EUROPEAN COMMISSION

SEVENTH FRAMEWORK PROGRAMME
FUEL CELLS AND HYDROGEN JOINT UNDERTAKING (FCH JU)
THEME SP1-JTI-FCH.2013.3.5
Field demonstration of large scale stationary power and CHP fuel cell system

GA No. 621256

DEMCOPEM 2MW

Demonstration of a combined heat and power 2MWe PEM fuel cell generator and integration into an existing chlorine production plant

Deliverable No.	D6.8	
Deliverable Title	Report on stack failure causes	
Dissemination level	Public	
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Issue date	29-06-2018	

Publishable summary

Not applicable

Contents

1 Executive summary

The stack maintenance of the DEMCOPEM-2MW power plant is evaluated for the first 18 months of operation in Yingkou, China. Only a very small number of stacks were returned to Nedstack for analyses and repair. During the testing and commissioning period, incidentally a defective CVM board was replaced. Since the Site Acceptance Test (SAT) in sept 2016, two batches of in total 12 stacks have been shipped back to Nedstack for repair.

After the first operational months a first return shipment of five stacks was received. Some performance decrease was observed, which was restored after reconditioning. Also a malfunctioning CVM board and erratic bipolar plates were encountered.

In the beginning of 2017, a second repair shipment of seven stacks has been investigated and repaired by Nedstack. Six of these stacks were returned due to repetitive low cell voltage trips for cell 75, being the first cell after the inlet. This was shown to be caused by clogging of the anode inlet for cell 75 by Teflon fragments, which must have originated from the upstream hydrogen subsystem. After repair and reconditioning the performance was recovered to virtually the original Beginning of Life (BoL) level. After reinstallation of these stacks the problem of faulty inlet cells seems to have disappeared, indicating that the Teflon particle contamination was an incidental event of limited quantity.

2 Introduction

The Demcopem-2 MW unit was installed at the Ynnovate site in Yingkou, Liaoning, China, during the summer of 2016. During August and Sept commissioning and SAT was carried out by Ynnovate, Nedstack and MTSA, after which the plant was put in normal operation. Also in Oct 2016 and Jan 2017 the plant has been visited. During these visits it appeared that Ynnovate's site utilities were not always completely according to the required specifications.

During the first 18 months of operation two return shipments have been received: after the first operational months a return shipment of five stacks was received to check the performance and to repair malfunctioning stacks; In the beginning of 2017, a second repair shipment of seven stacks has been investigated and repaired by Nedstack. Very recently another repair batch of 7 stacks has been shipped, but since investigations just started these have not been considered for this report. The relevant data of the investigated stacks are summarized in Table 1 below:

Table 1 - return stacks during the first 18 months of operation

no	Stackno.	Group	Position	reason of return /		removal	arrival	operational
		1 - 6	1 - 14	cell	plant observation	date	date	hrs
1	2083	2	14	1-3, 75	reduced cell voltage	aug	15-Sep	~10
2	2004	1	5	2-5	stack trip/no OCV	sept	10-Nov	10
3	2245	5	8	1	stack trip	15-Oct	10-Nov	431
4	2026	1	13	40, 41	low cell voltage	21-Oct	10-Nov	476
5	2252	5	1	8	low cell voltage	21-Oct	10-Nov	431
6	2028	1	1	1	stack trip	02-Nov	17-02-17	484
7	2001	1	2	75	stack trip	13-Jan	17-02-17	1634
8	2342	6	11	75	stack trip	13-Jan	17-02-17	222
9	2325	6	4	75	low cell voltage	15-Jan	17-02-17	1239
10	2332	6	4	75	low cell voltage	17-Jan	17-02-17	1048
11	2334	6	13	75	stack trip	25-Jan	17-02-17	1379
12	2162	3	9	75?	stack trip	dec	17-02-17	1450

As can be seen the first shipment contained stacks with up to about 500 hrs of operation, while the second shipment had stacks with up to 1600 hrs of operation. Most of the stacks possessed specific cells with reduced cell voltage. In some cases this voltage was even below the threshold value, which caused a trip of the respective group (indicated as stack trip, since the specific stack causes a stack group to shut down).

3 Stack performance and repair activities of returned stacks

Two return shipments took place in the first 18 months of operation, one in 2016 and one in 2017. Since also the characteristics such as operation time and reason for return were different these will be discussed separately

3.1 First return shipment (2016)

After the first months of operation some stacks were returned for a routine check and some stacks showed either reduced cell voltages or had (repeatedly) caused stack trips, i.e. triggered automatic shutdown of a group of stacks. After analyses the following repair actions took place:

- Replacement faulty CVM board (1x)
- Replacement erratic cell plates (2x)
- None (2x)

All stacks were QC tested before return to China. Performance curves of a typical stack are shown in Fig 1 for the Beginning of Life (BoL), after 430 operational hrs in China, and after reconditioning.

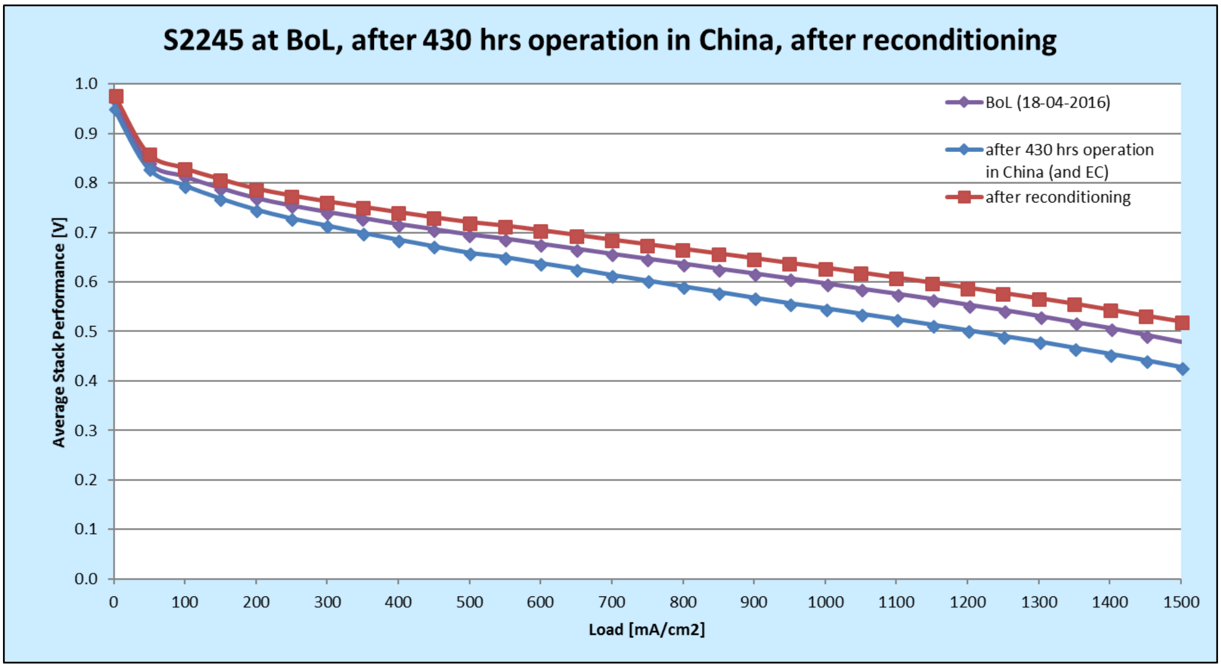

Fig. 1 – IV curves of a typical stack showing some voltage loss between BoL and return from China, and a (more than) full recovery after reconditioning.

Upon arrival from China, first ElectroChemical analyses (EC) have been performed such as impedance measurements, cyclic voltammetry, and hydrogen cross-over (HXO) measurements to provide more information on the cause of the initial voltage decay.

3.2 Second return shipment (2017)

The second return shipment contained stacks with substantially higher operating hours and typically, cell voltage collapse in the entrance cell of the stack, frequently causing stack group shutdowns.

Stack analyses
The stacks have been analyzed to investigate the reason for cell faults and performance loss. In all cases the stacks were repaired successfully and performance was restored to (near) BoL level. Analyses included:

a) IV curves at several stages during the analysis
b) Electrochemical (EC) analyses, such as impedance measurements, cyclic voltammetry, Hydrogen cross-over (HXO) measurements. It should be noted that the order of analyses can have an influence on the results.

a) The first return batch of 5 stacks, all with operating times below 500 hs showed a minor performance loss only in the first recorded IV, while the second return batch with an avg. operating time of 1000 hs showed a substantially increased performance loss. Yet, a clear performance recovery was observed after Nedstack's reconditioning protocol. An overview of the performances at three stages (1-BoL, 2-return from China, 3-after repair and reconditioning) of the second return batch, with an avg operating time of 1000 hs. is shown in Table 2 below. These are referring to voltage loss at the fixed, nominal operating current.

Tabel 2 - Performance variations in % from BoL for stack repair batch 2

stack code	S2342	S2028	S2332	S2325	S2334	S2162	S2001	avg
1. Beginning of Life (BoL)	100%	100%	100%	100%	100%	100%	100%	**100%**
2. return from China (%)	95%	86%	98%	86%	89%	89%	66%	**87%**
3. after repair / reconditioning (%)	102%	98%	99%	98%	99%	98%	99%	**99%**
operational hours	222	484	1048	1239	1379	1450	1634	**1065**

A relatively high performance loss is measured upon return from China. In step 3, in total only 14 cells were replaced for the whole batch, so on average only 2 cells/stack, adding a negligible contribution to the performance raise as observed in the final performance curve. After Nedstack's reconditioning protocol in step 3, the original BoL performance was virtually restored.

b) The electrochemical analyses were not fully conclusive, however some important remarks can be made:

- Relatively high Cathode Effective Surface Area ECSA loss (much higher than anode), which can partially be recovered
- Normal (BoL) Hydrogen crossover values indicate no decline in membrane integrity up to 1500 hs
- More samples, which are progressively aged could provide more distinct results

The EC analyses did not result in clear indications for the root cause of the performance loss. In two specific cases, reversible degradation of the cathode catalyst (i.e. air side) was indicated, which can for example be caused by air contaminants.

In the next step, a visual inspection of the bipolar plate and MEA-surface and further analyses took place

4 Visual inspection and contaminant analysis

As also reported in the MS7.1 report most of the cell trips could be explained by clogged anode inlet areas in the entrance cells (75, 74). External particle contamination (i.e. from outside the stacks), is easily dragged downstream the anode-subsystem where it deposits in the first cells, i.e. cell 75 of stacks in G6 M4, see also Fig. 2.

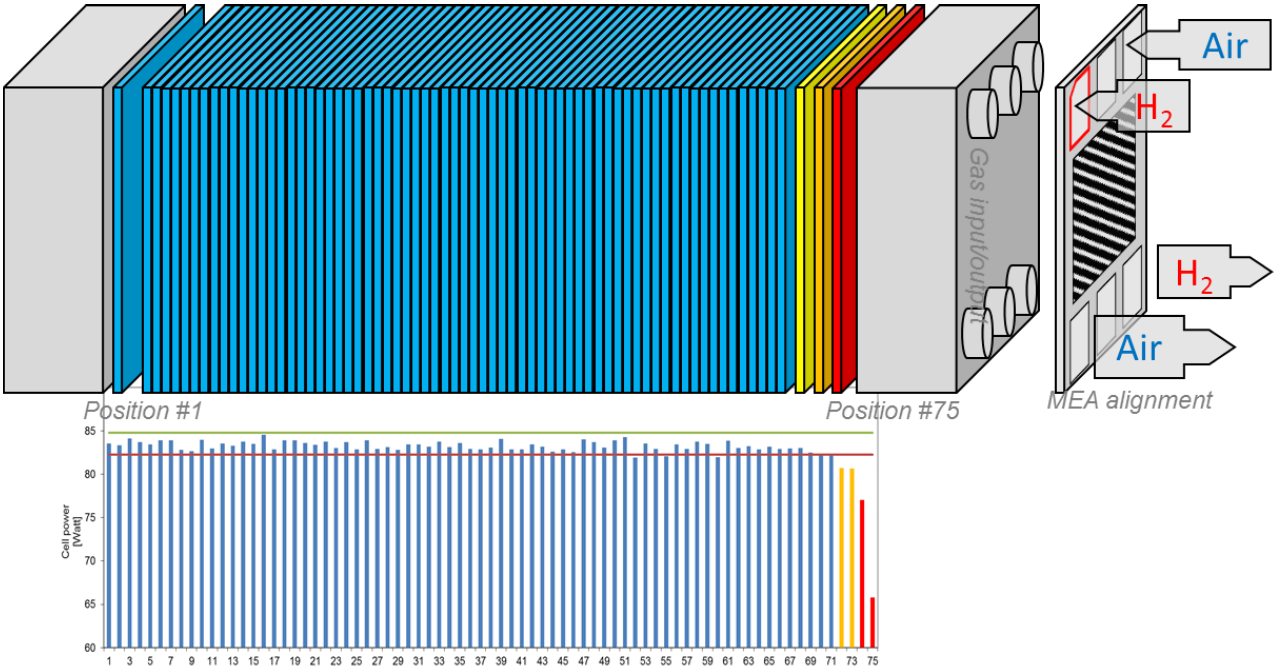

Fig. 2 – schematic representation of stack, combined with observed cell performance as a result of particle contamination.

4.1 Analyses of repair cells

The removed cells were visually inspected, which clearly revealed the cause of the low cell voltage trips in all cells 75. The entrance of the flow field channels on the anode (i.e. hydrogen) side was blocked, mainly by whitish, polymeric fiber fragments as shown in Fig 3. by light microscopy

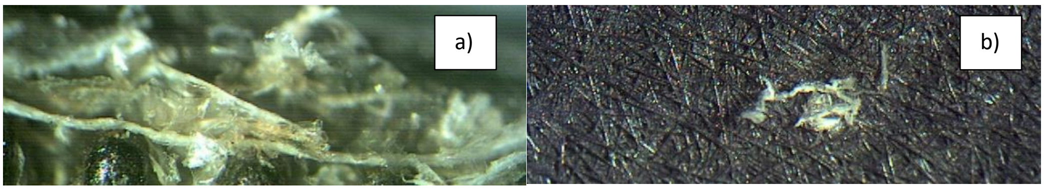

Fig. 3 a,b – light microscopy pictures of the particle contamination found, a) clogging the anode inlet side of cells 75 of repair stacks and b) detail of a similar fiber deposited on the GDL of the MEA

A typical particle was isolated and analyzed by IR and found to be Teflon as shown in Fig. 4.

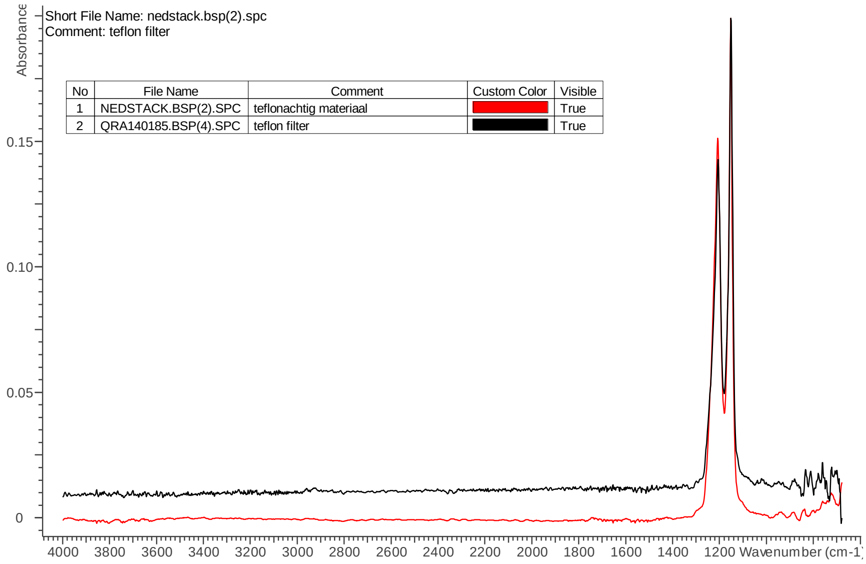

Fig. 4 - IR spectrum of particles clogging the anode of cell 75 vs. a Teflon reference

The obstructing particles from several cells 75 were collected and also analyzed via SEM-EDS. In addition to the Teflon particles, also some iron/stainless steel particles were found. Both materials are not used in the fuel cell stacks and must have an external origin (e.g. the hydrogen feed line or the anode sub-system of the BoP).

The Teflon fragments must have originated from the upstream system. Teflon tape is commonly used as thread seal tape (in hydrogen sub-) systems, also in the BoP of the 2 MW unit. Care should be taken to prevent the presence and release of loose fragments. Also improved filtration could be considered: the current hydrogen inlet filter is not optimal as it may allow leak through of particles, while also additional (temporary) filters could be considered, for example in the hydrogen recirculation loop.

5 Conclusion

The stack repair activities within the first 18 months of operation of the 2 MW plant have been very limited. Only a very small number of stacks were returned to Nedstack for analyses and repair: since the Site Acceptance Test (SAT) in Sept 2016, two batches of in total 12 stacks have been shipped back to Nedstack for analyses, and when necessary, repair.

After the first operational months a first return shipment of five stacks was received. Some performance decrease was observed, which was restored after reconditioning. Also a malfunctioning CVM board and erratic bipolar plates were encountered and replaced.

In the beginning of 2017, a second repair shipment of seven stacks has been investigated and repaired by Nedstack. Six of these stacks were returned due to repetitive low cell voltage trips for cell 75, being the first cell after the media inlet. This was shown to be caused by clogging of the anode of the inlet cell by Teflon fragments, that must have originated from the upstream system. After repair and reconditioning the performance was recovered to virtually the original Beginning of Life (BoL) level. After reinstallation of these stacks the problem of faulty inlet cells seems to have disappeared, indicating that the Teflon particle contamination was an incidental event of limited quantity.

6 Recommendations

A number of stacks at particular positions have shown to be susceptible to anode inlet clogging of fine particles, Teflon fibers in this specific case. For that reason, installation of an improved particle filter in the hydrogen feed line could be considered as well as installation of additional downstream filters.

Also, a noticeable reversible performance decay has been observed for the returned stacks. Electrochemical analyses could not reveal the nature of this reversible decay. In Q'2 2018 a new batch of 7 return stacks has been received, which is currently under investigation and may provide further information in this matter.

7 Acknowledgment

This project is co-funded by the 7th FP (Seventh Framework Programme) – Fuel Cells and Hydrogen Joint Undertaking

http://www.fch-ju.eu/
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The FP7 project has been made possible by a financial contribution by the European Commission under Framework Programme 7. The Publication as provided reflects only the author's view.

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