

## Pressurisation of IP-SOFC Technology for Second Generation Hybrid Application

### OBJECTIVES

- To develop active cell tubes, tube bundles and a 'strip' of tube bundles on a common manifold that will achieve a target performance for a sustained duration when tested under pressurised conditions.
- To develop reforming modules and bundles capable of being integrated with active cell bundles and strips.
- To design a multi-kW<sub>e</sub> fuel cell configuration to support the optimisation of performance, size, weight and cost parameters for integration into 1MW hybrid fuel cell system.

### SUMMARY

Rolls-Royce plc has developed a unique, cost competitive, clean, highly efficient form of a natural gas fuelled hybrid Solid Oxide Fuel Cell technology, that is ideally suited to segments of the distributed power generation market.

Sufficient confidence exists in a proprietary SOFC technology called the Integrated Planar (IP) SOFC concept (figure 1), that a

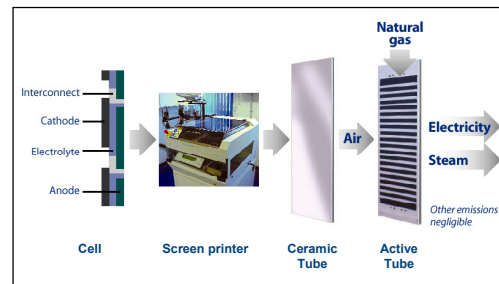


Figure 1. IP-SOFC Tube and Bundle

technology verification programme has been launched.

The broad aim of this project was to verify the technical viability of the

IP-SOFC technology and some of the associated hybrid system component technologies under pressurised conditions and to investigate the validity of predicted pressurisation phenomena.

Substantial progress was made during this project to successfully address the technical challenges associated with the development of the IP-SOFC concept for application within a hybrid system.

Experimental data obtained increased confidence in the design rules, performance models developed and justification for the research and technology development strategy employed.

The technology successfully evaluated during this project has provided important confirmatory evidence to support the technical and commercial viability of the IP-SOFC hybrid system concept.

## **CONTRACTOR**

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## **COST**

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The total cost of this project is £6,013k, with the Department of Trade and Industry (DTI) contributing £2,898k, and Rolls-Royce the balance.

## **DURATION**

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16 months – August 2003 to December 2004.

## **BACKGROUND**

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Over the past 10 years, Rolls-Royce plc, supported by the Department of Trade and Industry, the European Commission and partners, have invested significant funds into developing Solid Oxide Fuel Cells (SOFC) technology for stationary power generation applications.

This project complements previous DTI funded and existing

EC SOFC funded programmes and supports the initial phase of a broader pressurised hybrid SOFC technology verification programme, leading to a megawatt-scale demonstration.

To achieve the project objectives, the challenge of designing and constructing an acceptable gas tight IP-SOFC configuration with required electro-chemical performance and durability, would have to be successfully addressed.

To facilitate this evaluation, the scope of the project included the design and development of a pressurised IP-SOFC test capability and the continued development and verification of IP-SOFC materials and construction processes.

## **THE WORK PROGRAMME**

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Detailed analyses of IP-SOFC construction processes were undertaken to identify and characterise critical material specifications, construction processes, control parameters, verification equipment and inspection techniques. This work was instrumental in achieving improved consistency in IP-SOFC performance and yield.

### **IP-SOFC Development**

Two Multi-bundle strips were successfully tested at high temperature and atmospheric pressure. These tests provided confirmatory data supporting the technical feasibility of fuelling multi-bundle assemblies from a

common manifold, to produce increased levels of power.

A pressurized IP-SOFC test capability was successfully designed and commissioned (figure 2), to facilitate the testing of an active IP-SOFC bundle at high temperature and pressure. These tests provided the first opportunity to evaluate the behavior and performance of an active fuel cell bundle under pressurized conditions.

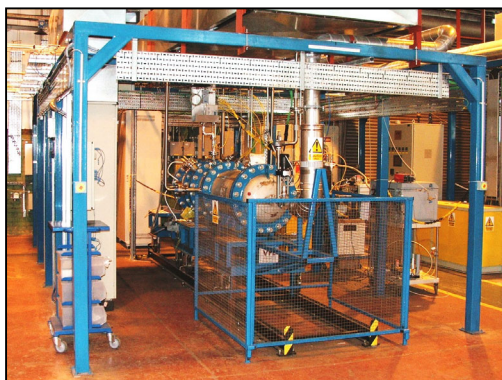


Figure 2. IP-SOFC Pressurised Rig

### Steam Reformer

Testing of an experimental steam reforming unit at high temperature and pressure confirmed the presence of a first order  $\text{CH}_4$  pressure-dependant reaction rate and provided data with which to improve reformer unit design rules.

### Off Gas Combustor

Testing of a novel low pressure drop, off-gas combustor concept was successfully completed under atmospheric and pressurized conditions. Excellent low emissions levels were achieved at pressure and high inlet temperature.

### Multi-kW<sub>e</sub> IP-SOFC configuration

Design studies were undertaken to evaluate IP-SOFC assembly and improved packaging configurations. A revised thinner IP-SOFC support tube geometry was developed to achieve increased volumetric power density.

## CONCLUSIONS

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- A major step change in reducing leakage was achieved with no detrimental impact on existing Fuel Cell performance and durability. This was achieved, in part, through an improved understanding and tighter control of, material specifications and process controls used during the construction of single active tubes and multi-tube assemblies.
- Testing the IP-SOFC technology at pressure provided the first experimental data confirming theoretic predictions of the IP-SOFC performance improvements to be gained by operating at elevated pressure.
- The introduction of a thinner revised IP-SOFC support tube geometry improved bundle packaging and utilization of available stack volume to achieve increased volumetric power density
- An innovative hybrid system Off-Gas Combustor concept

was successfully tested, which offers additional development potential for wider chemical and automotive industry application.

## POTENTIAL FOR FUTURE DEVELOPMENT

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A firm foundation has been established from which the integration of hybrid IP-SOFC technologies can be investigated to develop a mega-watt-scale hybrid system demonstrator.

To capitalise on results achieved during this project and ensure the potential for the low cost, durable IP-SOFC stack can be realised, continued research and technology evaluation will be required to address the following critical development issues:

- Verification of IP-SOFC stack performance and durability when fully integrated within the hybrid system.
- Development of IP-SOFC materials, powders and inks within a nascent supply chain, to facilitate the continued reduction of construction process steps.

- Development of fully automated IP-SOFC Tube construction and automated Stack assembly and handling processes to continue to improve build consistency and reduce lead-time.
- Development of low cost robust IP-SOFC stack to minimise part count through simplification of design and increased component functionality.

Further renewable energy information from the DTI Technology Programme: New and Renewable Energy, and copies of publications, can be obtained from:

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