

without an extensive background in engineering or physics, and by engineers and industrial hygienists without medical training. In the later sections an attempt is made to review the pneumoconioses in sufficient detail to aid the physician called upon to examine employees whose work exposes them to dust.

A. PROPERTIES OF DUST

The important physical and chemical properties of dust have been summarized by Drinker and Hatch,² and much of the material presented here was obtained from that source.

1. *Settling rates.* Suspended microscopic dust particles, like any other free body, are attracted to the earth by gravity. However, because of their small mass and the relatively great resistance of the air, they do not fall according to the usual laws of gravity. Settling rates are much greater for large than for small particles. A settled dust, accordingly, may contain a proportionately greater percentage of large particles than the contaminated air from which it settled and in which the fines predominate. Ore as it is found in mines may contain a certain amount of quartz, which is frequently harder than the other minerals present. Because of this relative hardness the quartz may be ground less finely in drilling operations. Much of this coarser quartz dust may settle out from the air in the working area with comparative rapidity, leaving a smaller percentage of quartz in the atmospheric dust than may be present either in the parent material or in the settled rafter dust.

2. *Flocculation.* Dust produced by crushing or grinding a material such as quartz differs from fume such as magnesium oxide in respect to its tendency to flocculate. Freshly formed fume particles are usually well below 0.3μ and accordingly exhibit marked Brownian movement. Because of this and perhaps other factors, they tend to collide and form flocs which, because of their larger size, settle out relatively quickly. Such masses tend to adhere to vertical walls and projecting surfaces.

True dust is much less apt to flocculate than is fume, and any flocs formed are much more loosely bound together. Settling of dust clouds is therefore much less pronounced than is settling of fume clouds. As a dust cloud clears, the size of the particles remaining in suspension decreases and the degree of dispersion increases; that is, the ratio of flocculated to discrete particles becomes less. In a metallic fume, on the other hand, both the percentage of flocs and their size increase with the age of the cloud.

Turbulence in the air increases floc formation in fume clouds by increasing the collision frequency, but it does not improve the settling rate of dust.

Humidity below saturation is said to have little effect on flocculation time. However, humidity to the point of supersaturation is an important factor, as the dust particles function as nuclei on which water may condense, thus increasing particulate size.

*P. Drinker and T. F. Hatch, *Industrial Dusts*. 2nd ed., McGraw-Hill, New York, 1954.

3. *Wetting.* Wetting is primarily an adsorption phenomenon in which the surfaces of the particles become covered with a film of water. Most liquids tend to spread on plane surfaces, but great force must often be used to wet dust, probably because the particles are already surrounded by a film of air. Wetting is of importance in dust sampling and in control of dust.

Three factors have been described by Drinker and Hatch as of importance in the wetting of dust. First, it is necessary to maintain intimate and vigorous contact of long duration between the dust and liquid. Second, it is advantageous to apply the liquid immediately at the dust source, because the heat usually generated in producing dust by drilling or grinding hampers air adsorption and because continuous flooding at the source excludes air. Third, wetting agents may be used to increase the wetting power of water.

4. *Electrical properties.* Dust particles are electrically charged and accordingly are attracted to oppositely charged particles. If, therefore, particles in a dust suspension are given an electrical charge, the tendency for floc formation should be increased. Attempts have been made to utilize electrically induced flocculation as a method of air purification but without great success. Electrostatic precipitation, on the other hand, has been used quite successfully for collection of dust and fume, but such precipitation depends upon the attraction of the electrically charged particles to an oppositely charged plate rather than upon flocculation.

5. *Optical properties.* Dust or moisture particles reflect light and it is this light, reflected from dust particles otherwise too small to be seen, that makes them visible when a beam of light enters a darkened room. The scattering of a beam of light by dust or mist is known as the Tyndall phenomenon. The optical properties of suspended particles in air vary with their shape, their transparency, and especially their size. With particles larger than the wave length of light (about 0.7μ), the strength of the Tyndall beam varies directly with particle surface area and concentration; thus, for a given weight concentration it varies inversely with the particle size. Attempts have been made to utilize these optical properties in the measurement of dust concentration, but variation in the size of the particles makes such determinations unreliable.

B. ATMOSPHERIC DUST CONCENTRATIONS AND PARTICLE SIZE

Whenever a solid or liquid is ground or broken into particles as small as dust, the surface area is greatly increased. Thus, if a cube of mineral 1 cm. in each of its dimensions is ground into small cubes $1 \text{ cu. } \mu$ in size, there will be 10^{12} particles with a total surface area of 6 sq. meters as compared with 6 sq. cm. for the original cube. This great increase in surface area is largely responsible for the increased chemical activity of finely ground materials and may be an important factor in the production of silicosis.

Industrial dust concentrations may range from the amounts present in "pure air" in operations where no dust is produced or where there is adequate dust control to as high as 2 billion particles per cubic foot of air, in rock drilling. Dalla-