principle. Donoghue and Mack[2] have noted the effect with cotton fibres, and Davies, Aylward and Leacey[3] with dust particles. It has been assumed that particles deposited in the second half of one stroke when the air velocity is low may be blown off by the high velocities in the early part of the succeeding stroke.

It is understood that no such phenomenon occurs when isotropic particles such as coal or silica dusts are sampled in the thermal precipitator; but we have not heard whether the instrument has given satisfactory results elsewhere with asbestos or other fibrous dusts.

C. G. ADDINGLEY

British Belting and Asbestos, Ltd.,
Cleckheaton, Yorks.

R. GAZE

The Cape Asbestos Co. Ltd.,
Central Laboratory,
Harts Lane, Barking, Essex.

August 5.

[1] Hamilton, R. J., *J. Sci. Instrum.*, **33**, 395 (1956).
[2] Donoghue, J. K., and Mack, C., *Brit. J. App. Phys.*, **4**, 316 (1953).
[3] Davies, C. N., Aylward M., and Leacey, D., *Amer. Med. Assoc. Arch. Indust. Hyg.*, **4**, 354 (1951).

Sedimentation Rates, Fluidization and Flow through Porous Media

IN a previous communication[1] I proposed a correlation of sedimentation rates by dimensionless groups, thus:

$$\psi = \frac{K}{B^N} \qquad \text{(I)}$$

The symbols throughout have the same meaning as before[1].

By analogy with the derivation of a correlation for a single free-settling particle, the resistive force per unit area for a suspension of particles sedimenting under hindered settling conditions is $\varepsilon(\sigma-\rho)g/S$. Thus, by the same procedure as before[1]:

$$B = \frac{U\rho}{(1-\varepsilon)S\eta} \qquad \text{(II)}$$

and

$$\psi = \frac{\varepsilon^3}{U^2 S}\,\frac{\sigma-\rho}{\rho}\,g \qquad \text{(III)}$$

Equation III differs from the corresponding previous equation[1] in the ε^3 term and it is proposed here because it is analogous to the equations for correlating fluidization phenomena[2]; sedimentation and fluidization are essentially similar.

Coinciding with the earlier communication[1] Orr and Dallavalle[3] proposed:

$$\frac{U^2}{Dg}\,\frac{1-\varepsilon}{\varepsilon^3} = \frac{1}{K}\,\frac{UD\,(\sigma-\rho)}{36\eta} \qquad \text{(IV)}$$

where D is equivalent diameter. This is an alternative form of equations I ($N=1$), II and III and was derived from Kozeny's permeability equation. Consequently, it assumes $N=1$ in the Blake-Carman correlation, thus losing generality. However, its authors, perhaps recognizing this, afterwards stated it in functional form.

The groups in equation IV are a modified Froude group and a modified Reynolds number (not the Blake number); thus, it is not in line with the usual methods for correlating similar flow phenomenon. However, its authors report successfully correlating a range of published data, some of which were mentioned previously[1], and an estimate indicates $K \sim 4 \cdot 3$. In addition, particle agglomerates, adhered fluid and surface area estimates have been dealt with by this method. These applications were mentioned previously[1] and consequently the two investigations overlap.

An empirical relationship for sedimentation which has recently been given a theoretical basis[4], is:

$$U = U_0 \varepsilon^n \qquad \text{(V)}$$

The range of n was summarized previously[1]. At low Reynolds numbers the equation for a sphere settling under Stokesian conditions is usually used for U_0. Consequently, when $\varepsilon=1$ equation V reduces to the relationship for a single sphere. However, because of the theoretical model, equations II and IV have no such meaning.

By examining the relationship between equations I, II, III and V, Table 1 was obtained:

Table 1. VARIATION OF N AND K WITH ε AND n

	N			
ε	$n=4$	$n=5$	$n=6$	$n=7$
1·0	0	0	0	0
0·9	0·39	0·50	0·60	0·69
0·8	0·63	0·79	0·90	1·00 ($K=6·11$)
0·7	0·79	0·96 ($K=3·40$)	1·08 ($K=4·86$)	1·18
0·6	0·91	1·08 ($K=3·48$)	1·20	1·29
0·5	1·00 ($K=2·00$)	1·17	1·29	1·37

Thus, if equation V holds, then equations I, II and III will give a shallow curve. This is not unexpected, because the correlation extends the Blake-Carman beyond its limit [$\varepsilon \sim 0·5$ to $0·7$] which occurs in the region of transition from flow through porous media to fluidization or to sedimentation.

Permeability equations of the form $u \propto \varepsilon^n$ ($n=3·3$–$7·0$), where u is the rate of flow, have been proposed[5] but are rarely used in comparison to Kozeny's equation. These resemble equation V both in the porosity function (ε^n) and in the range covered by n. Data fitted by the Blake-Carman correlation[6,7] ($K=3·93$, $N=1·062$) were excellently described by the semi-empirical equation[7]:

$$kS^2 = 3 \cdot 3\varepsilon^{4 \cdot 95} \qquad \text{(VI)}$$

k is Darcy permeability and hence equations V and VI are of the same form in ε.

The flow phenomena considered here are fundamentally equivalent and similar correlation methods would reflect this. Although equations of the form V and VI have wide application, there appears to be more support for the Blake-Carman and similar correlations. The difference lies in the form of the porosity function; ε is possibly the most important variable whose influence is yet to be fully understood. Thus improved relationships might follow from introducing empirical porosity functions into the friction factor. However, the mention of correcting factors raises numerous possibilities. For example, tortuosity, particle shape and orientation and kinetic energy losses, which may be of considerable importance under certain conditions, might be treated thus.

COLIN C. HARRIS

Department of Mining,
The University,
Leeds 2.

[1] Harris, C., *Nature*, **183**, 530 (1959).
[2] Othmer, D F., "Fluidization" (Reinhold, New York, 1956).
[3] Orr, C., and Dallavalle, J. M., "Fine Particle Measurement" (MacMillan, New York, 1959).
[4] Maude, A. D., and Whitmore, R. L., *Brit. J. App. Phys.*, **9**, 477 (1958).
[5] Dallavalle, J. M., "Micromeritics" (Pitmans, New York, 1948).
[6] Harris, C. C., and Smith, H. G., "Second Symposium on Coal Preparation" 1957 (University of Leeds, 1959).
[7] Harris, C. C., Thesis, University of Leeds (1959).