



# CERAMIC FUEL CELLS LIMITED

Clean power for your home

## FUEL CELL MANUFACTURING PLANT - BACKGROUND PAPER

### Introduction

Ceramic Fuel Cells Limited is a global leader in fuel cell development. Our technology converts natural gas into electricity and heat through ceramic fuel cells. The process is highly efficient and can significantly reduce carbon dioxide emissions and energy costs.

The first products to be powered by the Company's fuel cells will be small scale units for homes and other buildings that produce up to two kilowatts of power as well as heat for hot water or space heating. The Company is developing products with leading energy and appliance companies in Germany, France, the United Kingdom and Japan. In 2009 the Company also developed a modular co-generation product called BlueGen. These products will meet the growing need for energy whilst also reducing greenhouse gas emissions.

The Company's strategy is to make fuel cell 'modules' which appliance companies can integrate into different products for many large global markets. The Company's first target markets are Europe, Japan, Australia and then North America.

To successfully commercialise its technology the Company is progressing from making a small number of fuel cell modules, to lower cost volume production. This is a critical step for fuel cell companies to make in order to generate revenue and profits.

In line with this commercialisation strategy the Company has built a plant in Heinsberg, Germany for the volume production of the Company's fuel cell stacks. The plant will be one of the first in the world for the volume production of solid oxide fuel cell stacks.

Formed in 1992, Ceramic Fuel Cells has invested more than 140 million Euros in developing its technology. The Company employs 90 staff in Australia, the United Kingdom and Germany and is listed on the Australian Securities Exchange and the London AIM market (code CFU).



Figure 1 – Ceramic Fuel Cells' building at Industriepark Oberbruch

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## Overview of the Plant

Ceramic Fuel Cells has built a manufacturing plant in Heinsberg, 40 minutes drive from Dusseldorf in the North Rhine Westphalia region of Germany. The factory has an area of 4,200m<sup>2</sup> and is located in an existing building in the Industriepark Oberbruch.

The Company announced that it would build the plant in February 2008. During 2008 the Company and its contractors completed site preparation work, obtained full environmental and building permit approvals and placed orders for the major pieces of equipment. In 2009 the equipment was built and installed and commissioned on-site.

The plant was completed in September 2009 for a final cost of 9.5 million Euros. The Company was advised on the project by CEL International Limited, an international engineering consulting firm with significant experience in building manufacturing facilities. The project was also managed by Ceramic Fuel Cells' local staff in Heinsberg. The Company opened an office and hired three local staff in May 2007.

The plant will assemble the Company's fuel cells into 'stacks'. (A fuel cell 'stack' is integrated with other components to make a fuel cell 'module'.) The plant has been designed with the capacity to make 10,000 fuel cell stacks per year. The building works and all of the equipment, including the major cost items of furnaces, ink mixing equipment and robotic assembly units have been designed to meet this capacity.

The key items of equipment at the plant include:

- Ink Mixing Equipment to produce seal material
- Two Robotic Seal Dispensing Machines for automatically dispensing seal material
- Two Curing Ovens for pre-drying dispensed seals prior to assembly
- A Robotic Assembly Machine for automated 'pick and place' assembly of fuel cell stacks
- Three Furnaces for firing fuel cell stacks
- Three Testing machines to test fuel cell stacks before delivery

Several versions of the Company's complete fuel cell systems are also installed at the plant – including the Company's latest BlueGen modular generator. The BlueGen is connected to existing natural gas and water services at the plant, to generate power and heat in real world operating conditions.

For future growth the plant can be expanded to a capacity of up to 160,000 fuel cell stacks per year in the same building. The Company also holds an option over a nearby parcel of land for future 'greenfield' expansion.

## Location

Ceramic Fuel Cells chose to locate its fuel cell manufacturing facility in the Oberbruch Industriepark in Heinsberg for several reasons. Germany is one of the Company's most important early markets. Heinsberg is centrally located between the main cities of Dusseldorf, Cologne and Aachen, and is near to The Netherlands, Belgium and France.

The North Rhine Westphalia region of Germany has highly skilled labour and is strongly supporting new clean energy technologies, especially fuel cells. The North Rhine Westphalia Government has established a network of local suppliers and fuel cell research bodies, and has also agreed to provide financial support for the Ceramic Fuel Cells' project.

Finally, the Company was attracted by the innovative and flexible offering from the Industriepark Oberbruch, which provided a range of additional services to help the Company establish its operations.

Ceramic Fuel Cells acknowledges the contribution and support of many partners and key suppliers during the Heinsberg project, including:

- The Government of North Rhine Westphalia
- The City of Heinsberg
- Industriepark Oberbruch
- Project Managers CEL International Limited and key contractors BFT Planung
- Key suppliers including:
  - o BIS HIMA GmbH
  - o Eisenmann Anlagenbau GmbH
  - o Intega GmbH
  - o Netzsch Feinmahltechnik GmbH
  - o TF Automation Ltd
  - o Theod. Mahr Söhne GmbH

## Manufacturing Process

In simple terms, the plant takes individual fuel cells plus other components, and assembles them into a fuel cell 'stack'. The fuel cell stack is the core component of the Company's fuel cell modules. The fuel cell stack is the part of the system that generates electricity.

Assembling the fuel cell stacks involves the following components and processes:

The basic ceramic fuel cell 'chips' are made by external suppliers to the Company's specification and design. Each fuel cell is 7cm square and about 230 microns thin (about the thickness of a business card). Each cell is made up of six layers of very fine ceramic materials including Yttria doped Zirconia Oxide.

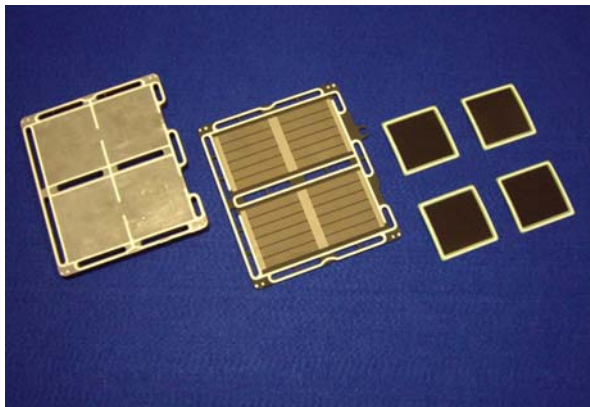


Figure 2 - Plates and four Fuel Cells



Figure 3 - A completed 2kW Fuel Cell Stack

Robotic assembly units place four of the fuel cells on a stainless steel base plate. The stainless steel is coated with a specially patented coating to allow the steel to be used at high temperatures. The fuel cells are covered with a cover plate. An interconnect plate is then placed on top, to form a 'layer set'.

(The holes in the plates are for the gas and air to circulate within the fuel cell stack, passing across both sides of the fuel cells to generate electricity through an electrochemical reaction. More information on how the fuel cells work is available at [http://www.cfcl.com.au/Fuel\\_Cell\\_Facts/](http://www.cfcl.com.au/Fuel_Cell_Facts/))

The fuel cells and the steel plates are 'glued' in place by a proprietary sealing material, made from glass and other chemical compounds.

The seals are dispensed onto the fuel cells and the plates by automatic dispensing machines.

The dispensing machines are loaded with pre-filled cassettes of either fuel cells or interconnect plates and cartridges of seal paste. The robot then selects a part from the cassette and places it

on a table where a computerised vision system checks that it passes quality control tests. The part is then moved into the dispensing area for dispensing.

Once dispensed the part is re-inspected by the vision system to check the quality of the seal. The robot exchanges the part for the next one to be dispensed then transfers the finished part to another cassette.

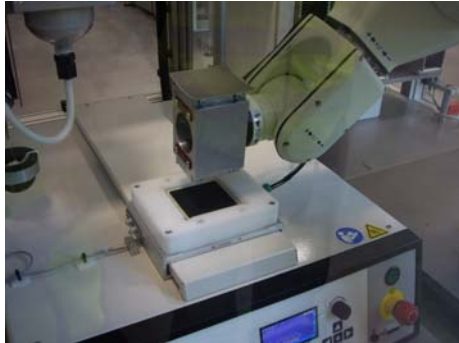


Figure 4 - Automated Quality Control



Figure 5 - Automated Seal Dispensing

Once a batch of cassettes has been completed they are moved out of the dispensing station and a second batch moved in. Completed cassettes are then transferred to a drying oven for curing before assembly.

Cassettes full of both dispensed parts and parts that do not require dispensing are loaded into the Robotic Assembly Station and indexed into the work area. The robot selects its next part based on a pre-programmed Stack configuration and begins the assembly sequence.

Parts are initially placed on an inspection table to be verified as the correct item and, if applicable, that the integrity of the seal is acceptable. Once the vision system has confirmed that the part is acceptable, the second robot picks up the part and places it into its appropriate position in the stack. As each layer is completed, a second vision system verifies that all parts are correctly located.

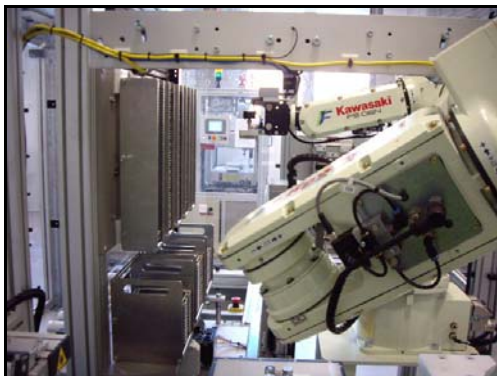


Figure 6 - Robotic Assembly Machine



Figure 7 - Robotic Assembly of Fuel Cells

The assembly process continues until the pre-programmed configuration has been achieved. The completed fuel cell stack is then moved out of the work area for unloading while the assembly of the next stack begins.

The completed fuel cell stacks are then mechanically loaded into a furnace and positioned on a process gas distribution manifold with the appropriate seal ready for firing. (This process is known as “reduction”.) Once the furnace has been filled the firing cycle begins. During the firing

cycle, and based on a predefined temperature profile, process gases are introduced to aide the reduction process.



**Figure 8 - Furnaces for Firing Fuel Cell Stacks**

At the end of the firing cycle the fuel cell stacks are then transferred to a testing machine for testing under operational conditions. Tested fuel cell stacks are then given a final quality assurance check and are ready to be shipped to appliance and manufacturing partners for integration into fuel cell modules and complete fuel cell products.

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