Test report

Test number	TV500837_1
Test descriptive name	DOE Data

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Revision log

Revision	Date	Change	By
a0	2022-11-21	First version	Patrik Karlsson
a1	2022-11-24	Aligned parameters table	Patrik Karlsson

1 Introduction

Here follows the documentation for the design of experiment (DOE) fuel cell stack dataset.

2 Method

The test was performed in the PowerCell lab facilities. In *Appendix B. Test setup images* the test object is shown in the lab environment.

2.1 Test object

Stack platform	P-stack
Stack reference	P10
Number of cells	455

2.2 Test equipment

Test station	Greenlight Innovation G900 150kW.
Additional sensors	Fuel cell stack was mounted with CVM on both sides of the stack to enable detailed study of voltage behavior. Ambient temperature sensor hanging in the air next to the stack.

2.3 Test procedure

The fuel cell stack was operated at a total of 505 different operating points with the purpose of serving as a basis for a design of experiment (DOE) stack data model. The test sequence applies a randomized structure with adaptation to the cooling system capabilities. A stabilization criterion was applied before each test point, waiting for all setpoints to be met before starting a 15-minute data collection. The operating points themselves were chosen to cover the fuel cell operating parameter space while considering the existing test stand capabilities and non-destructive testing.

2.4 Data analysis

For each of the 15-minute load point steady-state data, all the parameters of the last 50s seconds have been sampled and averaging performed. See *Appendix A: Test station critical operating condition parameter accuracy list and Appendix C: All parameters* for data parameter information and description.

3 Results

The averaged data output presented as a table file named “DOE data_TV500873.xlsx” is the result and delivery of the test campaign.

4 Summary

The DOE test has here been documented to serve as a description of the data table file named “DOE data_TV500873.xlsx”.

Appendix A: Test station critical operating condition parameter accuracy list

Description	Component type	Measurement accuracy	Control accuracy	Log data variable name	Unit
Stack current	Electric load measurement	1 (0.1% of 1000A)		current	A
Stack voltage	Electric load measurement	0.79 (0.1% of 790V)		voltage	V
Total anode flow	MFC		For >1670NLPM: 1% of full range For <1670NLPM: ±0.5% of reading and ±0.1% of full range.	total_anode_stack_flow	NLPM
Total cathode flow	MFC			total_cathode_stack_flow	NLPM
Anode hydrogen flow	MFC			flow_anode_h2_mfc_total	NLPM
Anode nitrogen flow	MFC			flow_anode_n2_mfc_total	NLPM
Cathode air flow	MFC			flow_cathode_air_mfc_total	NLPM
Coolant flow	Flow meter	±1% of reading		flow_coolant	LPM
Anode gas dewpoint	Thermocouple	±0.5°C	<±2°C	temp_anode_dewpoint	°C
Anode temperature gas stack inlet	Thermocouple	±1°C	<±1.5°C	temp_anode_inlet	°C
Anode temperature gas stack outlet	Thermocouple	±1°C	<±1.5°C	temp_anode_outlet	°C
Cathode gas dewpoint	Thermocouple	±0.5°C	<±2°C	temp_cathode_dewpoint	°C
Cathode temperature gas stack inlet	Thermocouple	±1°C	<±1.5°C	temp_cathode_inlet	°C
Cathode temperature gas stack outlet	Thermocouple	±1°C	<±1.5°C	temp_cathode_outlet	°C
Coolant temperature stack inlet	Thermocouple	±1°C	<±2°C	temp_coolant_inlet	°C
Coolant temperature stack outlet	Thermocouple	±1°C	<±2°C	temp_coolant_outlet	°C
Anode pressure stack inlet	Pressure transmitter	±0.02bar	±0.03bar at steady state	pressure_anode_inlet	barg
Anode pressure stack outlet	Pressure transmitter	±0.02bar	±0.03bar at steady state	pressure_anode_outlet	barg

Cathode pressure stack inlet	Pressure transmitter	±0.02bar	±0.03bar at steady state	pressure_cathode_inlet	barg
Cathode pressure stack outlet	Pressure transmitter	±0.02bar	±0.03bar at steady state	pressure_cathode_outlet	barg
Coolant pressure stack inlet	Pressure transmitter	±0.02bar	±0.03bar at steady state	pressure_coolant_inlet	barg
Coolant pressure stack outlet	Pressure transmitter	±0.02bar	±0.03bar at steady state	pressure_coolant_outlet	barg
Cell voltage monitoring, CellSense (mounted on anode outlet side, meaning right side when facing the power terminals).	Voltage measurement	±10mV		CellSense_ …	V/mV
Cell voltage monitoring, Metis (dev. prototype) (mounted on anode inlet side, meaning left side when facing the power terminals).	Voltage measurement	<±10mV		metis_ …	V

Notes:

- Control accuracy tells us how close to the set-points we can expect to reach in general.
- NLPM defined at 0°C and 101325 Pa(a)

Appendix B. Test setup images

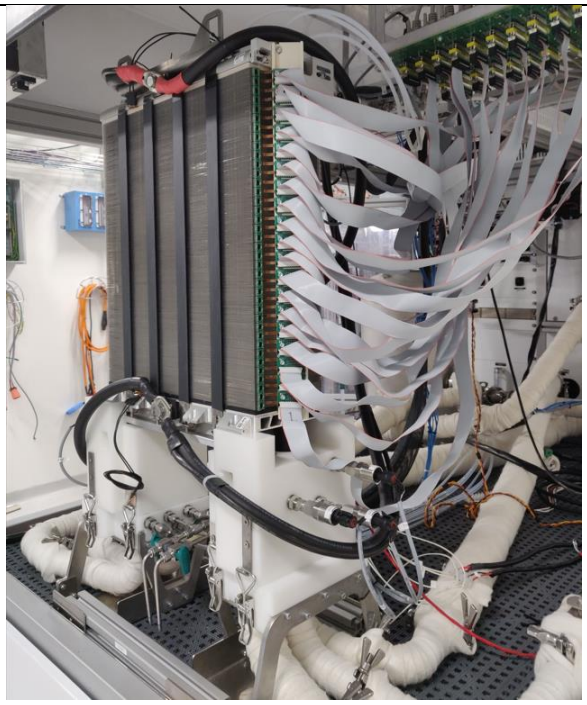

Image 1. As seen from the right side (when facing the stack power terminals).

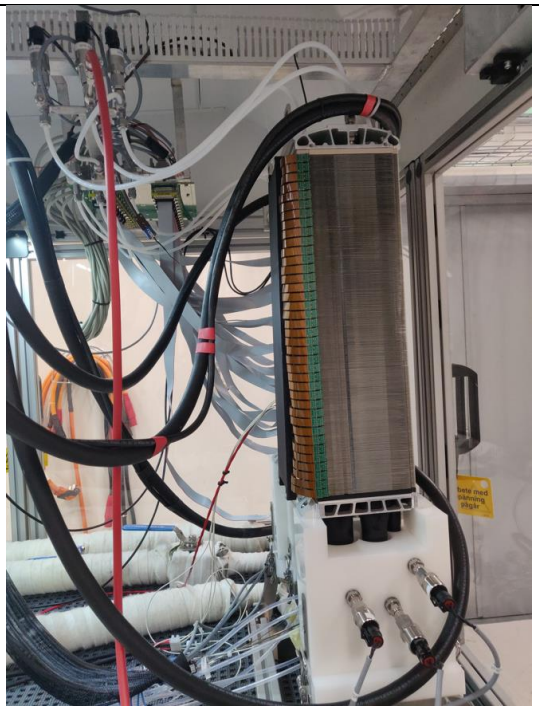

Image 2. As seen from the left side (when facing the stack power terminals).

Appendix C: All parameters

Variable name	Unit	Description
CellSense_Avg	V	
CellSense_Max	V	
CellSense_Max_min	mV	
CellSense_Min	V	
CellSense_std	mV	
Temperature_ambient_stack	°C	Ambient temperature sensor (next to stack)
anode_inlet_rel_hum	%	Calculated from gas temperature and dewpoint (indicates gas RH not stack/membrane RH)
anode_stoich	N/A	
anode_stoich_set	N/A	
cathode_inlet_rel_hum	%	Calculated from gas temperature and dewpoint (indicates gas RH not stack/membrane RH)
cathode_stoich	N/A	
cathode_stoich_set	N/A	
cell_active_area	cm^2	
cell_count_total	cells	
current	A	
current_set	A	
flow_anode_h2_mfc_total	NLPM	
flow_anode_h2_mfc_total_set	NLPM	
flow_anode_n2_mfc_total	NLPM	
flow_anode_n2_mfc_total_set	NLPM	
flow_cathode_air_mfc_total	NLPM	
flow_cathode_air_mfc_total_set	NLPM	
flow_cathode_n2_mfc_total	NLPM	
flow_cathode_n2_mfc_total_set	NLPM	
flow_coolant	LPM	
flow_coolant_set	LPM	
level_anode_exhaust_drainer_high	0/1	Test station diagnostic variable
level_anode_exhaust_drainer_mid_low	0/1	Test station diagnostic variable
level_cathode_exhaust_drainer_high	0/1	Test station diagnostic variable
level_cathode_exhaust_drainer_mid_low	0/1	Test station diagnostic variable
metis_CVM_Cell_Voltage_Max	V	
metis_CVM_Cell_Voltage_Max_Position	N/A	
metis_CVM_Cell_Voltage_Mean	V	
metis_CVM_Cell_Voltage_Min	V	
metis_CVM_Cell_Voltage_Min_Position	N/A	

metis_CVM_Stack_Voltage	V	
power	kW	
pressure_anode_inlet	barg	
pressure_anode_outlet	barg	
pressure_anode_set	barg	
pressure_cathode_inlet	barg	
pressure_cathode_outlet	barg	
pressure_cathode_set	barg	
pressure_coolant_inlet	barg	
pressure_coolant_outlet	barg	
pressure_coolant_set	barg	
signal_in_h2_sensor	% LEL	Test station diagnostic variable
signal_in_h2_sensor_second	% LEL	Test station diagnostic variable
system_state	<enum>	Test station diagnostic variable
temp_anode_dewpoint	°C	
temp_anode_dewpoint_set	°C	
temp_anode_gas_inlet_set	°C	
temp_anode_in_out_diff	°C	
temp_anode_inlet	°C	
temp_anode_outlet	°C	
temp_cathode_dewpoint	°C	
temp_cathode_dewpoint_set	°C	
temp_cathode_gas_inlet_set	°C	
temp_cathode_in_out_diff	°C	
temp_cathode_inlet	°C	
temp_cathode_outlet	°C	
temp_coolant_in_out_diff	°C	
temp_coolant_inlet	°C	
temp_coolant_inlet_set	°C	
temp_coolant_outlet	°C	
total_anode_stack_flow	NLPM	
total_anode_stack_flow_set	NLPM	
total_cathode_stack_flow	NLPM	
total_cathode_stack_flow_set	NLPM	
valve_anode_exhaust_drainer	Off/On	Test station diagnostic variable
valve_cathode_exhaust_drainer	Off/On	Test station diagnostic variable
variable_01		Test point reference
voltage	V	Stack voltage measured at power terminals