This Week's Citation Classic

Richardson J F & Zaki W N. Sedimentation and fluidisation. Part 1.
Trans. Inst. Chem. Eng. **32**:35-53, 1954.

This paper describes a method of calculating the sedimentation velocity for a suspension— or fluidisation velocity in a liquid-solid system — as a function of the free falling velocity of a single particle and the concentration of particles. [The *SCI*® indicates that this paper has been cited 151 times since 1961.]

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"This paper is the first of a series and reports work on the effect of particle concentration on the sedimentation rate of a suspension of uniform particles. During the course of the experimental work, it was found that it was not practicable to make measurements on the sedimentation of very coarse particles because first the velocities were then too rapid to measure accurately, and secondly the sedimentation was complete before the convection currents which were set up whilst the suspension was mixed had died out.

"It then occurred to us that, if the fluid were passed upwards through the particles to maintain them in a fluidised state, the conditions should be hydrodynamically similar to those existing in the sedimenting suspension. During sedimentation, the particles move vertically downwards and the only fluid motion is that arising from the upflow of displaced fluid. In fluidisation, the particles do not undergo any net movement and the relative velocity between fluid and particles arises from the continuous upward flow of fluidising liquid.

"Several workers had already suggested that the sedimentation velocity of a suspension (u_C) of uniform particles is equal to the free falling velocity of an individual particle (u_o) multiplied by a correction factor equal to the voidage (e) raised to some power *n:*

$$\text{i.e.,}\ \frac{u_C}{u_0} = e^n = (1-c)^n \ldots\ldots\ldots 1$$

where c is the fractional volumetric concentration of particles in the suspension. If the particle is settling under conditions where Stokes' law is valid, *n* has a value of about 4.65. Lewis and his co-workers found that this relation was also valid for the fluidisation of uniform fine particles. [1]

"In our own work we were able to confirm the validity of equation (1) and to show that provided wall effects could be neglected it was equally valid for sedimentation and fluidisation, u_0 being either the observed sedimentation rate or the fluidisation velocity averaged over the total cross-section of the bed. 1 he value of the index *n* had a constant value of about 4.65 for particle Reynolds numbers less than about 0.2 (Stokes' law region), but for high Reynolds numbers became progressively less until it reached a second constant value of about 2.3 at Reynolds numbers exceeding about 500 (Newton's law region). For the intermediate range of Reynolds numbers (0.2 to 500), approximate equations were given for the calculation of the index *n.*

"Our main contribution was, I think, in providing a means of calculating the value of *n* over a wide range of conditions whereas previously a value had been given only for the Stokes' law region. Furthermore, the correlation has the great merit of being simple!"

1. **Lewis W K,Gilliland E R & Bauer W C.** Characteristics of fluidized particles. *Ind. Eng. Chem.* **41**:1104-17, 1949.