STATUS OF SOLID OXIDE FUEL CELL DEVELOPMENT IN AUSTRALIA

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ABSTRACT

Ceramic Fuel Cells Limited, owned by a consortium consisting of BHP - Australia’s largest company; CSIRO - Australia’s major R & D organisation; Energy Research and Development Corporation - Federal Government agency; Strategic Industry Research Foundation - Victorian State Government agency and five major main land electricity utilities - Pacific Power (New South Wales), ETSA (South Australia), Generation Victoria (Victoria), QEC (Queensland), SECWA (Western Australia) has been established to provide a national focus for the development of SOFC technology in Australia with a number of universities and research organisations contributing to its program. In this paper the status of solid oxide fuel cell R & D in Australia and within Ceramic Fuel Cells Ltd has been described. The SOFC development effort, the R&D infrastructure and significant achievements made since the incorporation of the Company in manufacture of single cells and stacks and their performance has been discussed.

CERAMIC FUEL CELLS LIMITED AND AUSTRALIAN EFFORT

Ceramic Fuel Cells Limited (CFCL) was established with the aim to create a competitive Australian - based enterprise which researches, develops, manufactures and markets internationally SOFC-based products.

The Company’s development team of about 50 scientists, engineers, technologists, and in addition several consultants and collaborators, is built around a core staff of twenty scientists and engineers seconded from CSIRO and BHP. Extensive expertise exists in the key materials/component development and cell and stack testing areas, and systems engineering/integration expertise is provided by utility partners. In order to enhance the expertise base even further, the Company has established collaborations with a number of organisations and universities across Australia, including the Australian Nuclear Science and Technology Organisation, Pacific Power Energy
Efficient Research Centre, both in Sydney, Swinburne University of Technology, RMIT and Monash University in Melbourne, and University of South Australia in Adelaide.

CFCL operates R&D facilities at three sites. Major activities are located at CFCL headquarters at Monash Science and Technology Park, and at CSIRO, Division of Materials Science and Technology (CSIRO-DMST) both in Clayton (Melbourne). The third facility is located at the Churchill campus of Monash University in the Gippsland region (about 150 km southeast of Melbourne. Gippsland is the centre of Victoria's power generation industry where over 80% of the State's electricity is generated.

CFCL has access to the major R&D infrastructure of CSIRO-DMST for materials R&D (up to date materials characterisation and testing equipment). Thus, CFCL carries out at the CSIRO laboratories development and optimisation of SOFC materials, development of fabrication technology for components, and materials/component testing and characterisation. Stacking technology is being developed at the company's headquarters, a task which includes development of sealing options and extensive testing of single cells and stacks. BHP at its Melbourne Laboratories, also located in Clayton, provides the computing infrastructure for cell and stack performance as well as structural modelling work. The new facility established at the Churchill campus of Monash University in Gippsland is a purpose built R&D complex for scale-up of component manufacture and testing of larger prototype SOFC modules. Facilities are being installed to fabricate several thousand PEN structures per year ranging in size from 50 mm x 50 mm to 150 mm x 150 mm, including fabrication of electrolyte sheets and production of electrode powders. A significant number of test stations for evaluation of stacks in the kW range are planned for operation in Churchill, and some have already been designed and constructed.

CFCL DEVELOPMENT PROJECT

The company has selected planar SOFC technology, which offers the most economic route for the fuel cell manufacture. The first stage of the R & D (five year stage from July 1992 to June 1997) program is fully funded by the consortium partners (about AUD $ 30 million). During this period the Company plans to develop SOFC stacks and prototype modules in the multi - kW range. Following conclusion of this five year R & D stage, the Company will evaluate the status of its own technology as well as the status of SOFC developments around the world, and then will progress its main objective of establishing a major SOFC business located in Australia.

At this initial stage CFCL is concentrating on development of materials and fabrication techniques of components, development of stacking technology, performance and stress modelling of components and stacks as well as extensive evaluation of cell
components, single cells and stacks. The R & D effort is structured into smaller teams
each focussing on the development of key components and technologies. For stacking
cells together, the Company is evaluating different interconnect concepts with major
emphasis on metallic (e.g. Plansee alloy) and cermet interconnects.

Stack testing, with the metallic interconnect and standard electrode and
electrolyte materials, within Ceramic Fuel Cells Limited, is currently performed in the
temperature range 920 - 970°C. However, in recognition of the significant advantages, a
lower operating temperature will bring to SOFC technology in terms of stack life,
production costs and systems integration, CFCL has devoted significant resources
towards operation of fuel cells in the 800-850°C temperature range, and R&D focuses
on (i) development of new electrode and electrolyte materials and (ii) investigation of
thin film electrolyte concepts.

**MAJOR ACHIEVEMENTS OF CFCL R&D EFFORT**

Since its incorporation in 1992 CFCL has made very considerable progress, and
is moving rapidly towards evaluation/testing of large fuel cell stacks in the near future.

Electrode materials and coating techniques have been developed and optimised
and now give consistently:
- Air electrode: < 50 mV overpotential losses at 500mA/cm² current density.
- Fuel electrode: < 75 mV overpotential losses at 500mA/cm² current density.

Electrolyte plates are manufactured for several compositions and from powders
from different suppliers of zirconia-yttria in single firings with specifications of:
- flatness: within a few microns;
- sizes: 50 mm x 50 mm x 50-100 μm;
  100 mm x 100 mm x 150 μm.

Procedures for preparing complete PEN structures (electrolyte plates coated
with air and fuel electrodes) with dimensions 50 mm x 50 mm and 100 mm x 100 mm
have been established. The performance from single cells with tetragonal zirconia-yttria
as the electrolyte (three times lower conductivity compared to fully stabilised zirconia)
is:
- over 400 mW/cm² from 5 cm² active area cells;
- over 350 mW/cm² from 15 cm² active area (50 mm x 50 mm) cells at 1000°C
  and with electrolyte thickness 150-200 μm.
- stability tests on several single cells up to 2500 hours have been performed,
  and the longest single cell test to date ran for about 5700 hours (175 mW/cm²
  working output) with no deterioration observed over the last 3000 h.

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Manifold concepts and manifolds for testing 50 mm x 50 mm and 100 mm x 100 mm stacks have been developed. Durable edge and corner seals which allow cell testing/evaluation to continue for several months have been successfully developed. Recycling trials for sealing materials have commenced. Several 3 and 6-cell stacks have been evaluated using Plansee/Siemens interconnect material. Suitable functional layers for this metallic interconnect material have been developed for short term testing of stacks based on contact resistance and polarisation measurements. Further work to improve long term stability of stacks is continuing. A 12-cell stack (with 50 mm x 50 mm PEN structures) has been assembled and is under test. A 25-cell stack will be assembled shortly.

Hardware and software for thorough evaluation of single cells and stacks have been developed. The current test stations allow 100 - 200 W stacks to be tested over a considerable length of time, and incorporate extensive diagnostics. A limited number of test stations for testing stacks in the kW range have been constructed, and more are in the design and construction phase.

A focussed effort on stack design and system engineering/integration for the initial multi-kW prototype units has commenced which aims to be completed by mid 1996.

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REFERENCES

1. S.P.S. Badwal, K. Foger, Proceedings of the 3rd Internat. Symposium on SOFC, Honolulu, May 1993, Eds. S.C. Singhal and H. Iwahara (The Electrochemical Society Inc., Pennington, NJ, 1993), p 21.
2. S.P.S. Badwal, K. Foger, Austceram, Sydney, July 1994.
3. S.P.S. Badwal, European SOFC Forum, Luzern, Switzerland, October 1994.