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## HYDROGEN-OXYGEN PROTON-EXCHANGE MEMBRANE FUEL CELLS AND ELECTROLYZERS

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Hydrogen-oxygen SPE fuel cells and SPE electrolyzers (products of Hamilton Standard) both use a Proton-Exchange Membrane (PEM) as the sole electrolyte. These solid electrolyte devices have been under continuous development for over 30 years. This experience has resulted in a demonstrated ten-year SPE cell life capability under load conditions.

Ultimate life of PEM fuel cells and electrolyzers is primarily related to the chemical stability of the membrane. For perfluorocarbon proton-exchange membranes an accurate measure of the membrane stability is the fluoride loss rate. Millions of cell hours have contributed to establishing a relationship between fluoride loss rates and average expected ultimate cell life. Figure I shows this relationship. Several features have been introduced into SPE fuel cells and SPE electrolyzers such that applications requiring  $\geq 100,000$  hours of life can be considered.

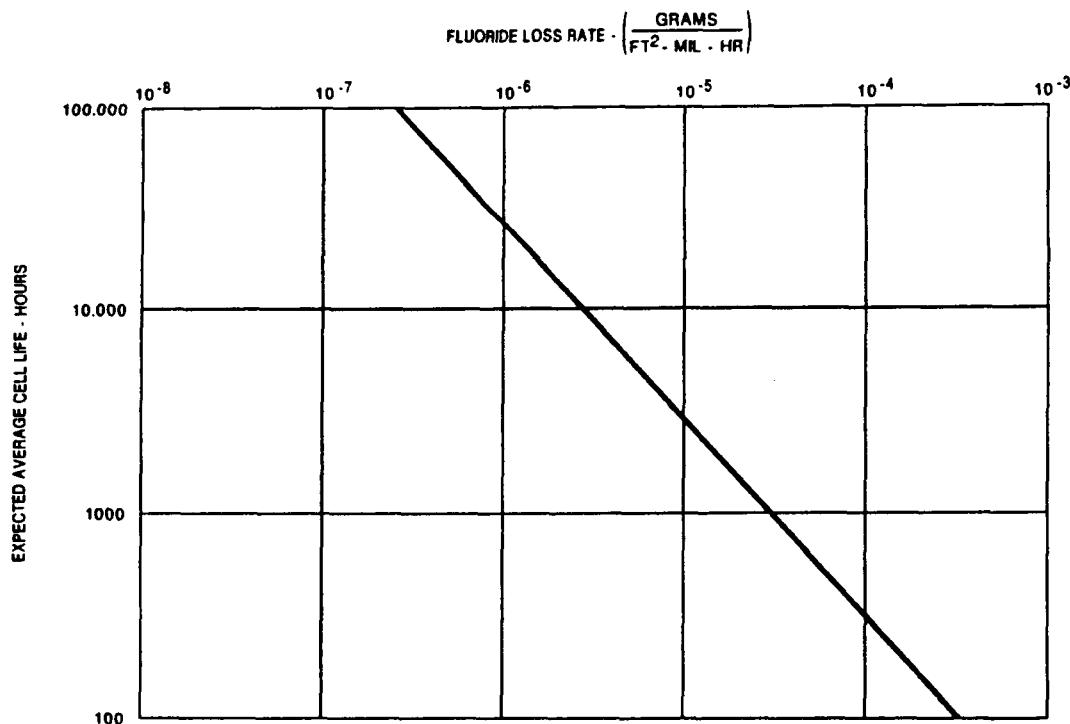


FIGURE I. EXPECTED LIFETIMES OF SPE CELLS WITH PERFLUOROCARBON PROTON-EXCHANGE MEMBRANES

Equally important as the ultimate life is the voltage stability of hydrogen-oxygen fuel cells and electrolyzers. Here again the features of SPE fuel cells and SPE electrolyzers have shown a cell voltage stability in the order of 1 microvolt per hour. That level of stability has been demonstrated for tens of thousands of hours in SPE fuel cells at up to 500 amps per square foot (ASF) current density. SPE electrolyzers have demonstrated the same at 1000 ASF.

Many future extraterrestrial applications for fuel cells require that they be self recharged (i.e., regenerative fuel cells). This requirement means that a dedicated fuel cell and a dedicated electrolyzer work in tandem as an electrical energy storage system. Some applications may find advantage with a unitized regenerative fuel cell (i.e., one cell that operates alternately as a fuel cell and as an electrolyzer). Electrical energy storage for earth orbits via hydrogen-oxygen regenerative fuel cell systems can have specific energies in excess of 50 watt-hours/kg. For extraterrestrial surface electrical energy storage the hydrogen-oxygen regenerative fuel cell can have significantly increased specific energies:

- Mars Base ~ 500 watt-hours/kg
- Lunar Base ~ 1000 watt-hours/kg

To translate the proven SPE cell life and stability into a highly reliable extraterrestrial electrical energy storage system, a simplification of supporting equipment is required. Static phase separation, static fluid transport and static thermal control will be most useful in producing required system reliability. Although some 200,000 SPE fuel cell hours have been recorded in earth orbit with static fluid phase separation, no SPE electrolyzer has, as yet, operated in space.

Under NASA sponsorship a flight experiment of a unitized regenerative fuel cell is being studied. If selected for actual flight under the NASA OAST Outreach Project, several advanced features will be tested in space:

- reversible SPE cell (unitized)
- passive fuel cell product water separation and removal
- passive electrolyzer process water introduction
- passive electrochemical gas pumping
- passive heat management

The objective of the flight experiment is to test the space viability of the incorporated features, and not to imply that the specific configuration of the flight experiment is optimum for any given extraterrestrial application. With a successful flight experiment, supported by terrestrial experiments, the system designer can select the proven advanced system features that are appropriate for any particular extraterrestrial application.