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Nomogram for Relating Particle and Particle Cloud Parameters

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Three concentration units, i.e., mass density, number density, and surface area, often are alternatively used to describe an aerosol cloud. While most aerosol clouds are composed of polydisperse particles, the nomogram based upon monodisperse spherical particles (Figure 1) has been found useful for relating these different concentration values.

Assuming that particles have smooth surfaces and negligible porosity, the nomogram is constructed from these independent functions, F_1, F_2, and F_3, where

$$F_1 = m - \frac{\pi}{6} d^3\bar{\rho} = 0$$

$$F_2 = \rho - mn = 0$$

$$F_3 = s - \pi d^2 n = 0$$

where m is the particle mass, d is particle diameter, $\bar{\rho}$ is the material density of the particle, ρ is the mass density of a particle cloud, n is the number density of the particle cloud, and s is the surface area of the particle cloud. The nomogram is constructed by normalization to convenient units for each of these parameters.

For example, assume that particle diameter, material density, and number density of the particle cloud are known to be 5.50 μm, 1.20 g/cm^3, and 4.95 $\times$ 10^3 particles/cm^3 (1.40 $\times$ 10^8 particles/ft^3), respectively. On the accompanying nomogram, draw straight line 1 from scale d, particle diameter, to scale $\bar{\rho}$, material density. Intersection of the line on scale m gives the mass of the particle as 1.05 $\times$ 10^{-7} mg/particle. From this point, draw the line 2 to scale n, number density of cloud. Intersection of the line on scale ρ gives the mass density of the cloud as 517 mg/m^3 (2.26 $\times$ 10^{-1} grain/ft^3). From this point, draw the line 3 to scale d. The point of intersection on scale s, which shares the same line of ρ, gives the surface area of the particle cloud as 4.70 $\times$ 10^{-3} cm^2/cm^3.

Dust concentrations of polydisperse particles can be determined in two ways. Method 1 is to determine the concentrations for each individual segment of the composite particle size from the nomogram and sum them to the total dust concentration. Method 2 is to obtain a single value of dust concentration from the nomogram using a proper mean particle size. For nonspherical particles, experimentally determined shape factors, such as sphericity, can be incorporated into the results obtained from the nomogram. The sphericity of a given particle is the ratio of the surface area of a sphere having the same volume as the particle to the actual surface area of the particle. Thus, a sphere has a value of 1 for sphericity.

Consider a dust cloud composed of particles with the size ranges and number densities of the particle cloud given in Table I. The particle sizes are the equivalent volume diameters which are diameters of spheres having the same volume as the particles and can be obtained, for example, from Coulter counter measurements. The material density of the particle is taken to be 1.30 g/cm^3 and sphericity 0.92. Table I lists the results using method 1. The surface concentration of the dust cloud is (10.03 $\times$ 10^{-4})/(0.92) = 10.90 cm^2/cm^3.

For method 2, the mean volume diameter determines the mass concentration and the mean surface diameter determines the surface concentration. From the measured particle sizes and the measured size distribution given in

Table 1. Method 1.

Size distribution measured (μm)	Number density of particle cloud, n, measured (particles/ft^3) 10^6	Average particle size, d (μm)	Mass per particle, m, from nomogram (mg/particle)	Mass density of particle cloud, ρ, from nomogram (mg/m^3)	Surface area of particle cloud, s, from nomogram (cm^2/cm^3)
0.6 to 1	107	1.3	1.50×10^{-9}	5.65	2.01×10^{-4}
1 to 2	126	1.5	2.30×10^{-9}	10.30	3.15×10^{-4}
2 to 3	30	2.5	1.06×10^{-8}	11.30	2.08×10^{-4}
3 to 4	9	3.5	2.90×10^{-8}	9.20	1.22×10^{-4}
4 to 5	4	4.5	6.20×10^{-8}	8.80	0.90×10^{-4}
5 to 6	2	5.5	1.13×10^{-7}	8.00	0.67×10^{-4}
Total	278			53.25	10.03×10^{-4}

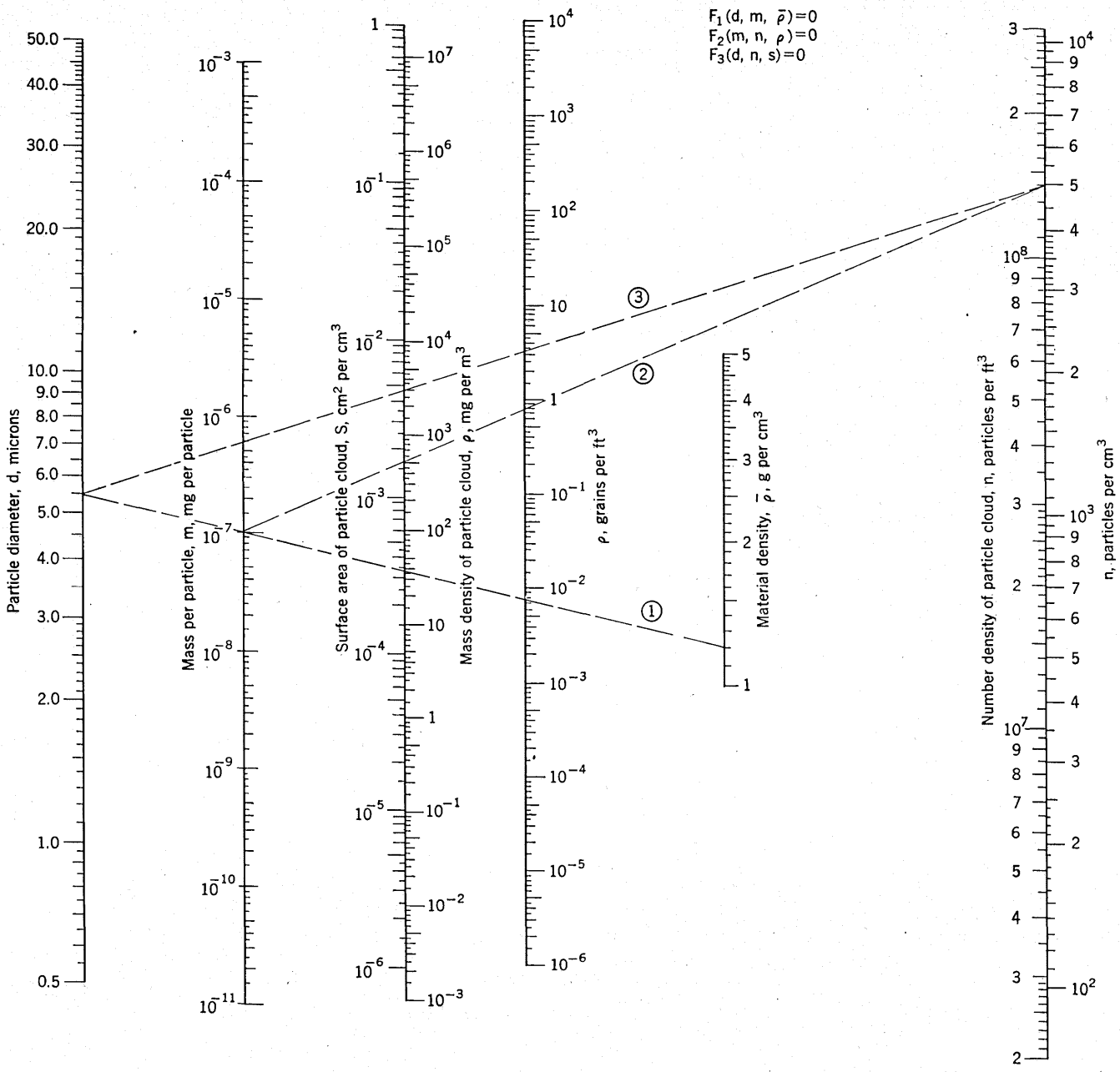

Figure 1. Nomogram for relating particle and particle cloud parameters.

Table I, these mean diameters can be calculated by standard textbook methods and are 1.99 and 1.80 μm, respectively. From the nomograph the resulting mass density of the cloud is 53.3 mg/m³, and the surface concentration of the dust cloud is $(10.00 \times 10^{-4})/(0.92) = 10.87 \times 10^{-4}$ cm²/cm³, which are closely equal to those obtained by method 1. Method 1 is slightly less accurate than method 2 since it involves repeated use of the nomogram and attendant graphical estimations. However, method 1 should be sufficiently accurate for most purposes and is more straightforward.

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