MTU CFC Solutions GmbH

- Subsidiary of DaimlerChrysler AG
- Established January 2003
- Located near Munich / Germany
- Total Area: 5000 m²
- Research & Development
- Power Plant Assembly and Test
- Pilot Cell Manufacturing
The HotModule – Fuel Cell Programme

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- Technology und Plant-Design
- Advantages compared to conventional power plants
- Biogas and the carbonate fuel cell
- Next steps, Commercialisation

Principle of the Carbonate Fuel Cell

\[
\text{Reforming reaction:} \quad 
\begin{align*}
\text{Catalyst:} & \quad \text{CH}_4 + 2 \text{H}_2\text{O} &\rightarrow & \text{CO}_2 + 4 \text{H}_2 \\
\text{Anode:} & \quad \text{H}_2 + \text{CO}_3^- &\rightarrow & \text{H}_2\text{O} + \text{CO}_2 + 2 \text{e}^- \\
\text{Cathode:} & \quad \text{CO}_2 + 1/2 \text{O}_2 + 2 \text{e}^- &\rightarrow & \text{CO}_3^-
\end{align*}
\]

\[
\text{Anode reaction}: \quad \begin{align*}
\text{H}_2 + \text{CO}_3^- & \rightarrow \text{H}_2\text{O} + \text{CO}_2 + 2 \text{e}^-
\end{align*}
\]

\[
\text{Cathode reaction}: \quad \begin{align*}
\text{CO}_2 + 1/2 \text{O}_2 + 2 \text{e}^- & \rightarrow \text{CO}_3^-
\end{align*}
\]

\[
\text{Offgas}: \quad \begin{align*}
\text{O}_2, \text{CO}_2
\end{align*}
\]

\[
\text{Reforming reaction}: \quad \begin{align*}
\text{CH}_4, \text{H}_2\text{O} & \rightarrow \text{CO}_2 + 4 \text{H}_2
\end{align*}
\]
Single Carbonate Fuel Cell

Integration - Fuel Cell Stack
Hot Module packaging priniziple

Process Flow Diagram
Prototyp, Dezember, 2001

Electrical efficiencies of power plants

- MCFC, High temperature fuel cell
- PAFC, Low temperature fuel cell
- Gas engine
- Gas turbine
- Steam power plant
- Future technology
- Today’s technology
Options for the use of high temperature heat (400°C)

**Process steam and/or heating heat**

**Coldness in combination with absorption chiller engines**

- Better utilization of the power plant
- Higher coldness to heat ratio
- Compact shelving
- The market for cooling is growing worldwide

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**Applications & Customers**

- Hospitals
- Beverages
- Pharmaceutical
- Commercial Facilities
- Utilities
- Food Industry
- IT-Sector
- Telecommunication
Fuel Flexibility

Die Zellspannung profitiert vom CO$_2$-Gehalt des Gases
Variation der Gaszusammensetzung

Renewable Energies

Agriculture waste
Biogas Plants
Sewage Plants
Residual Gas
Coal-Mine Gas
Landfill Gas
Field trial in Germany

Gesamtanlage HM300-3
Rhön-Klinikum AG

Krankenhaus
Energieversorgung
In Bad Neustadt/Saale
betrieben von der Rhön-Klinikum AG
Emission Measured

<table>
<thead>
<tr>
<th></th>
<th>HotModule Pilot Plant</th>
<th>Piston Engine Cogeneration Unit</th>
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</thead>
<tbody>
<tr>
<td>CO mg/m³</td>
<td>14</td>
<td>30 – 480</td>
</tr>
<tr>
<td>NOx mg/m³</td>
<td>&lt; 2</td>
<td>10 – 750</td>
</tr>
<tr>
<td>Total Carbon (incl. CO) mg/m³</td>
<td>5</td>
<td>310 –</td>
</tr>
<tr>
<td>Organic Carbon mg/m³</td>
<td>&lt; 1</td>
<td></td>
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</tbody>
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Clinic Magdeburg - Germany
The HotModule System confirms an excellent part load efficiency.
Efficiency of the power plant

Telekom - München
Operation and Monitoring
Entirely remote controlled test operation
Ongoing Field Test Installations

- Grünstadt Hospital
- RWE / Germany
- Otto-von-Guericke Clinic / Germany
- Telekom / Germany
- IZAR / Spain
- Mercedes Benz / USA
- LADWP / USA
- Michelin / Germany
- Rhön Klinikum / Germany
- Grünstadt Hospital
- RWE / Germany
- Otto-von-Guericke Clinic / Germany
- Telekom / Germany
- IZAR / Spain
- Mercedes Benz / USA
- LADWP / USA
- Michelin / Germany
- Rhön Klinikum / Germany

Load Profile of the Bad Berka-unit

Load Profile Diagram from 10/01/03 to 03/05/04

- Power-DC [M30253]
- Power-AC [M10146]
**Field Test Experience**

- **Electrical Plant Efficiency**: 47% Demonstrated
- **Operating Time of one Field Test Unit**: > 19,000 hrs.
- **Total Accumulated Operating Time**: > 80,000 hrs.
- **Variable Power to Heat Ratio**
- **Over 90% Total Efficiency**
- **Multistage Heat Utilization**
- **Trigeneration Demonstrated: Power, Heat, Cooling**
- **DC Application Demonstrated**
MTU CFC Solutions GmbH