

ADVANCES IN SELECTED FUEL CELL TECHNOLOGIES
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A Two-part Presentation

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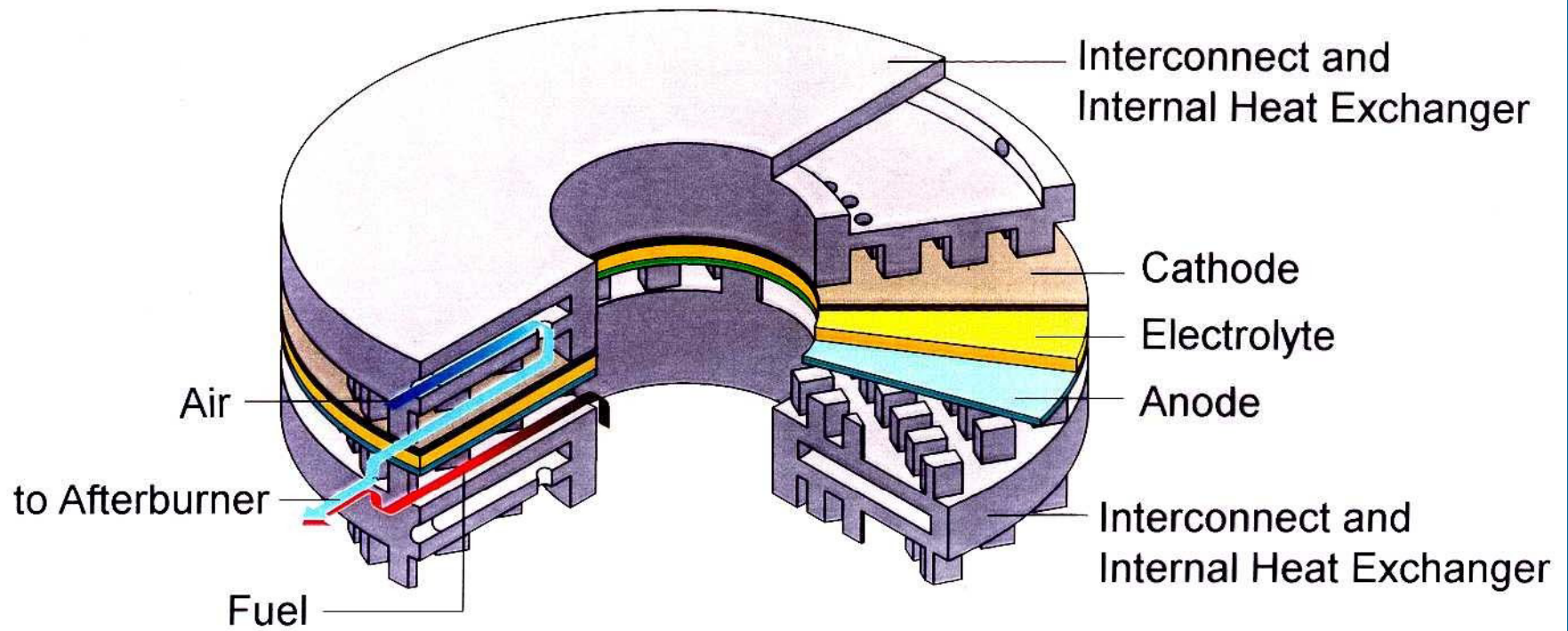
Massachusetts Electric Narragansett Electric Granite State Electric
Nantucket Electric Niagara Mohawk New England Power (Transmission)



National Grid

Review of Solid-oxide Fuel Cells

- Very high operating temperature (1,000 C typical)
- Internal fuel processing eliminates the reformer
- Planar or tubular cell configurations
- CHP or electricity-only designs
- Many companies, but very few commercial products



Drawing courtesy of Sulzer Hexis, Ltd

LATEST VERSION OF THE S-H RESIDENTIAL HEATING SYSTEM



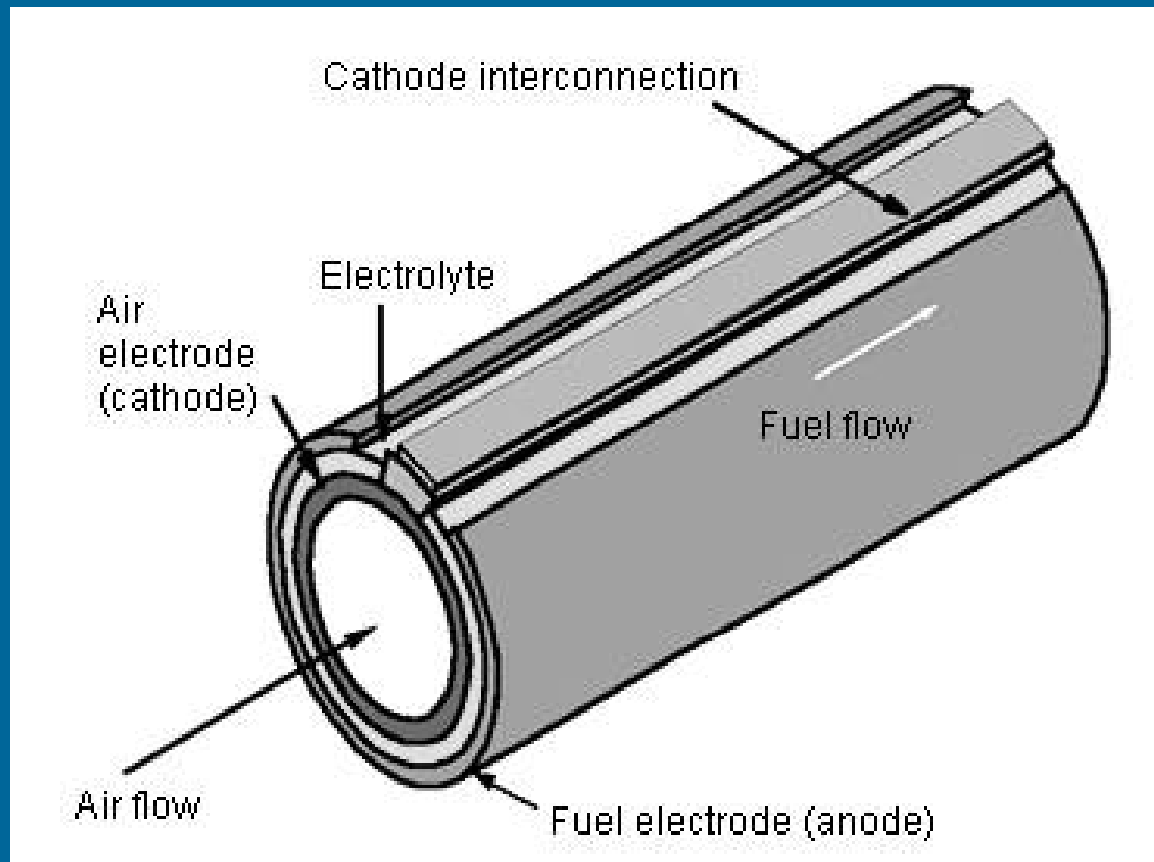
Sulzer Hexis CHP System Components © 1 kWe, 2.5 kWt

OVERVIEW OF SOFC COMPANIES*

Company	Power ¹	Cell Type	Status
Acumentrics	2 – 10 kW	Tubular	On Market
Ceramic FC Ltd	< 50 kW	Planar	Concept Test
Delphi Corp.	1 – 25 kW	Planar	C.T. & Proto.
Fuel Cell Tech.	5 kW	Tubular	Prototypes
Global Thermo. ²	2 – 5 kW	Planar	Prototypes
Sulzer Hexis Ltd	1 kW	Planar	More tests planned
Siemens/West.	125 kW	Tubular	Proto. Testing
Rolls-Royce	250 kW	Planar	In development
Ztek	25 kW	Planar	Prototype

*Mid-2005; subject to Change 1 Upper limits may vary 2 New owner is third

Siemens Westinghouse Tubular SOFC Configuration



Drawing courtesy of Siemens Westinghouse Power Corp.

SIEMENS-WEST. HYBRID: SOFC + GT

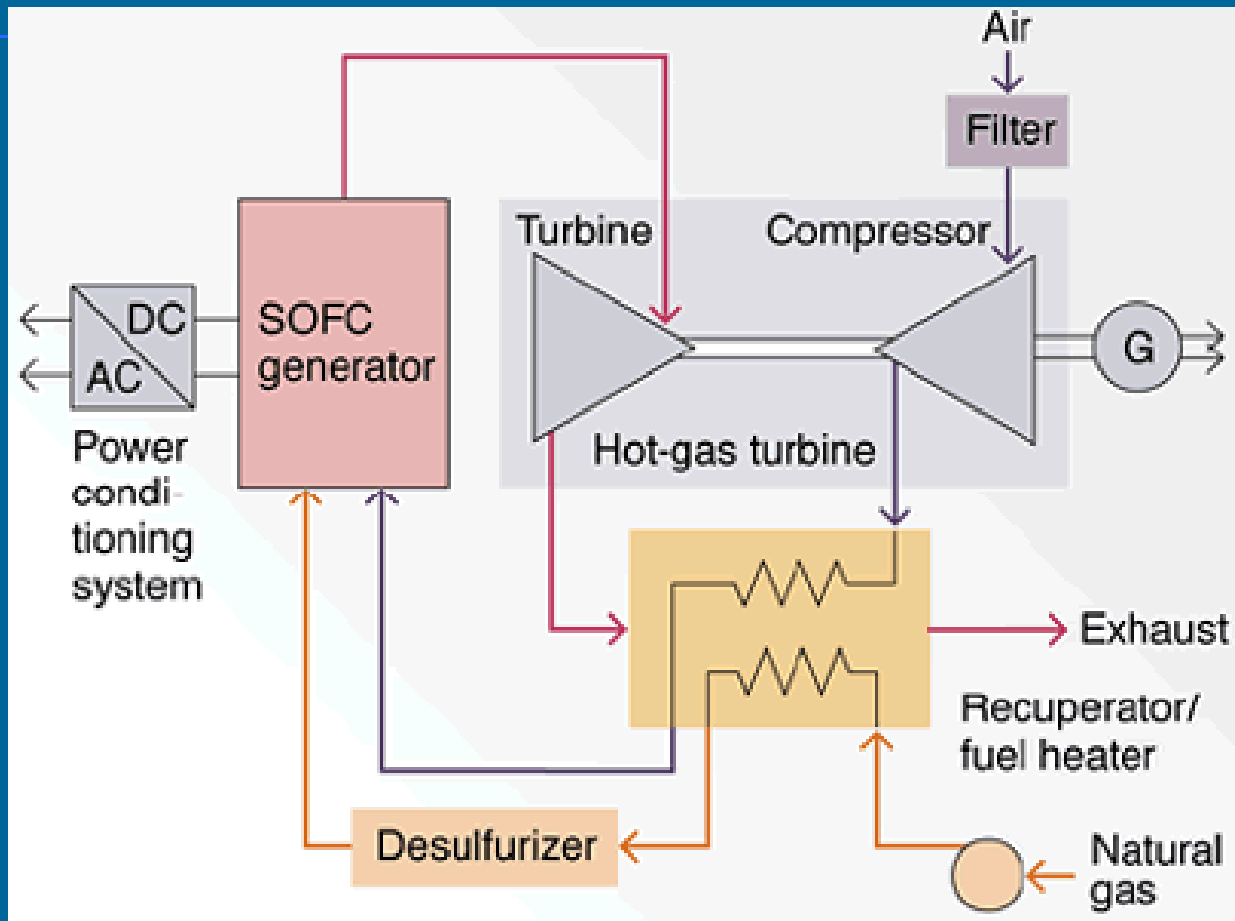


Illustration from Siemens-Westinghouse web site – URL listed later

220-KW S-W HYBRID: SOFC + GT



Illustration from Siemens-Westinghouse web site – URL listed later

FCT's Prototype 5-kW CHP System



Photo from Fuel Cell Technologies web site, www.fct.ca

SOFC FIELD TESTS or DEMONSTRATIONS

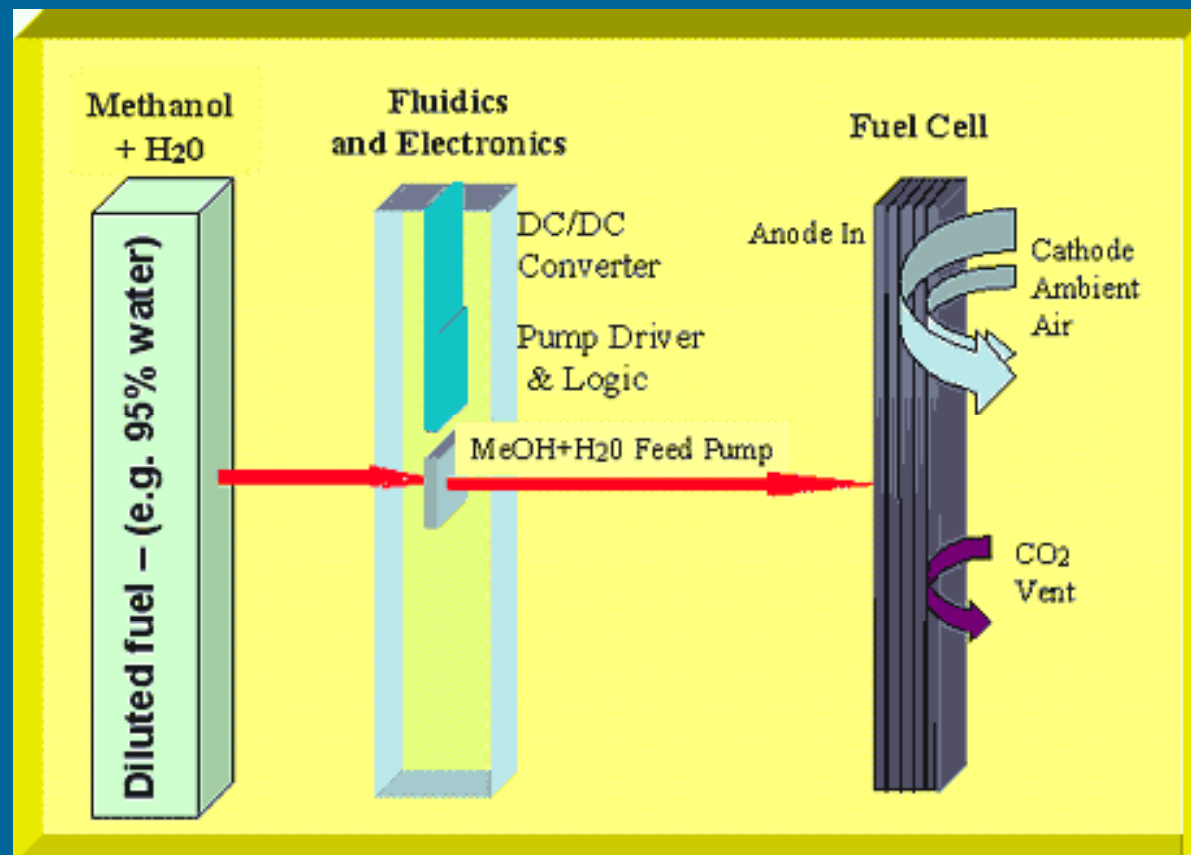
Company	# In Test ¹	Location	Status
Acumentrics	9+	U. S.	Ongoing
Ceramic FC Ltd	N.A.	Australia	Prototype
Delphi Corp.	1	U. S.	Pre-prototype
Fuel Cell Tech.	4	US, J, G	1 st -gen. systems
Global Thermo.	5	U.S., Canada	Ongoing
Sulzer Hexis Ltd	?? *	Europe	Uncertain
Siemens/West.	4	CA, E, Canada	Ongoing
Ztek	2	CA, CT	Prototype

1 Numbers subject to change * Planned

Direct-Methanol Fuel Cells (DMFC)

- Operating temperature from 50 – 120 C
- Methanol (CH_3OH) broken down by catalyst to make H^+
- Planar cell configurations
- Dilute methanol predominates at present
- “Many companies, but very few commercial products”

DMFC Overview – “Dilute Fuel”



Drawing from MTIMicro web site – URL at end of presentation

DMFC CHEMICAL REACTIONS

- Anode: $\text{CH}_3\text{OH} + \text{H}_2\text{O} \Rightarrow \text{CO}_2 + 6\text{H}^+ + 6\text{e}^-$
- Cathode: $3 \text{O}_2 + 12 \text{H}^+ + 12 \text{e}^- \Rightarrow 6 \text{H}_2\text{O}$
- Overall: $2 \text{CH}_3\text{OH} + 3 \text{O}_2 \Rightarrow 2 \text{CO}_2 + 4 \text{H}_2\text{O}$

DMFC – MILITARY POWER UNIT

2" x 5" x 9"

12 V

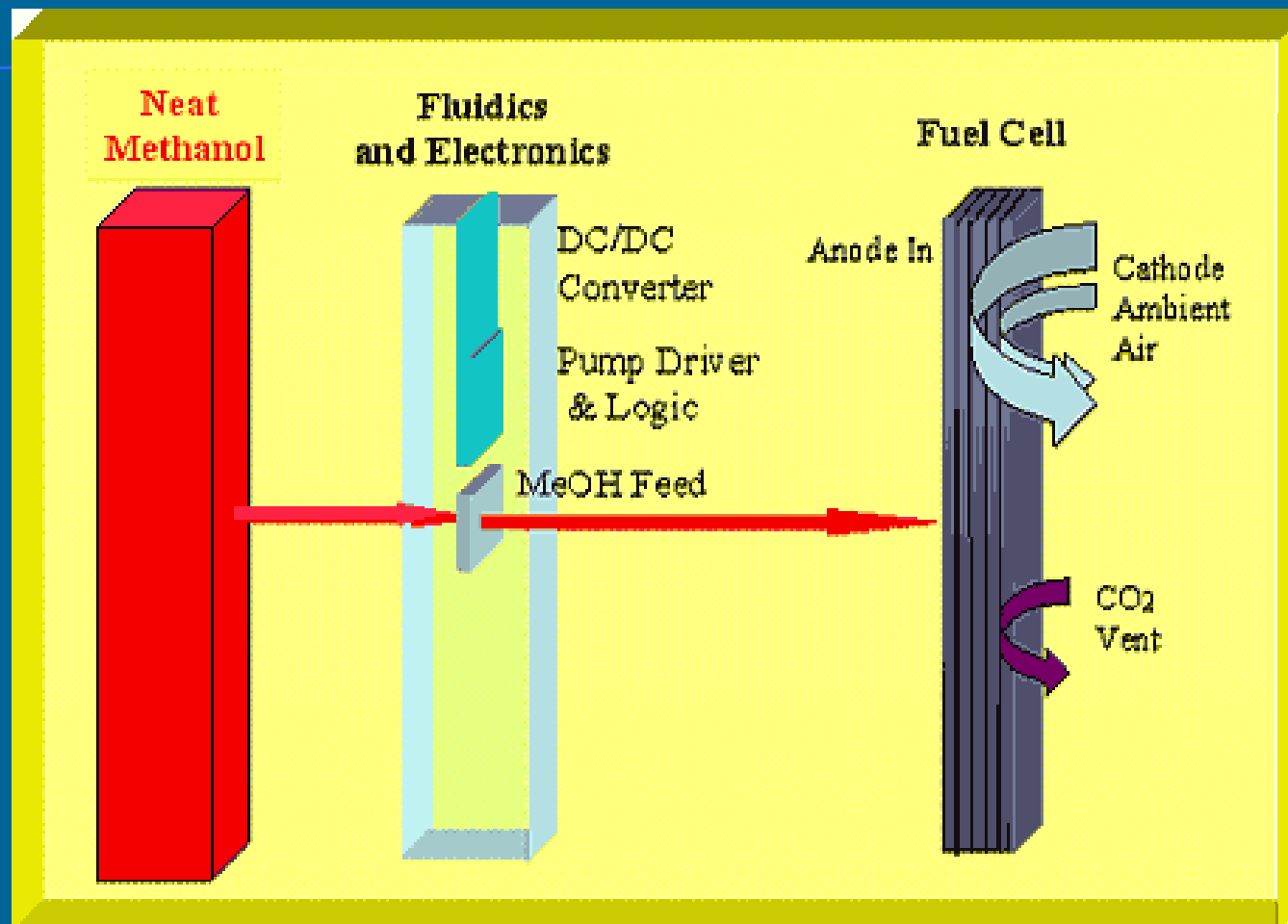
20W

1kWh



Photos from Ball Aerospace web site – URL at end of presentation

DMFC – PURE METHANOL FUEL



Drawing from MTIMicro web site – URL at end of presentation

Companies with DMFC Programs

- MTI – Mechanical Technology, Inc – Albany, NY
- Hitachi
- Samsung
- Toshiba
- Ball Aerospace – Boulder, CO
- Direct Methanol Fuel Cell Corp. – patents
- Smart Fuel Cell AG – near Munich, Germany
- IdaTech – (but more emphasis on PEM)

DMFC COMPETITION

- PEM FC systems using other liquid fuels, such as borohydrides, ethanol and other alcohols
- Zinc-air batteries of several varieties
- Very advanced batteries – lithium polymer, etc.

CONCLUSIONS

- DMFC development is active on three continents
- Primary goal: replace batteries in laptops, PDAs, cellular phones, military systems and other portable devices
- Advanced catalysts & materials should reduce costs
- If current products perform well, scale-up to larger power systems (multi-kW) are very likely

SOFC Web Sites for Inquiries

- <http://www.acumentrics.com/SOFCTechnology.htm>
- <http://www.cfcl.com.au>
- <http://www.delphi.com>
- <http://www.fct.ca/>
- <http://www.globalte.com/>
- <http://www.sulzer.com/com/ProductsAndServices>
- <http://www.siemenswestinghouse.com>
- <http://www.rolls-royce.com/energy/default.jsp>
- <http://www.ztekcorp.com/index.htm>

DMFC Web Sites for Inquiries

- <http://www.ballaaerospace.com>
- <http://www.mtimicrofuelcells.com>
- <http://www.smartfuelcell.de>
- <http://idatech.com>