Air-Borne Matter, Part II

Characteristics and Industrial Implications

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INDUSTRIAL process air-borne matter covers the whole size range from heavy particles of ¼-in. diameter to industrial smoke of sub-micron dimensions. Because of the extreme diversity of kinds, sizes, shapes and densities of dust, variable percentages of concentration and different volumes and temperatures of the gaseous medium, almost every problem in this branch requires individual study.

It may be that the dust is the direct commercial product of a process and should be retained for economic reasons, or it may be that its dispersion in the free atmosphere would prove to be a community nuisance, and with these and other points in mind it is for the engineer to design the equipment on a practical and economic basis.

These collecting or separation methods can be classified in the following manner:—

Method	Equipment	Particle Size Collected
Inertial ..	Cyclonic or centrifugal apparatus	Down to 60 microns, dry method Down to 5 microns, wet method
Filtration ..	Filter bags	Down to 0·3 microns
Sprays ..	Scrubbing towers ..	Down to 0·2 microns
Electrical .	Precipitation	Down to the smallest detectable dimensions

Gravitation

The gravitational method is exemplified by the ordinary settling chamber and is only applicable to mechanical and solid dispersoids because its effectiveness depends on the rate of fall of the particles and, as has been pointed out, this rate is dependent upon the size and weight of the particles. The rate of fall becomes so slow for the condensed dispersoid that it makes this method impracticable.

The actual rates of fall are from 50 to 60 per cent. of the theoretical as calculated by Stokes' law. It is evident, therefore, that particles of 75 microns will have an actual rate of fall of 0·8 ft. a second, and this is too slow to use this method.

Settling chambers should be designed to give sufficient settling time for the smallest particle it is desired to remove and this demands that chambers should be made wide and low rather than high and narrow. Wire curtains are often fitted to minimise eddies and these also tend to remove the finer dust through contact.

The actual settling rate of the finest particle to be collected should preferably be determined experimentally. When this is not practicable, but where this particle size is known the theoretical rate can be calculated from the following approximate numerical expression for Stokes' law:—

$$C = \frac{D^2 S_1}{10^4} \times 60$$

Thus, if the smallest particle to be settled out is 50 microns with a sp. gr. 4, the theoretical rate is 1 ft. per second. Assuming 50 per cent. of this figure for the actual rate, the result is a figure of 0·5 ft. per second.

Inertial Method

Although with certain apparatus some condensed dispersoids may be collected by the inertial method, it, like the gravity method, is chiefly applicable to mechanical dispersoids, but on account of the much larger separational forces available, smaller particles may be collected. As gravity is the separating force in the settling chamber, so centrifugal force causes the separation of dispersoids from the gas in the centrifugal apparatus. This force, being directly proportional to the gas velocity and inversely proportional to the radius of curvature of the gas path, can, therefore, be made very large by designing the equipment to have a large gas velocity and a small radius gas path. Although Stokes' law is not strictly applicable to moving gases, it can be assumed that in this case also the resistance to the motion is proportional to the effect of the net force and the resisting or frictional force on the same factors.

On this assumption the separating velocity in cyclonic or inertial apparatus corresponds to the settling rate of the gravitational method and may be expressed as—

$$\text{Separating velocity} = \frac{S_1 D^2 Z Y^2}{HQ}$$

Since ZY equals the tangential gas velocity V, the above relations can also be expressed:—

$$= \frac{S_1 D^2 V^2}{Q Z H}$$

In the inertial or cyclonic apparatus the important factor is not so much the separating velocity but the "separating distance" that the particle will move under the action of the centrifugal force in the time the gas remains in the apparatus. There is little data on the distribution of gas velocities in such gas streams, but for the purpose of approximate calculation it can be assumed that the tangential velocity is constant, that the average time the gas remains in the apparatus is that required for the gas moving with the maximum radius for the maximum angular distance U. Furthermore, while in the inertial apparatus the gas path may be simple and almost parallel, its path in the ordinary cyclone is very complicated and involves a double vortex. It is highly probable, however, that the majority of the separating action takes place in the outer vortex, so we may consider the gas path in all apparatus as simple and approximately circular.

Considering the above remarks in conjunction with Stokes' law for moving gases:—

$$\text{Separating distance} = \frac{S_1 D^2 U V}{QH}$$

For a specified gas and a uniform size of dispersoid this simplifies to:—

$$\text{Separating distance} = QUV$$

Process Dust

The table on the next page gives cyclonic values for air of standard viscosity, spherical particles of sp. gr. 3. It has been assumed that for the above conditions Stokes' law gives values of twice the actual values.

Filtration

The filtration method of dust separation is generally considered a sieving action and this method is well exemplified by the bag filter system used in processes of every kind.

The bag, or its equivalent, is a screen or sieve of certain size through which the particles like gas molecules and