

# Effect of Activated Carbon Pore Structure on Dynamic Adsorption Zone, Paper II

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**Abstract.** This paper presents results of additional studies on the equation presented at the Sixteenth Biennial Conference on Carbon which relates pore structure to adsorption rate. The equation was modified to bring the correlation of pore structure and test parameters even closer to the adsorption zone profile.

## Introduction

This paper is a second presentation on the results of an on-going investigation of carbon pore structure and other properties of the carbon-adsorbate system on the adsorption rate of vapor from the air stream, using acetone as the medium of study. The rate is measured in terms of the adsorption zone length and vapor concentration profile in the adsorption zone. Figure 1 shows the role of the adsorption zone in the overall air-cleaning process of carbon filters. The vapor-laden air enters the carbon bed at concentration  $C_1$  and in a course of time develops an essentially saturated layer LS, in which little or no vapor is adsorbed, and the adsorption zone LZ.

## Service Time Equation

Equation 1 gives the numerical relationships in the overall air-cleaning process as related to the service time,  $t$ , when vapor penetration of the bed occurs at a designated concentration  $C$ .

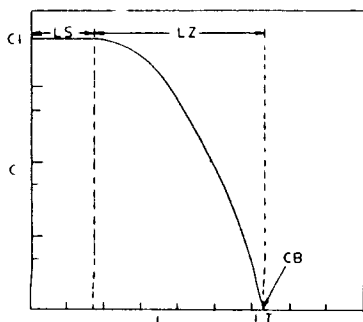


Figure 1. Adsorption zone profile in carbon bed at steady state.

$$t = \frac{w d A}{F(C_1)} [LT - LZ + f(LZ1)]^{**} \quad (1)$$

This is a material balance equation in which the quantity,  $tF(C_1)$ , is equal to the balance of the equation. LZ1 is the adsorption zone length when CB is the lowest effluent concentration measurable, which in this study is 0.1 ppm. LZ is the adsorption zone within the carbon bed at any  $C$  from CB to  $C_1$ . When the effluent concentration,  $C$ , equals  $C_1$ , LZ is zero and all of (LZ1) is outside the effluent end of the carbon bed. LS is then the same length as LT. When effluent concentration,  $C$ , equals CB, LZ is the same length as LZ1 and all of LZ1 is then within the carbon bed. LS equals  $LT - LZ1$ . The quantity  $f$  is the area under the curve divided by  $(LZ1)C_1$ .

The unknowns in this equation are  $t$ , LZ, LZ1, and  $f$ . The subject of this study is the determination of these quantities.

## Activated Carbons

Carbons of very diverse pore structure were used in this study. They are commercially available; made from bituminous coal, lignite, and coconut. All were treated with HCl, HF, and pure water to remove essentially all of the inorganic oxides. The pore size distribution curves are shown in Figure 2. Water adsorption data yields a curve based on distribution of pore diameter constrictions, and one based on distribution of cavities. The dividing pore diameter between macropores and micropores is 30A. The concept of pore diameter constrictions and cavities, and also, the use of 30A as the dividing diameter for the large and small pore classifications are an integral part of the adsorption rate theory presented in this paper.

## Adsorption Zone

The solid line curves, 1 through 4, in Figure 3 show concentration profiles for the carbons at carbon-bed face velocity of 23.56 cm/sec, and effluent concentration of 0.1 ppm. The sieve size was 8 by

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\*\* Terms defined on next page

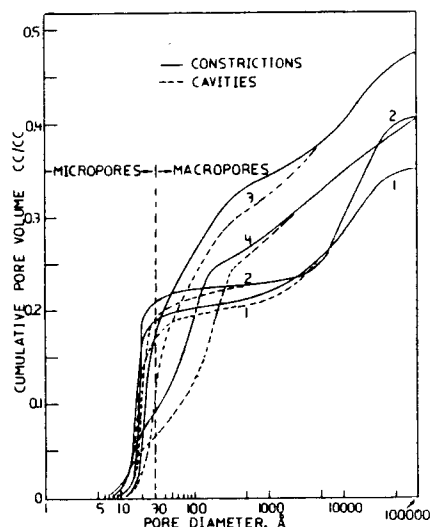


Figure 2. Pore size distribution curves.

16 US although some variation occurred in the distribution.

The broken line curves, 1 through 4, give the concentration profiles as calculated with the equations 2, 3, 4, and 5.

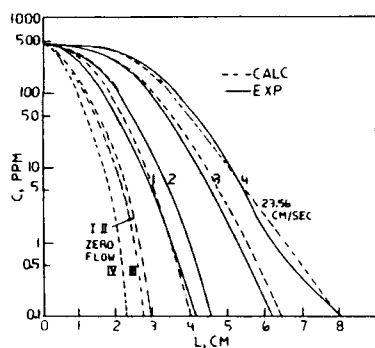


Figure 3. Adsorption zone profiles.

The equation has three parts; a, b, and d, and their associated logarithmic functions. The one associated with (a) predominates when the flow rate is zero, but vapor is supplied to the influent side of the carbon bed. The vapor will diffuse into the bed forming a concentration profile. The concentration profiles are shown in Figure 3, curves I, II, III, and IV. The (b) part predominates at the low concentration end of the concentration profile, and where transport of vapor to the exterior of the carbon surface is controlling. Part (d) predominates at the mid-section of the concentration profile where the adsorption processes within the carbon are controlling. At C equal to C1 all adsorption processes stop.

$$LZ = a \ln \left[ \frac{C1}{CB(1+C)} \right] + b \ln \left[ \frac{C1}{C} \right] + d \ln \left[ 1 + \frac{(C-CE)^2}{C} \right] \quad (2)$$

$$a = \left[ \frac{DG \times DV}{VS} \right] \left[ \frac{DH}{\left[ \frac{AT}{AM} \right] \left[ \frac{DP}{30} \right]^{\frac{1}{2}}} \right] (C1-C)^{0.44} \quad (3)$$

$$b = \left[ \frac{DP}{30} \right]^{\frac{1}{2}} \left[ \frac{AT-AC}{AM-AC} \right]^2 \left[ \frac{ATG-ACC}{AM-AC} \right]^2 \left[ \frac{DG}{VS} \frac{U}{(AP)^2} \right] \quad (4)$$

$$d = \left[ \frac{DP}{30} \right] \left[ \frac{AT-AC}{AM-AC} \right] \left[ \frac{ATG-ACC}{AM-AC} \right]^2 \left[ \frac{DG}{VS} \frac{U}{(AP)^2} \right] \quad (5)$$

### Conclusions

Seventy-eight test runs were made, of which seventy were acceptable; i.e., no known experimental errors were committed in their performance. On most of the accepted seventy runs, the correlation between the calculated and the experimental curves fall in the range shown in Figure 3. Additional work is required on the effects of concentration on adsorption rate. At high influent concentrations, the zone appears to approach a constant length, a fact which the equation in its present form does not take into consideration. The major pore structure characteristics that contribute to the difference between the zone lengths are the surface areas, AT, AM, and ATC.

In the development of this equation, the need never arose to introduce the concepts of active sites, intermediate pore sizes, submicropores, or pores of slit shape.

### Glossary

- A - carbon-bed face area.
- AC - surface area submerged by liq acetone, calc from pore dia constriction curve.
- ACC - surface area submerged by liq acetone, calc from pore dia cavity curve.
- AM - micropore surface area, calc from pore dia constriction curve.
- AP - external surface area of carbon granules.
- AT - total surface area, calc from pore dia constriction curve.
- ATC - total surface area, calc from pore dia cavity curve.
- C - acetone vapor conc in carbon bed.
- CB - lowest measurable effluent conc, 0.1 ppm.
- CE - equilibrium conc of acetone in bed at any C.
- C1 - influent conc.
- db - bulk density of carbon.
- DG - density of air.
- DH - mean distance between carbon granules.
- DP - mean micropore dia of pores not submerged by adsorbed liq acetone.
- DV - coefficient of diffusion of acetone.
- F - volume flow rate.
- LT - total bed length.
- LZ - adsorption zone length, conc C1 to C range.
- LZ1 - adsorption zone length, conc C1 to CB range.
- 30 - pore dia that divides macro- and micro-pores, detr from constriction pore dia curve.
- t - service time.
- U - face velocity of acetone-air mixture.
- VS - viscosity of air.
- w - adsorptive capacity of carbon.