

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 breakthrough if it offers new opportunities, meeting the requirements of resource preservation and emission restrictions. Fuel cell technology offers the possibility to excel in today's motive power techniques in terms of environmental compatibility, consumer's profit, costs of maintenance and efficiency. The key question is economy. This will be decided by the costs of fuel cell systems if they are to be used as power generators for future electric vehicles. The alkaline hydrogen–air fuel cell system with circulating KOH electrolyte and low-cost catalysed carbon electrodes could be a promising alternative. Based on the experiences of Kordesch [K. Kordesch, Brennstoff-batterien, Springer, Wien, 1984, ISBN 3-387-81819-7; K. Kordesch, City car with H₂–air fuel cell and lead–battery, SAE Paper No. 719015, 6th IECEC, 1971], who operated a city car hybrid vehicle on public roads for 3 years in the early 1970s, 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 alkaline fuel cell (AFC), is characterised by a simple design and high efficiency. © 2000 Elsevier Science S.A. All rights reserved.

Keywords: Hybrid car; Alkaline electrolyte; Ammonia dissociator

1. Process principle

Early alkaline fuel cells (AFCs) used liquid electrolytes like solutions of potassium or sodium hydroxide or diluted acids. The advantages of the 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 AFCs 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; the exchangeability of the KOH makes it possible to operate on air with less com-

plete removal of CO₂. AFCs were developed by ELENCO in Belgium with circulating electrolyte until 1996. ZEVCO (Zero Emission Vehicle) restarted the AFC work in Geel, 1997 [2,3].

The fuel cell city car of Kordesch used a commercial type CO₂ 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-kW h SLI-lead–acid battery. No power converter was used. This hybrid system was fitted into a four-passenger Austin A40, 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 one-third 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 city car [4]. Fig. 1 shows the layout of the ammonia/hydrogen fuel cell system. Modelling and opti-

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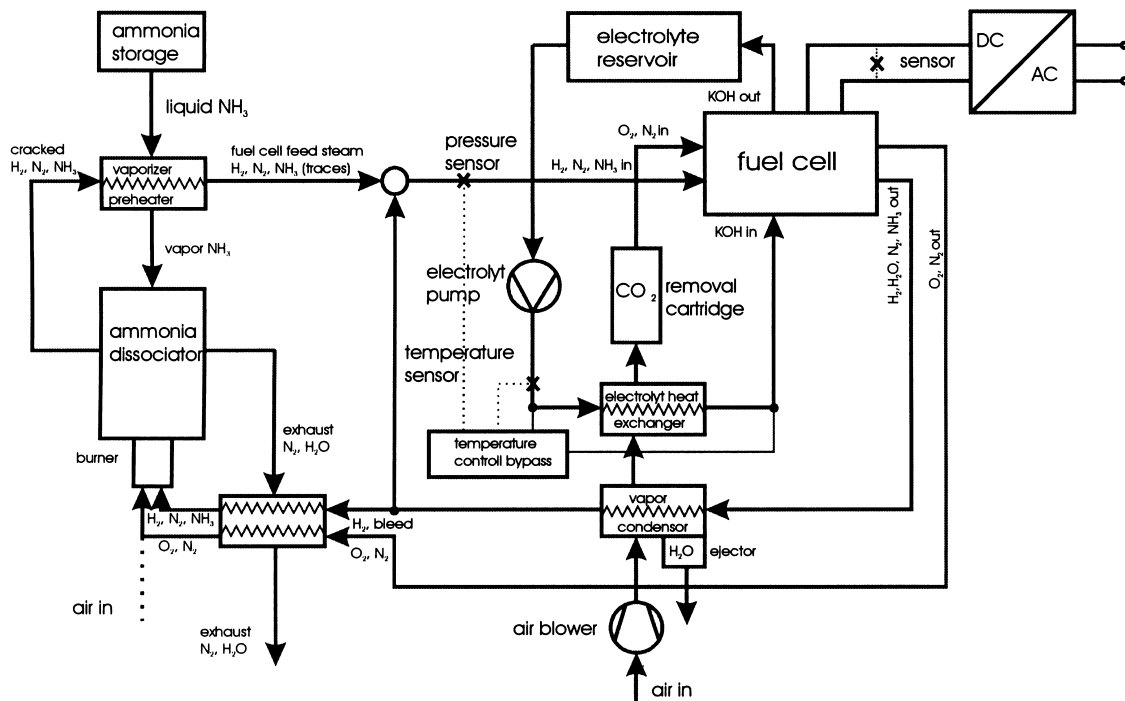


Fig. 1. Layout of ammonia/hydrogen–air fuel cell system.

misation of the system was carried with the software MATLAB.

2. Fuel cell stack

Fuel cell electrodes and catalysts degrade on activated standby 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 remain in the cells, residual carbonate (from any incomplete air clean-up) accumulated, separators (matrices) deteriorated, gas cross-over began during drying out or crystallisation periods during storage times without careful maintenance. There-

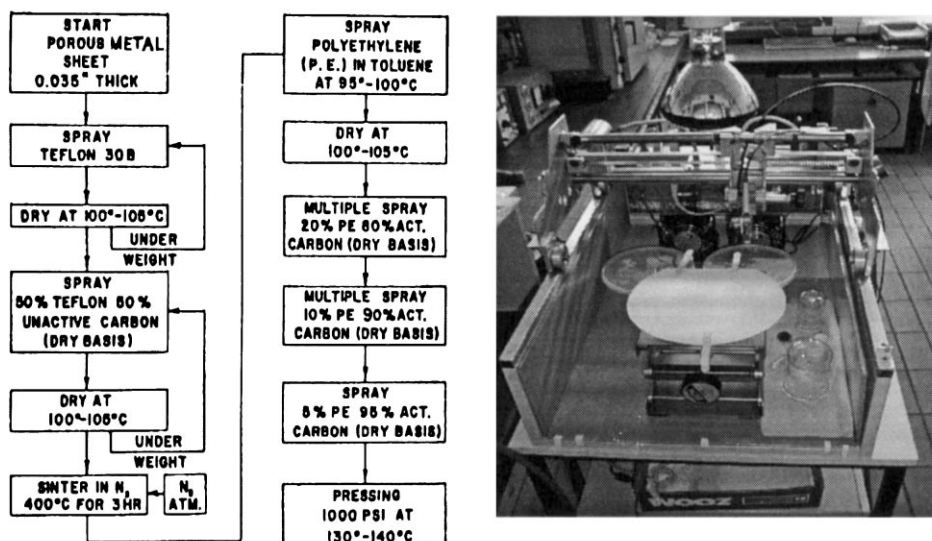


Fig. 2. Spray-type Teflon–carbon electrodes (left) and computer-controlled spraying equipment for electrode production in small series (right).

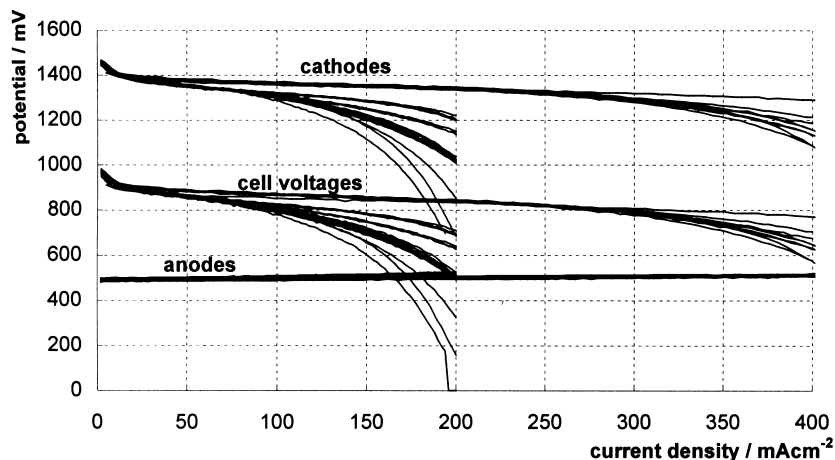


Fig. 3. Comparison of Union Carbide electrodes and new developed electrodes.

fore, life expectancy definitely increases with circulating electrolyte by emptying the electrolyte from the cells between operating periods. Isolation of the H_2 electrodes from air eventually 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 CO_2 .

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 [11] and at the Technical University Graz, Austria [5]. In a bipolar stack the current density over the electrode is uniform and far higher terminal voltages are achieved.

An operating “window” of 50 to 200 mA/cm^2 between 0.85 and 0.80 V is desirable for high efficiency [7].

3. Electrode preparation

New types of electrodes with better performance and improved stability are under development at the Technical University Graz. Fig. 2 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).

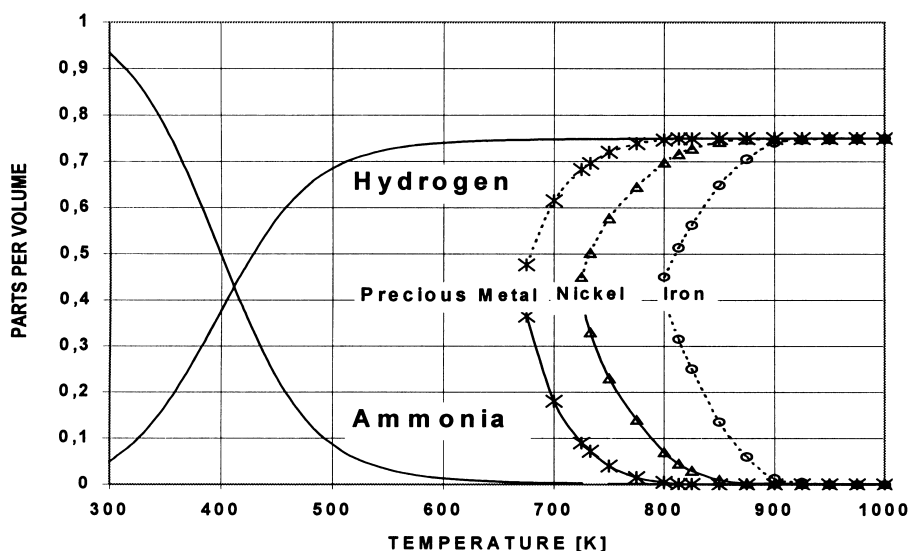


Fig. 4. Dissociation of ammonia $2NH_3 \rightleftharpoons N_2 + 3H_2$.

The performance of Union Carbide electrodes [6] (with a maximum current density of 200 mA/cm²) and of newly developed electrodes (patent applied for) are shown in Fig. 3. The curves for the air electrode especially indicate that the initial wetting process improves the voltage level with operating time. The anode curves do not show any change with time.

4. Ammonia as AFC fuel

Anhydrous liquid ammonia is still an interesting carrier of hydrogen, and its transport in low-pressure cylinders is a commercial practice. It could also be supplied from 60% aqueous solutions in a tank. The energy density of ammonia is 3.3 kW h/kg. The world-wide production of ammonia amounts to 100 million tons per year and it is one of the most widely 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 NO_x free [8].

The strong smell of ammonia is an advantage since it indicates any leakage in the system immediately. Ammonia poisoning is medically completely reversible. The 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. 4 shows the thermodynamic equilibrium of $2\text{NH}_3 \rightleftharpoons \text{N}_2 + 3\text{H}_2$ and kinetic curves of the amount of dissociation over catalysts (Geissler [10] and test results). Dependent on the maximum NH₃ content in the feed gas of the fuel cell the lowest possible temperature for the NH₃ dissociator can be determined. An ammonia cracker was built for US Army

500-W fuel cells [9]. It operated at high temperatures on noble metal, nickel or iron catalysts. New designs are now being investigated in our laboratories at the Technical University Graz and the Technical University Vienna in cooperation with Electric Auto Corporation (EAC), USA.

References

- [1] K. Kordesch, Brennstoffbatterien, Springer, Wien, 1984, ISBN 3-387-81819-7.
- [2] Y. Shen, K. Kordesch, R.R. Aronson, 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] V. Hacker, K. Kordesch, J. Gsellmann, G. Faleschini, P. Enzinger, M. Muhr, K. Friedrich, R.R. Aronson, Alkaline fuel cells for electric vehicles, 3rd International Fuel Cell Conference, Nagoya, Nov. 30–Dec. 3, 1999, Japan.
- [4] K. Kordesch, City car with H₂–air fuel cell and lead–battery, SAE Paper No. 719015, 6th IECEC, 1971.
- [5] K. Kordesch, J. Gsellmann, S. Voss, M. Cifrain, V. Hacker, R.R. Aronson, C. Fabjan, T. Hejze, J. Daniel-Ivad, Intermittent use of low-cost AFC-hybrid system for electric vehicles, J. Power Sources 80 (1999) 190–197.
- [6] K. Kordesch, J. Gsellmann, S. Voss, M. Cifrain, R. Aronson, Large fuel cells and a fuel especially for electric vehicles, Annual International Power Source Conference, Nagoya, Japan, August 1998.
- [7] K. Kordesch, G. Simader, Fuel Cells and Their Applications, Wiley-VCH, 1996, ISBN 3-527-28579-2.
- [8] L. Yang, D.P. Bloomfield, Ammonia cracker for fuel cells, Proceedings, Fuel Cell Seminar, Palm Springs, USA, November 1998.
- [9] P. Ross, Characteristics of an NH₃–air fuel cell system for vehicular applications, Proceedings 16th Intersoc. Energy Conv. Eng. Conference, 1981.
- [10] H.H. Geissler, Compact H₂ generators for fuel cells, 17th USA Power Sources Conference, 1963.
- [11] K. Tomantschger, F. McClusky, L. Oporto, A. Reid, K. Kordesch, Alkaline fuel cells with carbon electrodes, J. of Power Sources 18 (1986) 317.