D3.3: Report on assemblies, cells and SEU qualification tests

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Author(s)	E. Vøllestad, K. Nguyen, M.L. Fontaine
Lead participant	SINTEF
Contributing participants	CTMS
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Executive summary

In this deliverable, we report on the qualification of single engineering units (SEUs) prior to their delivery to WP4 for electrochemical testing and electrolysis measurements in pressurized conditions. Qualification tests are conducted at room temperature to ensure quality control with regards to acceptable leakage rates and electrical contact/insulation of the assembled parts, before it is subjected to temperature and pressure. At M18, a total of three SEUs, including assemblies and cells have been qualified prior to their delivery to WP4 for electrochemical characterization. Similar protocols are applied to the SEUs currently under production.

Contents

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1 Introduction

1.1 The GAMER project

The GAMER project aims at developing a novel cost-effective tubular Proton Ceramic Electrolyser (PCE) stack technology integrated in a steam electrolyser system to produce pure dry pressurized hydrogen. The electrolyser system will be thermally coupled to renewable or waste heat sources in industrial plants to achieve higher AC electric efficiency and efficient heat valorisation by the integrated processes. The project aims at establishing a high volume production of novel tubular proton conducting ceramic cells. The cells will be qualified for pressurized steam electrolysis operation at intermediate temperature (500-700°C). They will be bundled in innovative single engineering units (SEU) encased in tubular steel shells, a modular technology, amenable to various industrial scales. GAMER focuses on designing both system and balance of plant components with the support of advanced modelling and simulation work, flowsheets of integrated processes, combined with robust engineering routes for demonstrating efficient thermal and electrical integration in a 10kW electrolyser system delivering pure hydrogen at minimum 30 bars outlet pressure.

The consortium covers the full value chain of the hydrogen economy, from cell and SEU manufacturer (CMS), system integrators (MC2, CRI), through researchers (SINTEF, UiO, CSIC), to end users in refineries, oil and gas, chemical industry (CRI, Shell Global Solution International B.V., with advisory board members YARA and Air Liquide). All along the project, these experienced partners will pay particular attention to risk management (technical, economic, logistic, business) and ensure progress of the technology from TRL3 to TRL5. The overall consortium will perform strategic communication with the relevant stakeholders in order to ensure strong exploitation of the project's results.

1.2 The novel tubular SEU

In the GAMER project, we focus on the demonstration of an innovative, low cost and modular hydrogen production technology utilising *tubular proton conducting ceramic cells* and their inherent advantages for steam electrolysis:

- *Scalability and modularity* of the electrolyser system: the electrolyser is designed for scale (small, medium, large)
- *Reduced operation and maintenance costs* compared to planar stack towers: possible to "isolate" one or several SEUs from the system without shutting it done completely; possibility to change some SEUs
- *Reduced risks* in case of leakage due to low volume of SEU
- *Lower operating temperature* (600°C) than SOE reducing degradation associated to cation diffusion, and enabling use of lower cost steel for pressure vessel;
- *Production of pure dry hydrogen* at the anode side, preventing risk of oxidation encountered in SOE;
- *Increased safety*: In PCE, any increase in pH_2O increases the pH_2. In contrast, the SOE must have a high pO_2 alone at one electrode to balance the pH_2O+pH_2 at the opposite electrode. Pure hot high pressure O_2 is risky.

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- *Increased robustness of tubular cells*, in particular, when exposed to pressure differentials compared to planar cells
- *Reduced sealing area* compared to planar cells

This novel design concept has also some challenges, which are addressed in GAMER:

☝ Current collection is challenging compared to planar technology. This is alleviated in GAMER by the use of lower current density cells.

☝ Lower current density of the cells compared to SOE. This is compensated in GAMER by increased surface area and lower cost of PCE cells.

The tubular cells in GAMER integrate a proton conducting electrolyte based on Y-doped Ba(Zr,Ce)O_3 (BZCY). The cells will consist of a porous Ni-BZCY cathode for the H_2 side (also ensuring mechanical strength), a thin dense BZCY-based electrolyte, a porous anode for the H_2O+O_2 side, and a current collector system. They are bundled and assembled in a steel pressure vessel enabling safe pressurized operation of at least 30 bars and 700 °C in high steam content.

1.3 Deliverable 3.3

In this deliverable, we report on the qualification of cells, assemblies and SEUs prior to their delivery onto WP4 for electrochemical testing and electrolysis measurements in pressurized conditions. Qualification tests are conducted at room temperature to ensure quality control with regards to acceptable leakage rates and electrical contact/insulation of the assembled parts, before it is subjected to temperature and pressure. As the SEU design is currently under patenting evaluation, this deliverable will not provide a detailed schematic of the SEU. We only present the outcomes of the quality check evaluation at room temperature. Results of electrochemical measurements of SEUs are reported in another deliverable.

2 Methodology

The cells, assemblies and SEUs were individually qualified at room temperature. The primary qualification check is to monitor the leakage rate at 1 bar overpressure for each assembly, conducted using a test setup located in the labs of CTMS. The assemblies were also validated in terms of electrical resistance to ensure proper electrical contact across all current-leading interfaces and that there is no electrical short-circuit from negatrode to positrode in the SEU assembly. Details of the validation protocols are presented in earlier deliverables in GAMER.

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3 Qualification results

At this stage, 3 sets of SEUs have been assembled and quality-checked prior to their delivery to WP4 for electrochemical testing, as reported in the table below.

SEU nr	Cell + ferritic header	Vessel + austenitic header	SEU assembly	Negatrode feedthrough	Electrical contact
1	Leakage	Pass	Leakage: > 5 mbar L/min	Leakage	Pass
2	Pass	Pass	Leakage: 1.5 mbar L/min	Pass	Pass
3	Pass	Pass	Pass Leakage < 1 mbar L/min	Pass	Pass

While SEU-1 did not pass the qualification criteria, it was still delivered to WP4 for electrochemical testing to validate the experimental setup for SEU testing and quality check the test protocol. SEU-2 passed all qualification criteria for the different assembly parts, but the SEU assembly showed a leakage rate just above the acceptance criteria (1 mbar L/min). SEU-3 passed all acceptance criteria at room temperature. All three SEUs were delivered to WP4 for electrochemical testing.

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