

diameter, and are of little, if any, importance in considering dust. The influence of the viscosity and subsequent friction of the gaseous medium of suspension, which is usually air, is a factor which is of utmost importance in the determination of the rates of fall.

There is comparatively little data concerning the exact rates of fall for particles below this size ($\frac{1}{4}$ in. diameter) down to the 200-100 microns diameter range, where Stokes' law comes into operation. Study of this size range is still in progress, and in 1929, as the result of careful experiment, Prockat developed this formula:—

$$c = \frac{\sqrt{2gdS_1}}{3KS_2}$$

$$C = 24.9\sqrt{DS_1}$$

Particles of this range of sizes are, however, not of much importance, as their rate of settling is very great, and with the exception of liquid particles (rain) are very rarely found in the atmosphere, though they do occasionally occur as heavy industrial dust as the result of certain processes.

Below the 200 microns line is the great majority of air-borne matter that is of a scientifically important nature, and this range extends down to particles of approximately 0.1 micron. Below this infinitesimal size particles are of little practical importance, not having any appreciable effect on health or industry.

Stokes' Law

About 1902, G. G. Stokes formulated the well-known Stokes' law. This law states that particles of such size (200 microns down to 0.1 micron) will fall at a constant velocity, the viscous resistance of the air balancing the downward pull of gravity. This velocity will be in direct proportion to the square of the diameter of the particle. For different materials, the heavier particles will fall faster, but if at equal velocity will be of lesser dimensions than the lighter particles. This law is only exact for spherical particles, but subsequent experiments have shown that particles which do not vary too greatly from a spherical shape follow the law very closely. They include fly ash, silica and other materials of a crystalline make-up akin to them. For materials whose dust is of a scaly or fibrous nature, suitable correction factors must be brought into consideration, because these shapes assume a position in falling in which they encounter the maximum air resistance. Stokes' law can thus be expressed as:—

$$c = \frac{2}{9} r^2 g \frac{S_1 - S_2}{\eta}$$

For air at 70° F.,

$$c = 300,460 S_1 d^2$$

$$C = 0.00592 S_1 D^2$$

In applying Stokes' law it is apparent that the upper limit of particles size is dependent upon the density of the medium of suspension, as well as that of the falling body. The upper limit for fly ash has been determined as 100 microns, and for water droplets as 200 microns. It can be said that the rate of fall of particles depends upon the following factors: the size, shape and density of the particle; the density and viscosity of the medium of suspension; the gravitation attraction of the particles; and the nature of the fluid flow of the medium in the vicinity of the particles.

The attraction of gravity can be assumed as constant, although the separation force on the particle can be increased by centrifugal force as is applied in cyclonic separation in the ordinary cyclone. The nature of the fluid flow is brought into consideration in applying centrifugal force as a means of separation. This is either viscous or turbulent, as is indicated by the Reynolds number for the existing conditions.

The rate of fall of small particles settling in a fluid when the flow around the particles is of a viscous or streamline nature is proportional to the square of the size. As the size of particle is increased, the motion of the flow becomes turbulent, which causes an increase in the resistance offered by the fluid and the consequent rate of fall is less than that calculated from Stokes' law. If the motion becomes 100 per cent. turbulent, the rate of fall is proportional to the square root of the size of particle. The rate of fall of particles under only partially turbulent conditions can be calculated by using Stokes' law as a rough approximation and then applying factors of correction to allow for the degree of turbulence.

It must be remembered that Stokes' law assumes that the fluid which is the medium of suspension must be continuous and of uniform viscosity.

Fumes

The line of demarcation between the matter known as dust and that known as fumes or clouds is not a definite one. In the 10-1 micron range we find fumes as well as dust. This range is, perhaps, the most important when considered from a point of view of human health. From the 8 micron size to the 0.5 micron size is the particle which, if its concentration is sufficiently high, is very dangerous to the lungs.

Fumes are very unstable; the individual particles conglomerate to the order of 1 to 10 microns, and consequently settle out steadily in still air. This rate of settling, however, is so slow that fumes may be hindered or even prevented from settling at all by convection currents. This inability to settle out renders particles in the region of 1 micron and less to come under the influence of Brownian movement; this means that it is subject to the movement of the gas molecules, and in the case of fumes in the free atmosphere where there are constant convection currents, they practically never settle.

The mean free path of gas molecules is in the region of 0.1 micron, and where there are no convection currents particles approaching this size will find less resistance to the movement through the air than is shown by Stokes' law; they will, therefore, settle faster and their rate of fall is calculated by introducing Cunningham's factor:—

$$c = c' (1 + K \frac{\lambda}{r})$$

where $c' = c$ of Stokes' law.

It must be remembered, however, that convection currents are the ruling influence in the gravitational settling of fumes.

The particle size of 1 micron is generally accepted as a critical limit for gravity precipitation of matter suspended in the open atmosphere and that only on aggregation to this size will smaller particles settle.

Smokes

This range of air-borne matter is the most difficult to study and classify. The particles are so minute, being from 0.3 micron to sizes beyond the limits of the ordinary microscope, that gravity has little effect on them. They are bombarded by gas molecules and driven about at a much greater velocity than by gravity in a continuous Brownian movement. The larger diameter particles from 0.3 to 0.1 micron do settle when suspended in an absolutely still gaseous medium, but this rate of fall is so small that it is generally assumed that smoke is subject to Brownian movement all the time. By using Stokes' law with a suitable Cunningham's factor, a particle of 0.1 micron with a density of 1 only settles at 0.00007 ft. per minute in air at 70° F. W. E. Gibbs has said that smoke particles of 0.025 micron will only settle 10 ft. in 30 days. The behaviour of smoke in air is gradually to diffuse. The