



GAIA

NEXT GENERATION AUTOMOTIVE MEMBRANE ELECTRODE ASSEMBLIES

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DELIVERABLE REPORT

D2.3 – TEST PROTOCOLS DEFINED AND DOCUMENTS ISSUED. BASELINE CHARACTERISATION OF STATE OF THE ART AUTOMOTIVE MEAs IN FULL SIZE FC HARDWARE COMPLETED

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DISSEMINATION LEVEL		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	
NATURE OF THE DELIVERABLE		
R	Report	X
P	Prototype	
D	Demonstrator	
O	Other	

SUMMARY	
Keywords	<i>D2.3, Test protocols, automotive fuel cell baseline characterisation</i>
Abstract	<i>Test protocols for the GAIA Project and documents for the partners for testing are released. The state of the art cells were tested at BMW and the gap according to the project target is defined. Especially at operating points with low current densities the defined project target is reached within 95% of the actual performance. At operating points with high current densities the gap to the project target is much higher and the focus of the GAIA project will be on the increase of the performance at this operating conditions.</i>
Public abstract for confidential deliverables	

REVISIONS			
Version	Date	Changed by	Comments
0.1	20.08.2019	Markus Perchthaler	First version released
1.0	09.10.2019	Markus Perchthaler	Baseline cell results included.

**TEST PROTOCOLS DEFINED AND DOCUMENTS ISSUED.
BASELINE CHARACTERISATION OF STATE OF THE ART AUTOMOTIVE MEAs
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CONTENTS

1. Introduction.....	4
2. Scope	4
3. Discussion	8
4. Conclusions and future work.....	8
5. References.....	8
6. Appendix.....	8

1. INTRODUCTION

For component screening and verification of reaching of project milestones, appropriate test protocols according to BMW operating strategy are set up and protocols are shared among the project partners in WP2 and WP6. In D2.1 the operating conditions, performance and durability requirements based on a virtual fuel cell system were defined. This specifications were transferred into protocols for testing 50 cm² and 285 cm² (automotive size) test cells.

Moreover the first tests in automotive single cells were performed and new key requirements for MEAs at elevated operating temperatures were derived.

2. SCOPE

The scope of deliverable D2.3 is on the harmonisation of test protocols for the GAIA Project among the WP2 and WP6 participants. The testing protocols are derived from D2.1, where the automotive operating conditions are defined.

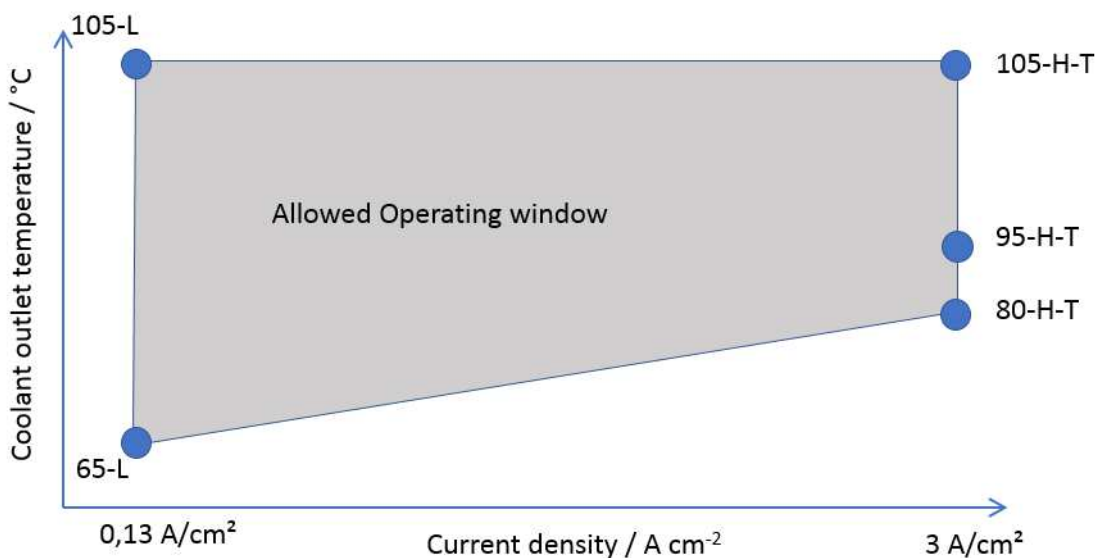


Figure 1: Desired allowed operating conditions for the GAIA automotive size short stack

In Figure 1 the operating window with respect to current density is shown. This graph was explained in D2.1 and is the basis for the MEA characterisation protocols, which are set up. The other basis is EU Project No. 303445, which defined the procedures for PEM Fuel cell stack tests for industry.

Start up (according to INSPIRE Project):

In the EU funded Project Inspire (Project. No 700127) a current density homogeneous start-up was developed for the cell hardware used in GAIA. This recommended start up procedure was taken over. The main message to point out is that the procedure consists the following three parts:

- 1.) Preparation of cell and test rig
 - a. inertisation with nitrogen
 - b. heating times
 - c. increases of gas pressures
- 2.) Start of current production and increasing of current to maximum current density
 - a. No fixed stoichiometry is used. Stoichiometry changes for every current density step.
- 3.) Preparation of cell for first Polarisation curve
 - a. The last operating point in the start-up prepares the cell for the first polarisation curve.

Details for the start-up can be found in the appendix.

Definition of polarisation curve testing protocol:

In Project Nr. 303445 (Development of PEM Fuel Cell Stack Reference Test Procedures for Industry) in Test Module P-08 the procedure for recording a polarisation curve is described. Following this procedure the specification 30201 was set up.

The polarisation curve 30201 consists of following steps:

- 1.) Pre-conditioning the cell at 0,3 A/cm² for 3600 seconds.
- 2.) Lowering the current density to 0,1 A/cm² for 300 seconds.
- 3.) Increasing the current density with 0,1 A/cm²/300 seconds up to 3 A/cm² or cell voltage lower than 0,3 V.
- 4.) Lowering the current density with different hold times.
- 5.) Holding OCV for 35 seconds.

Test conditions for Polarisation curve 1-5 for 1-4 cell stack:

Coolant inlet temperature (T_SI_CL):	60 °C
Coolant flow rate	1,5 l/min/cell
Fuel/Air dew points (DPT_Si_A / DPT_Si_C):	46 °C
Fuel Stoichiometry (Stoic_S_A):	1,5
Oxidant Stoichiometry (Stoic_S_C):	2,0
Fuel pressure stack outlet anode (P_So_A):	2,0 bara
Oxidant pressure stack outlet cathode (p_SO_C):	2,0 bara

Test condition for polarisation curve 6 for 1-4 cell stack:

Coolant inlet temperature (T_SI_CL):	105 °C
Coolant flow rate	1,5 l/min/cell
Fuel/Air dew points (DPT_Si_A / DPT_Si_C):	86 °C
Fuel Stoichiometry (Stoic_S_A):	1,5
Oxidant Stoichiometry (Stoic_S_C):	2,0
Fuel pressure stack outlet anode (P_So_A):	2,0 bara
Oxidant pressure stack outlet cathode (p_SO_C):	2,0 bara

The details of the procedure are shown in the appendix.

Definition of shut down procedure:

- 1.) Set current to 0.
- 2.) Set anode outlet and cathode outlet pressure to 0 bar(r).
- 3.) Purge anode and cathode with 1 l/min N2
- 4.) Switch off humidifier
- 5.) Optional: bypass humidifier
- 6.) Wait until cell voltage < 0,2 V or 10 min
- 7.) Switch off test rig.

Definition of operating point test protocol

The GAIA operating points test protocol consists of following steps:

- 1.) Start up (according to Inspire Project)
- 2.) Polarisation curve 1
- 3.) Polarisation curve 2
- 4.) Cell water content reset procedure (Appendix)
- 5.) Polarisation curve 3
- 6.) Polarisation curve 4

- 7.) Polarisation curve 5
- 8.) Defined transition to 65-L and hold time of 7200 seconds
- 9.) Defined transition to 80-M and hold time of 7200 seconds
- 10.) Defined transition to 80-M+ and hold time of 7200 seconds
- 11.) Defined transition to 80-H-T and hold time of 7200 seconds
- 12.) Defined transition to 95-H-T and hold time of 7200 seconds
- 13.) Defined transition to 105-H-T and hold time of 7200 seconds
- 14.) Defined transition to 80-M+ and hold time of 7200 seconds
- 15.) Polarisation curve 6
- 16.) Shutdown

Definition of degradation testing protocol:

In Deliverable D2.1 a typical drive cycle profile from a virtual fuel cell vehicle based on real customer data was calculated. With this information a degradation test protocol was set up. In Figure 2 the degradation test cycle is presented schematically.

The degradation test consists of four major parts:

- 1.) Start-up
- 2.) Polarisation Curve
- 3.) Transition to operating point 65-L
- 4.) Start of load cycle according to Figure 2.
- 5.) After 600 hours recording of polarisation curve
- 6.) Shutdown.

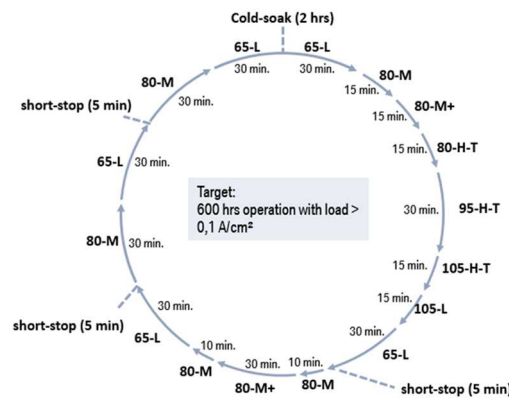


Figure 2: Degradation test cycle with an operating time of > 600 hours with a current > 0,1 A/cm²

After the degradation test cycle the GAIA operating points protocol has to be performed again. With the change in cell voltage at the GAIA operating points, individual degradation rates for every operating point have to be calculated.

In Figure 2 the concepts of short-stops and cold soaks are introduced. This stops are mimicking the idle phase, and the phases when the fuel cell system is switched off daily. The introduction of these phases is necessary to overcome platinum oxide formation and sulfonic acid adsorption, which are reversible degradation mechanisms in an operating fuel cell.

Definition of cold soak:

- Set current to 0
- Set H2 flow to 65-L conditions
- Decrease anode dew point to 20 °C
- Set air flow to 0

- Close cathode Valves at inlet/outlet
- Set coolant outlet temperature to 25 °C
- Keep temperature at 25 °C for 7200 seconds
- Set coolant outlet to 65 °C
- Set H2 Dewpoint to 65-L conditons
- Open cathode valves
- Switch air flow on
- Set current to 65-L conditions

Definition of short stop:

- Set H2 flow to 65-L conditions
- Set current to 65-L conditions
- Set air flow to 0
- Close cathode Valves at inlet/outlet
- When minimum cell voltage is lower than 0,3 V, set current to 0.
- Wait 5 min at 0 current.
- Open cathode valves
- Switch air flow on
- Set current to 65-L conditions

Baseline MEA characterisation of state of the Art MEAs in automotive size fuel cell hardware completed.

According to the description of Work BMW tested the fuel cell hardware, which was chosen in D2.2, according to the test protocol mentioned in section 2.

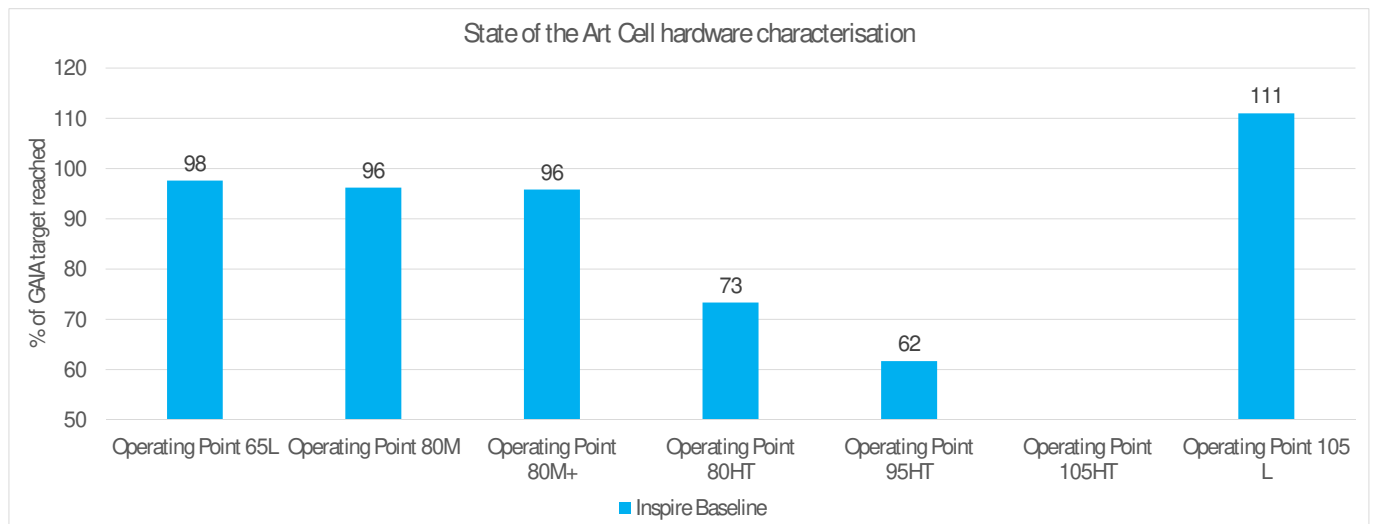


Figure 3: Results from the testing of the state of the art cell hardware with original Inspire Configuration and first GAIA configuration in relation to the GAIA project targets.

In Figure 3 the results from the state of the art cell hardware are shown and the comparison of Baseline to GAIA Project targets is discussed.

Especially at the low current densities (65L, 80M, 80M+, 105L) the target defined in D2.1 for the GAIA project is very close or even better compared to the GAIA project targets.

At higher current densities and higher operating temperatures the gap to the project targets becomes dominant. Especially for the cell hardware defined in D2.2 (INSPIRE Baseline), the gap increases to -27% for 80HT and to 38 % for 95 HT. At 105HT cell voltages < 0,3 V were measured, which leads to a skip of the operating point.

3. DISCUSSION

In Section 2 the test protocols which have to be used among the project partners, are defined. These conditions are agreed within the WP2 Project partners. Moreover the first cell hardware in the GAIA Project was received and the baseline was recorded. Especially at high current densities the gap to the GAIA project targets are becoming dominant. At lower current densities ($< 1 \text{ A/cm}^2$) the chosen hardware showed reasonable close cell voltages according to the GAIA Project target.

4. CONCLUSIONS AND FUTURE WORK

The test protocols are implemented in the individual test stations at the WP2 and WP6 project partners. Especially at higher current densities the results of the state of the art MEAs are showing that the focus of the GAIA project will be on the improvement of the performance under these operating conditions.

5. REFERENCES

<http://stacktest.zsw-bw.de/>

6. APPENDIX

STARTUP PROCEDURE:



Microsoft Excel
Macro-Enabled Wor

POLARIZATION CURVE 30201:



Microsoft Excel
Macro-Enabled Wor

GAIA OPERATING POINT TEST PROTOCOL:



Microsoft Excel
Macro-Enabled Wor