ALKALINE FUEL CELLS APPLICATIONS

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ABSTRACT
On the world-wide automobile market technical developments are increasingly determined by the dramatic restriction on emissions as well as the regimentation of fuel consumption by legislation. Therefore there is an increasing chance of a completely new technology to break through if it offers new potentials by its principle, meeting the requirements of resource preservation and emission restrictions. Fuel cell technology offers the potential to excel today's motive power techniques in terms of environmental compatibility, consumer's profit, costs of maintenance and efficiency. The key question is economy. It will be decided by the costs of fuel cell systems if they will be used as power generator for future electric vehicles. The objective is to lower the fuel cell system cost on a mass production scale to the range of $ 100 to $ 150 per kW. The alkaline Hydrogen-Air fuel cell system with circulating KOH-electrolyte and low-cost catalysed carbon electrodes could be able to fulfil these demands. Based on experiences of K. Kordesch, who operated a City Car Hybrid vehicle on public roads for 3 years in the early 1970´s, improved air electrodes plus new variations of the bipolar stack assembly developed in Graz, are investigated. Primary fuel choice will be a major issue until such time as cost-effective, on board hydrogen storage is developed. Ammonia is an interesting option. The whole system, ammonia dissociator plus AFC, is characterised by a simple design and high efficiency.

Keywords: Hybrid car, alkaline electrolyte, ammonia dissociator

1. PROCESS PRINCIPLE

Early Alkaline Fuel Cells (AFC's) used liquid electrolytes like solutions of potassium- or sodium hydroxide or diluted acids. The advantages of use of Hydrogen-Oxygen Fuel Cells for space applications was soon recognised and it was the only application which could afford them. To eliminate any moving parts, the development of AFC's shifted from circulating electrolytes to matrix AFC systems. The use of matrices soaked with KOH became standard for NASA space fuel cells and is still being used [1]. However, the use of circulating electrolytes is more advantageous for thermal and water management and the exchangeability of the KOH makes it possible to operate on air with less the complete removal of CO_2. AFC were developed by ELENCO in Belgium with circulating electrolyte until 1996. ZEVCO (Zero Emission Vehicle Co) restarted the AFC work in Geel, 1997 [2,3] and continued in the UK with a 5 kW-Hybrid Taxi demonstration in London (N. Abson, 1999).

The Fuel Cell City Car of Prof. K. Kordesch used a commercial type CO_2 absorber for air (e.g. soda-lime with indicator). The nominal 90 V / 6 kW Hydrogen-Air fuel cell system was connected in parallel to a 96 V, 8 kWh SLI-lead-acid battery. No power converter was used. This hybrid system was fitted into a four-passenger Austin A-40, weighing 730 kg before and 950 kg after the conversion. The combined weight of Fuel cells and Lead-acid Batteries was 400 kg, more than the desired 1/3 of the curb weight of the car. The report 'Intermittent use of low-cost AFC-hybrid system for electric vehicles' gives detailed descriptions about system design and operation experience of the Fuel Cell

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City Car [4]. Fig. 1 shows the layout of the ammonia/hydrogen fuel cell system. Modelling and optimisation of the system is done with the software MATLAB.

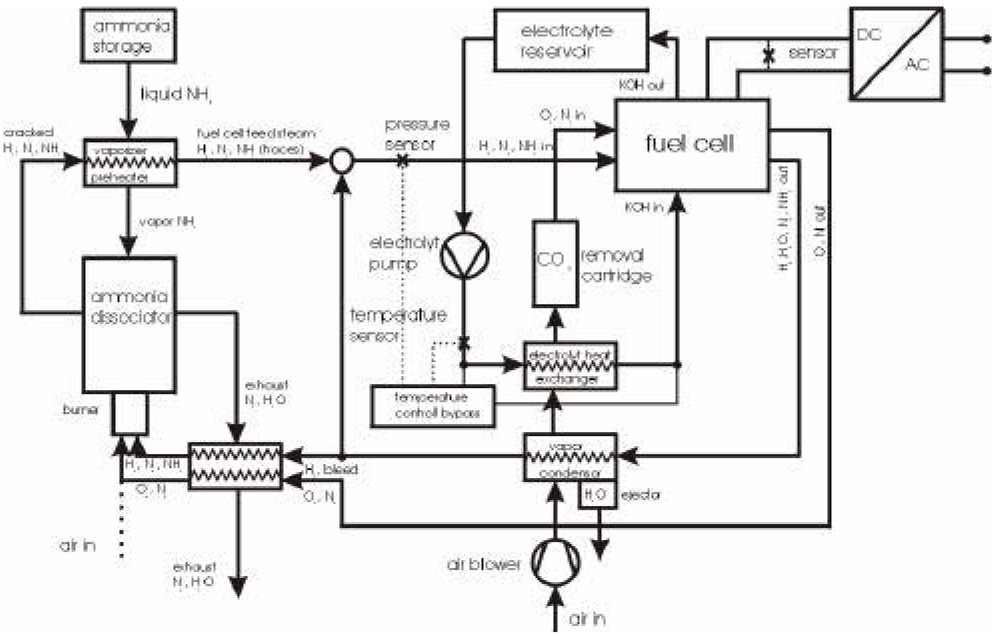


Fig. 1: Layout of ammonia/hydrogen-air fuel cell system

2. FUEL CELL STACK

Fuel cell electrodes and catalysts degrade on activated stand without load more than under load. The high voltage on open circuit is one of the reasons for carbon oxidation processes, catalyst changes, etc. Unfortunately, the AFC with immobilised KOH electrolyte combines all disadvantages: the electrolyte had to stay in the cells, residual carbonate (from any uncompleted air cleaner) accumulated, separators (matrices) deteriorated, gas cross leakage started during drying out or crystallisation periods during storage times without careful maintenance. Therefore life expectancy definitely increases with circulating electrolyte by emptying the electrolyte from the battery between operating periods. Shutting off the H_2 electrodes to air finally establishes a nitrogen atmosphere. This shut down also eliminates all parasitic currents. The exchangeability of the KOH offers the possibility to operate on air with less than complete removal of the CO2.

With edge-collecting electrodes the current distribution is not uniform. Therefore a bipolar stack design was preferred and developed at the Hydrogen Institute in Canada (Tomantschger 1986) and at the Technical University in Graz, Austria (Kordesch 1990). In a bipolar stack the current density over the electrode is uniform and far higher terminal voltages are achieved. An operating “window” of 50 - 200 mA/cm^2 between 0.85 V and 0.80 V is desirable for high efficiency.

3. ELECTRODE PREPARATIONS

New types of electrodes with better performance and an improved stability are under development at the Technical University Graz. Fig 4 shows a computer controlled spraying device for small series production. Since kinetics of oxygen reduction in alkaline electrolyte is essentially faster than in acid media AFCs can utilise large surface carbon supported low level Pt-metal catalysts (about 20% Pt compared with PEMFC).

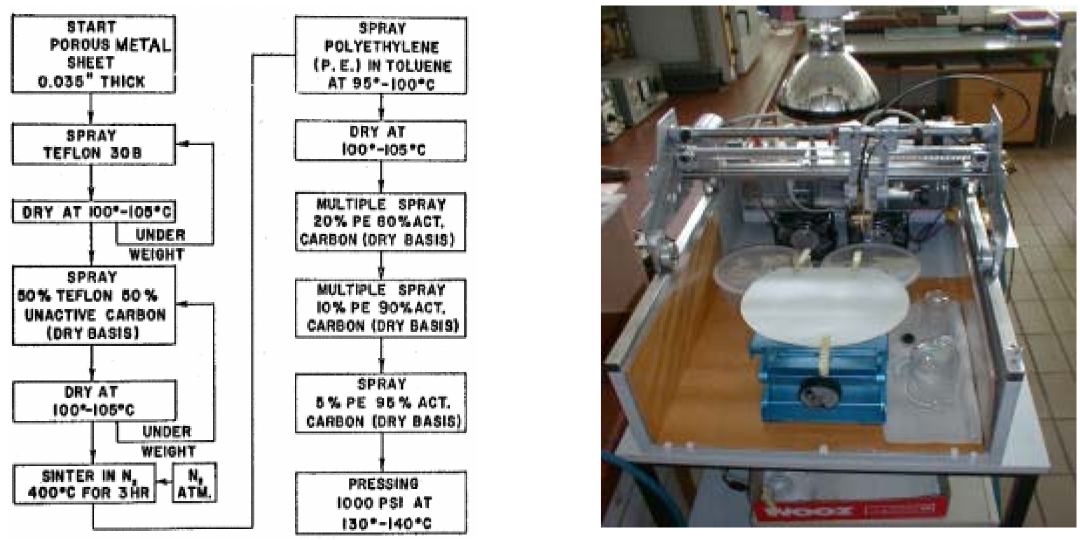


Fig. 4: Spray-type Teflon-Carbon electrodes (left) and computer controlled spraying equipment for electrode production in small series (right)

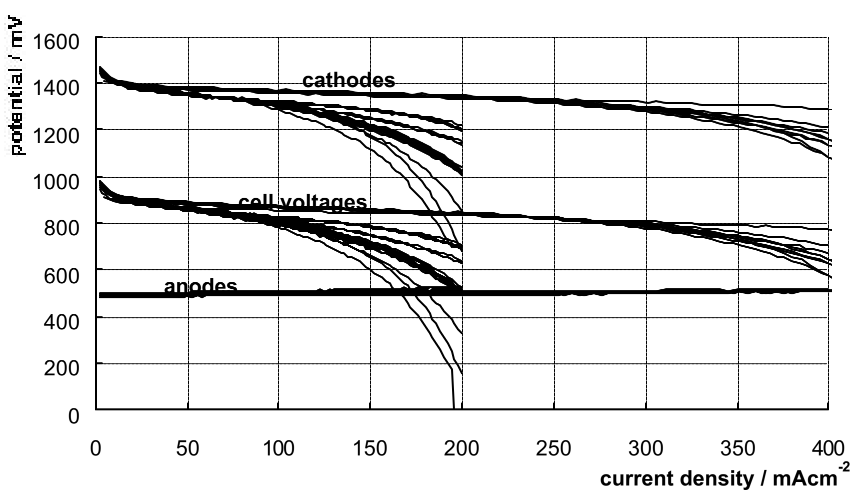
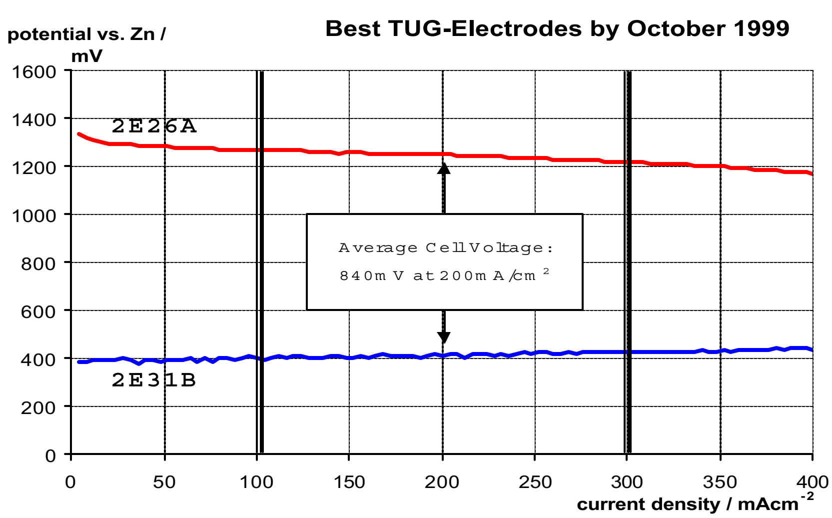


Fig. 5 a: Comparison of Union Carbide electrodes and 1998 electrodes.
Fig. 5 b: below, improved 1999 electrodes.



4. AMMONIA AS AFC-FUEL

Anhydrous liquid ammonia is still an interesting carrier of hydrogen and its transportation in low pressure cylinders is a commercial practise. It could also be supplied from 60% aqueous solutions in a tank. The energy density of ammonia is 3.3 kWh/kg. The world-wide production of ammonia amounts to 100 million tons per year and is one of the mostly used chemicals, produced from natural gas. The use of small amounts of ammonia as a gasoline additive is proposed to make the combustion engine exhaust gas absolutely NOx free.

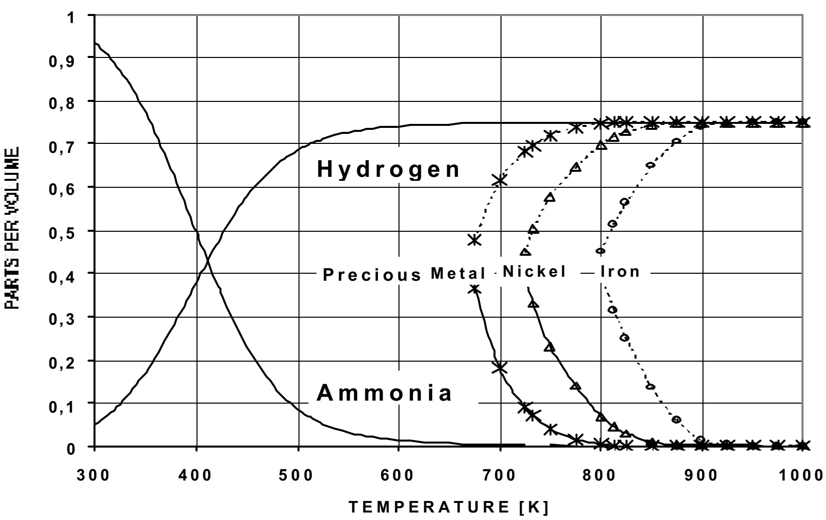


Fig. 3: Dissociation of ammonia $2NH_3 \Leftrightarrow N_2+3H_2$

The strong smell of ammonia is an advantage since it indicates any leakage in the system immediately. Ammonia poisoning is medically completely reversible. AFC is not very sensitive to ammonia in the fuel gas since the electrolyte rejects ammonia and the residual ammonia in the hydrogen can be recirculated through the dissociator catalytic heating unit. No shift converter, selective oxidiser or further co-reactants like water are required. This results in a compact light weight dissociator. Fig. 3 shows the thermodynamic equilibrium of $2NH_3 \Leftrightarrow N_2+3H_2$ and kinetic curves of the amount of dissociation over catalysts (Geissler [9] and test results). Dependent on max. NH_3 content in the feed gas of the fuel cell the lowest possible temperature for the NH_3 dissociator can be determined. An Ammonia Cracker was built for US-Army 500 W fuel cells [9]. It operated on high temperatures on noble metal, nickel or iron catalysts. New constructions are now investigated in our laboratories at the Technical University Graz and the Technical University Vienna in co-operation with Electric Auto Corporation EAC, U.S.A.

5. LITERATURE

[1] Kordesch, K., ‘Brennstoffbatterien’, Wien , New York, Springer, ISBN 3-387-81819-7, 1984

[2] Shen, Y., Kordesch, K., Aronson, R.R., ‘A Comparison between the Polymer Electrolyte Membrane Fuel Cells and the Alkaline Fuel Cells (AFC) with Liquid Electrolyte’, The NPC'99-Nagoya International Battery and Power Sources Conference 1999, Nagoya, Japan, September 1999

[3] Hacker, V., Kordesch, K., Gsellmann, J., Faleschini, G., Enzinger, P., Muhr, M., Friedrich, K., Aronson, R.R., 'Alkaline fuel cells for electric vehicles', 3rd International Fuel Cell Conference, Nagoya, Nov. 30-Dec. 3, 1999, Japan

[4] Kordesch, K., 'City car with H_2-air fuel cell and lead-battery, SAE-Paper No. 719015, 6th IECEC, 1971

[5] Kordesch, K., Gsellmann, J., Voss, S., Cifrain, M., Hacker, V., Aronson, R.R., Fabjan, C., Hejze, T., Daniel-Ivad, J., 'Intermittent use of low-cost AFC-hybrid system for electric vehicles', 21th Internatl. Power Sources Conf., Brighton, May 1999 (also: J. of Power Sources, 1999)

[6] Kordesch, K., Gsellmann, J., Voss, S., Cifrain, M., Aronson, R., 'Large Fuel Cells and a Fuel especially for electric vehicles', Annual International Power Source Conference, Nagoya, Japan, August 1998

[7] Kordesch, K., Simader, G., 'Fuel Cells and Their Applications', Wiley-VCH, ISBN 3-527-28579-2, 1996

[8] Yang, L. Bloomfield, D.P., 'Ammonia cracker for fuel cells', Proceedings, Fuel Cell Seminar, Palm Springs, USA, November 1998

[9] Ross, P., 'Characteristics of an NH_3-air fuel cell system for vehicular applications', Proceedings 16th Intersoc. Energy Conv. Eng. Conference, 1981

[10] Geissler, H.H., 'Compact H_2 Generators for fuel cells', 17th USA Power Sources Conference, 1963