Executive Summary

A Fuel Cell Technology Breakthrough: The SOFC Stick™

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Sustaining fossil fuels, reducing carbon dioxide emissions, achieving energy independence, and reducing reliance on oil are emerging as common goals for the modern world. Our understanding (or acceptance) of the cost of CO2 emissions is changing rapidly. There is growing consensus that our approach to deriving and using energy must be changed; this in turn drives a renewed search for more efficient technologies and credible alterative energies.

A novel technology with multiple international patents pending, the Solid Oxide Fuel Cell Stick™ has overcome the most significant hurdles facing fuel cells, enabling a key alternative technology. This white paper will introduce the merits of Solid Oxide Fuel Cell (SOFC) technology and at the same time examine the weaknesses of two existing SOFC technologies: Plates and Tubes. We then conclude with a description of the new SOFC Stick™ technology and its benefits, as well as benchmarks achieved that indicate that it is truly a breakthrough.

The internal combustion engine (ICE) has been the engine of choice for mobile applications such as vehicles, vessels, and auxiliary power for the last hundred years. Like coal burning power plants that supply much of our remaining needs, most ICEs suffer from poor fuel efficiency (typically less than 30%) and emit both local and greenhouse gas pollution.

By comparison, fuel cells emit no local pollution while demonstrating efficiencies above 60%, thereby reducing CO2 emissions by roughly half. Fuel cells can be powered by a diversity of fuels, besides gasoline and coal. The increased efficiency and fuel source diversity hold the promise of greater energy independence and reduced reliance on oil.

Proton Exchange Membranes (PEMs) Fuel Cells offer some hope as a fuel cell solution, but suffer from several fundamental technical flaws. Hydrogen is the only fuel that operates with PEMs, but hydrogen has limited storage options and low energy density. CO2 emissions are also problematical, because Hydrogen is not a fuel, but rather a product of fuel. PEMs also offer poor power density, near 2kW/liter.

Solid Oxide Fuel Cells compare favorably in most categories:

- Reduced CO2 Emissions: SOFCs are considered to have some of the highest efficiencies of fuel cell types, greater than the methods for producing hydrogen for PEMs.
- Complete Fuel Flexibility: SOFCs are unique in their ability to convert most hydrocarbon fuels (also including hydrogen), as well as next generation biofuels, into electricity in an efficient manner. Fuel source diversity is the key to energy independence and reduced reliance on oil.
- Excellent Energy Density and Specific Energy: Fuel flexibility allows energy density to be tailored to the application. Gasoline, Diesel, JP8, and Propane have all been successfully demonstrated with SOFC use. Specific Energy (Wh/Kg)

exceeds many current long-range battery technologies.

- Highest Fuel Cell Stack Density: As will be described, the SOFC Stick™ has demonstrated stack densities of 15kW/Liter and can achieve much higher densities, opening the door for use as primary power in automotive and other applications.
- Low Cost Materials: SOFCs and SOFC Sticks™ have been demonstrated using low cost Nickel anodes and conductive ceramic cathodes.
- Extreme Application Diversity: SOFCs and now SOFC Sticks™ are unique in their ability to serve diverse applications from handheld power in the Watt range to mobile vehicle and vessel applications in the kW range to stationary power in the MW range.

In the following pages we will examine the two traditional technologies for making SOFCs and the shortcomings of these methods. SOFC Plate technology is troubled by sealing, cracking, and manifolding problems. SOFC Tube technology suffers from poor volume density and manufacturing problems. Finally, we will formally introduce for the first time a novel technology, the SOFC Stick™, one that resolves the last of the technical hurdles of SOFCs and promises to bring them to the mainstream.

We will demonstrate how SOFC Stick™ Technology:

- Incorporates multiple integrated air and fuel pathways in a monolithic device, such that it is self-manifolded in a low cost manner.
- Adopts a willing form that can accommodate dramatic temperature differences along the length of the device, allowing low temperature and low cost connection points, simplifying construction, and increasing reliability. (Willing form is explained fully in the following paper.)
- Results in monolithic seal-less devices, with inherent air and fuel pathway separation, thereby increasing efficiency, simplifying construction, and increasing durability.
- Allows great design flexibility.
- Utilizes existing low-cost, high volume production methods, decreasing production and start-up time and cost.
- Has already demonstrated over 400mW/cm2 and density of 15kW/liter.

— **Alan Devoe and Lambert Devoe**
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Please download the complete White Paper at www.VioletFuelCellSticks.com

About Violet™

Violet™ **Fuel Cell Sticks**™ is based in San Diego, California, founded by brothers Alan and Lambert Devoe. Alan Devoe graduated from Massachusetts Institute of Technology, BS 1988, MS 1994 and has worked in the field of multilayer ceramics since 1980. Lambert Devoe, graduated from Massachusetts Institute of Technology, BS 1992, and graduated from New York University, MS 1994. He has also worked in the field of multilayer ceramics since 1980. Together they hold over 25 patents in the field of multilayer ceramics. They have been active in the field of fuel cells research and development since 2000.

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