# Data from Experimental Analysis of the Performance and Load Cycling of a Polymer Electrolyte Membrane Fuel Cell

**Andrea Ramírez-Cruzado [1,†], Blanca Ramírez-Peña [1,†], Rosario Vélez-García [1,†], Alfredo Iranzo [1,2,\*] and José Guerra [1]**

[1] Thermal Engineering Group, Energy Engineering Department, School of Engineering, University of Sevilla, Camino de los Descubrimientos s/n. 41092 Sevilla, Spain; andramvil@alum.us.es (A.R.-C.); blancarami13@gmail.com (B.R.-P.); Rosario.velez.garcia@gmail.com (R.V.-G.); jjguerra@us.es (J.G.)

[2] AICIA (Andalusian Association for Research & Industrial Cooperation)—Thermal Engineering Group, Camino de los Descubrimientos s/n. 41092 Sevilla, Spain

\* Correspondence: airanzo@us.es; Tel.: +34-954-487174

† Contributed equally to this work.

**Abstract:** Fuel cells are electrochemical devices that convert the chemical energy stored in fuels (hydrogen for polymer electrolyte membrane (PEM) fuel cells) directly into electricity with high efficiency. Fuel cells are already commercially used in different applications, and significant research efforts are being carried out to further improve their performance and durability and to reduce costs. Experimental testing of fuel cells is a fundamental research activity used to assess all the issues indicated above. The current work presents original data corresponding to the experimental analysis of the performance of a 50 $cm^2$ PEM fuel cell, including experimental results from a load cycling dedicated test. The experimental data were acquired using a dedicated test bench following the harmonized testing protocols defined by the Joint Research Centre (JRC) of the European Commission for automotive applications. With the presented dataset, we aim to provide a transparent collection of experimental data from PEM fuel cell testing that can contribute to enhanced reusability for further research.

**Dataset:** Dataset submitted and to be published as a supplement to this paper in the journal *Data* (www.mdpi.com/xxx/s1).

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**Keywords:** fuel cell; polymer electrolyte membrane; polarization curve; load cycling; New European Driving Cycle

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## 1. Summary

The presented dataset contains original raw data files corresponding to experiments carried out with a 50 $cm^2$ polymer electrolyte membrane (PEM) fuel cell, as reported in Ramírez-Cruzado et al. [1]. A detailed description of the test bench and the fuel cell components is provided in [1]. A 50 $cm^2$ single cell from ElectroChem Inc. (Woburn, MA, United States) was used in the experiments. Graphite bipolar plates were used, with a serpentine flow field in a cross-flow layout [1]. The membrane was a Nafion 112 (DuPont, Wilmington, Delaware, United States) with 1.0 mg Pt/$cm^2$ catalyst layers. Toray TGP-H-060 gas diffusion layers (GDLs) by Toray Industries, Inc., Tokyo, Japan, were used in the cell, without microporous layers (MPL).

The experimental testing was carried out according to the testing protocols defined by the Joint Research Centre (JRC) of the European Commission for automotive applications [2].

The dataset relates to two main kinds of experiments:

- Firstly, cell performance experiments, where the polarization curves were recorded for different operating conditions. All testing conditions were variations with respect to reference conditions representative of automotive applications. By doing this, the impact of different variations in the temperature of the cell, pressure of reactants, or cathode stoichiometry could be analyzed. The operating conditions tested are indicated in Table 1 [1]. For the cell performance experiments, most of the operating conditions were repeated three times in order to enable reproducibility of the experiments, as described in [1].
- Second, durability experiments, where an example of the application of load changes according to the New European Driving Cycle (once adapted to fuel cells as indicated in [2]) is provided. This data set contains data of the polarization curve at the beginning of the test and at the end of the test in order to assess the eventual cell degradation, which was discussed in Ramírez-Cruzado et al. [1].

**Table 1.** Operating conditions defined for the fuel cell (according to the testing protocol [2]) [1].

| Operating Condition | Reference Condition | Test Temperature | Test Pressure | Test Cathode Stoichiometry |
|---|---|---|---|---|
| Cell Temperature (°C) | 80 | 70, 85 | 80 | 80 |
| Anode Pressure (kPa) [1] | 250 | 250 | 160; 190 | 250 |
| Cathode Pressure (kPa) [1] | 230 | 230 | 140; 190 | 230 |
| Anode Relative Humidity (%) | 50 | 50 | 50 | 50 |
| Cathode Relative Humidity (%) | 30 | 30 | 30 | 30 |
| Anode Stoichiometry (-) | 1.3 | 1.3 | 1.3 | 1.3 |
| Cathode Stoichiometry (-) | 1.5 | 1.5 | 1.5 | 1.3, 2.0, 3.5 |

[1] Absolute pressure.

The dataset was obtained during cell testing research work corresponding to the development of the funded research projects referenced at the end of this paper:

- Spanish Ministry of Science, Innovation and Universities, grant number ENE2017-91159-EXP (Bio-inspired designs for bipolar plates of PEM Fuel Cells with optimized water management);
- Spanish Ministry of Economy and Competitiveness, grant number UNSE15-CE2962 (Characterization and optimization of fuel cells for their integration in mobile and stationary applications).

The main publication based on the dataset is Ramírez-Cruzado et al. [1].

The lack of availability of real experimental data is hindering the research and development of PEM fuel cell technology. With the presented dataset, we aim to provide a transparent collection of experimental data on PEM fuel cell testing that can contribute to enhancing reusability for further research.

## 2. Data Description

The data contained in this work (as Supplementary Materials) are the following. A compressed .rar file is provided (Experimental_performance_load_cycling_PEMFC.rar), wherein two folders are included:

- Cell_Performance_Data. This folder contains four subfolders, corresponding to the different groups of tests indicated in Table 1, named Reference_Conditions_tests, Cell_Pressure_tests, Cell_Temperature_tests, and Cathode_stoichiometry_tests. Each of the subfolders contains the original raw data files (compressed in .rar) corresponding to the different operating conditions for this group of tests, as follows:

○      Reference_Conditions_tests contains the Reference Conditions test;

○      Cell_Temperature_tests contains Temperature_70C.rar and Temperature_85C.rar;

○      Cell_Pressure_tests contains Pressure_anode160kPa_cathode140kPa.rar and Pressure_anode190kPa_cathode190kPa.rar;

○      Cathode_stoichiometry_tests contains Lambda_cat_3_5.rar (corresponding to $\lambda_c$ = 3.5), Lambda_cat_2_0.rar (corresponding to $\lambda_c$ = 2.0), and Lambda_cat_1_3.rar (corresponding to $\lambda_c$ = 1.3).

- Cell_Load_Cycling_NEDC_Data. This folder contains an ASCII (text) file with the experimental raw data of the test, named Cell_Load_Cycling_NEDC_experiment.rar. After decompression, the original raw data file can be obtained.

All raw data files are organized with the same structure. There is one raw datum for each clock time, where the acquisition time was 1 s. All variables recorded during the experiment are presented in columns. Table 2 indicates the original name of the column (in Spanish language), the translated name of the column, the units of the variable, and a brief explanation. The locations of the different instrumentation are shown in Figure 1, where a simplified P&ID (Piping and Instrumentation Diagram) is included for the sake of clarity.

**Table 2.** Description of the dataset variable contents.

| Column ID | Original Variable Name | Translated Variable Name | Unit | Description |
|---|---|---|---|---|
| 1 | FECHA | Date | dd/mm/yy | Actual date |
| 2 | HORA | Time | hh:mm:ss | Actual time |
| 3 | PT001 | PT001 | bar(a) | Pressure [1] |
| 4 | PT002 | PT002 | bar(a) | Pressure [1] |
| 5 | PT003 | PT003 | bar(a) | Pressure [1] |
| 6 | PT004 | PT004 | bar(a) | Pressure [1] |
| 7 | PT005 | PT005 | bar(a) | Pressure [1] |
| 8 | PT006 | PT006 | bar(a) | Pressure [1] |
| 9 | PT007 | PT007 | bar(a) | Pressure [1] |
| 10 | BP001 | BP001 | bar(a) | Pressure [1] |
| 11 | BP002 | BP002 | bar(a) | Pressure [1] |
| 12 | FT001 | FT001 | Nl/min | $H_2$ flow rate (low flow) [1] |
| 13 | FT002 | FT002 | Nl/min | $H_2$ flow rate (high flow) [1] |
| 14 | FT003 | FT003 | Nl/min | Air flow rate (low flow) [1] |
| 15 | FT004 | FT004 | Nl/min | Air flow rate (high flow) [1] |
| 16 | FT005 | FT005 | Nl/min | Coolant flow rate [1,2] |
| 17 | HT001 | HT001 | % | Relative humidity [1,3] |
| 18 | HT002 | HT002 | % | Relative humidity [1,3] |
| 19 | V001 | V001 | V | Cell voltage |
| 20 | V002 | V002 | V | Cell voltage [2] |
| 21 | V003 | V003 | V | Cell voltage [2] |
| 22 | V004 | V004 | V | Cell voltage [2] |
| 23 | V005 | V005 | V | Cell voltage [2] |
| 24 | V006 | V006 | V | Cell voltage [2] |
| 25 | V007 | V007 | V | Cell voltage [2] |
| 26 | TT001 | TT001 | °C | Temperature [1] |
| 27 | TT002 | TT002 | °C | Temperature [1] |
| 28 | TT003 | TT003 | °C | Temperature [1] |
| 29 | TT004 | TT004 | °C | Temperature [1] |
| 30 | TT005 | TT005 | °C | Temperature [1] |
| 31 | TT006 | TT006 | °C | Temperature [1] |
| 32 | TT007 | TT007 | °C | Temperature [1] |
| 33 | TT008 | TT008 | °C | Temperature [1] |
| 34 | TT009 | TT009 | °C | Temperature [1] |
| 35 | TT010 | TT010 | °C | Temperature [1] |
| 36 | TT011 | TT011 | °C | Temperature [1] |
| 37 | TT012 | TT012 | °C | Temperature [1] |
| 38 | TT013 | TT013 | °C | Temperature [1] |
| 39 | TT014 | TT014 | °C | Temperature [1] |
| 40 | TT015 | TT015 | °C | Temperature [1] |
| 41 | TT016 | TT016 | °C | Temperature [1] |
| 42 | TT017 | TT017 | °C | Temperature [1] |
| 43 | TT018 | TT018 | °C | Temperature [1] |
| 44 | TT019 | TT019 | °C | Temperature [1] |
| 45 | TT020 | TT020 | °C | Temperature [1] |
| 46 | TT021 | TT021 | °C | Temperature [1] |
| 47 | TT022 | TT022 | °C | Temperature [1] |
| 48 | TT023 | TT023 | °C | Temperature [1] |
| 49 | TT024 | TT024 | °C | Temperature [1] |
| 50 | TT025 | TT025 | °C | Temperature [1] |
| 51 | TT026 | TT026 | °C | Temperature [1] |
| 52 | INTENSIDAD | CURRENT | A | Cell current |

[1] refer to P&ID in Figure 1; [2] not used in the experiment; [3] not calibrated, not used in the experiment (Relative Humidity in reactant supply is set by adjusting humidifier temperature and line temperature).

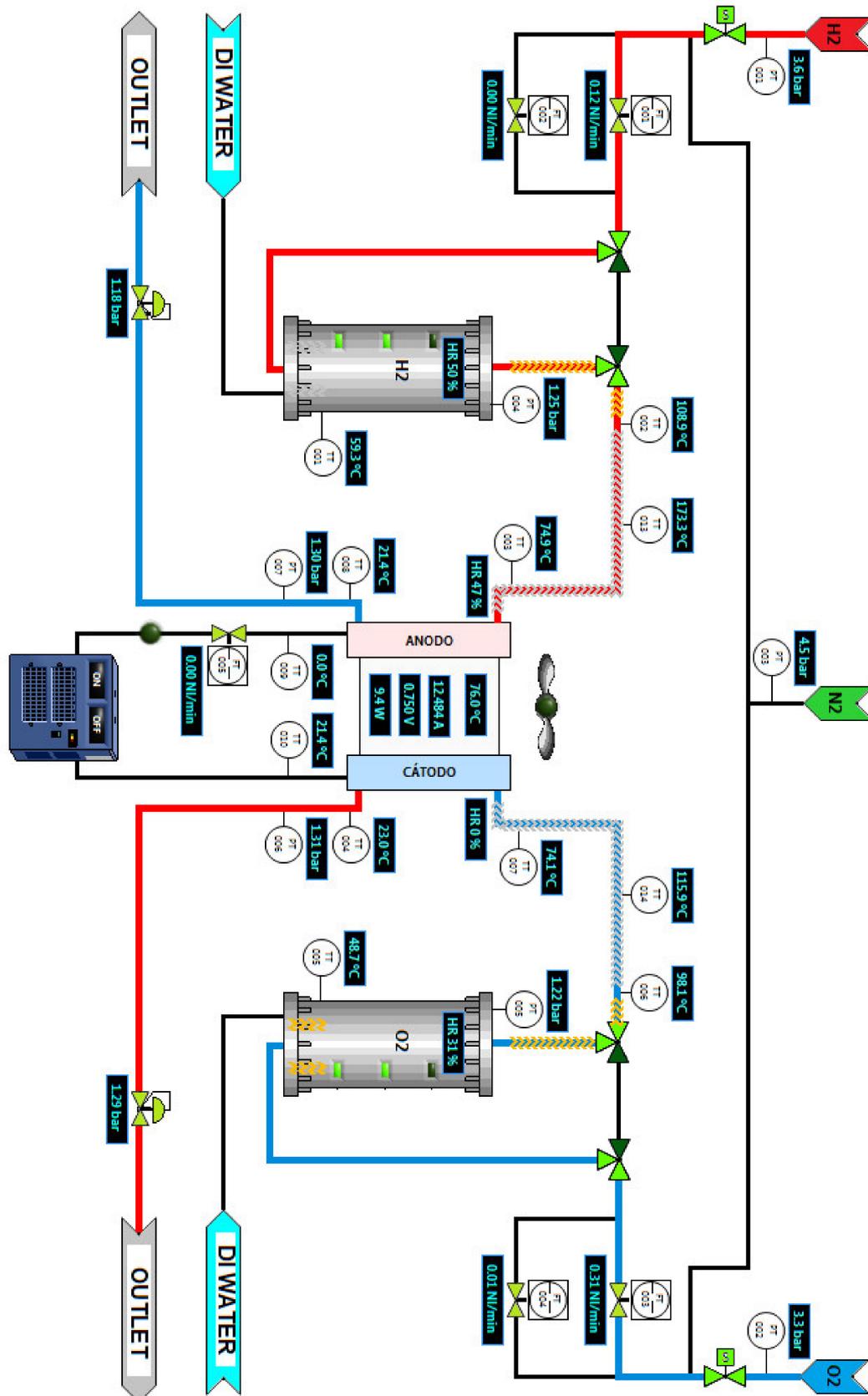**Figure 1.** Simplified P&ID of the test bench showing the instrumentation referred in Table 2.

## 3. Methods

The data were acquired with an acquisition time of 1 s and a dwell time of 200 s. The experiments were carried out according to the testing protocols described in [2], where the last 30 datasets for each current density were used for the derivation of the polarization curve (acquisition time). Most polarization curves were repeated three times in order to assess the reproducibility of the measurements. This was depicted in [2] by including error bars in the measurement points (calculated using the standard deviation of the three samples).

## 4. User Notes

The first part of the datafiles corresponds to the start-up of the cell in order to reach the current density defined for the conditioning step described in [2], which corresponds to 0.5 A/cm$^2$. The last column corresponds to the current, which can be easily converted to current density by dividing by the active area of the cell (50 cm$^2$). In order to have a quick overview of the data and the overall test contained in each datafile, it is recommended to create a graph representing cell voltage and cell intensity against time. The polarization curves consist of both the increasing current step and the decreasing current step, as described in [1,2].

**Conflicts of Interest:** The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

## References

1. Ramírez-Cruzado, A.; Ramírez-Peña, B.; Vélez-García, R.; Iranzo, A.; Guerra, J. Experimental analysis of the performance and load cycling of a Polymer Electrolyte Membrane Fuel Cell. *Processes* **2020**, in press. [CrossRef]

2. Tsotridis, G.; Pilenga, A.; De Marco, G.; Malkow, T. *EU Harmonised Test Protocols for PEMFC MEA Testing in Single Cell Configuration for Automotive Applications*; Publications Office of the European Union: Luxembourg, 2015; ISBN 978-92-79-54133-9/978-92-79-54132-2. [CrossRef]