

Analysis of Butane Diffusion in Activated Carbon Canister

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ABSTRACT

A canister filled with activated carbon prevents the emission of hydrocarbon into the air, through repeated adsorption and desorption process. A small amount of hydrocarbon, with n-butane as one of the major components, remains inside the canister. The diffusion of this residual n-butane affects Diurnal Breathing Loss performance. This study reports the quantitative difference of n-butane diffusion and breakthrough under three experimental conditions. Furthermore, diffusion speed, which is an important factor in the analysis of canister performance and the design development of canister, was also calculated.

INTRODUCTION

One of the exhaust gas emission regulations is the regulation of the amount of fuel vapor (hydrocarbon) emitted from a fuel tank, so-called evaporative emission that may be released into the air. As a means of meeting the standard values set within this regulation, a system featuring a canister filled with activated carbon is commonly used. The canister adsorbs hydrocarbon that is emitted from the fuel tank, when the vehicle is stopped or parked during day and night when temperature changes and during refueling. Also, the canister desorbs the hydrocarbon by supplying it as fuel when the engine is running. By repeating this adsorption and desorption process, the canister prevents the emission of hydrocarbon into the air (Figure 1).

In many cases, a small amount of hydrocarbon remains in the canister after the desorption process. Itakura et al [1]

has shown that the residual hydrocarbon is mainly n-butane and that it diffuses inside the canister to the drain port while the vehicle is parked. The same paper also reports that this diffusion of n-butane (inside the canister) is the main cause of a slight leakage from the canister.

However, case studies on the quantitative measurement of diffusion of n-butane, such as measurement result of n-butane diffusion coefficient, diffusion volume of n-butane inside the canister, have not been reported.

Therefore, this study examines the diffusion of n-butane under various experimental conditions and quantifies the diffusion of n-butane.

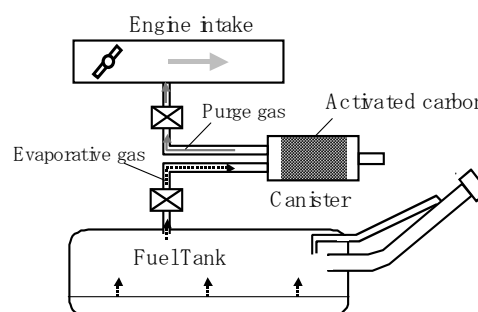


Figure 1. Evaporative emission control system

EXAMINATION OF DIFFUSION INSIDE A CANISTER

The study confirms the effect of n-butane diffusion on DBL (Diurnal Breathing Loss) performance by comparing breakthrough ratios. Conditions, such as shapes of adsorbent packed bed and soak times, were varied to examine if difference in ratios existed or not.

OUTLINE OF TEST FLOW

Figure 2 shows the basic test flow, using as a reference the test program reported in Parker et al [2]. The n-butane breakthrough characteristic of a canister was measured after stabilization, charging and purging of n-butane, and soaking. The conditions in each step are shown in the next sections.

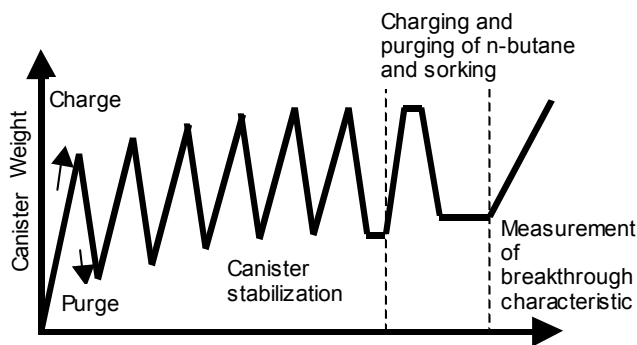


Figure 2. Test flow showing the three basic steps

Canister stabilization

The first step in the test flow, stabilization, was carried out using a test circuit as shown in Figure 3. A canister filled with 200 mL of new activated carbon (BET specific surface area: 1300 m²/g, fill density: 0.35 g/mL) was used in the test circuit. Then, at an ambient temperature of 25°C, gasoline (RVP=60kPa) in a tank was bubbled with dry air to promote evaporation, and breakthrough adsorption of the fuel vapor was carried out. Thereafter, air purging was performed at 3.0 L/min × 20 min. Six cycles of this charging and purging were carried out.

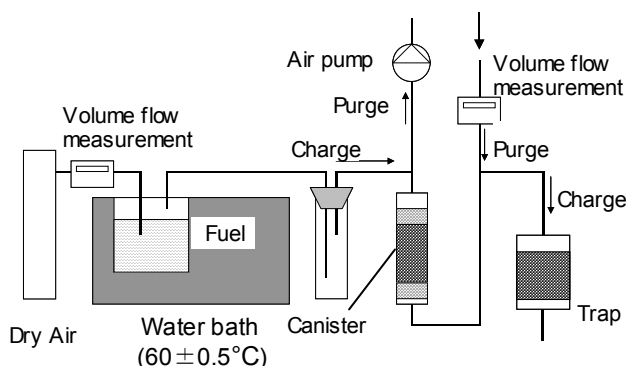


Figure 3. Test circuit used in stabilization

Charging and purging of n-butane and soaking

After the stabilization, the next step of charging and purging of n-butane and soaking was carried out. Under this step, mixed gas of n-butane/nitrogen = 50/50 (vol/vol) was charged into the canister at an ambient temperature of 25°C, at a speed of 40 g/h, to adsorb the n-butane until breakthrough at 2.0 g. Then, air purging was performed at 3.0 L/min × 7 min, and then the canister was soaked for 36 hours with the drain side opened.

Measurement of breakthrough characteristic

With the completion of steps 1 and 2 of the test flow, the last step is carried out using the test circuit as shown in Figure 4. At an ambient temperature of 25°C, charging the mixed gas of n-butane/nitrogen = 50/50 (vol/vol) at a speed of 4.0 g/h into the canister, the breakthrough characteristic was verified, as shown in Figures 5 and 6.

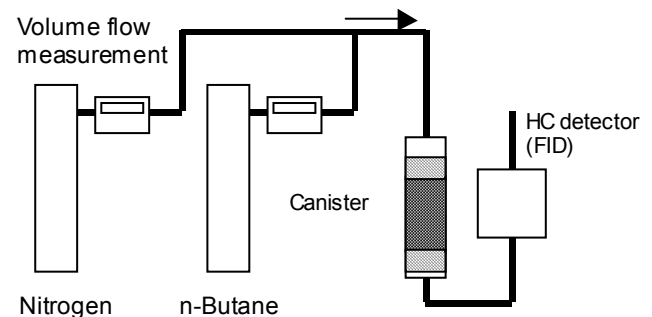


Figure 4. Test circuit used for measurement of breakthrough characteristic

Figure 5 shows the breakthrough (mg_{BT}) plotted against charge weight (g_C) on n-butane.

Then, based on the results from Figure 5, the breakthrough ratio per unit of charge weight (herewith below referred to as the breakthrough ratio, mg_{BT}/g_C) is plotted against the total charge weight (g_C) as shown in Figure 6.

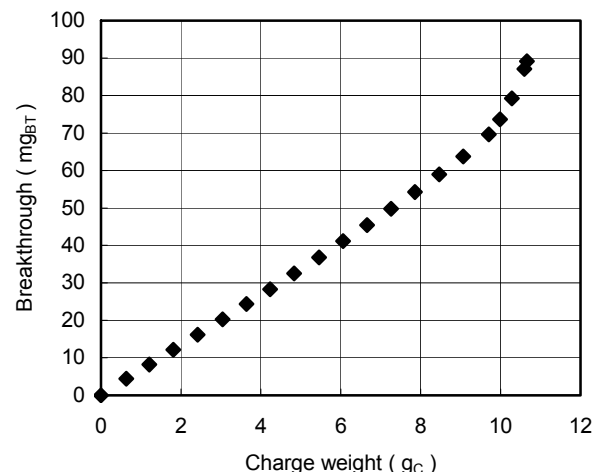


Figure 5. Relationship between charge weight (g_C) and breakthrough (mg_{BT})

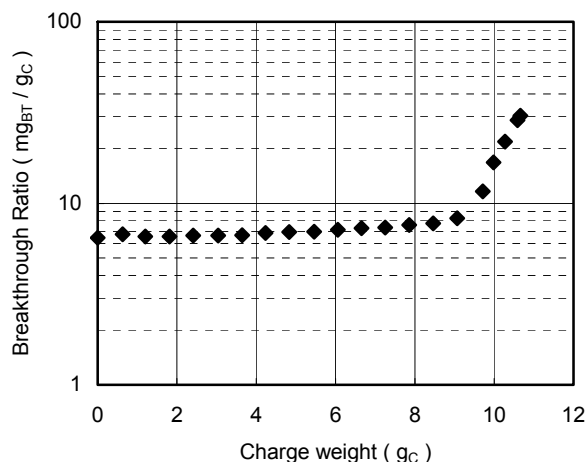


Figure 6. Relationship between charge weight (g_c) and breakthrough ratio (mg_{BT}/g_c)

The curve shown in Figure 6 is comparable to breakthrough curve drawn from adsorption time against adsorbate concentration at drain port. Also, it can be seen from Figure 6 that the breakthrough increases at a constant rate up until charge weight of approximately 9 g while a sharp curve appears after 9 g. Hashimoto and Miura [3] report that the sharp curve is due to shifting of the adsorption band to the drain port. Thus, it can be considered that within 9 g, breakthrough of n-butane diffusion occurs slightly under normal level and with the shifting of the adsorption band to the drain port after 9 g, breakthrough is at a normal level.

EFFECT OF SHAPE OF ACTIVATED CARBON PACKED BED

Next, in order to ascertain the effect of the shape of the adsorbent bed on the breakthrough characteristic, activated carbon was put into a range of metal canisters with various L/Ds as shown in Table 1.

Table 1. Shape of test canisters

L/D	Diameter mm	Length mm
3.0	44	132
3.5	42	146
4.0	40	160
5.0	37	185
6.0	35	209
8.0	32	254

At this point, initial breakthrough ratios were compared among the various case shapes, with a charge weight of 2.0 g. At this charge weight, as explained in the previous section, a breakthrough slightly under normal level is observed.

Initial breakthrough ratio is a means of measuring diffusion of n-butane. The results of this comparison are shown in Figure 7.

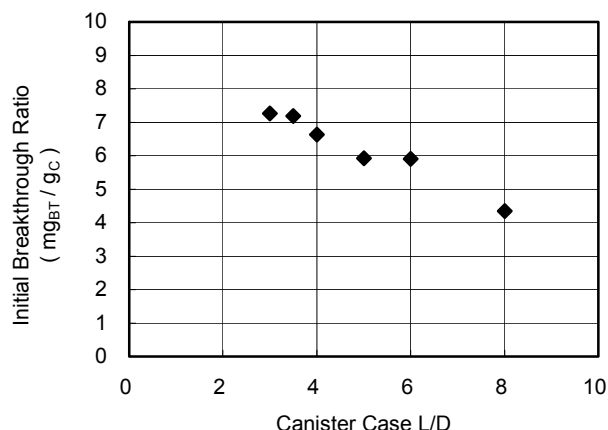


Figure 7. Relationship between canister L/D and initial breakthrough ratio

As shown in Figure 7, the larger the L/Ds, the smaller the initial breakthrough ratio. That is, as the L/D increases, the cross sectional area of the adsorbent bed becomes smaller and the length of the filled layer increases, the diffusion distance of the n-butane inside the canister becomes longer, so that the diffusion ratio becomes smaller. As such, n-butane concentration at the drain side becomes lower and the initial breakthrough ratio also becomes smaller.

EFFECT OF SOAK TIME

Next, in order to ascertain the effect of different soak times on the breakthrough characteristic, an experiment was made using the case with L/D=4.0 and L/D=5.0.

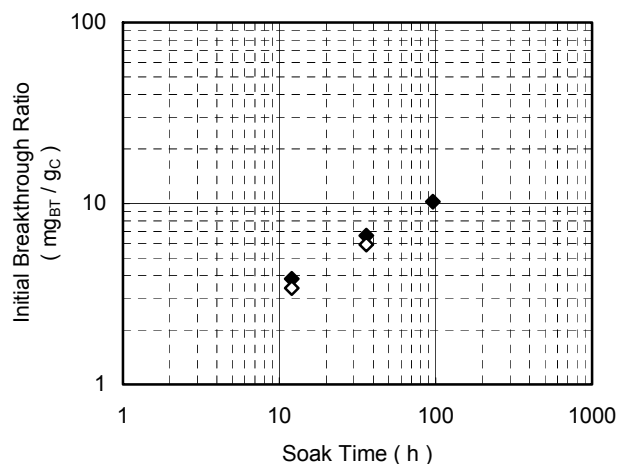


Figure 8. Initial breakthrough ratios at different soak times for L/D=4.0 (◆) and L/D=5.0 (◇) canisters