A number of velocities (about 75) had to be computed, so it appeared desirable to find some means of removing from this problem the mathematical indeterminacy inherent in the fact that the velocity equation involves both the unknown terminal velocity V and the unknown drag coefficient C_d. Such a method was found and is being reported in a separate paper. This method makes it particularly simple to identify and to handle separately the Stokes' law regime and the aerodynamic regime of airflow around the spheres.

In fig. 1, there are displayed the computed fall velocities for smooth spheres of 2.5 g per cm³ density having radii ranging from 20 to 500 μ falling at altitudes between 0 and 120,000 ft. Superimposed on the figure is a dashed line delineating the approximate limit of validity of Stokes' law.

Most of the differences between the present results and those of Kellogg and associates appear to lie in the neighborhood of this locus. Those investigators' velocity curves exhibit no maxima such as are found in the curves for the smaller particles represented in fig. 1, so they must not have sought very high accuracy in the transition region between the viscous and the aerodynamic regimes. Although the roughly 30 per cent maximum disagreement between the present velocities and those used by Kellogg and associates is

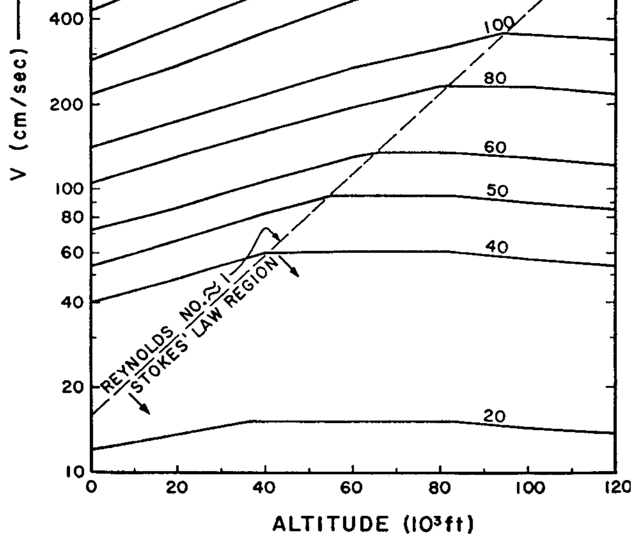

FIG. 1. Terminal fall velocity for smooth spheres of density 2.5 g/cm³ as a function of altitude in the I.C.A.O. Standard Atmosphere.

Rates of descent of fallout particles from thermonuclear explosions

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In using the graphical data on terminal velocities of spherical fallout particles presented by Kellogg, Rapp, and Greenfield (1957), I note what seem to be errors of the order of 20 to 30 per cent in the velocities of some of the smaller particles for which they provide graphical data. These discrepancies are maximal for the middle altitudes in question, roughly 40 to 80 thousand ft. Since these altitudes are of particular importance in the fallout meteorology of explosions in the megaton range, I have undertaken a systematic recomputation of the terminal velocities of smooth spheres of density 2.5 g per cm³ (accepted density typical of fallout formed by recondensation of soil materials).

not very serious when weighed against numerous other uncertainties in fallout prediction, it seems desirable to use the rather more accurate velocities of fig. 1 in future computations where the smooth-sphere assumption is valid (over siliceous soils, but apparently not over coral atolls).

In discussing the radiological consequences of fallout, one is chiefly interested in the total time of descent, or "time down," fallout particles of specified size originating at specified altitude in the mushroom cloud. Thus, the curves of fig. 2, derived from fig. 1, are of more immediate use. Because they are integrally related to the curves of fig. 1, these curves of time down smooth out both the real breaks in the velocity curves to be discussed in the next paragraph and also the less noticeable breaks due to computational effects.

The data of figs. 1 and 2 apply specifically to the I.C.A.O. Standard Atmosphere (see, for example, U. S. Air Force, 1957). This standard atmosphere has an isothermal region in the lower stratosphere from 11 to 25 km. In that region, all spheres falling with Reynolds numbers less than about unity will have terminal velocities *independent of height.* This is because, for cases such as the present one wherein buoyancy effects are negligible, the Stokes' law velocity of fall is dependent only upon the absolute viscosity of the medium, and the latter, in turn, is dependent only upon temperature through the Sutherland equation. This is the physical explanation of the distinct breaks seen in the computed curves of fig. 1. Note that a fallout sphere of 20-μ radius is *always* in the Stokes' law region, so its velocity is uniform throughout the entire isothermal region, as is also barely true of the 40-μ sphere. For larger radii, however, the particles fall out of the Stokes region, so to speak, while still descending through the isothermal region of the I. C. A. O. atmosphere; hence, their curves break sharply[1] upon crossing the locus $R = 1$. Finally, for radii of about 80 μ or greater, the Stokes' law region and the isothermal region simply do not overlap, so no constant-velocity segments are found on these curves. This general behavior of terminal velocities may be expected in cases other than the present one, so these features of the curves of fig. 1 are of some general interest.

Fig. 1 does not extend to altitudes high enough to show any part of the Stokes' regime for fallout particles of radius 200 μ or greater. The altitudes and associated velocities for the Stokes' limit for these cases were calculated to be the following: 200 μ, 140,000 ft, 14 m per sec; 300 μ, 165,000 ft, 27 m per sec; 400 μ, 190,000 ft, 48 m per sec; and 500 μ, 215,000 ft, 90 m per sec. One hopes that at least these latter data will remain of only academic interest.

[1] If velocities were computed for a much denser set of altitudes, the first-order breaks *as drawn* in fig. 1 would, of course, become second-order discontinuities.

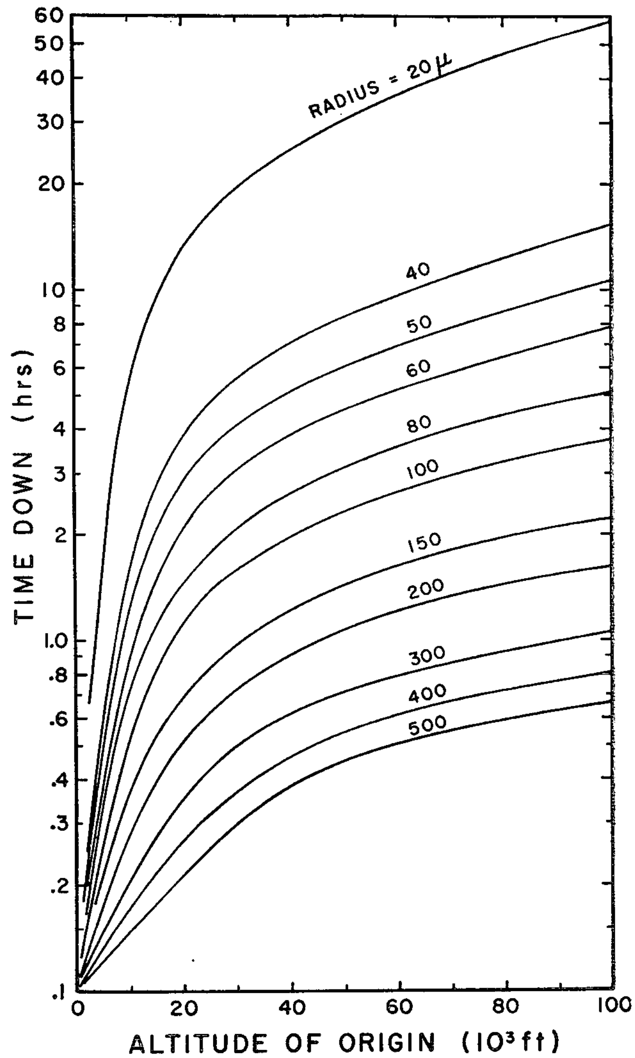

FIG. 2. Times of descent of smooth spheres of density 2.5 g/cm³ originating at various altitudes in the I.C.A.O. Standard Atmosphere.

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