Grove Medal Award Address

Total development of fuel cells in Japan

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My Lords, Ladies and Distinguished Guests,

It is indeed a great honour to be recognized and to be awarded the prestigious Grove Medal Award.

I share this award with many. First and foremost, I am indebted to Fuji Electric Company, whom I have served over 45 years, for availing me of the opportunity to work in and contribute to the exciting field of fuel cells. I would also like to take this opportunity to thank my many colleagues, associates, friends and acquaintances worldwide. I wish to express my special thanks to Dr Acres and The Grove Symposium Organizing Committee without whom this event would not have been possible.

I am not very good at speech-making. I have thought long and hard over the past few months about what type of address would be appropriate for this occasion. Certainly, I would not dare to lecture experts such as yourselves on fuel cells, nor am I in any position to predict the future. What I have decided to provide you with this evening is my perspective on how Japan tackled the development of a major programme such as fuel cells.

The research and development philosophy adopted by the Japanese Government and the Japanese companies is quite different from those of the USA and Europe. Our development process could best be classified as 'TOTAL DEVELOPMENT' involving the Japanese Government (MITI and NEDO), electric and gas utilities and manufacturers.

History has revealed to us that 'large scale' technology developments are generally strongly supported by government initiatives. A great many of these initiatives were pursued for military application. Take nuclear power generation for example. It is well known that the military application of nuclear technology led to the remarkable progress in light water nuclear power stations and subsequent commercial versions of today's nuclear generating plants. Let us look at another example: jet propulsion. Tremendous research and developmental resources have been channelled into the development of fighter jets. Today, commercial aviation in my opinion owes much of its progress to the multitude of developments for military application.

What about fuel cells? The only government initiatives I am aware of are relatively small scale. The alkaline and PEM fuel cells for space application are one notable example. PEM for submarines is another example. The influence of these programmes towards commercialization of fuel cells unfortunately is rather insignificant.

Elsevier Sequoia
SSDI 0378-7753(93)01786-H

Of course, I am not suggesting that we would urge our governments to start considering fuel cells for large military projects. However, it is obvious that without government support, 'large scale technology developments' such as fuel cells will have a difficult time succeeding in the commercial arena.

Early development of fuel cells in Japan was based on the need for an energy-efficient technology utilizing fuels such as natural gas. Prompted by the oil crisis in 1973, together with the fuel cell initiatives launched in the USA in the late 60s and mid-70s, 'TARGET' and the GRI/DOE Project (Gas Research Institute and Department of Energy), the Japanese Government decided to start a major national fuel cell programme under the well-known name 'Moonlight Project', the national development programme focusing on energy saving technologies.

Today, in addition to energy savings benefits, escalating environmental pressure has prompted the Japanese Government to further recognize the importance of fuel cells. In light of these circumstances, in 1990 Japan's MITI (Ministry of International Trade and Industry) published a report entitled the 'Long-Term Energy Supply and Demand Prospects' which estimated that fuel cell plants of approximately 2200 MW were expected to be built by the year 2000 and of approximately 10 800 MW by the year 2010. To realize these estimates the Japanese Government has adopted an active supporting role in providing 'subsidies' to many pre-commercial fuel cell activities. The Japanese Government recognizes that a 'large scale' commercialization effort cannot be shouldered by the private sector alone, particularly in light of the fact that the benefits of fuel cells extend far beyond just profits for manufacturing companies to include substantial environmental and energy benefits to Japan and to the world at large.

There are several types of subsidies currently granted by the Japanese Government to foster and accelerate the commercialization of fuel cells.

(i) Full support: Expenditures including the design, construction and operation of pilot plants are fully supported by the Government. This support is meant to cover the cost of basic research as well as to prove the overall performance of the fuel cell plants in question.

(ii) Partial support: A 50% subsidy is provided for demonstration plants intended to accelerate commercialization and a 33% subsidy is provided for field tests. The latter subsidy for field tests is granted for the construction and operation costs of any plants installed in Japan from 1992 to 1994 (with possible extension) and does not distinguish between fuel cell plants built by Japanese manufacturers or those built by foreign manufacturers. The primary purpose of this latter subsidy is to reduce the 'cost' barrier to entry and to increase the marketability of fuel cells via accumulating actual field experience for various applications. Both types of partial support subsidies are quite unique, diverge from past practice and break away from past common understanding of the government subsidization philosophy towards stimulating commercialization.

Japanese fuel cell development is also unique from the standpoint of the very close working relationship between the utilities (electric and gas utilities) and manufacturing companies. In general, utility companies invest enormous amounts of resources towards the development of fuel cells. These resources are not only in the form of money but more importantly in the form of engineering expertise and in defining users' requirements. For Fuji Electric, the success of the first packaged type experimental plant owed much to the progressive attitude of Tokyo Gas Company. This type of successful initial cooperation subsequently led to more fruitful cooperation between manufacturers and gas and electric utilities.

An example of such subsequent cooperation is that which occurred between the electric utility company and manufacturer during the construction of a 1 MW PAFC plant, sponsored by NEDO. The plant was to be installed in the premises of Kansai Electric Power Company, but prior to construction, Kansai Electric Power Company strongly requested assurance of the safety of the plant, and in particular of the natural gas reformer (where fuel is converted into hydrogen). Over the years, electric utilities in Japan have amassed a great deal of operating and safety experience on conventional boilers where the liquids in question are generally non-flammable. However, a fuel cell reformer, although it has a similar structure to a boiler, is potentially explosive due to the presence of high pressure hydrogen and natural gas under high temperature conditions. An accident may lead to loss of life and result in extensive liability for all parties. Together with Kansai Electric management and technical staffs, an explosion test was performed on the reformer under simulated conditions. A large scale government test facility was eventually used to implement this explosion test.

Further design changes were also suggested by Kansai Electric to improve the extinction of the reformer burner under various operating conditions. Countermeasures were assured through the reconfirmation experiment conducted jointly by both companies.

Japanese manufacturers such as Fuji Electric derive great benefit from the experience and the high level of engineering skills offered by Japanese utilities. This is another unique feature of the 'TOTAL DEVELOPMENT' concept.

The characteristics of manufacturing companies represent another unique facet of the fuel cell development effort in Japan. All PAFC developers are electric-oriented companies, that is their business involve supplying electric equipment, components and peripherals to the electric industry. Moreover, these fuel cell developers are vertically integrated, possessing capabilities ranging from robotics manufacturing to electronic controls. It is because of these characteristics together with a good understanding of end-users' needs that Japanese developers such as Fuji Electric have been able to 'catch up' with their US counterparts in a relatively short time span of 10 to 15 years.

Thus, as I have described, in Japan, fuel cell development is best classified, as 'TOTAL DEVELOPMENT', in which resources are effectively drawn from the Government, utilities and manufacturers. The rapid advancement of PAFC from the development to the pre-commercialization phase in Japan is the result of such close cooperation.

Then, because of the success of the 'TOTAL DEVELOPMENT' process in bringing PAFC to the pre-commercialization phase, is it possible to predict the commercialization target date? Today the answer is still unclear. Although in Japan more than 100 PAFC plants have been installed and many of them are in operation today, the longest accumulative hours logged are just over 20 000 h, which is a far cry from the 40 000 h economic target necessary for commercialization. Moreover, the current plant cost is substantially higher than the commercial target selling price. The lack of reliability of these demonstration plants and the high cost of pre-commercialization plants are unquestionably barriers to market entry.

What can we do to overcome these hurdles? Our earlier conclusions led us to believe that the accumulation of manufacturing and operation experiences would be the most effective way to solve these difficulties. Indeed the large scale field tests that have been conducted in Japan under close cooperation between the utilities and manufacturers have been effective in improving the engineering designs of PAFC plants. Valuable experience has been obtained under various operating conditions at different sites. But it became apparent that we cannot reasonably achieve our cost

target and operational reliability via only limited mass production and engineering improvement. Instead, key PAFC developers have to struggle to overcome current difficulties through strengthening their basic research activities.

Plant cost is heavily dependent on the cost of the fuel cell stack, and so is reliability. Although stack performance for PAFCs has been greatly improved over the past several years, even at the greatly reducing platinum content in the catalyst, these improvements however are still insufficient. Serious and urgent issues requiring substantial R&D include: increasing power density, maintaining long stack life at variable operating conditions, improving uniformity of electrochemical reactions at the cell surface, adequate acid management technologies and materials development. In addition, engineering development such as plant simplification and standardization, mass production techniques, quality control and so on should also deserve significant development attention.

It has been said frequently in Japan that the European people consider before walking, American people consider while walking, but Japanese people consider after walking. This means that European people tend to conduct a great deal of in-depth thinking before the first step, and the US people tend to conduct thinking while walking, but in Japan, once basic ideas have been exposed, we have the tendency to quickly apply engineering principles and move aggressively to production of the products based on such ideas. I feel now, however, it is important for all developers of fuel cells to re-consider fundamental guiding principles periodically. In other words, for a technology so complex as fuel cells and so intertwined with issues such as the environment, energy, infrastructure, etc., we need to utilize our limited resources wisely in basic research as well as in system demonstration.

Recently in Japan, the Government, utilities and manufacturers have further strengthened their cooperation effort and are devoting even larger amounts of private resources to promote the industrial development of fuel cells and to basic R&D. Such additional investment appears to be bearing fruit and has prompted renewed confidence in the Japanese fuel cell community. Slowly but surely, we are marching towards our common goal.

The global request for clean energy efficient technology such as fuel cells is clear. The mission and challenge is to deliver cost effective and reliable products to the world community to help improve our quality of life.

I thank you for your kind attention and patience. And once again it is a great honour for me and for Fuji Electric to accept this prestigious Grove Medal Award.