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State of development of fuel cell technology

Summary

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SUMMARY

Fuel cell technology offers an attractive combination of highly efficient fuel utilisation and environmentally-friendly operations. In the near future, some fuel cell systems could be an accessible and attractive alternative to conventional electricity generation and vehicle drives. The intensified research and development in the field of fuel cell technology particularly in recent times, are the basis for the present status report, which inquires into the technical and economic aspects of how fuel cell systems presently available can be used in mobile and stationary applications.

WHY FUEL CELLS?

The principle of fuel cells and also their potential for reaching higher efficiency than steam power stations has been known since the 19th century. A fuel cell can be described as a closed container to which a fuel such as hydrogen and oxygen is added and which generates electrical energy, heat and water. The cell contains two electrodes and one electrolyte, after which the fuel cell type is usually named. The electrolyte divides the cell into separate areas so that the electro-chemical energy transformation takes place in separate reactions and a »detonating gas reaction« does not occur.

The advantages of the fuel cell, in addition to its comparatively high electrical efficiency, are that it has limited or zero local emissions, allows very flexible operations, has a modular construction and produces low noise emission. Despite considerable scientific progress (e.g. in the materials used) and clearly changed energy-policy framework conditions (e.g. carbon dioxide problem), fuel cell technology has not yet developed into a competitive option in series production, and is therefore not used on a large scale.

WHICH FUEL CELL SYSTEMS ARE OF INTEREST?

Of the several fuel cell types available, five have proved to be viable. These are, in the sequence of their operating temperature, the alkaline fuel cell (AFC, c. 80ºC), the proton exchange membrane fuel cell (PEMFC, c. 80ºC), the phosphoric acid fuel cell (PAFC, c. 200ºC), the molten carbonate fuel cell (MCFC, c. 650ºC) and the solid oxide fuel cell (SOFC, c. 1,000ºC). Another frequently mentioned type of fuel cell is the direct methanol fuel cell (DMFC) which can be considered a variation of the membrane fuel cell.

These fuel cell systems are in very different stages of development. The phosphoric acid fuel cell is the only fuel cell type already introduced onto the civilian market. The alkaline fuel cell, which has long been technically optimised for special applications but is extremely expensive, is being increasingly overtaken by the membrane fuel cell, developed in recent years in close response to the market needs; direct methanol fuel cells are still in their early development stages. Most high-temperature fuel cells are also still in the development stage, although for historical reasons the molten carbonate fuel cell is a further developed than the solid oxide fuel cell. However, the latter in particular offer flexible applications and highest efficiency.

WHAT ARE FUEL CELLS USED FOR?

The principal application areas for fuel cells are the cogeneration of heat and electricity and the transport sector. Applications are evolving: The PAFC which is ready to be launched on the market, is used for the cogeneration of power and heat, for example in power stations delivering decentralised energy supply to buildings and is acting as the so-called market opener; intensified PEMFC developments have particularly focused on automotive engineering applications and several prototypes are available for busses and passenger cars; high temperature fuel cells (MCFC, SOFC) are presently being intensively developed for use in the power station sector, although this will probably not be an initial market for fuel cells.

The potential for using fuel cells is determined in each case by the cost factor and the not-yet-fully-exhausted potential to optimise conventional energy generation technologies and vehicle drives. A comparative analysis in terms of greenhouse gas emissions, for example, would also have to take into account the entire fuel cell system including all its upstream processes such as fuel processing to generate hydrogen.

WHAT IS THE STATUS OF INTERNATIONAL FUEL CELL RESEARCH?

International research and development activities on fuel cell technology are centred in North America, Japan and Western Europe, although to varying intensities – primarily reflecting the different energy and environmental policy framework conditions. Japan is undertaking intensive efforts to make fuel cell technology available as soon as possible, particularly to generate electricity and heat (PAFC, MCFC, SOFC). fuel cell technology development has been continuing at a steady pace in North America and efforts are now directed at maintaining and further developing the technology lead in several areas (e.g. USA: production know-how on PAFC, own concept on SOFC; Canada: PEMFC). Developments in Western Europe have been less continuous. The renaissance in fuel cell research observed in recent years particularly relates to PEMFC in the automobile sector and high temperature fuel cells (MCFC, SOFC), whereby cooperation with non-European companies is quite frequent. A comparison of public funds used for fuel cell technology development indicates that in terms of per capita or gross national product Germany devotes far less funds to fuel cell technology than the USA or Japan.

WHAT ARE THE DEVELOPMENT FIELDS AND KEY PROBLEMS INVOLVED IN FUEL CELL TECHNOLOGY?

International research on fuel cell technology has reached a development stage which makes it potentially feasible for some fuel cell types to be introduced on a wide-scale in the medium term (around 2005 to 2010). The technical maturity reached by fuel cells is quite advanced; process engineering problems are more frequent on the peripheral installations needed for fuel processing and control, and the optimisation of the overall system.

A major disadvantage of fuel cell systems presently available is their high manufacturing costs compared to conventional technologies for electricity generation and vehicle drives. These costs result from the fact that most fuel cells are still manufactured as »one-off« items, and require expensive materials (such as platinum and gold as catalysts in low temperature fuel cells). To reduce costs further efforts must also tackle the fuel cells themselves – the materials used, for example, the catalysts and the composition of the membrane in low temperature fuel cells or materials resistant to high temperatures and erosion in medium and high temperature fuel cells. Not just the peripheral equipment but also the systems have to be simplified. In order to reach costs in similar ranges to those of conventional energy generation plants, today's fuel cell costs would have to drop by a factor of up to ten; vehicle drives require even greater cost reductions.

One major feature of fuel cell systems is that only a limited range of fuels are suitable, although the range widens the higher the operating temperature. In low temperature cells, for example, the alkaline fuel cell can only be operated with purest hydrogen and oxygen, the most expensive fuel supply option. In membrane fuel cells, hydrogen already reformed from methanol outside the fuel cell can be used with air (PEMFC) or methanol directly (DMFC); the use of reformed petrol/gasoline is being debated. In the high temperature molten carbonate and solid oxide fuel cells, different gases such as natural gas or coal gas with air can be used (thanks to internal fuel cell reformation), possibly making it feasible to connect to an existing supply system. The automotive engineering sector has basically different fuel supply concepts: hydrogen, compressed natural gas or liquid fuels (methanol, petrol/gasoline) are used, each of which require different supply structures. To set up a hydrogen supply, for example, a completely new infrastructure would be necessary; whereas this would be an expensive step to take, the use of hydrogen would be far more efficient than natural gas. Hydrogen can also be obtained using regenerative sources of energy. If methanol were used, on the other hand, today's petrol station system could initially act as supply network.

In summarising it can be stated that while fuel cell technology is very attractive in terms of research, energy and environmental-policy, it has not yet been exhaustively developed from the technical viewpoint and still a cost intensive option today. In order to assess future, wider potential applications for low-emission fuel cell technologies, further investigations are necessary.

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