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SUMMARY

Developing clean, efficient, and cost effective technologies for future power generation is essential to meeting the world’s energy needs, while helping to clean up pollution and conserve valuable natural resources. Westinghouse is pioneering the development of solid oxide fuel cell (SOFC) technology as one of the promising technologies that will lead the world into a new generation of power production.

The Westinghouse SOFC consists of tubular cells that can utilize fuels such as natural gas, coal derived fuel gas, biomass gas, and distillate fuels. Besides fuel flexibility, tubular SOFCs promise very high efficiencies, low cost, low plant maintenance, and ease of operation, and they have already demonstrated essentially no acid rain pollutants.

Development of tubular SOFC technology is being supported by Westinghouse and the U.S. Department of Energy - Morgantown Energy Technology Center (DOE-METC), under a multi-year cooperative agreement, and by other domestic and international utility participants.

SOFC TECHNOLOGY UPDATE

Solid oxide fuel cells are highly efficient devices that convert chemical energy directly into electricity. They operate at atmospheric or elevated pressures at a temperature of approximately 1000°C to produce electricity using a variety of fossil fuels. The temperature of the exhaust gases from the cells is between 500 to 850°C — a temperature which is attractive for cogeneration applications, but even more attractive for use in combined cycles for making additional electricity.

Westinghouse's SOFC program is aimed at commercializing tubular SOFCs before the end of this decade. It is generally held that, to achieve commercialization, fuel cells have to be able to operate reliably for at least five years, be able to operate on natural gas, and cost less than $1500 per kilowatt. Westinghouse is making significant progress in reaching these goals and with recent successes is on target to achieve commercialization before the end of this decade. The unique tubular design eliminates the need for high temperature seals and facilitates thermal management, thus solving some of the critical problems that face all fuel cells.
On February 4, 1995 a pair of cells passed six years of continuous power production, and continue to operate. These cells are believed to be the world's longest running cells of any type of fuel cell. Thus Westinghouse has shown that prototype tubular SOFCs are capable of achieving the operating lifetime and performance necessary for commercial operation. Westinghouse has also demonstrated successful operation of large systems using similar cells. Two integrated SOFC generating systems in the 20-40 kW range operated successfully and produced power in the U.S. and Japan for periods of over 6000 and 7000 hours before being voluntarily shut down. These units contained a small integrated reformer and operated directly on natural gas without the need for additional heat or steam. These recent achievements were focused on precommercial cells, 50 cm in length, and proved that tubular SOFC technology is viable and ready for the commercialization phase.

Broadly speaking, the next steps involve scaling up and reducing costs. The length of the cells will be increased for greater power, and larger demonstration systems will be operated using these cells. The materials and processes used will be refined to reduce production costs and prepare the way for mass production of cells to achieve commercially acceptable prices. All of these activities are underway. In particular, a new type of tubular cell has been developed that will be cheaper to manufacture and will also be more reliable thanks to a simpler design. One 25 kW system using these new cells started operation in March 1995 and is operating well. A similar system will begin operation in the summer of 1995 and will be used to demonstrate the capability to operate on diesel and jet fuels.

In the latest development, Westinghouse was recently awarded a contract by a group of Dutch and Danish utilities for a 100 kW cogeneration demonstration unit. This unit will be built using 150 cm cells of the new design as prototypes of the cells for commercial modules. The ultimate goal of Westinghouse's program is to develop a megawatt-class module using cells up to two meters in length for operation in distributed power generation applications. These or larger modules could also be used to construct multi-megawatt power plants for utility applications. Conceptual designs of these modules are already underway in collaboration with utilities in the U.S. and Japan.

COMMERCIALIZATION

Westinghouse has demonstrated conclusively that tubular SOFC systems work. After scaling up, the next steps are to demonstrate commercially viable systems, and build a commercial factory.

Once SOFCs are technically ready for commercialization the market for SOFC systems will be determined by a number of commercial and economic factors. Capital cost will be the major factor, especially as the cost of gas turbines has been going down and their performance has been improving. However, the price of fuel, the cost for other technologies to meet ever increasing environmental regulations, and O&M costs will also affect the picture strongly.

Market entry for tubular SOFCs is expected to be in the distributed generation range of 1-20 MW or higher, in applications such as substations which can be located strategically close to appropriate industrial/commercial loads, and downtown or remote applications where added or upgraded transmission would otherwise be difficult. As costs come down the learning curve with increased production the market segment for tubular SOFCs will broaden to include larger units, and eventually they should compete effectively in a broad
range of power plant applications. Of course there will be applications where fuel cells will generally not be suitable in the foreseeable future, such as those that cannot take advantage of their exhaust heat, those that require rapid cold start ups, or those that have low capacity factors.

In getting ready for a commercial factory for tubular SOFCs we first have to expand our production capacity and pilot the processes that we will be using in a commercial factory. Accordingly we are in the process of moving from our pre-pilot plant into a much larger pilot plant that will also have the capability of making larger, commercial sized cells. Eventually, mass production will reduce the cost of tubular SOFCs and will ensure consistent quality. We are also looking, where possible, to make the operation of the plant as simple as possible by taking advantage of the inherent simplicity of SOFCs. We believe that if the large distributed generation market really develops it will do so because SOFC systems will have low maintenance needs and will be operated unattended.