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# PERFORMANCE EVALUATION OF A FUEL CELL WITH MEMBRANE ELECTRODE GASKET ASSEMBLY (MEGA) TECHNOLOGY

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Actual spread diffusion of fuel cells for energy power generation depends strongly on the capacity to apply present manufacturing methods and up-to-date technologies in order to reduce production cost of fuel cell components and related auxiliaries. Polymer electrolyte membrane (PEM) fuel cell, for its high power-density performance and low operating temperature, looks as that fuel cell technology capable to exploit such technologies and methods, already well established in other traditional industrial sectors.
Industrial expertise in Roen Est Fuel Cell and R&D competence in fuel cell electrochemistry and engineering in ENEA laboratories were combined to focus the common efforts on design, development and production of main components of stack system. At first Partnership was addressed to development of an effective and reliable way to produce MEAs (Membrane/Electrode Assembly) and assembly them into a stack, resulting in the MEGA (Membrane Electrode Gasket Assembly) technology.
As further step a prototype of PEM fuel cell for portable energy generation was realized with this innovative features and tested at the ENEA laboratories (Rome).

## MEGA TECHNOLOGY

In ordinary PEM fuel cell, in order to contain gases flowing inside cell compartments, two sealing gaskets are put on both side of the MEA, all sandwiched in between the bipolar plates. Sealing must not come into contact with the surface of electrode, whose porosity causes gas leakage. For this reason the membrane overhangs the four sides of the assembly and, given its non-porous nature, provides an adequate surface to the gasket.
Such a sealing configuration has a variety of drawbacks due to the need of accurate assembling and aligning operations and the waste of membrane, whose area exceeding over the electrode ones is not useful for the ionic exchange.
The MEGA technology has the purpose of eliminating, in principle, these drawbacks by devising a "drowning" process of the MEA in the gasket, according to a known process of material injection moulding. This purpose is attained by a device that is characterised by being basically made up of a MEA assembly, without overhanging membrane, and a bi-component silicone based liquid mixture injected, in a special mould, directly on the perimeter of each MEA (fig. 1).

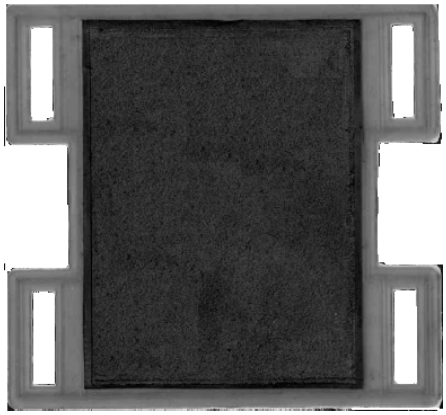

**Figure 1 - Membrane Electrode Gasket Assembly (MEGA)**

The gasket materials is compatible with the chemical and thermal conditions of PEM fuel cell (tested between –50° and +180°C) and pressure tests on assembled stacks were carried out up to 10 bar.
With this patented MEGA technology [(1)], after moulding operation, there is only one single component against previous three ones (two gaskets and the MEA), and both centering difficulties and stack assembly time are considerably reduced.

## STACK MATERIALS AND PREPARATIONS

After positive preliminary tests on mono-cell and mini stacks[2], 21 MEGA elements, with an active area of 106 $cm^2$, were prepared following the methods previously adopted [3,4,5] . Catalyst ($Pt_{an,cat}$ 0.5-0.75 mg $cm^{-2}$) and diffusive layer carbon (0.91-2.4 mg $cm^{-2}$) compositions and some MEA production parameters were varied to check their effects on final performance of single cells.

Three-layers cathode and anode electrodes were prepared by successive spray deposition technique of catalytic and diffusive inks. Electrodes were then hot pressed on a Nafion 115 membrane (Du Pont). MEA assembly were successively "dropped" in a heated aluminium mould for injection of a proprietary silicone based liquid mixture, in order to obtain a well-defined shape gasket (fig. 1). In figure 1, on the lateral borders of the MEGA, the holes for gas feeding/discharging are visible.

After MEGA production phase, they were fully immersed in distilled water for storage. The simply storage (and delivery as well) of ready-to-use MEGA shows another good point of this technology.

Graphite bipolar plates were realised with a typical parallel channel configuration using commercially available graphite materials produced by SGL Carbon Group (Germany).

## TESTING STATION

A test facility was specifically designed for test of small PEM fuel cell stacks. Such facility allows the complete control of input gases (flowrate, temperature, pressure, relative humidity) and monitoring of the stack (voltage, current, anodic and cathodic pressure drops) and of the external cooling system. Furthermore it provides capability to configure the flow paths of both gases (one-through, dead-end or recycle; humidifier by-passes), in order to compare stack performance in different operation conditions.

Monitoring of fuel cell operation and part of control operations of station is carried out by a data acquisition system that uses a HP-75000 as data logger and Labview® as developing software. Data acquisition programming was specifically developed internally to better adapt it to experimentation needs.

Fuel cell cooling was performed putting entire stack in a small sink filled with a no-conductive liquid. Liquid was then pumped to an external air-heat exchanger for cooling.

## STACK CHARACTERIZATION

After assembling of a 20-MEGA-cell stack, preliminary operations showed a progressive increase of maximum output current, due to the continuous release of pore generating material, present in diffusive layer, and detectable in trace amount in fuel cell output streams.

After some few tests, an uneven behaviour of voltage in few cells (inversion of polarity) forced us to stop experimentation for checking status of defective cells. A corrosion attack, caused by wet reducing environment, underwent at the poor-quality Nickel coating of anodic end-plates, producing a large quantity of flake-like debris. Clogging of anodic entrance to two defective cell compartments could be the cause of anomalous "electrolysis operation" observed in those cells during testing. Defective cells were eliminated, the others cleaned from debris, and the two Ni-plated aluminium end plates substituted with alike stainless steel terminal plates. Stack was then reassembled with remaining 18 cells.

With this stack configuration, stack performance was stable and capable to reach maximum power of the electronic power load, obtaining a maximum power output of 294 W at 30 (figure 2). Power density appears to be about 3 kW $m^{-2}$.

It was observed that the cathode humidifier temperature plays a

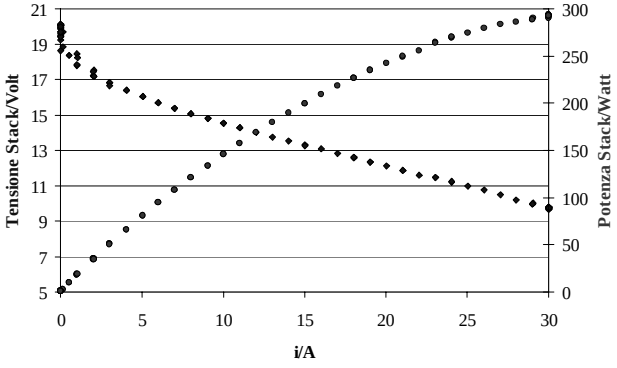


**Figure 2 - Polarization and power curves of MEGA stack ($H_2/O_2$ @1.7bara, $T_{cell}$=75°C, $T_{anode}$=85°C, $T_{cathode}$=75°C, SR $H_2/O_2$ 2/4)**

very important role in relation to the working current densities and to the produced water amount. In fact the water produced in the catalytic layer at the cathode side can spread in the membrane maintaining it wet and avoiding an increase of ohmic resistance, or diffuse into the electrode and flooding it. Therefore it is necessary a control of the air humidity to equilibrate these two different phenomena.
Hydrogen humidity control looks less restrictive as some short tests with dry anodic gas didn't show an evident decrease of performance. Switching from one-through anodic flow to dead-end one displayed even a slightly increase in cell voltage, caused from the absence of water entrainment in the hydrogen outlet stream.
Along stack testing the measured pressure drop along cathode side showed always a very limited range (40-60 mbar), showing a good design of collector plate flow field.
By the way, respect to the mono-cell preliminary tests, it was observed a slight decrease of performance, probably due to an uneven distribution of gas supply to the cell inside the stack.

During stack inspection and failed element substitution it was possible to disassemble the stack and replacing only the failed cell, showing an effective operation of MEGA. No evident chemical or mechanical degradation was observed on the silicon gaskets. Even the possibility to reuse MEGA elements several times without any change or decrease of performance was demonstrated, envisaging a pre-assembling MEGA quality control.

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