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Performance of Activated Carbon in Evaporative Loss Control Systems

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ABSTRACT

Although activated carbons have been used successfully for approximately 20 years for control of hydrocarbon evaporative emissions from motor vehicles, the correlation of fundamental activated carbon properties, molecular scale pore size/volume characteristics, to carbon performance has not generally been available. Improvements in wood-based carbon have focused on the pore size/volume characteristics resulting in a doubling of performance, as measured by butane working capacity, over the past few years. In addition to relating the butane working capacity for different types of carbon to pore characteristics, laboratory studies using new carbons have demonstrated that the capacity for adsorption of vapors from gasoline is also related to this fundamental property. Furthermore, different types of in-use carbons from vehicle canisters have been evaluated to confirm that the key to carbon performance is pore characteristics and also, that laboratory evaluations of carbons, using proper conditions, can realistically simulate the performance of actual in-use carbons.

BACKGROUND

Automotive evaporative emissions control systems were instituted in 1970 for cars sold in California as the result of regulations promulgated by the California Air Resources Board (CARB). Beginning in the 1971 model year, all cars sold in the United States were required to use evaporative control systems. These national evaporative emission control regulations were mandated by the U.S. Environmental Protection Agency and have become increasingly stringent as shown in Table 1.

Current U.S. regulations require the control of diurnal and hot soak emissions. Although these and other regulations have achieved substantial reductions in vehicle emission levels, previously unexamined factors have uncovered higher levels of evaporative emissions than were once thought to occur. These factors include high fuel volatility, higher ambient temperatures, multiple day

Table 1. Summary of U. S. Evaporative Emmission Control Standards

Model Year	Test Method	Limit (g/test)
1970 (Calif.)	Carbon Trap	6
1971 (U.S.)	Carbon Trap	6
1972 (U.S.)	Carbon Trap	2
1978 (U.S.)	SHED	6
1980 (Calif.)	SHED	2
1981 (U.S.)	SHED	2

parking events, fuel permeation and vapor migration. In January 1990, EPA published a proposed rule for evaporative emission control that would not only tighten existing standards, but also would include the control of hydrocarbon losses while the vehicles are running.(1)* The EPA proposal relies on test procedure changes that influence purge volume and a design review process to control running losses. General Motors Corporation has proposed a procedure that includes real-time diurnal testing as well as the direct measurement of running losses.(2) Another new test procedure from CARB also includes direct measurement of running losses and real-time diurnal testing.(3) Regardless of the final form of a new national test procedure, it appears that future evaporative loss control systems will have to perform at higher efficiencies.

Evaporative loss control systems primarily consist of an activated carbon canister for the adsorption and desorption of hydrocarbons, control hardware and the associated piping. Although evaporative emissions can be influenced by control hardware, purge systems and materials of construction, this paper will focus on the design and testing of activated carbon products for the automotive application.

Activated carbon used in the automotive canisters in the early 70's was typically coal-based granular carbon with a butane working capacity (BWC)(4) in the range of 5 g/100ml. In the mid 70's, wood-based granular carbon was introduced in the United States for the automotive application and rapidly gained a large market share as a result of product advantages. The initial wood carbons also had a typical BWC level of 5 g/100ml.

The butane working capacity of wood carbon has more than doubled to 11 BWC since 1975 in response to more stringent regulations (Figure 1). Improvements have also provided for more flexibility in the canister geometry and size. Further wood carbon performance improvements are now in the plant trial stage with an objective of 13 BWC or higher. To date, wood carbon has been used in over 150 million vehicles for control of evaporative emissions.

The strategy for wood carbon improvements has focused on defining the optimum pore size characteristics that are important for the automotive application, and developing laboratory test methods to accurately simulate the characteristics and performance of in-use carbons.

In activated carbon terminology, pore size characteristics refers to investigation of carbon properties on a molecular scale. Optimum pore size characteristics have been defined for gasoline fuels and are currently being investigated for alcohol blends. Evaluation of in-use carbons have confirmed that pore size distribution is the key parameter for the automotive application and that laboratory test procedures are available for realistic simulation of a carbon's performance in an actual canister.

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* Number in parentheses designates reference at end of paper.

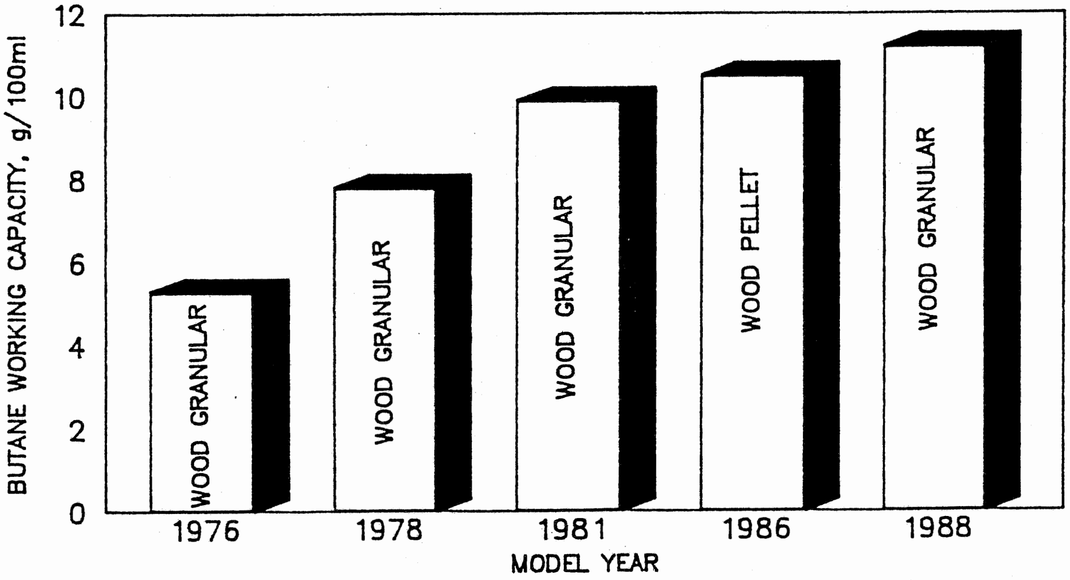

Figure 1. Performance Improvement History For Wood Carbons

EXPERIMENTAL

EQUIPMENT DESCRIPTION - Evaluation of carbon performance for adsorption of fuel vapors was conducted using the canister test system shown in Figure 2. The system, fully instrumented and computer controlled, has the capability of automatically testing carbon canisters for adsorption/desorption performance with a variety of fuels.

The fresh and spent fuel tanks are located remotely. Both tanks have a capacity of approximately 40 liters. Fuel is delivered via nitrogen pressure from the fresh fuel storage tank to the fuel volume charge vessel. The charge vessel is equipped with a level sensor so that a precise volume of fresh fuel is delivered for each adsorption cycle. Fuel flows from the charge vessel to the vapor generator on demand and once the temperature in the vapor generator is below a set point. Heat transfer fluid is then pumped into the water bath to heat the fuel to a desired temperature.

After the desired fuel temperature is reached, clean, organic-free, dry air is bubbled through the fuel in the vapor generator. The air flow rate is controlled by a mass flow instrument with the actual air rate predefined to give the desired vapor generation rate and vapor concentration. The air/fuel vapor passes through coalescing filters to remove any liquid droplets prior to the carbon canister.

During the adsorption cycle, internal canister temperature and the canister weight are continuously measured and recorded. The hydrocarbon content of the air exiting the canister is also continuously monitored by a Beckman Model 400A Total Hydrocarbon Analyzer (THA). When breakthrough from the canister reaches the equivalent of 0.5% volume butane, the adsorption cycle is stopped by terminating airflow to the vapor generator and closing the appropriate valves.

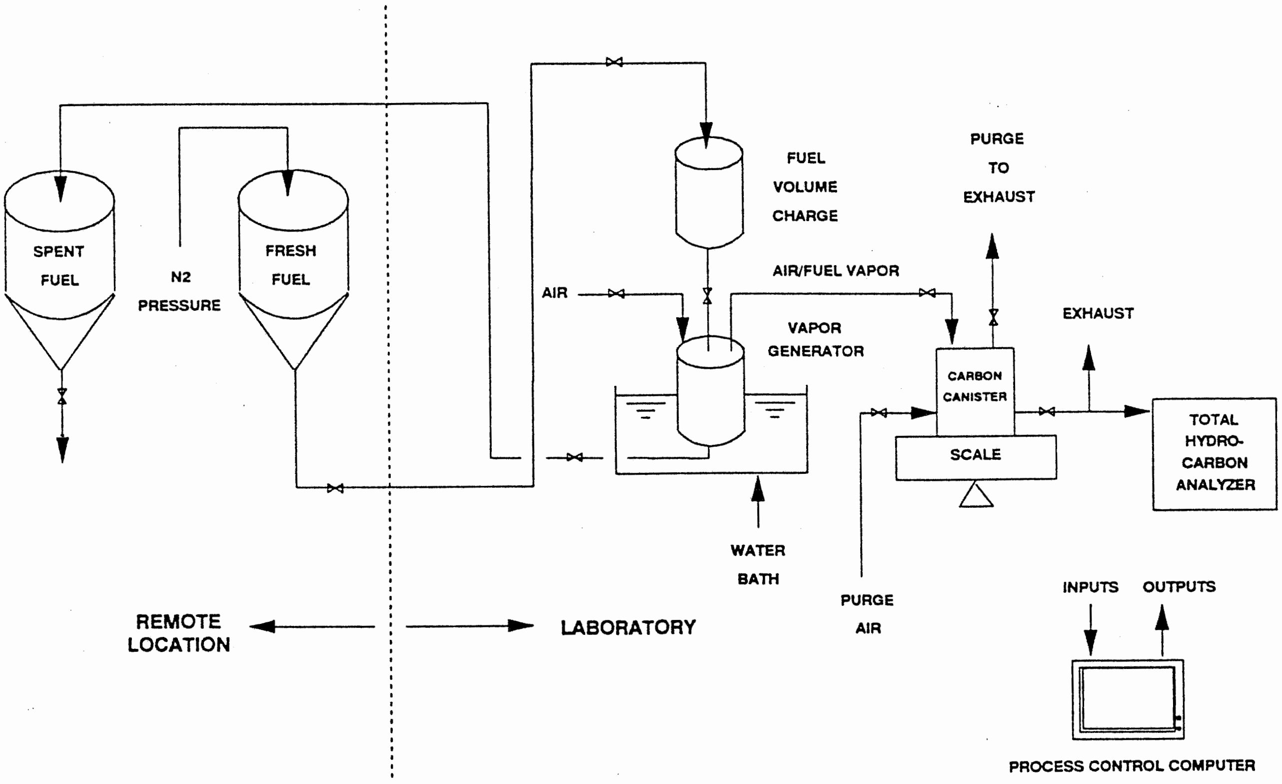

Figure 2. Westvaco Automotive Canister Cycle Test Equipment

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