$$G_1 = \frac{2\pi\mu R_1^3(\Omega_2-\Omega_1)}{R_2-R_1}\left[1 - \frac{mN_0\tau R_1(R_2-R_1)}{4\mu(\Omega_2-\Omega_1)^2}(\Omega_2^4-\Omega_R^4)\right] \quad (2)$$

where $\Omega_R = \Omega_2-(\Omega_2-\Omega_1)(R_2-R)/(R_2-R_1)$, and the formula has been simplified by assuming $R_2-R_1 \ll R_1$. The torque per unit length on the outer cylinder then follows from (1) with $rV^3 = R_2^4\Omega_2^3$.

It follows from (2) that the magnitude of the torque on the inner cylinder is reduced or increased according as Ω_2 is greater than or less than Ω_1. In Sproull's experiments, the inner cylinder was at rest, $\Omega_1 = 0$, and the torque on it would therefore be reduced by the outwards migration of the dust, which is in accordance with the observations. With typical values of $mN_0 = 2 \times 10^{-4}$ gm./c.c., $\tau = 4 \times 10^{-3}$ sec., $R_2-R_1 = 7 \cdot 5$ mm., $R_1 = 5$ cm., $\Omega_2 = 6$ sec.$^{-1}$, $\mu = 1 \cdot 8 \times 10^{-4}$ poise, the percentage reduction in torque is of the order of 15 per cent, which is of the order of magnitude as that observed. A more precise comparison with experiment would need to take account of the variations of size of particle in the dust and would also need a better knowledge of the distribution of dust in the gap between the cylinders.

Sproull[1] also reports the observation that adding dust to a turbulent flow of air through a pipe or other system reduces the loss of pressure for given rate of flow. The explanation of this phenomenon seems to be that when the dust particles are not too small, their 'relaxation time' τ will be comparable with, or greater than, the time-scale of the turbulent fluctuations. The dust particles do not then follow the air motion but lag behind the turbulent fluctuations of velocity. The relative velocity of dust and air causes an extra dissipation which extracts energy from the turbulence and presumably damps it, thereby reducing the Reynolds' stresses and the loss of pressure. (Preliminary calculations have indicated that this damping effect of coarse dust may be sufficient to stabilize a laminar flow of air which is otherwise quite unstable.) On the other hand, with fine dust for which $\tau \ll$ turbulent time-scale, the dust follows the air motion closely and its main effect is to increase the effective density of the air, thereby increasing the effective Reynolds' number of the flow and the Reynolds' stresses.

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[2] Landau, L. D., and Lifshitz, E. M., *Fluid Mechanics*, 76 (Pergamon Press, London, 1959).
[3] Lamb, H., *Hydrodynamics*, sixth ed., Sec. 337 (Camb. Univ. Press, 1932).

IN the article to which Dr. Saffman refers[1], it was stated that tests in 1958 using horizontal disks showed a decrease of about 40 per cent in the viscosity of air when dust was suspended in it at a concentration of about 0·25 kgm./m.^{3}. Subsequent tests in 1960 using vertical cylinders yielded the same result, within experimental error.

In the 1958 tests, the gravitational field was normal to the horizontal test surfaces, whereas in the 1960 tests, the gravitational field was parallel to the vertical test surfaces. This field, having a strength of about 980 cm./sec.^{2}, is about six times as strong as the centrifugal field produced when one of the test cylinders, about 12 cm. in diameter, was rotated at 50 rev./min. Thus, in the 1958 tests, the dust particles, because of gravity, drifted downward, away from the sensing disk, obeying Stokes's Law, at a rate about six times that at which the dust particles, because of centrifugal forces, drifted outward, away from the sensing cylinder, obeying Stokes's Law, in the 1960 tests.

If Dr. Saffman's theory that this drift plays a key part in the phenomenon be accepted, then the observed reduction in 'apparent viscosity' (Dr. Saffman infers that it is not really a reduced viscosity) should have been (six times ?) greater in the 1958 tests than it was in the 1960 tests. This, however, is contrary to the facts, so I cannot accept his explanation, but still maintain that the gas viscosity is really greatly reduced by the suspended dust. Moreover, his explanation would predict a different result when the driven cylinder rotated at 25 rev./min. from that obtained at 50 rev./min., but no difference was observed.

Regarding Dr. Saffman's comments about dusty gas flowing turbulently, I certainly agree with him that "the dust particles do not then follow the air motion but lag behind the turbulent fluctuations of velocity". Here we are confronted with inertial forces hundreds or thousands of times as great as the weight of the particles. Nevertheless, a simple calculation based on well-established equations such as those of Darcy or Fanning[2] shows that the observed reduction in the difference of pressure necessary to maintain the turbulent flow can be accounted for exactly (within experimental error) by ascribing it entirely to the reduction in viscosity observed in my experiments. In fact, the observed reduction in difference of pressure led me to look for a viscosity reduction of about 40 or 50 per cent at this concentration of dust, and this is just what was found.

Dr. Saffman's statement that my explanation "contradicts the Einstein formula" is not alarming because Einstein's formula was derived for the case of particles suspended in a liquid, in which the basic phenomena of viscosity are quite different from those in a gas. Moreover, Einstein's formula does not agree with experiment, even for a liquid suspension[3].

Dr. Saffman's comments introduce some challenging ideas and some nice mathematics which I appreciate. I regret that I cannot agree with his conclusions.

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Complexes of Amino-Acids with Oxygen

IT has been well established by Evans[1-4] that oxygen will form contact charge transfer complexes with a wide variety of hydrocarbons. The formation of the complex is observed spectroscopically. It is seen that when oxygen is dissolved in solutions of hydrocarbons under very high pressure, a new broad absorption band appears to the long wavelength side of the first singlet absorption band of the hydrocarbon. In many cases there is superimposed on this broad band a structure which is the first triplet absorption spectrum. This has been used by Birks and Slifkin[5] for measuring the first triplet-levels of the polycyclic aromatic hydrocarbons.