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SULZER INNOTEC

Natural Gas Fuel Cells for Residential Applications
The SULZER HEXIS SOFC Project

Summary

SULZER is developing SOFC systems (SULZER HEXIS SOFC) for small scale cogeneration.
The systems are based on a ceramic/metal hybrid stack with circular, planar SOFC elements. The special design, with heat exchangers built into the stack, allows efficient operation of very small systems.

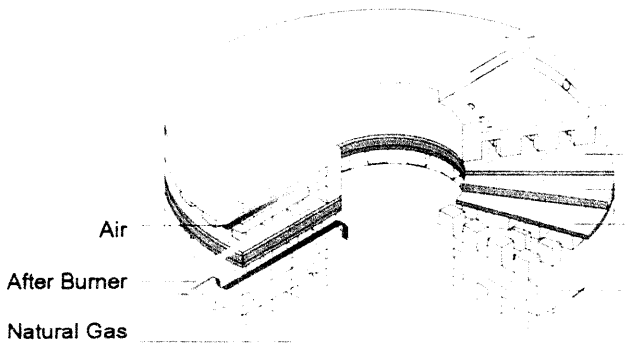
Development has now reached a stage which allows the operation of demonstration units and prototypes outside the lab under field conditions. Upscaling of cells to larger dimensions is well under control. Solutions for the problem of stack degradation have been successfully developed. Operation with different qualities of natural gas is continuing successfully in the labs.

The SULZER HEXIS Design Concept

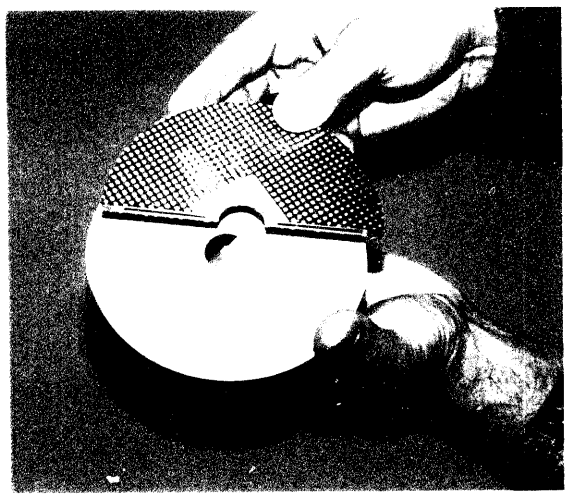
SULZER HEXIS systems use a ceramic/metal hybrid stack with circular, planar SOFC elements. The unique design features are:

- System with integrated gas burner, specially designed for flexible heat production in small scale heat and power cogeneration applications.

- Design concept optimized for high energy density of the total system, not only of the cell stack:
  - Every stack repeat element serves as electrochemical reactor, heat exchanger and after burner.
  - The integrated heat exchanger allows to operate with low mass flows of cooling air.
  - The hybrid metal/ceramic stack concept, results in small internal electrical power losses.
  - No hard seals between air and gas are necessary. Therefore, mechanical stresses in the cells can be kept low.
  - The circular, axisymmetric design, together with the integrated heat exchanger minimizes the thermal stresses in the cells.
  - Easy maintenance.



Schematic cross section of a stack repeat element.
Air is fed into the heat exchanger/interconnect through six small air inlets at the periphery. Gas is fed through the center bore.



Current design of the stack repeat elements.
Each stack repeat element consists of two components, the electrochemically active ceramic element (electrolyte with anode and cathode) and the metallic heat exchanger/interconnect with six ceramic air inlet tubes (not shown on the photograph).

The stack design allows the integration of any commercially available - self supported or substrate type - ceramic element. For strategic reasons, Sulzer does not develop zirconia-based ceramics, but rather relies on proven technology developed and manufactured by others. Partners for cell elements are SOFCo, Salt Lake City, Utah, the Dutch laboratories ECN and Medicoat in Switzerland. The interconnect material is usually from Plansee, Austria.

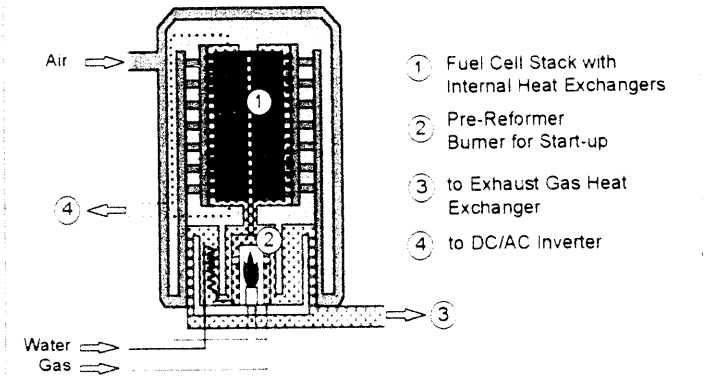
The first generations of systems will be made using zirconia-based ceramic elements and conventional partial steam reforming of the natural gas. As technology progresses, other ceramic elements or reforming systems may be adapted.

The patented HEXIS design allows building thermally self sustaining systems even in the size of one kW electric power.

The building blocks of the SULZER HEXIS SOFC systems are so called system modules with cell elements of 120 mm and 200 mm diameter.

With the two sizes of modules, the whole power range of residential cogeneration systems can be covered.

SULZER HEXIS SOFC System-Module

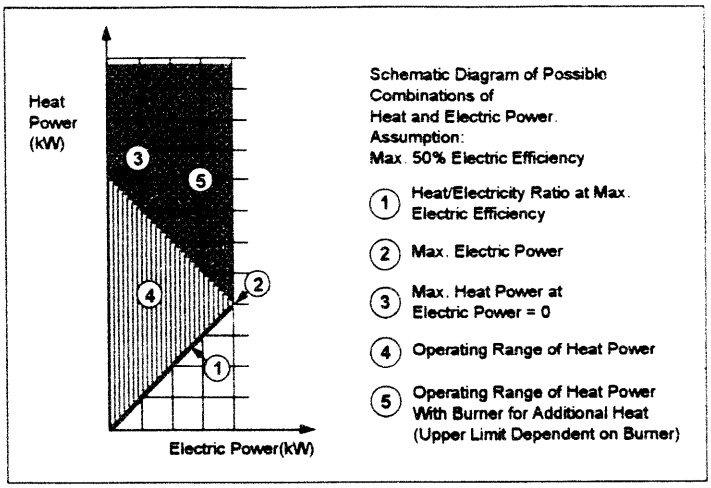


Schematic arrangement of a HEXIS system module.

Each module contains a fuel cell stack, a pre-reformer and a start-up burner.

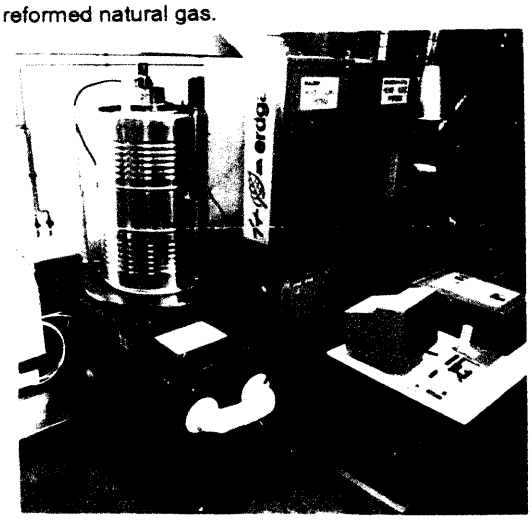
A varying number of modules, together with the exhaust gas heat exchanger and the electrical periphery are assembled to systems of different sizes.

Operation of a Fuel Cell as Cogeneration System

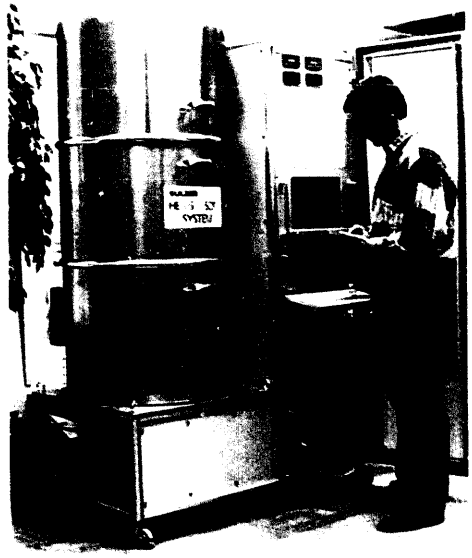


Fuel cell systems allow to vary the heat output relative to the electric power in a range which can be approximated by a triangle (shown in blue). HEXIS SOFC fuel cells are equipped with a special start-up burner, which can deliver additional heat according to user needs. This flexibility in operation makes the SULZER HEXIS SOFC fuel cell an ideal system for small scale residential cogeneration applications.

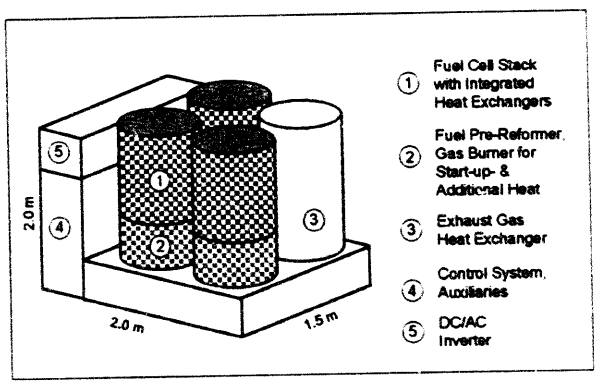
1 kW lab unit for operation with hydrogen and externally reformed natural gas.



7-15 kW lab unit, using 200 mm cells. Thermal commissioning was successfully performed.
The unit has an integrated start-up burner and pre-reformer for natural gas operation. Electrochemical testing will start in 1997.

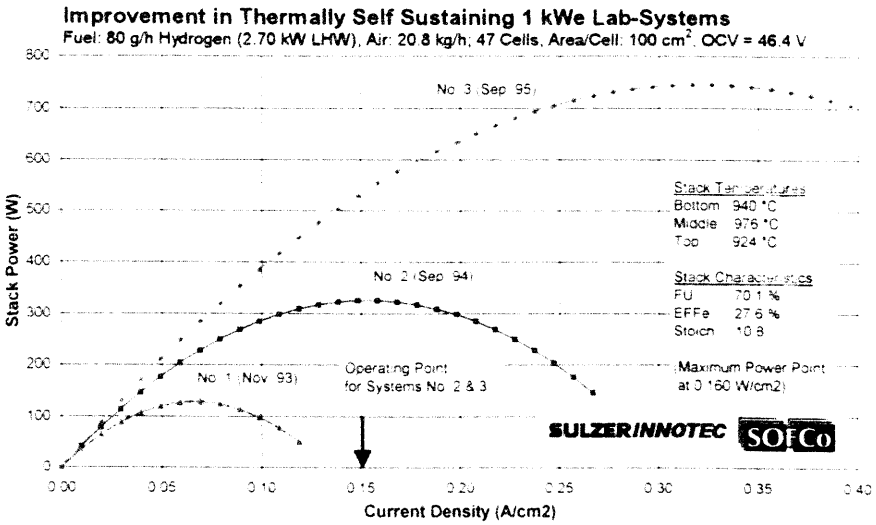


Conceptual design of a larger cogeneration system



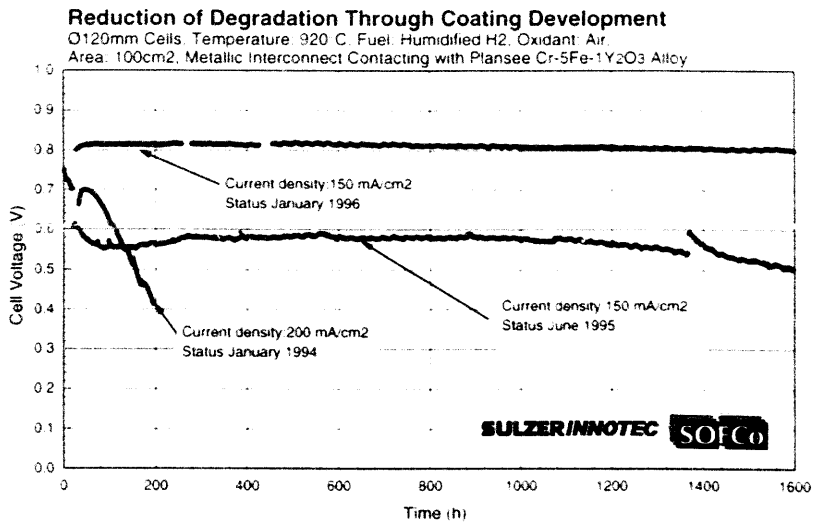
Approximate dimensions of a 50 kWe prototype cogeneration system, based on the 7-15 kW lab modules.

Technical Status and Further Development Challenges

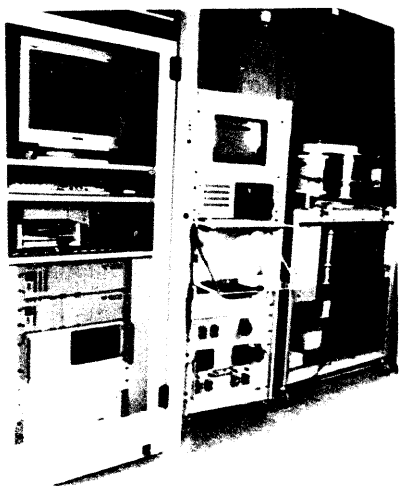


The diagram shows the progress in power density and overall electric efficiency over the last few years. For practical reasons, lab testing is still mostly performed with hydrogen.

Data with cells from SOFCo.



Coating and bonding materials development resulted in highly reduced cell degradation. Cell degradation is now acceptable for prototype testing outside of the labs.



Automatic, remote controlled lab system for unattended operation. The SULZER HEXIS SOFC lab system at „Dortmunder Energie und Wasser" in Dortmund, Germany is used for long term testing of the cell behaviour with different qualities of natural gas from the pipe line.