# D2.1 Delivery of individual components and assemblies for qualification tests in WP3

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| Author(s) | M. Budd (CTMS), Marie-Laure Fontaine (SINTEF) |
| Lead participant | CTMS |
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## Executive summary

Deliverable D2.1 of the GAMER project covers delivery of individual cells, key enabling technology (KET) components and assemblies for evaluation of their integrity and functionality under steam electrolyser conditions in WP3.

## Contents

# 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 10 kW electrolyser system delivering pure hydrogen at minimum 30 bars outlet pressure.

Partners of GAMER are:

| ***Partner (short name)*** | ***Country*** |
|---|---|
| *SINTEF (SINTEF)* | *Norway* |
| *Coorstek Membrane Science AS (CMS)* | *Norway* |
| *CSIC, Instituto de Tecnología Química (CSIC)* | *Spain* |
| *Carbon Recycling International (CRI)* | *Iceland* |
| *University of Oslo (UiO)* | *Norway* |
| *MC2 Ingenieria y Sistemas SL (MC2)* | *Spain* |
| *Shell Global Solutions International B.V. (SGSI)* | *Netherlands* |

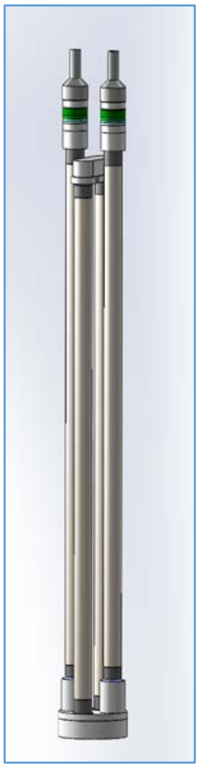
The consortium covers the full value chain of the hydrogen economy, from cell and SEU manufacturer (CMS), system integrators (MC2, CRI), through researchers (SINTEF, UiO, CSIC), to end users in refineries, oil and gas, chemical industry (CRI, SGSI, with advisory board members YARA and Air Liquide). All 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 relevant stakeholders in order to ensure strong exploitation of the project's results.

## 1.2 Deliverable D2.1

Deliverable D2.1 of the GAMER project covers delivery of individual cells, key enabling technology (KET) components and assemblies for evaluation of their integrity and functionality under steam electrolyser conditions in WP3.

The originally foreseen design for the single engineering unit (SEU) was based on a U-bend configuration for the first generation SEU, and a W-bend configuration for the second generation SEU, as shown in Figure 1:

1st generation SEU
'U-bend'



2nd generation SEU
'W-bend'

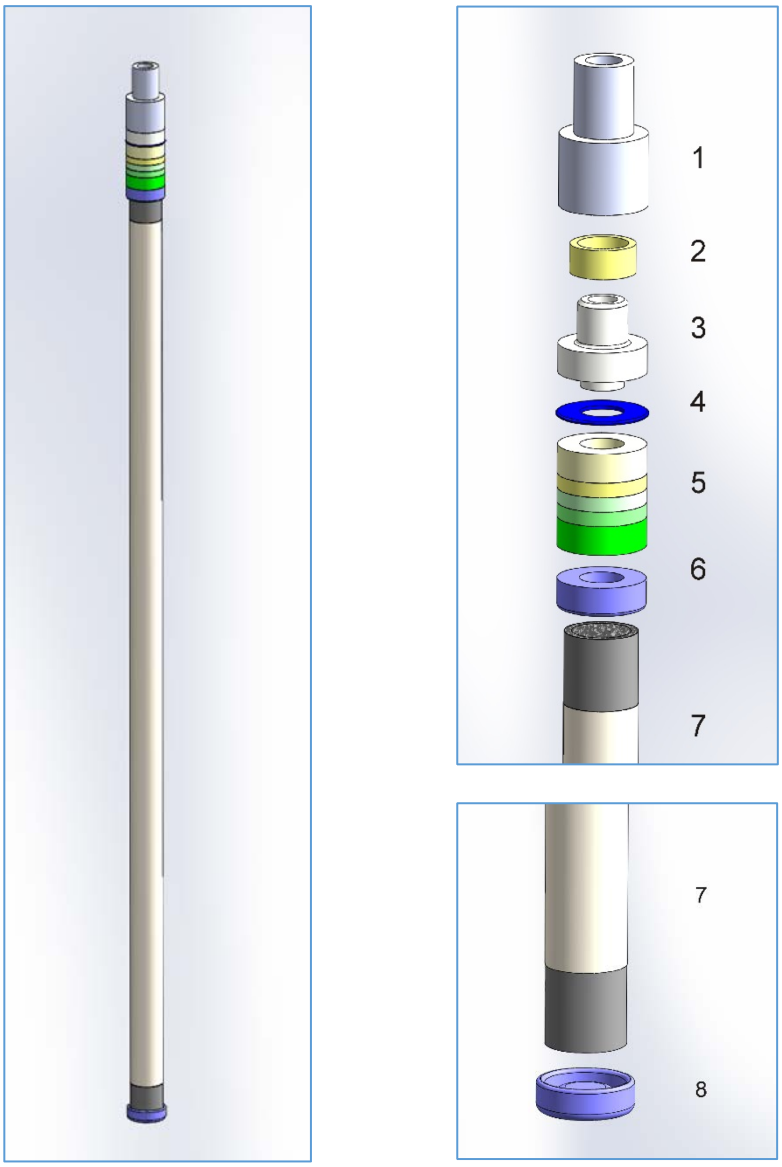
Figure 1. SEU designs originally proposed for testing in WP4 and WP5 – now superseded by a more robust, 'tube-in-shell' design

An early assessment of these SEU configurations identified some aspects of the design which were considered to be of unacceptably high risk; i.e. difficulty of current collection from the external electrode (positrode), the increased probability of leakage due to the large number of seals, lack of mechanical robustness, and the challenge of implementing a redox-stable interconnect between the membrane tube segments. A decision was made to adopt a simpler, more robust design, based on a tube-in-shell concept, where a single membrane tube is placed in a steel tube (the shell), and current collection is achieved by ensuring good electrical contact between the two. The simpler design does not employ interconnects or gas manifolds, or the seals which are used to join these parts together;

nor does it include current feed-throughs; and as such, these components are now not included in D2.1.

## 2 Components, KETs and assemblies delivered under D2.1

The parts and assemblies of the re-designed SEU which are for delivery under D2.1 for evaluation in WP3 are shown in Figure 2:




Component

1. Ferritic header
2. PSZ top seal
3. PSZ ferrule
4. PSZ to gradient sealing gasket
5. Gradient segment
6. Gradient to BCZY face seal
7. BCZY membrane tube with electrodes
8. End cap seal

Figure 2. Components which make up 'tube-in-shell' assembly (shell not shown)

The steel shell is not included in D2.1, as material selection is dependent on the results of on-going high temperature oxidation/corrosion trials on a range of candidate materials in oxygen/steam atmospheres.

The delivery status of the D2.1 components shown in Figure 2 is as follows (* indicates KET component)

1. Ferritic header
   20 pieces produced, 4 of which have been used in gradient/header assemblies

2. PSZ top seal*
   700g of precursor glass powder has been produced, and 20 seal preforms fabricated by machining from sintered discs. Approximately 3g of precursor glass powder is required per seal. Four of the machined preforms have been used in gradient/header assemblies.

3. PSZ ferrule
   20 pieces procured, 4 of which have been used in gradient/header assemblies

4. PSZ to gradient sealing gasket*
   700g pre-cursor glass produced in powder form. This is mixed with binder and applied as a paste when sealing the PSZ ferrule to the gradient section: usage approx. 0.1g precursor glass powder per seal.

5. Gradient segment*
   The gradient segment is made from two glass-ceramics with different coefficients of thermal expansion (CTE). It is built-up in layers with each layer containing different proportions of each glass-ceramic such that the segment as a whole covers the required CTE range. In total, 1.4kg of the precursor glass powders have been produced – sufficient for approximately 200 gradient segments. Of this approximately 140g has been used to produce 20 gradient segments, 4 of which have been used in the fabrication of gradient/header assemblies.

6. Gradient to BCZY face seal*
   Approximately 1.3kg of precursor glass powder has been produced for fabrication of this face seal – enough for approximately 2500 seal preforms. The precursor glass powder has been supplied to a sub-contractor for production of seal preforms by pressing and sintering. 150 sintered seal preforms have been produced and delivered to CTMS.

7. BCZY membrane tube with electrodes*
   The complete BCZY membrane tubes with internal and external electrodes are produced in a multi-stage fabrication process, with CTMS and SINTEF each being responsible for different processing steps. As a first stage, sintered half-cells (BCZY membrane on composite BCZY/NiO support) are produced by CTMS and supplied to SINTEF for application of a porous outer layer (backbone) which will act a functional skeleton for the external electrode (positrode).

   At present, there are two routes being pursued for application of the positrode, with each route involving different electrode chemistries which require different processing stages.

Approximately 190 short half-cells have been delivered for positrode development studies, and some of these will be evaluated in WP3. Positrode process development is not fully complete and currently still requires development work to improve the adhesion of the electrocatalysts for one of the routes.

Approximately 25 half-cells coated with 1 set of electrodes for the second route have been supplied by SINTEF for testing in WP3. It is planned to obtain results of testing by M8, and thereafter to select one route of electrode.

8. End cap seal*
   Approximately 1.3kg of precursor glass powder has been produced for making the end cap seal: - enough for approximately 1500 seal preforms. The precursor glass powder has been supplied to a sub-contractor for production of seal preforms by pressing and sintering. 200 sintered seal preforms have been ordered and delivered to CTMS.

# 3 Conclusions

A review of the originally proposed SEU designs has led to changes which are expected to provide greater robustness and reliability. Many of the components which were part of the original 'U-bend' and 'W-bend' designs (gas manifolds, interconnects, electrical feed-throughs, and several seals) are not present in the revised 'tube-in-shell' design.

Production and delivery of components and KETs for the tube-in-shell design has proceeded well under WP2, and most are ready for evaluation in WP3. Delivery of electrolyser cells (BCZY membrane tube with both internal and external electrodes) is delayed, pending completion of positrode process development.

Sealed assemblies for testing under WP3 are expected to be ready for delivery at short time after BCZY electrolyser cells are available.

# 4 Acknowledgements

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