COMPETITIVE POSITIONING 
OF PLANAR SOFC TECHNOLOGY – 
CFCL’S EXPERIENCE

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ABSTRACT

Since 1992, Ceramic Fuel Cells Limited (CFCL) has grown to what is now one of the largest single-purpose programs globally for development of planar ceramic (solid oxide) fuel cell (SOFC) technology. Over A$60 million in funding for the activities of the company has been raised from private companies, government-owned corporations and government business-support programs, including from energy – particularly electricity – industry shareholders that can facilitate access to local markets for our products. CFCL has established state-of-the-art facilities for planar SOFC research and development, with their expansion and scaling-up to pilot manufacturing capability underway. We expect to achieve commercial introduction of our market-entry products in 2002, with prototype systems expected to be available from mid-2000. This paper will discuss some of the experiences and challenges we have encountered along the way, including those before us to competitively position planar SOFC technology in distributed generation markets.

INTRODUCTION

The venture to develop and bring to market ceramic (solid oxide) fuel cell (SOFC) products based on Australian-owned and developed technology was launched in November 1991. The base technology and knowledge of zirconia ceramics and their application in high temperature electrochemistry, on which the venture was founded, derived from the CSIRO Division of Manufacturing Science and Technology.

The interest of the initial, and subsequent, venture partners – Australian and New Zealand electricity businesses, Australian companies, government technology investment organisations and CSIRO – was driven by the:

• Potential market opportunities within the fast-growing distributed generation sector for clean, reliable and cost-competitive electricity supply systems based on the highest efficiency conversion technology known – solid oxide fuel cells;

• Prospects for establishment of a major, new, Australian-based, high-technology manufacturing enterprise; and
• Credibility of the technology base and its promoters from within CSIRO to achieve the technical goals of the venture.

To undertake the technology development and demonstration activities, the company – Ceramic Fuel Cells Limited (CFCL) – was incorporated in July 1992.

**CFCL’S TECHNOLOGY**

CFCL’s stack design is based on rectangular/square PENs and an array interconnect design (Figure 1). It provides maximum flexibility in scaling without changing the stack design or fabrication process and enhanced reliability through parallel interconnection of PENs in each array layer. Fuel cell units will be packaged for both electricity and heat supply, eg, steam or hot water (Figure 2).

![Illustrative Layout of Array Stack Design](image1)

**Figure 1. Illustrative Layout of Array Stack Design**

![Illustrative Components of CFCL's SOFC System](image2)

**Figure 2. Illustrative Components of CFCL’s SOFC System**
OUR TECHNOLOGY EXPERIENCE

CFCL’s approach has been to develop technology packages to give flexibility to designers and to meet the commercial imperatives for a competitive product. In brief, our cell and stack technology paths have been:

- Electrolyte-supported, high temperature PENs $\Rightarrow$ anode-supported, intermediate temperature PENs
- Mono stacks $\Rightarrow$ array stacks
- Ceramic interconnects $\Rightarrow$ machined, high Cr metal $\Rightarrow$ sheet steels
- External manifolding $\Rightarrow$ internal manifolding

Our experience is that driving our technology bases, stack designs and system designs by a constant focus on production cost and product reliability has resulted in significant innovation. After all, the fuel cell package must be affordable, reliable and easily maintained and refurbished. To that end, CFCL has established aggressive performance and cost targets for its SOFC system products of:

- Unit production cost of $< \$500$ per kW (in volume production)
- Minimal installation and commissioning costs (not including site works)
- Remote operation, dispatch and monitoring
- Efficiency $\geq 50\%$ in open cycle
- Low aging: $\leq 15\%$ over seven years
- Low operating and maintenance costs: $< 0.5\$ per kWh
- Modular, connectable units
- Reliability at least on a par with grid-connected system

While we would not claim to have all technical challenges overcome to meet these targets, we have made significant progress:

- Intermediate temperature cell technology based on anode-supported cells has achieved $> 900$ mW cm$^{-2}$ at 770 $^\circ$C (50mm x 50mm, moist H$_2$)
- Developed sealing technology for a number of different designs and temperature ranges, including seal concepts for easy assembly and mass fabrication.
- Direct internal reforming technology for CH$_4$ has been demonstrated to be stable and non-coke forming in medium term tests ($> 1500$ h) at steam to carbon ratios of approximately 1.5:1 to 2.5:1 and fuel utilisations of up to 85%.
- Developed a stacking concept based on sheet metal interconnects which promises low costs and better lifetime. A 10 layer 2x2 array stack (100 mm x 100 mm 3YSZ cells) has been tested at an output of approximately 400 W at 820 $^\circ$C for around 3,500 hours. Better performing layers achieved a degradation rate of 1–2% per 1000 hours.
- A 25 kW demonstration system (natural gas fuelled, a.c. power out) is nearing design completion and is expected to be operational around October 1999.
- Established extensive facilities for cell production, interconnect coating and cell, stack and system testing.
THE COMMERCIAL IMPERATIVES

This is an expensive technology to bring to market – and we understand CFCL to be one of the most cost-effective programs to date. We have raised A$60 million in funding from our investors and Australian government R&D support programs. To date, around A$45 million has been expended to achieve our competitive technology base. It’s going to take at least that much again in RD&D expenditure alone to bring our first product to market by our target of 2002. Sourcing funding to a level adequate to meet this challenging commercial target is an ever-present task and one familiar to many fuel cell developers.

Like all other fuel cell proponents, CFCL is targeting distributed generation applications for our products. We will do this in North America, Europe and locally, and later other geographic areas. However, where to enter the market in a time of turbulence in the energy industries is not an easy decision. Market forces unleashed by deregulation are reshaping energy utility industries worldwide (Figure 3). As with banking and telecommunications before them, these sectors are being transformed through political, competitive and innovation pressures.

![Figure 3. Influences on competitive energy markets](image)

These unprecedented changes in and forces on industry sectors which enjoyed "natural" monopolies for some three generations prior provide many threats and opportunities to existing and new businesses that participate in the provision of energy services to customers.

We strongly believe that it is necessary – but not sufficient – that the capital cost of planar SOFC systems quickly match (in volume production) that being achieved by competitive products: microturbines, gas turbines and internal combustion engines. Further, the energy cost for end-users must be lower than that available to them now via, generally, wires. The other product features such as high-quality power, quietness and cleanliness can then be brought in to play.
CONCLUSIONS

Building a sustainable, growing business on a base of competitive, distributed-generation products – derived from planar SOFC technologies – is CFCL’s goal. However, competitive positioning of planar SOFC technology in commercial markets will take significant commercial, financial and technical expertise. Market access and a good market-entry product are key to ramping production to volume levels quickly. Demonstrating prototype product and manufacturing capability is necessary to build market confidence. Having a technology base that can deliver the production cost and system reliability targets is the starting point.

Our experience to date suggests that CFCL is well on its way to achieving its business goal.

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