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LDA SEEDING SYSTEM
FOR
THE LANGLEY LOW TURBULENCE PRESSURE TUNNEL

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Introduction

A Laser Velocimetry seeding system has been specifically developed for the Langley Low Turbulence Wind Tunnel (LTPT), and it has been successfully used for LV measurements in two major tests (Juncture Flow Experiment and Görtler Experiment). Detailed description of the LV system is found in Ref. 1. The LTPT (Fig. 1) is capable of operating at Mach numbers from 0.05 to 0.50 and unit Reynolds numbers from 100,000 to 15,000,000 per foot. The test section is 3 feet wide and 7.5 feet high. The turbulence level in the test section is relatively low because of the high contraction ratio and because of the nine turbulence reduction screens in the settling chamber. A primary requirement of the seeding system was that the seeding material not contaminate or damage in any way these screens. Both solid and liquid seeding systems were evaluated, and the results are presented herein. They can provide some guidelines for setting up seeding systems in other similar tunnels.

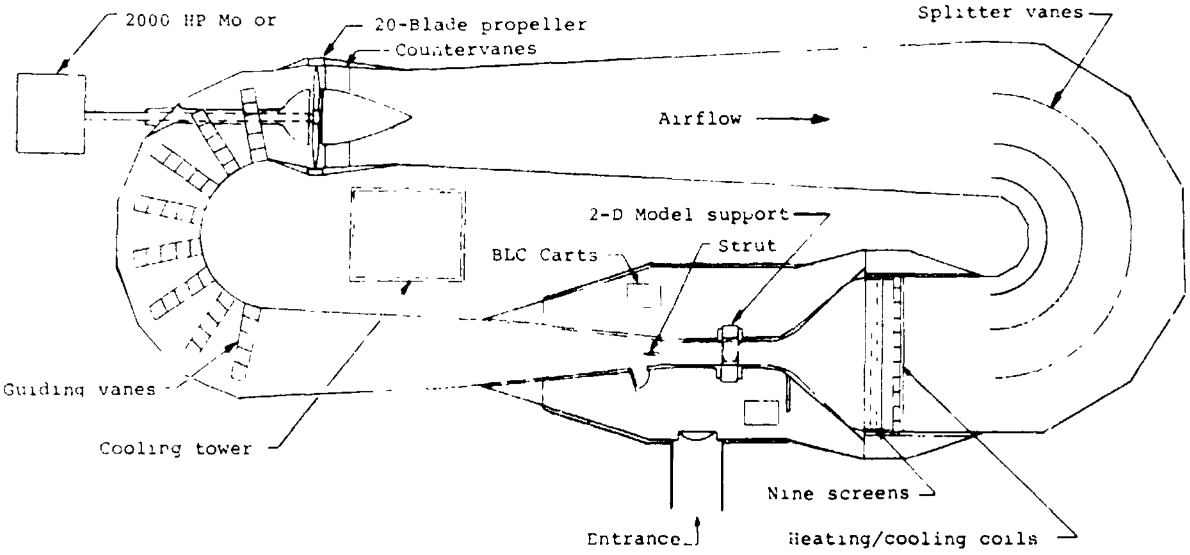

Figure 1

Desired Size of Seeding Particles

Since the LDV measures particle velocity and not fluid velocity, the particles must be small enough to follow the flow stream but large enough to be detected. The particles must have small diameter variation (mono-dispersed) in order to make reliable turbulence measurements.

The particle size is also governed by the requirement that there be no deposits on the screens. A potential flow analysis of kaolin particles of various sizes moving past a cylinder was conducted, and the results are shown in Fig. 2. These results indicate that the fraction of particles impacting on the cylinder increases with increasing particle size. It was concluded from these results that the desired size of the particles should be below one micron in diameter, in order to minimize particle build-up on the screens.

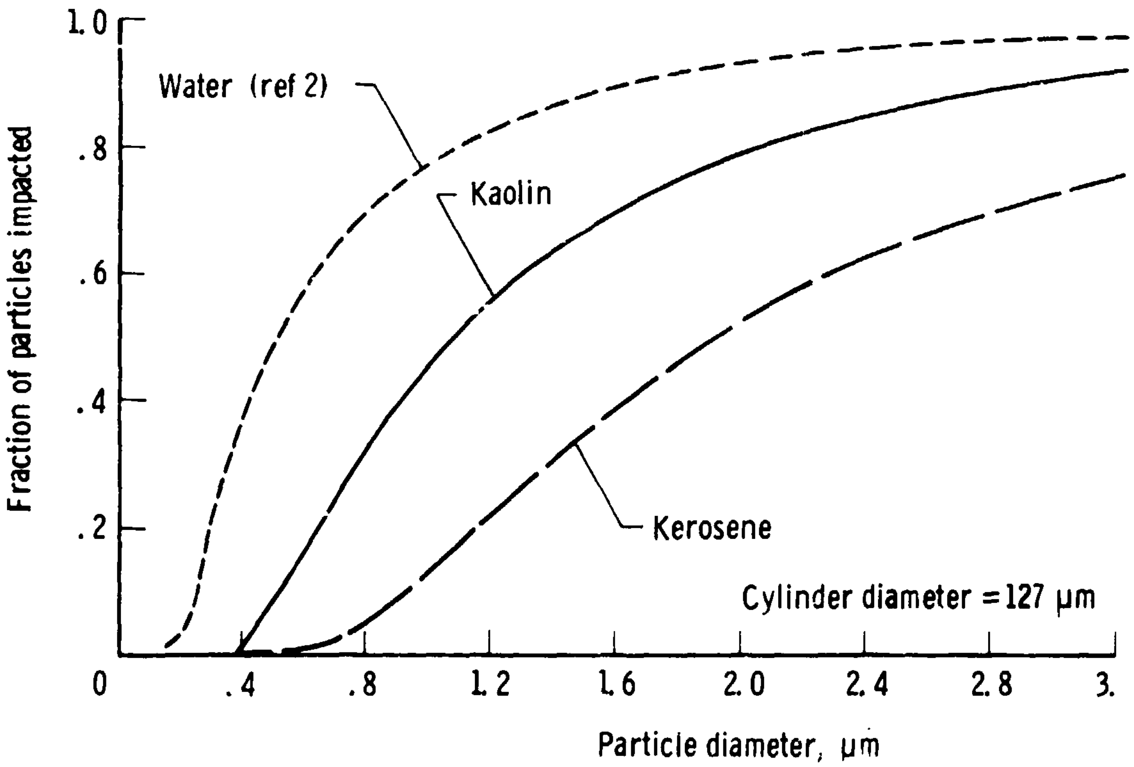

Figure 2

Solid Particle Seeding

A special experiment was set up to evaluate and gain insight into solid-particle seeding problems. In an attempt to minimize electric forces exerted on electrically charged particles, kaolin, an inert material, was chosen first. The particles were injected into the flow stream in the diffuser between the test section and the drive fan, and the particle data rate was measured with a Laser Transit Anemometer. The particle data rate is shown in Fig. 3 as a function of time.

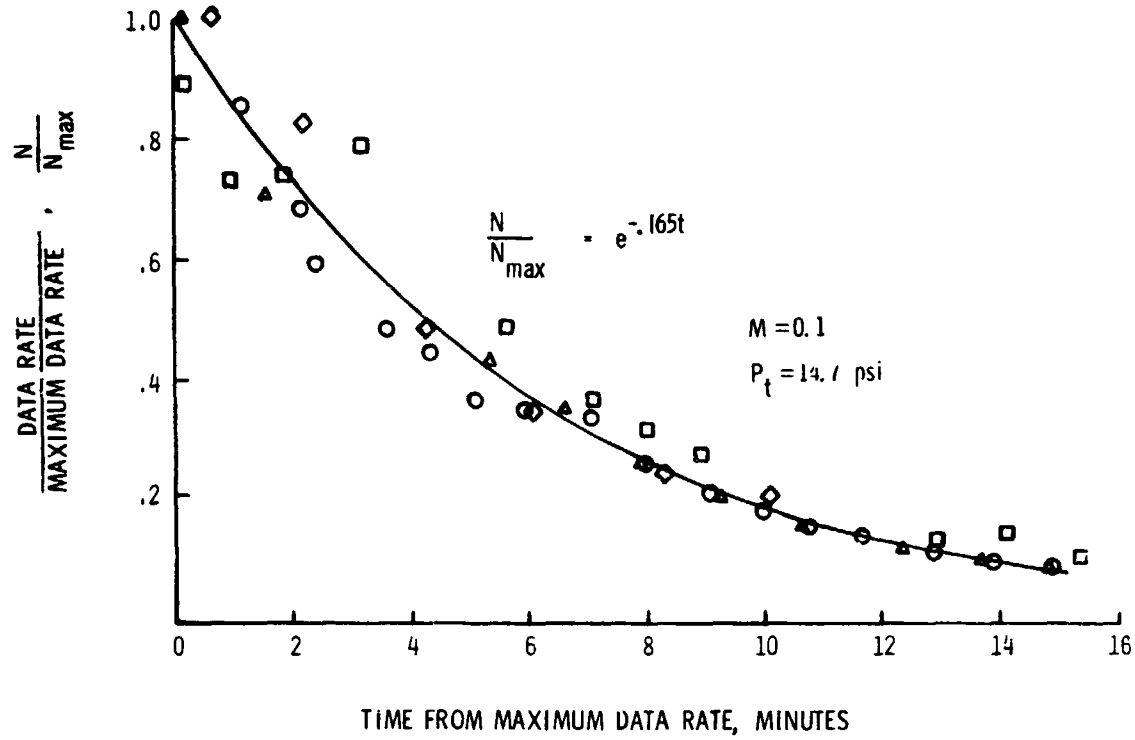

Figure 3

Solid Particle Seeding

In order to evaluate gravitational settling the wind tunnel was turned off for a 10-20 minute time period and then the tunnel was restarted. Fig. 4 shows that the particle decay rate is not a function of time when there is no flow, i.e., gravitational settling rate is insignificant. Figs. 3 and 4 indicate that the decay rate is proportional to tunnel speed, with a 15% loss of particles every minute at M=0.1. Globs of particles were found just downstream of the insertion point, usually on the tunnel turning vanes. Tests conducted with gold particles yielded similar results. This implies that continuous tunnel operation will require continuous seeding. But, accumulation of solid particles inside a closed-cicuit tunnel is not considered desirable since this will involve frequent, time-consuming tunnel cleanups.

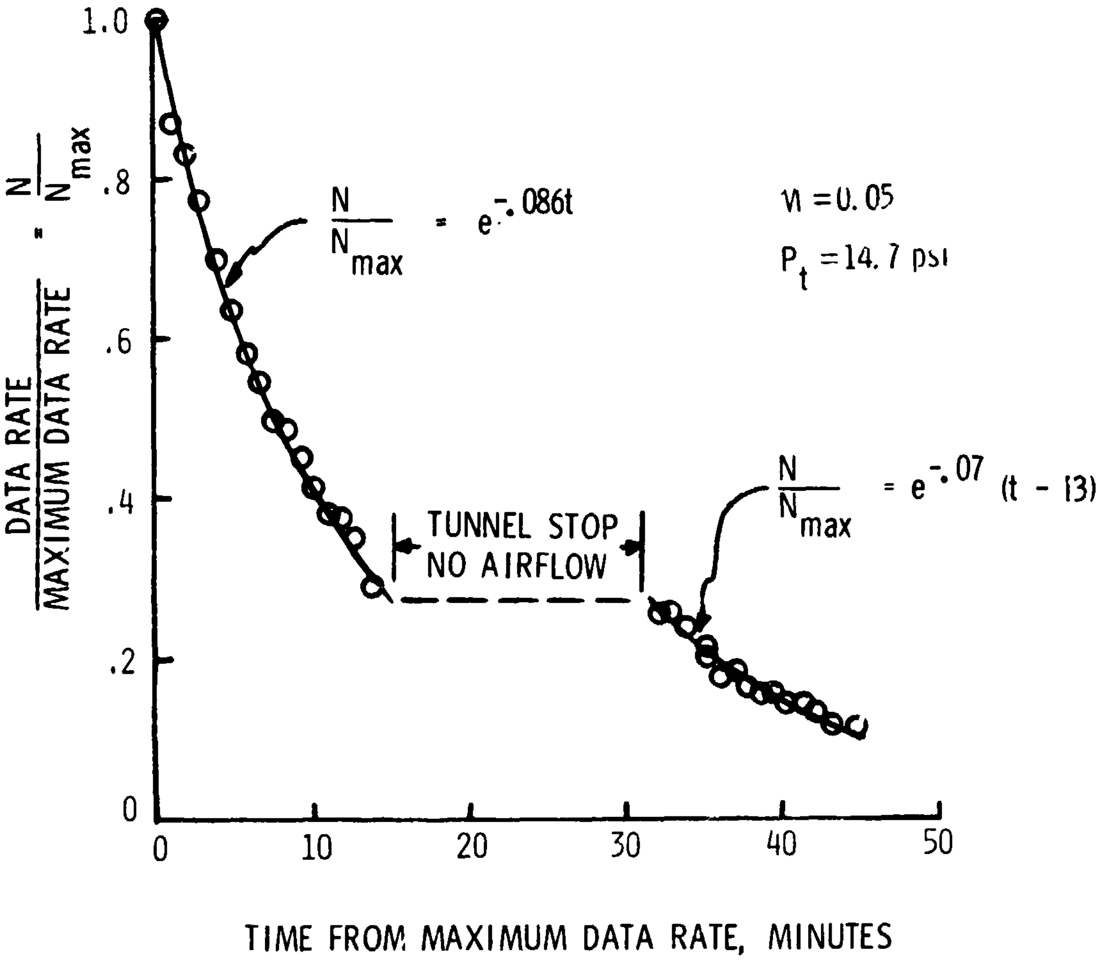

Figure 4

Liquid Particle Seeding : Choice of Particles

If the liquid particles are too large, then a larger percentage of them will impact on the screens (Fig. 2). If the screen wetting rate is faster than the drying rate due to liquid evaporation, the liquid could collect dirt in the tunnel. Therefore, it is desirable to generate small particles and to use a liquid which is volatile enough that it will evaporate. Further, a safe and readily available liquid is desirable.

Kerosene, which satisfied most of the requirements, left residues on a test screen, and therefore it was not acceptable.

However, kerosene is made up of a number of purer hydrocarbon components. Of these, dodecane, tridecane, and tetradecane have droplet forming characteristics very nearly equal to that of kerosene. These hydrocarbon fluids can be obtained in a highly refined state, and they evaporated completely from the screens.

Ethanol also has very good seeding characteristics, but it is highly volatile.

Particle Size Evaluation : Evaluation of Analyzer

Before the particle size analyzer could be used for evaluating the seeding particles, it was important to check the calibration of the analyzer. Ref. 3 indicated that the percentage of ambient particles of radius greater than r varies as r^{-3} for particles between 0.05 micron and 1 micron in diameter. The particle size analyzer was used to sample ambient particles, and the sample data in Fig. 5 are shown with different symbols for each ambient particle size test. Also shown on the figure is the r^{-3} line, which is straight on the log-log plot. In general the measured ambient condition agrees fairly well over the particle diameters of interest. It was concluded from ambient measurements that the particle analyzer was working properly and would be adequate for measuring the particles generated by the generator.

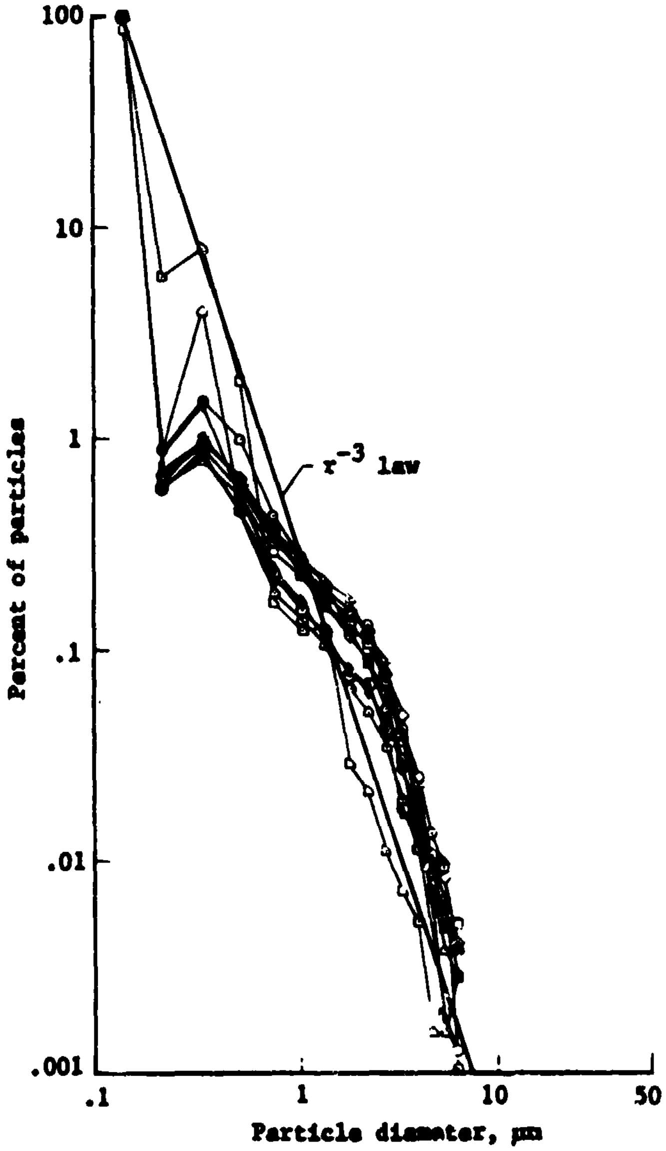

Figure 5

Particle Size Evaluation : Solid Particles

Polystyrene particles of very small size (e.g., 0.5 micron) with a very narrow variation in particle size can be commercially purchased. But in order to have mono-dispersed particles in the flow stream the ability to maintain these individual particles is important. This aspect was evaluated by dispersing polystyrene particles with an atomizer and analyzing the resulting size distribution. The results (Fig. 6) showed that a substantial percentage of the particles is larger than the original particle size. This illustrates the difficulty in maintaining the particle size.

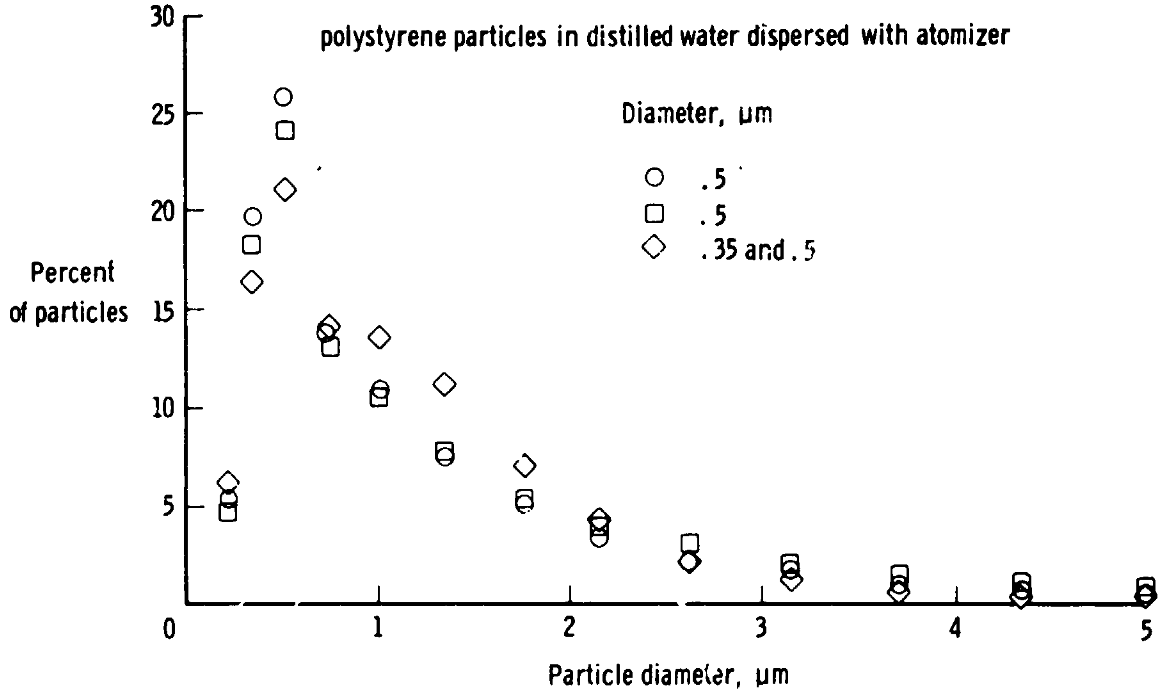

Figure 6

Particle Size Evaluation : Liquid Particles

The size of the liquid particles generally depends on seeder/nozzle characteristics and seeding-material characteristics. But, once generated, the particles can coagulate, evaporate or condense. These factors can and do affect the size of the generated particles after they leave the nozzle.

Kerosene, ethanol, dodecane, and tridecane were tested; an atomizer type generator was used to generate the particles. Kerosene particle distribution included a significant percentage of particles larger than one micron, whereas ethanol, dodecane, and tridecane were very nearly mono-dispersed with very small mean particle diameter. Fig. 7 shows the particle size distributions of dodecane and tridecane.

When dodecane was used as seeding material, it was found that the seeding rate and particle size could be controlled by varying the tunnel temperature.

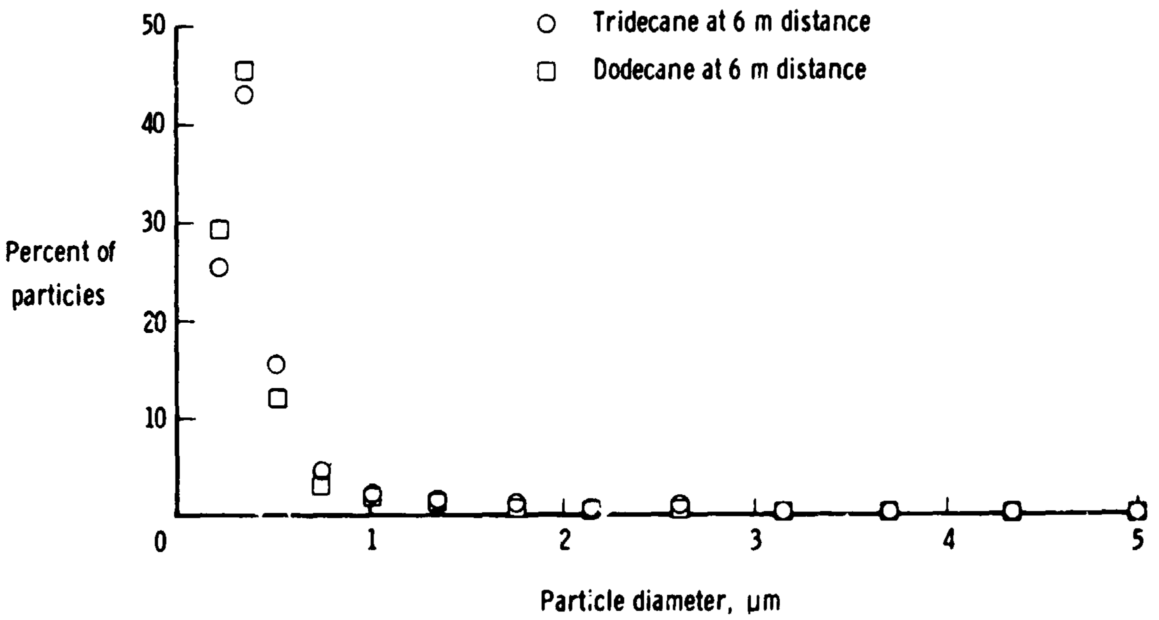

Figure 7

Conclusions

The desired seeding particles should be below 1 micron in diameter to minimize screen contamination.

Solid particles decay as a function of tunnel speed, resulting in 15% loss of particles/minute at a Mach number of 0.1.

Particle size analysis in the flow stream indicates the presence of particles larger than originally dispersed ones.

Kerosene leaves residue on the screens; its particle size distribution is poly-dispersed.

Ethanol, dodecane, and tridecane particles are nearly mono-dispersed.

Dodecane and tridecane evaporate completely, without leaving any residues on the screen, satisfying the tunnel requirement.

The most successful application and LV measurements were obtained using liquid particles (tridecane and dodecane) injected through a liquid atomizer.

References

1. Meyers, J. F.; and Hepner, T. E.: "Velocity Vector Analysis of a Juncture Flow Using a Three-Component Laser Velocimeter," Second Annual Symposium on Application of Laser Anemometry to Fluid Mechanics, July 2-4, 1984, Lisbon, Portugal.

2. Ormancey, A.; and Martinon, J.: Numerical Simulation of Particle Behavior in a Turbulent Flow. Rech. Aerosp. No. 1983-5, 1983.

3. Mason, B. J.: The Physics of Clouds. Clarendon Press, 1971.