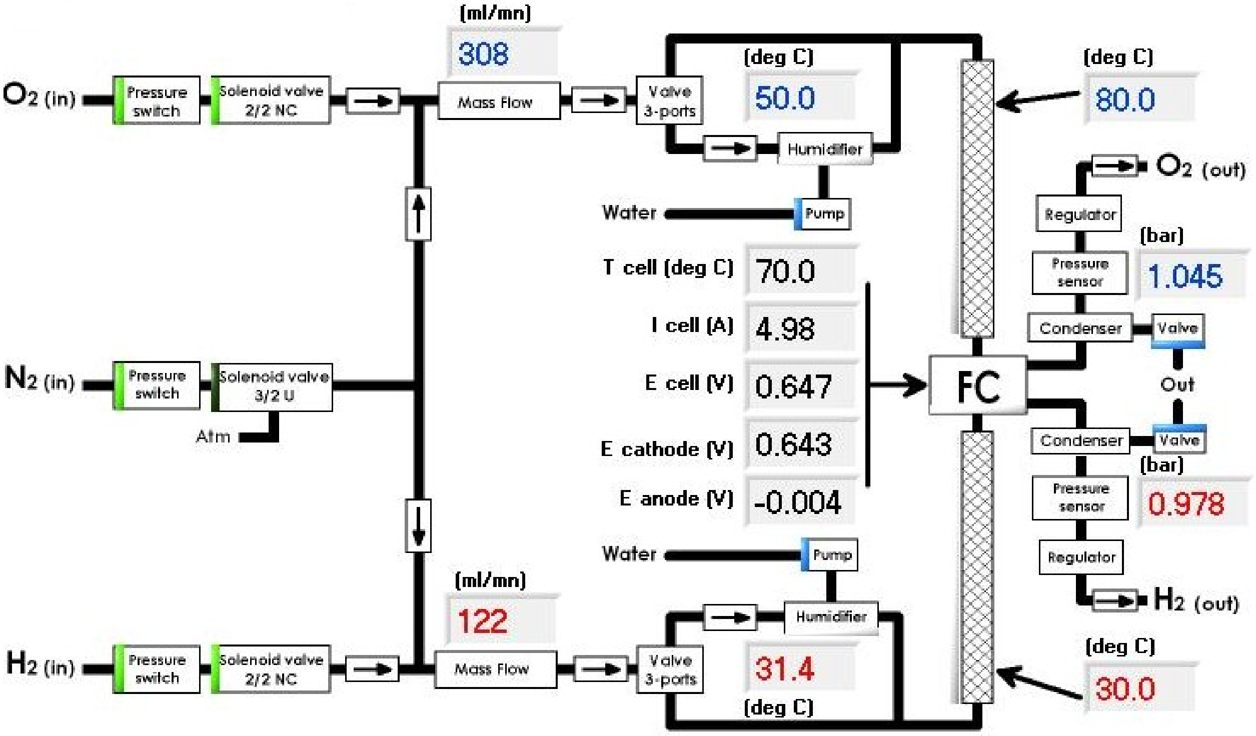
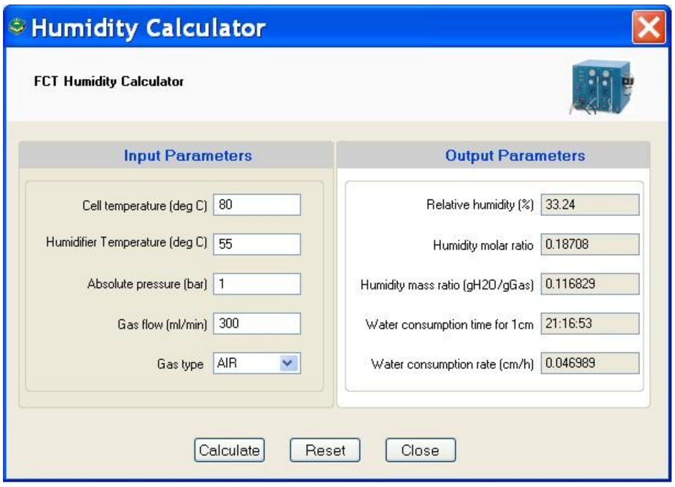


Fig. 4: Synopsis tab.

III.3 Humidity Calculator tool

Humidity of gas affects strongly the fuel cell performance. That's why, in order to optimize fuel cell performance, FC-Lab® software enables the user to calculate the optimal humidity condition through the "Humidity Calculator" tool (Fig. 6) available in the "Help" menu of FC-Lab®.



Cell temperature (deg C): 80
Humidifier Temperature (deg C): 55
Absolute pressure (bar): 1
Gas flow (ml/min): 300
Gas type: AIR

Relative humidity (%): 33.24
Humidity molar ratio: 0.18708
Humidity mass ratio (gH2O/gGas): 0.116829
Water consumption time for 1cm: 21:16:53
Water consumption rate (cm/h): 0.046989

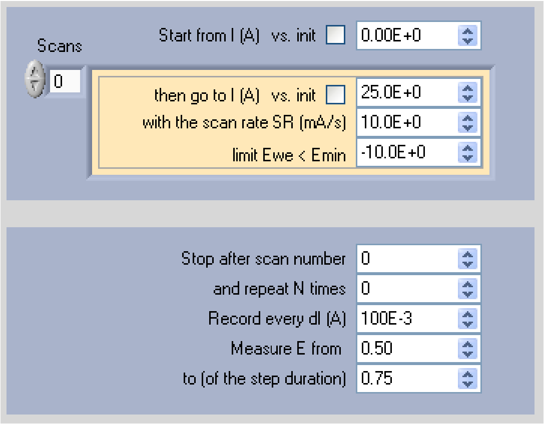
Fig.6: Humidity Calculator window.

IV-Characterizations

To illustrate common fuel cell investigations, current polarization and pulses measurements are shown in this paragraph.

IV.1 Polarization

Polarization is performed at low current scan rate (few mA.cm^{-2}) from current of zero to a limit value of potential, defined as $E_{we} < E_{min}$. Parameters are described in Fig. 7.



Start from I (A) vs. init ☐ 0.00E+0
then go to I (A) vs. init ☐ 25.0E+0
with the scan rate SR (mA/s) 10.0E+0
limit Ewe < Emin -10.0E+0
Stop after scan number 0
and repeat N times 0
Record every dI (A) 100E-3
Measure E from 0.50
to (of the step duration) 0.75

Fig. 7: Polarization technique parameters window.

Resulting curves of E and P *vs.* current density (i) are displayed in Fig. 8.

Power is defined as follows:

$$P_i = E_i I_i$$

where P is the power, E the potential and I the current.

This *E vs. i* curve is usually divided in three regions [2]:

1. Activation polarization: from 0 to 100 mA.cm^{-2} (Fig. 8) in which reaction rate loss dominates,
2. Ohmic polarization: from 100 to 600 mA.cm^{-2} (Fig. 8) in which ohmic drop dominates,
3. Concentration polarization: from 600 mA.cm^{-2} to the end (Fig. 8) in which mass transfer dominates.

The fuel cell power *vs.* current can be plotted. In the example given in bottom of Fig. 8, the maximum power is 6.5 W and this maximum power is reached at 580 mA.cm^{-2}.

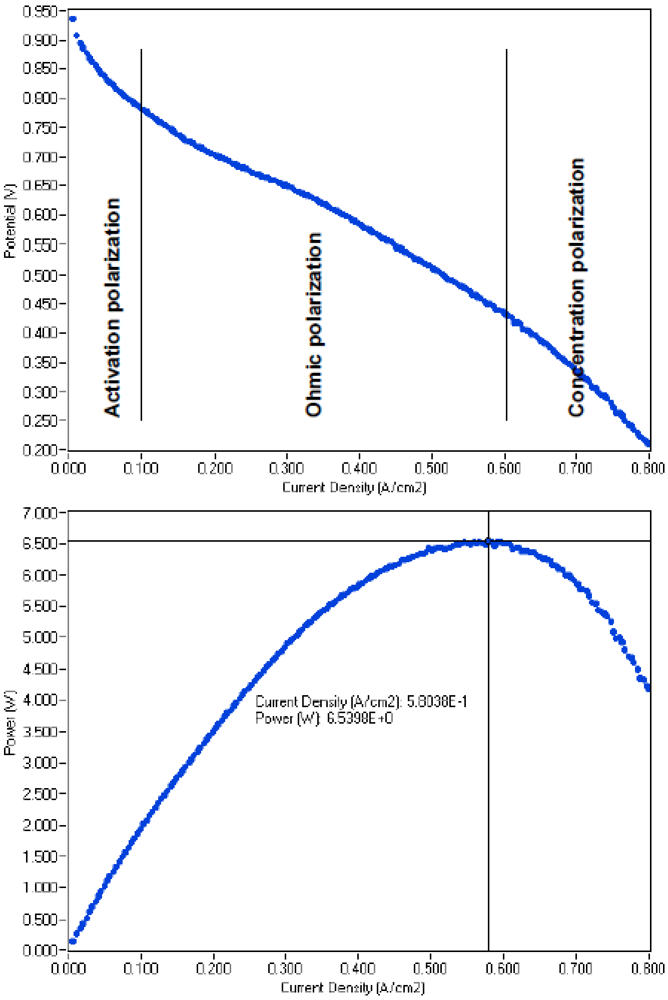


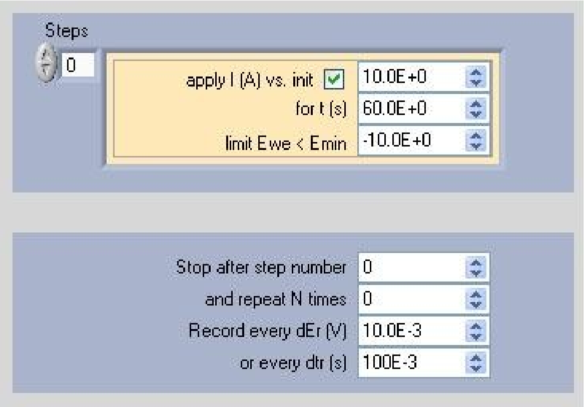
Fig. 8: E (top) and P (bottom) *vs.* current density polarization curves.

IV.2 Current pulse

In order to investigate fuel cell performance a discrete ramp of current can be applied. Two examples are given below. The first one illustrates the high current ability of the load box and the second one shows a long-term experiment.

IV.2.1 High current

Successive current pulses of 60 s are applied to the fuel cell by step of 10 A (Fig. 9). In the first step, 10 A are applied, in the second 20 A and so on up to 100 A. Note that this experiment is carried out on a fuel cell with a surface area of 50 cm^2.



Steps 0

apply I (A) vs. init ☑ 10.0E+0

for t (s) 60.0E+0

limit Ewe < Emin -10.0E+0

Stop after step number 0

and repeat N times 0

Record every dEr (V) 10.0E-3

or every dtr (s) 100E-3

Fig. 9: Current pulse technique parameters window.

Resulting chronopotentiometric curve is displayed in Fig. 10.

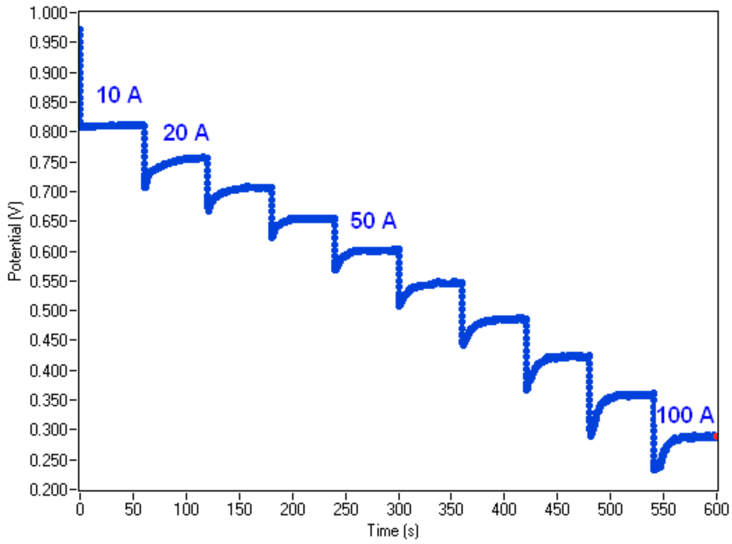


Fig. 10: Chronopotentiometric curve.

IV.2.2 Long term

Automatic gas and water managements allow user to perform long term measurements (thousands of hours). Current pulse technique with current intensity of 4, 5 and 2 A was performed over 60 h. The resulting chrono-potentiometric curve (Fig. 11) shows the stability of the fuel cell potential during the experiment.

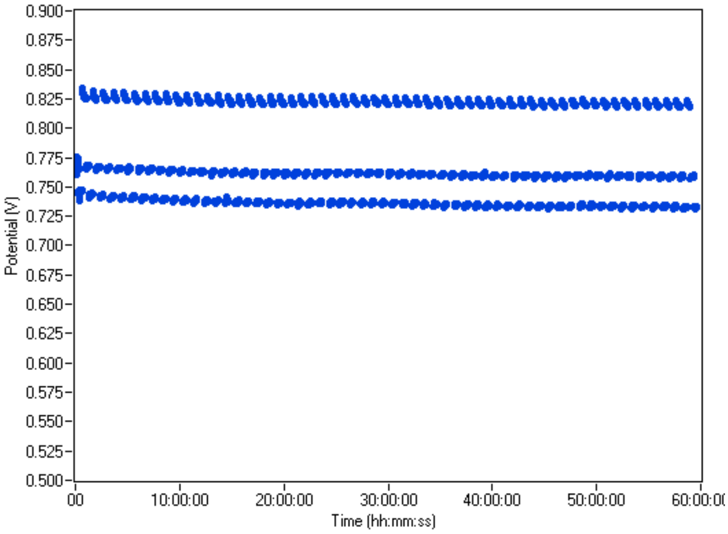


Fig. 11: Long term chronopotentiometric curve.

VI-Conclusion

This note presents the advantage of the association of the FCT series compactness with the FC-Lab® monitoring software. This association makes possible to control the fluidic parts (gas and water) and electrochemical part (control and measure of current and potential) of the fuel cell testing with the same system.

More information about EIS measurements and resulting data analysis are discussed in the following application note #32.

References

[1] Fuel Cell Systems Explained, J. Larminie, A. Dicks, ed. Wiley (Chichester) 2003.

[2] The Polymer Electrolyte Fuel Cell, V. Ramani, H. R. Kunz, J. M. Fenton, The Electrochem. Soc. Interface, Fall 2004, 17-19.

[3] Bio-Logic Application Note #32.
http://www.bio-logic.info/potentiostat/notes.html