The Impact of the Operational Parameters on the PEM Fuel Cell Long-Term Performance

V. Andrea, P.S.P. Oliveira, E. I. Santiago and M. Linardi

Instituto de Pesquisas Energéticas e Nucleares – IPEN-CNEN/SP.
Av. Lineu Prestes, 2242. Cidade Universitária – São Paulo – SP - Brazil

Durability represents one of the major barriers to the progress of the Proton Exchange Membrane Fuel Cells (PEMFCs). To elucidate the degradation of these devices, it is important to understand the issues regarding the long-term operation of PEMFCs. Thus, in this work it was analyzed the influence of the operational parameters such as relative humidity, cell temperature and the reactant flow rates on the long-term performance through experiments of 500 hours at steady state. It was observed that the degree of humidification strongly influences on the long-term performance. The test which presented the lowest global loss of performance (with both irreversible and reversible losses) was the one with the temperatures of the humidifiers and cell all set as 75°C and the reactants flow rates set as 300 and 200 ml.min^{-1} for the H_2 and O_2, respectively. Therefore, the water management is a key point in order to obtain better performances in long-term operation of PEMFCs.

Introduction

Durability still represents one of the major barriers to the entry of Proton Exchange Membrane Fuel Cells (PEMFCs) in the market. It is therefore important to understand the main phenomena involving the long-term operation of PEMFCs, since the best way to elucidate the degradation issues of these devices is operating them the closest manner to real operating conditions as possible. Relative humidity, cell temperature and the reactant flow rates are the main parameters influencing on the long-term performance, once the water management plays a crucial role on it (1). Although sufficient water content is required to maintain high proton conductivity of the membrane, excessive liquid water in the fuel cell can flood and block the pores of the Catalytic Layers (CLs), Gas Diffusion Layers (GDLs), and gas channels. Both a dry membrane and flooded electrode hinder the performance and lead to an accelerated degradation of the fuel cell (2). Other than that, when evaluating the fuel cell durability, an inadequate water management can cause a reversible loss of performance which conceals the actual degradation rate (3). Thus, in this work long-term tests were performed with variations of the main operational parameters in order to elucidate the influence of these settings on the operation of PEMFCs for long periods.

Experimental

Membrane Electrode Assembly (MEA)

The electrodes of the MEAs used in the tests were of 25 cm^2 and compounded by catalytic and gas diffusion layer. The catalytic layer was prepared through a ink made of 20 wt% Pt/C catalyst (BASF), 5% Nafion solution (Dupont) and organic solvents. This catalytic ink was applied by a sieve printing machine (EKRA, model E1) over carbon cloth (Electrochem, coated with 30wt% of PTFE), which worked as subtracts and gas diffusion layer. The platinum loading was of 0.4 $mgPt/cm^2$ for both anode and cathode. For all the MEAs, Nafion® 115 membranes (DUPONT) were used. The MEAs were put between two graphite plates with serpentine flow channels held in place by two end gold-plated plates.

Long-term tests

The long-term tests were performed using fuel cell test stations (FuelCon, model Evaluator-C) fully automated. The procedures used on the tests are the ones shown in the **Figure 1**. During the stationary procedure, the current was kept constant and the potential analyzed during 500 hours.

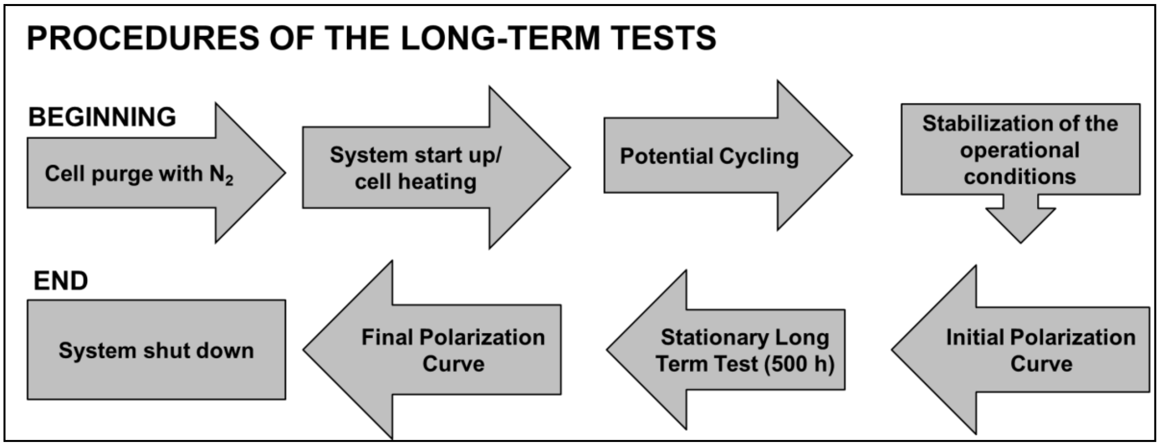

Figure 1. Procedures applied through the long-term tests.

Among the tests, cell temperature, relative humidity, H_2 and O_2 flow rates were varied according to the **Table I**, so that the influence of these parameters on the performance could be compared. For this study, around 10 tests were performed, but only 3 of them are presented here, once they can summarize what was the influence of operational parameters observed on all the tests implemented.

TABLE I. Operational parameters applied to the long-term tests.

		Operational Parameters							
		H_2			O_2			Cell	
		Temp. (°C)	**R. H. (%)**	**Flow ($NL.min^{-1}$)**	**Temp. (°C)**	**R. H. (%)**	**Flow ($NL.min^{-1}$)**	**Temp. (°C)**	**R. H. (%)**
Test #	**1**	90	100	220	80	100	185	70	100
	2	90	100	300	80	100	220	75	100
	3	75	100	300	75	100	220	75	100

The electrical profile of the MEAs were analyzed via polarization curves and the long-term performance were assessed by these three indexes, given in $\mu V.h^{-1}$:

Global Loss of Performance (GLP): it is the slope obtained from the linear regression applied over the curve described by the cell potential through the time. It is assumed this measure comprises both reversible and irreversible losses of performance.

Irreversible Loss of Performance (ILP): it is calculated by the difference between the cell potentials at the same current density (the same current density in which the cell was kept at the steady state) in the initial and final polarization curves, divided by the test time (500 hours).

Reversible Loss of Performance (RLP): it is obtained from the difference between the GLP and ILP.

Results

The **Fig. 2-a** presents the cell voltage vs. time profile of the *Test #1*, which was a single fuel cell operated at 70°C, RH= 100%, and hydrogen and oxygen flow rates of 220 mL min^{-1} and 185 mL min^{-1}, respectively. As it can be seen, the cell voltage sharply dropped after ~330 hours of operation. A comparison with the polarization curves (**Fig. 2-b**) obtained from the initial and final stages of the long-term test showed a slightly decrease in the performance, indicating that a good share of the decay of the potential observed in **Figure 2-a** is reversible. Such feature is probably resulting from the water accumulation (flooding) in the gas channels of the electrodes.

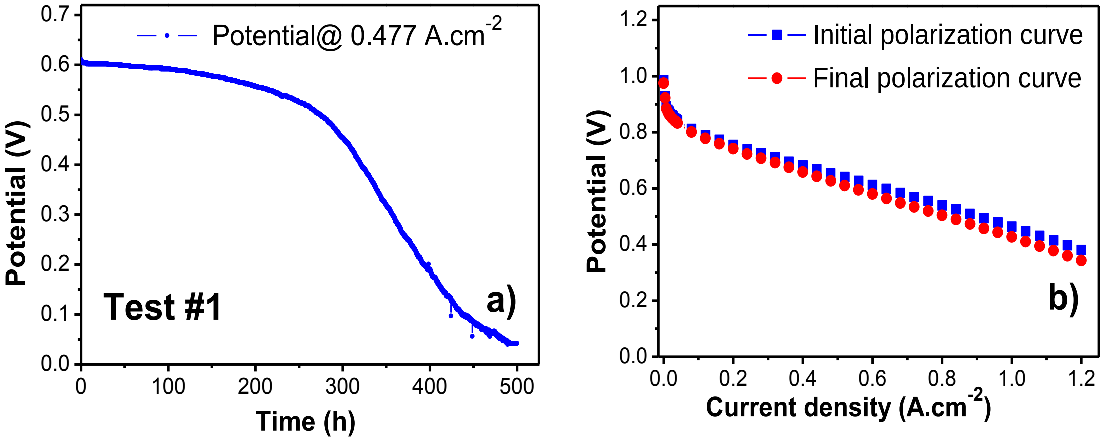

Fig. 2- data obtained from the Test #1 **a)** cell voltage vs. time profile; **b)** Polarization curves obtained immediately before and after the long-term test.

In the *Test #2*, represented by the **Fig. 3-a**, the temperature of the cell was raised to 75°C, as well as the reactant flow rates (300 and 220 mL min^{-1} as hydrogen and oxygen flow rates, respectively). A lower decay in the potential as a function of the time was evidenced, however, the reversible voltage loss persisted. The corresponding polarization curves at initial and final long-term test stages (**Fig. 3-b**) revealed no significant change in the fuel cell performance.

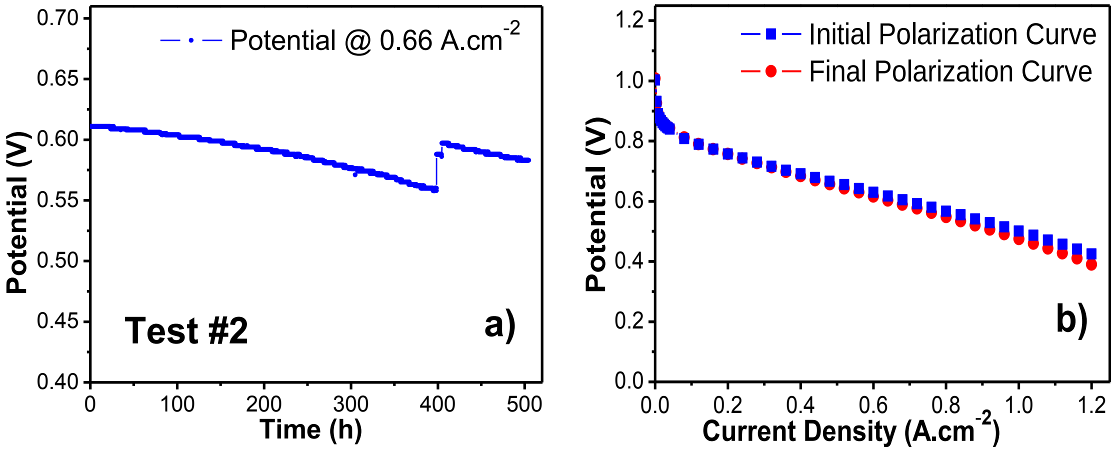

Fig. 3- data obtained from the Test #2 **a)** cell voltage vs. time profile; **b)** Polarization curves obtained immediately before and after the long-term test.

Fig. 4-a shows the *Test #3* cell voltage vs. time curve for a single fuel cell with hydrogen and oxygen humidifiers and cell temperature all set at 75°C. The hydrogen and oxygen flow rates were maintained at 300 mL min^{-1} and 220 mL min^{-1}, respectively. In this experiment, no appreciable voltage loss was evidenced, probably, as a result of a suppressed condensation of water due to lower humidification temperature. In comparison with the previous tests, the polarization profile (**Fig. 4b**) seems not to be altered, demonstrating that there is no important irreversible voltage loss. Nevertheless, as it can be analyzed in **Figure 4-a**, the reversible loss of performance still remains, indicating that either the chosen set of the operational parameters is still not the ideal ones for managing the water during these long-term operations or the cell engineering is not able to control the humidification inside the electrodes.

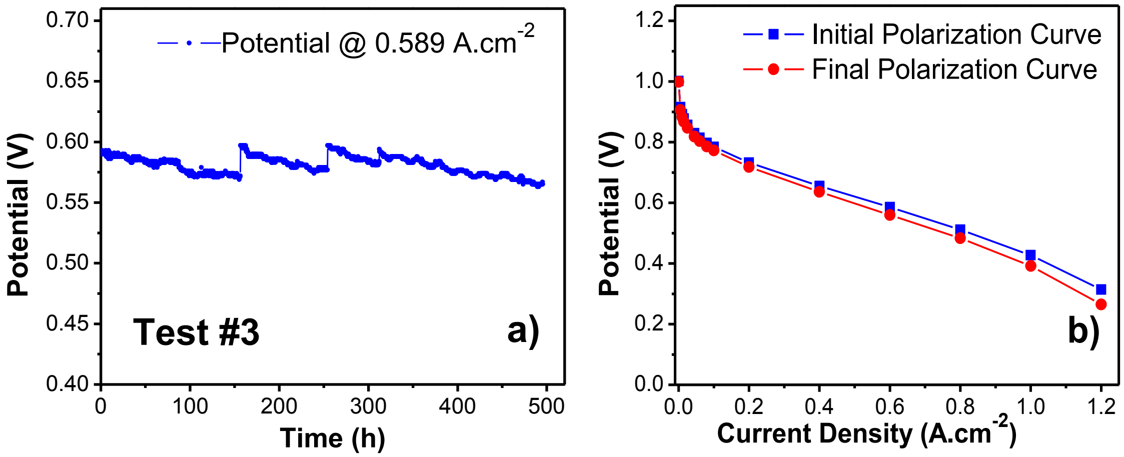

Fig. 4 - data obtained from the Test #2 **a)** cell voltage vs. time profile; **b)** Polarization curves obtained immediately before and after the long-term test.

The long-term performance losses estimated from tests are presented in Table II. As it can be observed, the Test #3 presented the lowest global and reversible performance losses, although the lowest irreversible performance loss was assessed from the Test #2.

Table II- Long-term performance losses assessed from the tests studied.

	Global Performance Loss (μVh^{-1})	**Reversible Loss (μVh^{-1})**	**Irreversible Performance Loss (μVh^{-1})**
Test #1	318	266	52
Test #2	133	101	32
Test #3	132	94	38

Conclusions

In this work, long-term tests with different operational parameters settings were investigated. It could be observed that the degree of humidification strongly influences on the long-term performances, once the excess of water contributes both to the reversible and irreversible performance loss through the time of operation. The water management is the key point for achieving better performances in long-term operations of PEMFCs. Even though the adjustments of the operational parameters done in the tests have largely improved the long-term performance of the cell, more refinements shall be made.

Acknowledgments

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