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HYDRIDE BED ENGINEERING

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Abstract

Two of the engineering projects completed this year are described. In the first, an air-cooled hydride bed for use in a fuel cell laboratory at the University of Alaska, Fairbanks, was built. The second project is the conversion of a battery operated robotics vehicle to fuelcell operation with onboard hydride-based hydrogen storage.

Introduction

Metal hydrides have inherent safety and volume density advantages over compressed gas hydrogen storage. However, these advantages are often offset in many applications by the weight, cost and thermal integration requirements of hydride systems. The utilization of hydride technology for hydrogen storage in energy systems, therefore, requires improvements in hydride bed design and implementation, as well as in improved hydride materials.

Our approach is to use modeling, lab-scale experimental measurements and tests on technology validation beds to develop and evaluate efficient designs for:

1. Minimizing weight and volume.
2. Maximizing internal thermal conductivity and external heat transfer in order to reduce thermal requirements and to reduce fill times of storage tanks.
3. Reducing the cost of fabrication.

This engineering activity is integrated with our materials development program (see "Hydride Development for Hydrogen Storage" in this report) and attempts to improve the overall performance characteristics of storage systems based on hydrides.

Previously, we developed a modular hydride storage system for a fuel cell powered vehicle which utilized the water coolant loop of the fuel cell for thermal management. The beds were configured in a planar array with a height of only two inches and were designed for mounting as, or in conjunction with, a base plate under other equipment. Thus, the storage system had nearly zero impact on the limited volume available on the vehicle. In addition, the beds were demonstrated to be capable of filling to >95% of total capacity in about 5 minutes.

This year, in contrast, we have designed and fabricated two air-cooled beds, one for a fixed site application and one for a mobile application. These are described in the following sections.

Results and Discussion

RAPP Hydride Bed

The University of Alaska, Fairbanks (UAF), is constructing a laboratory to evaluate distributed power systems for use in arctic areas. Initially, these systems are home-sized hydrogen fuel cell units with integral reformers to generate hydrogen from available hydrocarbon fuels. The UAF laboratory also includes an electrolyzer for evaluating fuel cell operation independently of the reformer systems.

A hydride-based hydrogen storage bed was fabricated for use in the UAF laboratory in two applications. First of all, it will provide a means of accumulating hydrogen from the electrolyzer for use in short term fuel cell tests. Secondly, the concept of using hydrogen storage as a load leveling device between reformers and fuel cells will be tested. Since typical time constants for electrical load variations can be much faster than response times of reformers, some form of energy storage may be needed for distributed power units. Hydrogen storage provides an alternative to the use of batteries and their inherent maintenance issues.

The storage unit which was built also served to demonstrate several new fabrication methods for hydride beds. A photograph of the bed is shown in Figure 1. An air cooled design was chosen to eliminate the need for a liquid coolant loop in the installation at UAF and for flexibility in use with different fuel cells and experiments as described above. As is typical, a cylindrical geometry was used; however, the overall size (6 inches in diameter) is large for an air-cooled hydride bed and, hence, thermal requirements were an important consideration in the design. Pressure safety was also an important factor. Although not obvious in the photograph, the end plates are dome shaped. Finite element modeling was used to determine minimum wall thickness and shape, and to identify potential stress concentrations. Furthermore, a multidisciplinary design review team was convened to oversee design safety decisions.

A new approach to a layered structure was used internally which provided easy and rapid assembly, containment of the hydride powder to prevent deformation of the container with repeated operation, and sufficient thermal conductivity to assure effective operation during filling and unloading. Within each layer, a commercially available Al honeycomb was used to contain the hydride powder and provide additional thermal conductivity. The honeycomb material is inexpensive and very lightweight, accounting for less than 1% of the overall weight.

The electrolyzer output hydrogen stream can be put directly into the unit; no additional pumps or compressors are needed. The reformate stream, however, will require filtration to remove constituents which could poison the hydride material. The storage capacity of the bed in its present configuration is 30 grams, or 336 standard liters, of hydrogen. The capacity could be increased simply by adding additional layers and extending the length of the containment vessel, or by using additional units.

The unit was formally released as a Sandia-reviewed pressure vessel suitable for manned hydrogen operation and is currently undergoing extended performance testing before being supplied to UAF.

RATLER Robotic vehicle

The RATLER (Robotic All-Terrain Lunar Exploration Rover) is a Sandia-designed robotic vehicle for use over rough and uneven terrain (Figure 2a). It can be fitted with a number of different sensors and devices for reconnaissance, search or probing operations. The vehicle is articulated in the center to allow each half to rotate independently over uneven surfaces. Each wheel is driven independently with an electric motor and, as originally designed, used batteries for motive power and instrumentation. Units have been built in sizes ranging from a few inches to about 3 feet in wheelbase.

We have converted a vehicle with about a one foot wheelbase to fuel cell operation with onboard hydrogen storage. This system provides a number of advantages over battery operation. First of all, the vehicle has a much greater operating range (4 times the original range) and twice the power availability for equivalent weight and volume compared to the original battery configuration. The additional power is important for scaling steep grades, overcoming obstacles and for payload operation. Secondly, no degradation in performance occurs near end-of-range, as is typical for batteries. Full voltage and power is available until the fuel supply is exhausted. Finally, the hydride beds can be refilled in much less time than was required to fully recharge the batteries.

An overall view of the interior arrangement is shown in Figure 2b. The fuelcell power system is seen to consist of two identical modules, each with a fuelcell and hydride bed, supplying power to the two electric motors mounted at the wheels. Fuelcells and hydride beds are air operated; no liquid coolant loop is used. In operation, cover plates enclose each of the power modules, forming a channel for air to flow across the components. Air intakes are on the front and rear panels.

The layout of a single power module can be seen in more detail in Figure 3. A single fan (at the left side) supplies the cooling air flow required by the fuelcell during operation. The air warmed by the fuelcell then flows over the hydride beds to provide the energy needed to release hydrogen from the hydride. Below the photograph in Figure 3 is a schematic diagram showing the location of the ancillary valves, regulators, filters, etc. which complete the operating fuelcell units.

A single hydride bed assembly is shown in the photograph in Figure 4. It can be seen that the bed consists of six identical cylindrical units mounted on a U shaped frame. The frame provides added rigidity to the modular structure and also serves as a mounting platform for the assembly. An open, modular configuration was chosen to achieve a high external surface area and channeled air flow. This approach eliminated the need for cooling fins and reduced the thickness requirements of the radial plates, therby resulting in a lower volume and weight for the overall assembly. Stainless steel construction was used throughout for strength, ease of welding and compatibility with hydrogen and the hydride. The hydride is a commercial alloy (GfE C-15), which has a relatively low operating pressure over the anticipated operating temperature range of 0–60 C.

As in the larger hydride bed described earlier, an Al honeycomb structure was used internally to provide containment of particulate and for enhanced thermal conductivity. The internal structure adds less than 1% to the weight of the overall assembly. The performance of a bed module during hydrogen filling is shown in Figure 5. Here, the hydrogen flow rate and temperature of the assembly are shown as functions of time during a filling operation. One can see that a flow rate of 800 sccm could be maintained with a modest and constant temperature increase of only 8 C. The constant values indicate that heat removal by air flow across the unit matched the heat generated by the hydride formation rate dictated by the input flow. The entire unit was refilled in about 50 minutes, much faster than the time required to recharge batteries used in the original unit.

The vehicle assembly has been delivered to the robotics engineers for integration of the drive controls and subsequent field testing.

Acknowledgements

The RATLER conversion project was performed in collaboration with A.R. Miller, Fuelcell Propulsion Institute. The vehicle was provided by K. Miller, Sandia National Laboratories, Albuquerque, NM.

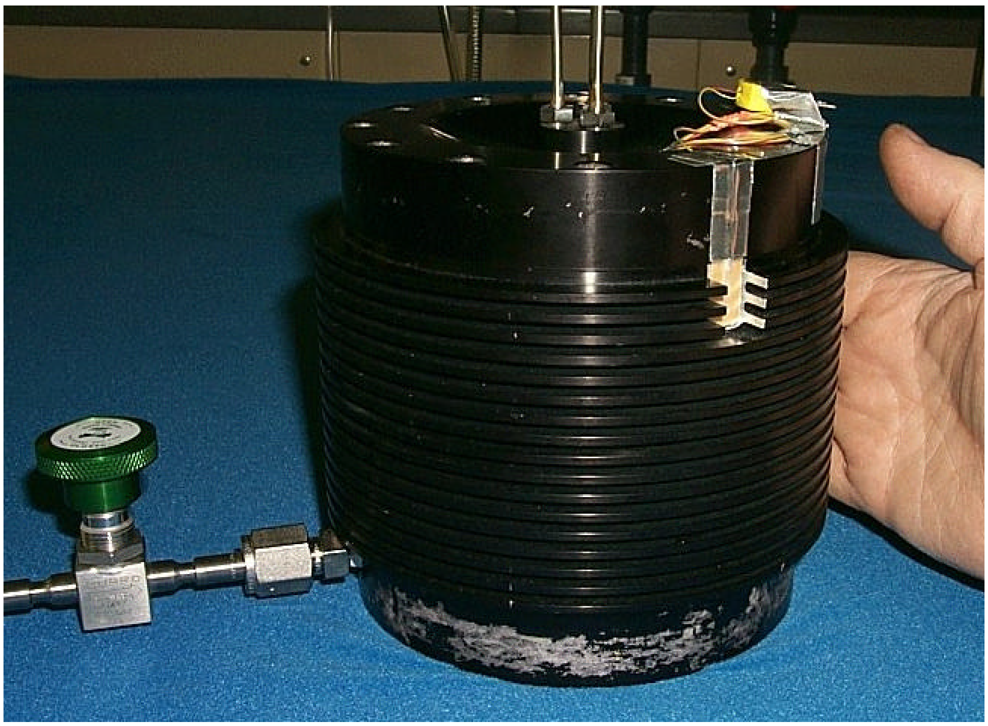
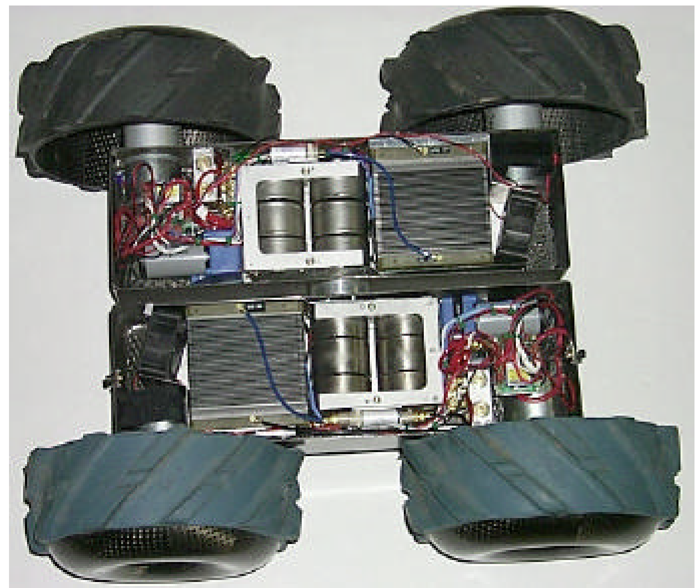


Figure 1. A photograph of the hydride bed assembled for use in the laboratory at the University of Alaska, Fairbanks.

Figure 2a.

RATLER^{TM} operating in the field

Figure 2b.



(a): Photograph of a RATLER vehicle in the field outfitted with a video camera.
(b) Interior arrangement of the modified vehicle showing the two identical assemblies which supply power to each of the articulated halves.

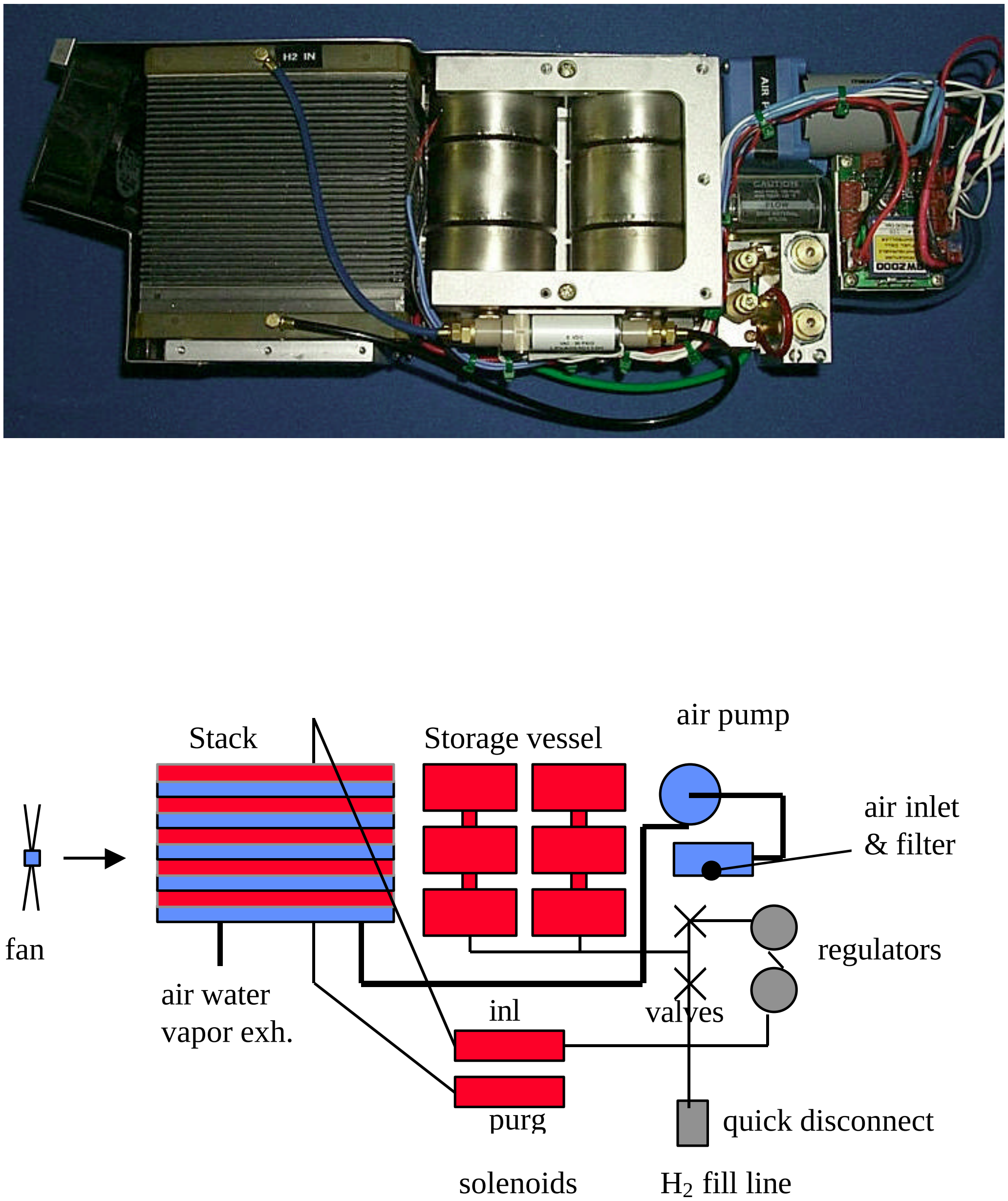


Figure 3. An individual power assembly with a schematic diagram showing positions of components.

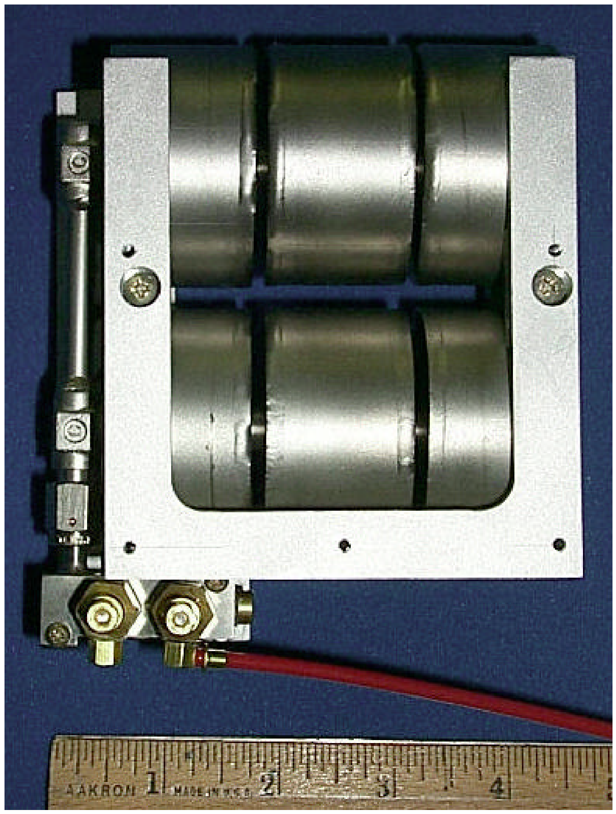


Figure 4. One of the hydride bed assemblies.

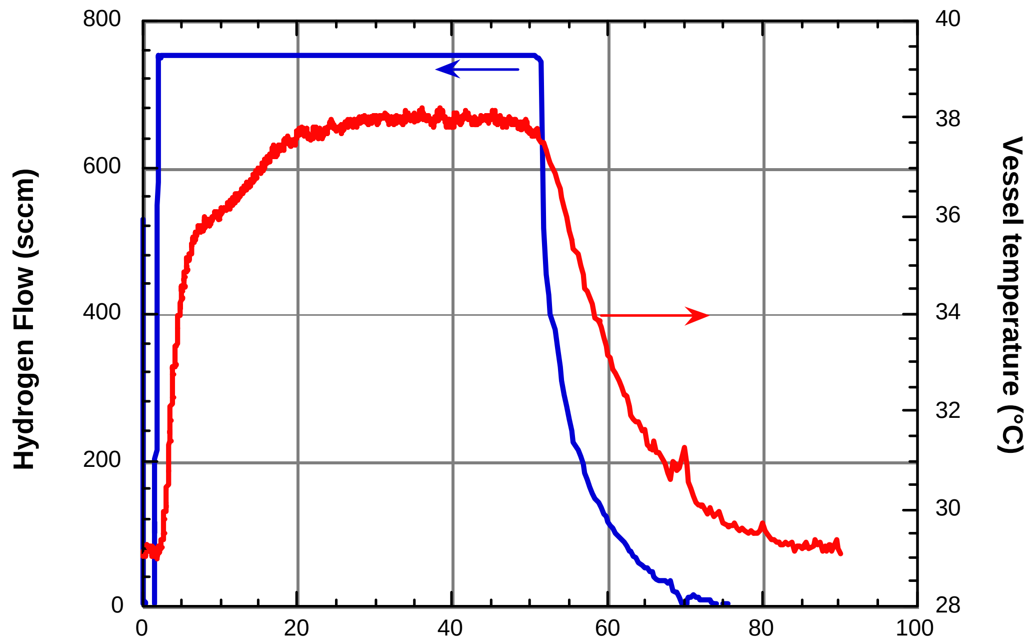


Figure 5. Plots of hydrogen flow rate and bed temperature vs. time during filling of a hydride bed assembly.