PERFORMANCE OF AN ELECTRICAL POWER ENHANCED METHANE-ACTIVATED CARBON ADSORPTION CELL

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Introduction

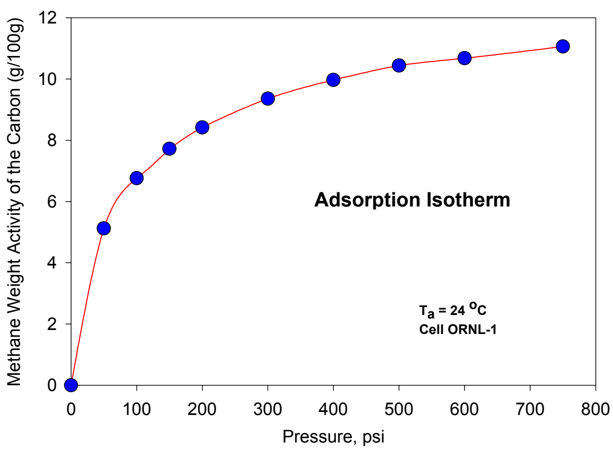
Experiments at ORNL using laboratory scale specimens of custom designed activated carbon for methane adsorption indicated the potential of containing 100-110 gm/liter (140-to-155 V/V) or more volumes of methane for each volume of carbon and to contain this quantity of methane at significantly lower pressure than simple compression. A storage tank was designed and built to test predicted scaled up performance from bench scale experiments. The tank contained 5,801.5 gm of 42% burnoff carbon, a volume of 12.027 liters. At 107 gm/liter (150 V/V), predicted charging of the cell to an operational target of 34 atm (500 psi), maximum of 61 atm (900 psi), showed the potential of containing 1800 STP liters of methane at 34 atm and 3,240 STP liters at 61 atm. Without adsorption, simple charging of the cell to 34 atm compressed 558 liters of methane with 61 atm capturing a maximum of 1,005 liters, substantially less than predicted for adsorption. Utilizing the equivalence of 3,540 liters (125 cubic feet STP) of methane equals 1 Gasoline Gallon Equivalent (GGE) at ambient, the cell with 150 V/V was projected to contain 0.51 GGE at 34 atm and 0.92 GGE at 61 atm. To evaluate predicted performance, the tank was used as a fuel supply to an internal combustion engine under various conditions of load.

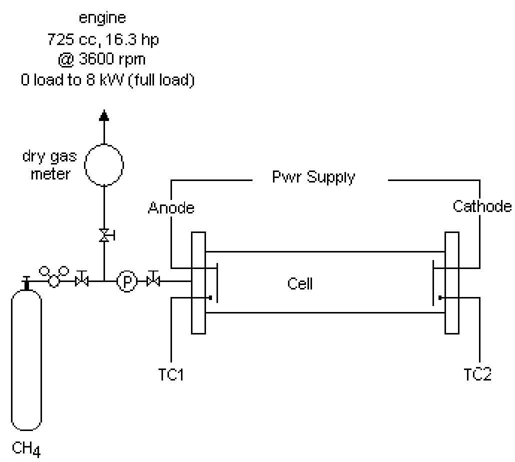
Experimental

The physical principle of the ORNL Activated Carbon Fiber Storage System is classic Van der Waals adsorption (physisorption). Methane weight adsorption in carbon can be measured in various ways, such as by relative volume (V/V) or by weight percent (wt%) in grams per gram of carbon. Methane storage in activated carbon is a function of several variables such as carbon density and activation.

The cell was constructed to contain 39 monoliths of about 0.31 liters and 149 grams each, comprising a total volume of about 12,000 cc. Each monolith was right circular cylinder in shape and was made from the same “recipe”. Activation in CO_2 averaged 42% burnoff. Monoliths were stacked in physical contact in slight compression within an acrylic sleeve with many slots. The sleeve also contained electrodes at each end. The electrodes were made of metallic screen of dimensions similar to the faces of each monolith. Resulting electrical resistance of the stack of ~1 Ω was found to vary slightly, inversely with pressure.

Bench scale experiments established a methane mass:pressure adsorption isotherm as the basis for predicting performance in scaled up form as shown in the following diagrams.





Results and Discussion

Targeted performance was delivery of approximately 150 V/V (1800 L @ 34 atm) of methane to a test engine under conditions of no load to full load. Actual run-to-empty performance produced an average delivered volume of 804 L at 34 atm with best case of 74 V/V. At 61 atm, average delivered volume was 1167 L with best case of 97 V/V. Electrical power (up to 20A and 20V instantaneous) was introduced at various pressures but determined to be most effective at around 7 atm (100 psi).

Carbon temperature was monitored and revealed expected decline in bulk temperature with desorption, about 6ºC from ambient, and a rise in bulk temperature when charging with methane, about 4ºC. Application of electrical power as supply neared depletion increased bulk temperature by about 6ºC from a low of about 16ºC shown in the no applied power case. Maximum power of 3600 watts produced a small increase in methane output that increased engine run time by a maximum of 14.5%. In all cases, electrical power enhancement was marginal, even when the carbon was heated above ambient.

Rather than enhanced performance from electrically stimulated release of methane, the effect of introducing electrical power during desorption resulted in bulk heating that tended to maintain carbon temperature for behavior closely predicted by isotherm data.

Conclusions

Given STP energy equivalence of 3,540 L of methane equals the energy in 1 gallon of gasoline, the cell of 0.58 cubic feet (4.3 gal) required delivery of 15,210 L of methane to produce equivalent vehicle range when using gasoline. The delivered volume of methane of 804 L (34 atm case) yielded just 45% of methane storage predicted from lab tests. In the 61 atm case, delivery of 1167 L was 36% of predicted volume. Electrical enhancement during the desorption phase proved marginal in each case.

Compared to the STP energy of gasoline, these tests showed methane delivery of just 5.2% (34 atm case) and 7.7% (61 atm case) of gasoline equivalence. Although delivered methane was normalized to tank volume that contained 7.8% free volume, performance of the custom recipe activated carbon in this application failed to approach bench test results. Subsequent analysis of bench scale samples taken from selected monoliths used in the tank showed repeatable performance at higher adsorption levels indicating that failure to achieve predicted performance in bulk can be attributed to the carbon failing to scale up proportionately, probably due to non-uniform activation within the larger monoliths.