RFB scale up experience from cell to stack

First Project Workshop

In Pilsen and Online

John Collins, C-Tech Innovation Ltd

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Introduction

- C-Tech & Redox Flow Batteries
- Organic vs Inorganic RFB Stacks
- Opportunities for Cost Savings with ORFB
- Scale up Steps
- HIGREEW Stack Engineering Work Package
  - Ambition
  - Initial Approach
  - Current Approach

C-Tech Innovation Ltd

C-Tech INNOVATION

- Independant Technology Development Company located near Chester in NW England.
- Origins were a UK R&D Centre for the Electricity Industry. C-Tech has about 25 staff, mostly engineers & scientists.
- Key Technology Areas:
  - Electrochemical Engineering
  - Process Heat (Microwave, RF, Ohmic, Induction)
  - Plasma Processing
  - Nuclear Decontamination
- C-Tech produce bespoke and standard products from laboratory scale to turn-key production plants.
- The company has design capability (mechanical, electrical, chemical), modelling, laboratories, pilot areas, workshops and analytical equipment.

Electrochemical Technology at C-Tech

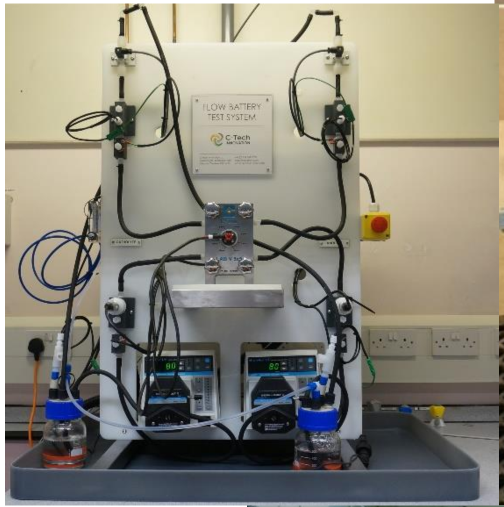
C-Tech INNOVATION

Selected Electrochemical Experience Highlights

- Electro-synthesis – organic and inorganic
- Recycling & hydrometallurgy
- Ionic liquids including aluminium electroplating systems
- Decontamination of nuclear infrastructure.

Flow Battery Experience (consultancy & projects)

- Design & build of cell / stack / balance of plant / control
- Vanadium Electrolyte Production Systems – turn key modular systems at full plant scale.
- Tests systems, process development, validation and Due Diligence.
- Soluble Lead (Innovate UK with Pletcher/Walsh/Wills)
- Vanadium (Contract & own funded)
- Zinc Air (FP7 Powair), Zinc Nickel and Zinc Cerium (Plurion)



Vanadium Electrolyte Manufacture

- C-Tech have a developed an electrochemical process to produce electrolyte for vanadium redox flow batteries requiring just vanadium oxides, sulfuric acid and electrons with no requirement for additional chemicals reagents.
- The process offers very high electrolyte purity and low production costs.
- C-Tech are supplying plant / process design services and the turn-key electrochemical systems including control.
- We have supplied vanadium electrolyte production systems to multiple large-scale manufacturers around the world **ranging from 1,000,000 litres to 8,000,000 litres per annum** with several additional installations currently in development**.**

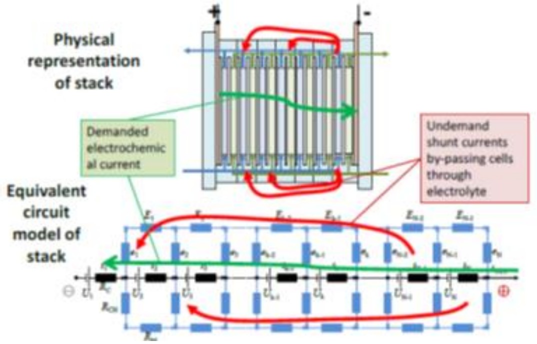
Organic vs Inorganic RFB Stacks

- The requirements of a flow battery stack for an organic redox flow battery are identical to those of an inorganic redox flow battery – low resistance, high power density, low parasitic losses and a low manufacturing cost.
- The same fundamental building blocks are required → unit cells in series separated by bipolar plates with each unit cell comprised of electrodes separated by an ion exchange membrane.
- Differences in the design and manufacture of the a stack between applications are due to the specific physical, chemical and electrochemical properties of the chemistry and design optimisation point used rather than organic vs inorganic.
- However areas where the biggest differences might be seen between ORFBs vs RFBs are:
  - More viscous electrolytes (increased pumping losses, higher stack pressure drops limiting current density and discharge range)
  - Bigger difference in properties between posilyte and negalyte requiring pressure differences to be accommodated – limiting performance or requiring different components on the different sides.
  - Bigger changes in electrolyte properties during use (cross over and degradation). To what composition do you design the stack?
  - Lower corrosivity of electrolytes allowing a wider range of materials to be used (cheaper?, easy manufacturing, better performance)

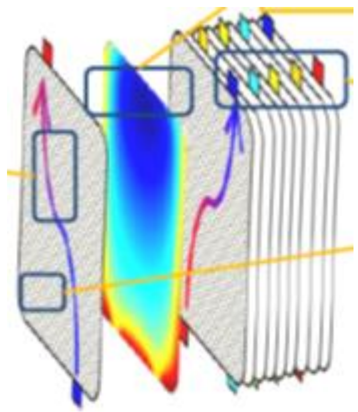
Potential Advantages from Lower Corrosivity Electrolytes

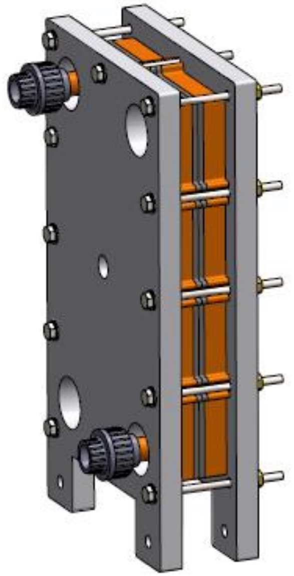
- A wider range of seal materials can be used rather than the traditional choices of EPDM and Viton which can be much cheaper and injection moulded.
- A wider range of stack cell frame materials can be used which unlike traditional hard plastics (e.g. PP) can have some elastomeric properties allowing incorporation of seals and assembly features into the cell frames during injection moulding reducing the number of components required and simplifying assembly.
- Less chemically stable and lower cost membranes can be used.
- Metallic bipolar plates are more viable, offering lower manufactured cost, much reduced thickness and ease of forming electrolyte distribution channels if required which are too expensive in carbon BPPs.

Scale up from single lab cell to a stack



1. Establish materials, chemistry, cell parameters, operating ranges at lab scale
2. Agree a clear specification for stack including the key parameters to prioritise as any stack design is a series of compromises.
3. Outline design of the stack – size, orientation, manufacturing method, sealing, assembly and disassembly. Supported by experimental trials starting at single cell and progressing to short stacks.
4. Verify Properties at Stack Scale e.g. variations in felt properties and required contact pressures.
5. Detailed design of internal flow system –for uniform flow distribution, reduced pumping losses and reduced leakage currents by validated computational models.
6. Detailed stack design taking the outline design and incorporating material property data at stack scale, flow design and manufacturing methods used.
7. Testing and revision of Stack design





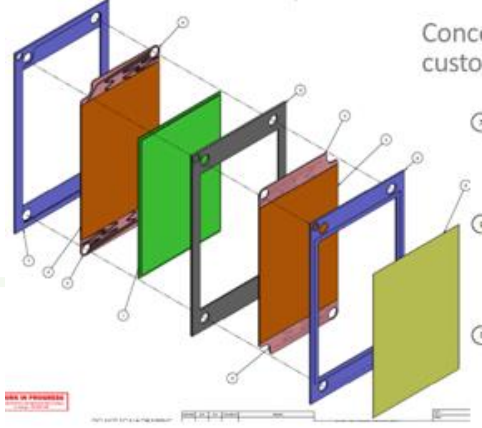
HIGREEW Stack Ambition

HIGREEW project aims the development of optimal cell and stack designs based on minimizing the **low internal resistance** and **limiting the shunt currents** selecting and using **low-cost materials, packaging and seals**, and targeting in the design and easy of (dis)assembly and recyclability schemes.

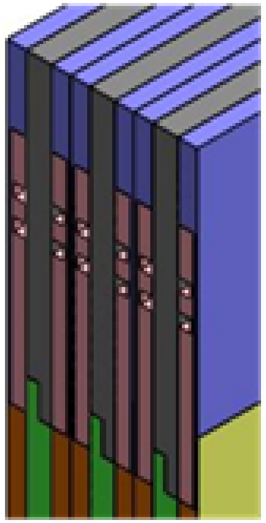
Specific targets are:

- Development and testing of single cell prototype and stack prototype with an **electrical resistance less than 0,6 Ω cm2** .
- Build a stack prototype with a reduce **pressure drop of 0,8 bar** and with **shunt current losses** reducing the coulombic efficiency about **less than 1%.**
- **Demonstrate a stack design and manufacturing route with potential to deliver at MW production scale a low cost stack (<600 €/kW).**
- Demonstrate stacks in a **5 kW** demonstrator within the project timescale

Initial HIGREEW approach to Stack Engineering



- Design for manufacturing approach using the skills of partner HEIGHTS in injection moulding, automated assembly and VRFB systems.
- Lower corrosivity of electrolytes gave confidence in allowing the use of stack frame materials which allowed simplification of the stack design particularly involving sealing and assembly. (HEIGHTS IP).
- The timescales involved in injection mould tooling required “freezing” of the electrolyte and cell component properties between around 15 months to allow stack design and then tooling design for a stack delivery around month 24.
- This tight timeline was impacted upon by COVID-19 and complexities in the electrolyte development before a ‘frozen’ specification could be agreed.
- COVID-19 also significantly impacted upon HEIGHTS who dropped out of the project which meant a loss of their key skill sets.
- The loss of HEIGHTS and the continuation of electrolyte development meant that a change of approach was required and the project scope was amended.



Current HIGREEW approach to Stack Engineering

- A more flexible approach to stack development was necessary to accommodate the continuing chemistry / materials developments and it was agreed to change to a machined stack design. This allowed:
  - Decisions on the final electrolyte and materials to be delayed
  - Time for optimisation of the stack to the HIGREEW chemistry (chemistry, viscosity differences) using a mixture of experimental trials guided by computational models.
  - Extended learning around operation of the stack and demonstration of the HIGREEW chemistry at stack level.
  - Innovations in sealing / assembly for machined & prototyping stacks.
- The approach could not deliver a demonstration at 5 kW scale at Gamesa in WP5 within the project timescale. This was to be achieved with a commercial stack accepting the limits imposed by a commercial vanadium stack design.
- Instead extended characterisation of the HIGREEW stacks at around a 1 kW size will be carried out at C-Tech and PINFLOW.

Next Steps in HIGREEW

- Finish innovative seal development
- Finish outline stack design
- Incorporate flow field designs
- Short stack testing
- Design revisions
- Detailed design and manufacture
- Extended stack characterisation

Thank you!

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