Environmental Evaluation and Analysis of Man-Portable Fuel Cell Power Generators

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Various 50W portable fuels obtained from several manufactures were subjected to a number of "real-world" test environments including Durability, Electromagnetic Interferance, Environmental Stress Screening, Sand/Dust, etc. The research team has developed a comprehensive suite of real-world test protocols based on enhanced Military Standard tests which have been adapted directly to the unique requirements of fuel cells. This is necessary since as the maturity of fuel cell systems progress from the laboratory to the marketplace, end-user environmental requirements are becoming the true benchmark determining whether fuel cells systems will be able to successfully enter the marketplace and compete as robust power sources. It is no longer sufficient for the fuel cell to be able to operate effectively only under laboratory conditions. As non-laboratory environmental conditions more accurately reflect real-world conditions, fuel cells need to be monitored and tested while being subjected to various non-ideal conditions. This presentation will discuss the results obtained from the environmental exposure of variety of fuel cells including; over data obtained on >100 reformed methanol fuel cell units tested over 40,000 hours of operation and SOFC and RM based fuel cell systems tested over an 18 month period.

Electromagnetic Interference (EMI) evaluation experiments were performed on both PEM and SOFC based technologies. The conducted emissions of the units were evaluated between 10 kHz and 10 MHz, while their radiated emissions were evaluated between 2MHz and 18GHz. These experiments demonstrated specific frequencies generated by the test unit that could result in interference with nearby electronic devices. Our experiments also evaluated the susceptibility of the test units to external fields of 30MHz to 18GHz. Results of EMI experiments demonstrated that various segments of the fuel systems' Balance of Plant (BOP) are highly susceptible to failure as a function of frequency. Failures such as a sudden decrease or complete loss of output power of the test units were observed and monitored as a function of EMI susceptibility. Figures 1 and 2 illustrate typical EMI test data for susceptibility and emissions.

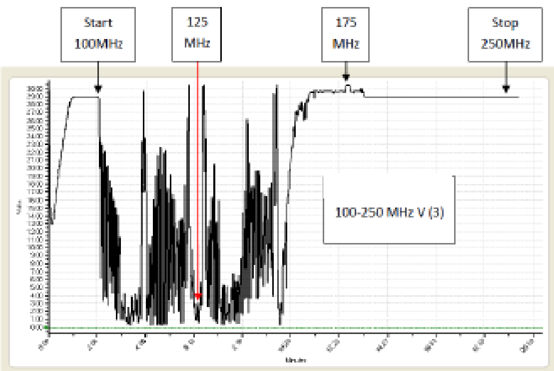

Figure 1 EMC Analysis RS103
100-250 MHz Vertical Orientation

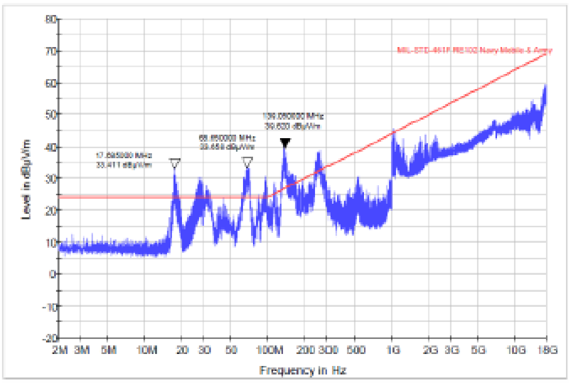

Figure 2 EMC Analysis RE102
2MHz-18GHz Vertical Orientation

Effluent analysis experiments were also performed employing a mass spectrometer. The closed ion source, 100 amu, quadrupole mass spectrometer (MS) was first calibrated and a multi-capillary sampling system was attached to the input gas stream entering the fuel cell unit under test and to the output gas stream leaving the fuel cell. Computer software was developed during these experiments that was capable of capturing, in real-time, the full diagnostics of the fuel cell test unit operating conditions, the input and output gas streams, temperatures, etc. By analysing the data, it was possible to determine a number of important parameters critical to the operation of the fuel cell including:

A) Evaluate the effluents for possible environmental hazards such as carbon monoxide, formaldehyde, etc.
B) Evaluate reformer and/or stack true efficiency; i.e. hydrogen content, carbon dioxide, water, etc.
C) Assist in the diagnostic performance of the fuel cell as a unit and of its various subsystems
D) Monitor performance as a function of time during start-up, periodically throughout its lifetime, etc.

Figure 3 below shows the equipment of our effluent analysis experiment. Figure 4 shows several gas concentrations as a function of time plotted over a one hour time interval. This type of data is extremely useful in determining the actual operation of the fuel cell, and can be employed to identify system weaknesses and inefficiencies in order to improve design and operation. The sampling of the process is a flow rate of 10 sccm which is a small compared with most process flow rates. Thus the process is not disturbed by the measurement.

Figure 3: An example of a MS connected to the effluent output side of a small portable fuel cell that is being load tested and monitored via PC.

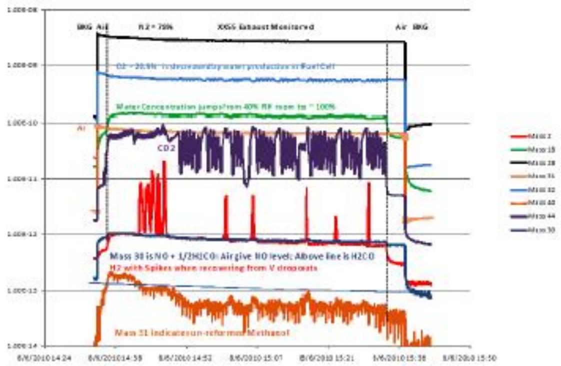

Figure 4: Example MS output graph showing from top to bottom as a function of time: nitrogen, oxygen, water, carbon dioxide, etc.

The research demonstrated that the mass spectrometer is an extremely valuable diagnostic tool that can be employed in the environmental testing of fuel cells under real-life operating conditions. Our experience has determined that MS is highly useful in analyzing reformer and fuel cell performance, increasing efficiencies, diagnosing system failures and indentifying unwanted effluents. The developed experimental procedures have been instrumental in helping to design fuel cells that will operate efficiently and safely during their intended lifetimes.

Durability and Performance Over Time evaluation experiments must be designed with control over many operating paramters and frequent and continuous logging of a comprehensive array of operational data. Data that must be logged include:

A) Load profile
B) Output voltage and current
C) On/off cycle count
D) Duration of run-time
E) Fuel delivery system type and composition
F) Ambient air
G) Hybridized battery status

Of particular importance is the design of experiment. Our data illustrates that units tend to present longer operational life when exposed to fewer on/off cycles, longer run times without fuel interuption, and constant purely resistive loading that maintains output power between 75% and 95% rated output.

Our experience tells us that the durability evaluation of any unit should include variation in test conditions to provide a more comprehensive analysis of operating performance. Analysis of operation with various potential load conditions and fuel sources produces optimum experimental data. Real-world applications present a multitude of operating conditions. The design of the durability experiment should strive to incorporate operation replicating a broad-spectrum of conditions.

This study demonstrated that the testing of man-portable fuel cell power generators is a complex effort requiring high attention to the control and measurement of various test parameters and the utilization of proper test protocols. By utilizing comprehensive control of test parameters, one achieves accurate and reproducible results that are truly representative of the unit under test operation rather than a function of the test parameters. A comprehensively controlled test yields significantly more reliable and reproducible data, which results in more efficient use of test time labor.

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TEST	PROTOCOL
Electromagnetic Compatibility (EMC)	MIL-STD-461
Sand/Dust	MIL-STD-810F Method 510.4
Environmental Stress Screening (ESS)	MIL-STD-810F
Durability	Comprehensive variable control, standard development
Heat generation	Thermal Imaging, TC profiling Various ambient conditions
Sound generation	Aural non-detectability level, MIL STD 1474 D
Physical durability	Interface cables, labels, push buttons, displays, carrying cases, fuel interconnects, case
Gas emissions	Mass Spectrometer and specific sensor analysis for hazardous effluent or poor performance
Fuel compatibility	Containers, composition
Load testing	Active, passive loads, on/off cycles
Many additional tests	Numerous product and component testing