Step on the gas -- New fuel cell design adds control, reduces complexity

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When Princeton University engineers want to increase the power output of their new fuel cell, they just give it a little more gas – hydrogen gas, to be exact. This simple control mechanism, which varies the flow of hydrogen fuel to control the power generated, was previously thought impossible and is a potentially major development in fuel cell technology.

The secret of their success is a system in which the fuel input itself changes the size of the reaction chamber, and therefore the amount of power produced. The breakthrough design also adds to the understanding of water management in fuel cells – one of the major obstacles to large-scale deployment of the technology in automobiles.

"It's almost so simple that it shouldn't work, but it does," said Jay Benziger, a Princeton professor of chemical engineering. Benziger developed the technique with Claire Woo, who graduated from Princeton in 2006 and is now pursuing a Ph.D. at the University of California, Berkeley. They will publish their findings in the February issue of the journal *Chemical Engineering Science*.

The first applications of their design are likely to be in small machines such as lawn mowers, the researchers said. The machines would be easy to use, incorporating a design similar to the familiar acceleration systems of cars that use a pedal to increase the flow of fuel and the power output. More important, Benziger said, the use of fuel cells in lawn care equipment would cut down on a major source of greenhouse gases, especially as emissions from these machines are not currently regulated.

At the most basic level, all fuel cells work by combining hydrogen with oxygen in a reaction that generates electricity, water and heat. In the Princeton system, some of the water produced as a by-product collects in a layer at the bottom of the reaction chamber, while the rest drains to an external tank. By varying the height of the water level in the chamber, Benziger and Woo are able to enlarge or shrink the reaction chamber.

For example, an increased flow of hydrogen into the chamber pushes more water out of the system, lowering the water level and increasing the space available for the reaction to take place. Similarly, a decreased flow of hydrogen causes the pressure inside the chamber to drop, drawing some of the water from the tank back into the system and shrinking the reaction chamber.

The water at the bottom of the chamber also serves to maintain the needed humidity for the fuel cell reaction to take place. This patented "auto-humidifying" design demonstrates an innovative use for the water produced during the reaction, which causes problems in most fuel cell designs.

Conventional fuel cells feature a complicated network of serpentine channels to combine the gases, maintain the appropriate humidity levels and eliminate water from the system. Often, droplets of water clog the narrow channels, leading to inefficient and irregular power production. The Princeton system mixes the gases via diffusion in a simple reaction chamber and relies on gravity to drain the water produced.

Benziger and Woo's reaction chamber is effectively sealed by the water at the bottom of the tank. By preventing fuel from leaving the system, this design ensures that the gases remain in the reaction chamber until they combine. Most traditional fuel cells repeatedly run hydrogen and oxygen through an open reaction chamber, converting only about 30 to 40 percent of the fuel at each pass. Since the Princeton system is closed, 100 percent of the fuel can be used with no need for a large and expensive fuel recycling system.

Source: Princeton University, Engineering School