

N86-11443

SEEDING TECHNIQUES USED IN THE
VORTEX RESEARCH FACILITY

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VORTEX RESEARCH FACILITY

The Vortex Research Facility, shown schematically in figure 1 and described in reference 1, is a converted model towing basin about 1800 feet in length. An instrumented automobile-type research vehicle is used to accelerate the test model to a constant test speed of approximately 100 feet per second at the test section entrance. The test section is covered to prevent the vehicle wake from interfering with the aircraft model wake. A slot in the ceiling accommodates passage of the model support strut. This slot is lined with brush-like material to further block the vehicle wake downwash. The brushes are pushed aside by the passing strut and close together behind it. The model is instrumented to provide aerodynamic loads while flow visualization and a laser velocimeter (LV) provide details of the wake vortex flow field. During the last 10 years, the Vortex Research Facility has been active in the vortex wake research program. The research objective for the facility is to provide basic understanding of the physics of vortex flows. To achieve this objective, the facility has been upgraded and experimental data are being acquired for developing methods which reduce vortex wake intensity and for verification of computational methods which predict vortex flow behavior.

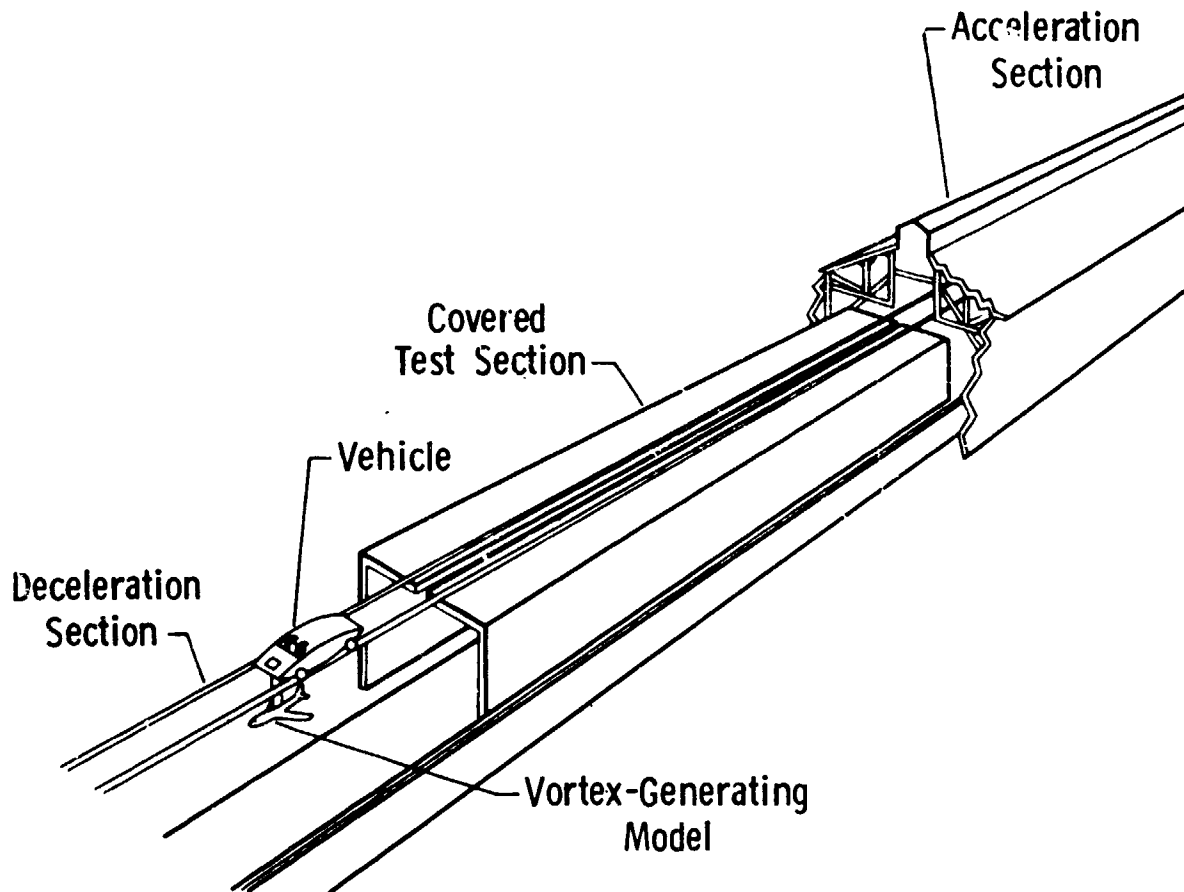


Figure 1

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LASER VELOCIMETER SCHEMATIC

Detailed flow field measurements are made with a laser velocimeter (LV) system. The laser velocimeter optics system, described in reference 2, has been modified from a back-scatter mode to a forward-scatter mode. This modification has increased the signal-to-noise level of the LV system by 30 dB and yielded better resolution of the velocities in the flow field. The LV system is currently being modified to provide dual optical paths in the test section (see Figure 2). For a single run, this will allow two sets of wake measurements. The LV system still incorporates the high speed scanning system which provides scan rates (longitudinal displacement of the focus along the optical axis) up to 30 times per sec, with 16 discrete individual measurement positions for each scan. The region scanned can be located over any region of the optical axis with the use of a zoom lens. With the original LV system, the laser velocimeter measurements were input into a separate, small minicomputer with 30 kilobytes of memory for data processing. This computer has been replaced with an LV data acquisition buffer which acquires the data and then transmits the data to a large minicomputer for processing.

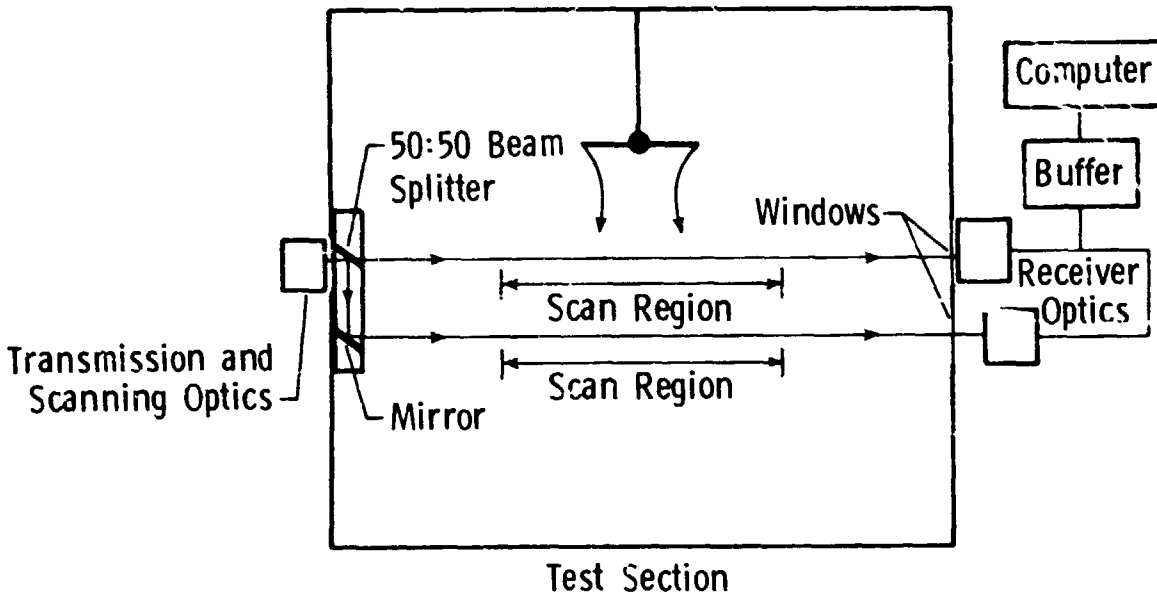


Figure 2

LV OPTICAL SYSTEM

The optical system is configured to operate in the forward-scatter mode (figure 3). The laser velocimeter uses an argon-ion laser that operates in the TEM_{00} mode and at .6 W of continuous power at the 514.5-nm wavelength. The laser output beam is focused by a 2-diopter lens into the center of a two-dimensional ultrasonic Bragg cell. The Bragg cell allows two orthogonal velocity components (axial and vertical) to be measured. The four orders from the Bragg cell are then collimated by a 1.5-diopter lens and imaged into the dead air space of an optical cell by a 20-diopter F1:1.5 lens. The optical cell is used to eliminate extraneous Doppler signals from particles passing through this primary focus. The beams emerging from the optical cell then pass through the scan wheel. This wheel is a 40.5-cm-diameter disk containing 16 windows. The windows vary in thickness from 0 to 30 mm, in 2-mm increments. The scan wheel operates on the refraction principle, whereby the insertion of plane parallel windows (of various thicknesses) between the primary focus in the optical cell and a projection lens arrangement produces an apparent incremental longitudinal displacement of the primary focus. This displacement is magnified (by a factor of approximately 50) by the 2-lens projection system. The receiving optics are adjusted to focus the scattered light from the sample volume onto the photomultiplier tube. Beam masks are used to block the primary beams.

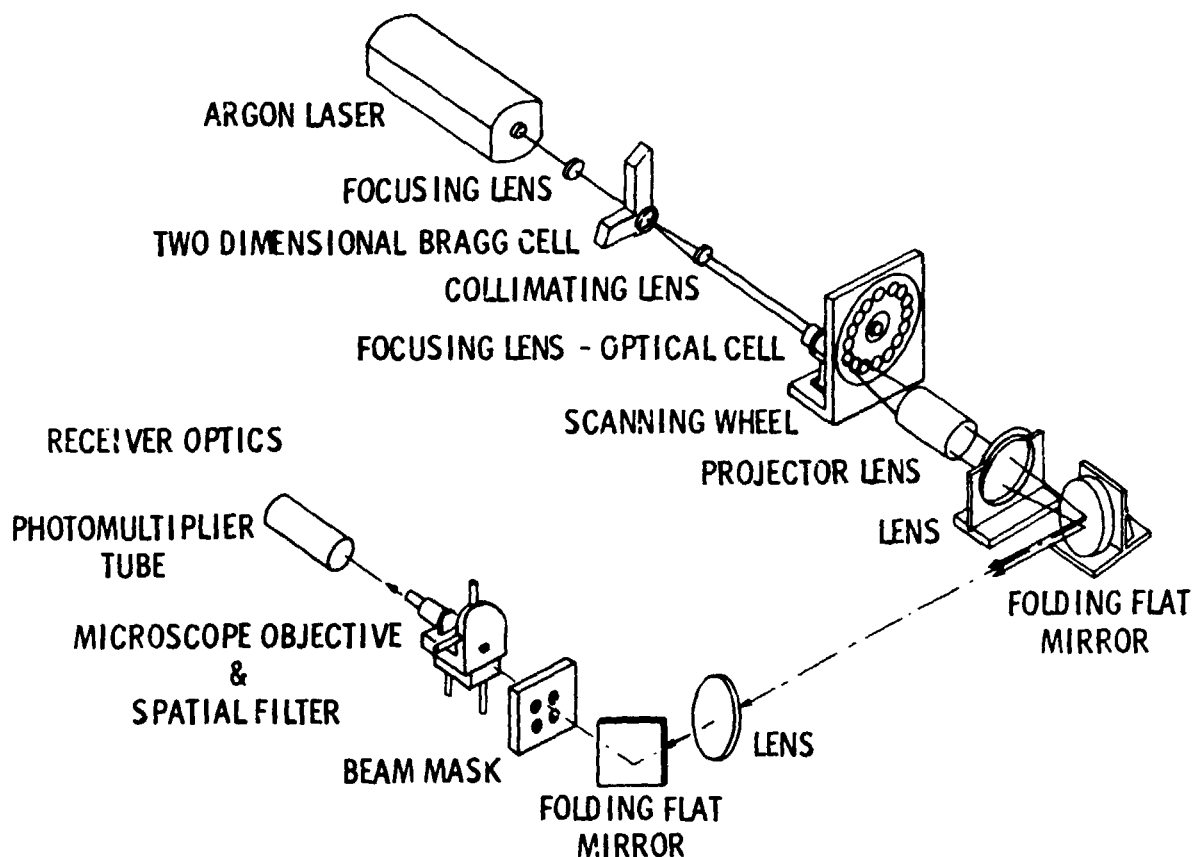


Figure 3

SEEDING PARTICLES

For many years, the Vortex Research Facility has used kerosene vapor as seeding particles. The kerosene vapor formed ($\sim 1\mu\text{m}$) particles initially. After injection into the test section, the vapor would begin to condense and form larger particles. By switching to solid particles, this has been eliminated. The solid particle size distribution is shown in figure 4. The uniform-sized ($\sim 1\mu\text{m}$) solid particle seeding is used both to seed the LV system and for flow visualization. After injection, the solid particles reach a uniform suspension before the vehicle is launched. It was found that the kerosene vapor posed a problem because it is a heated gas which modified the test section temperature distribution. It also produced high turbulence and secondary air currents because it was continually injected from the time of vehicle launch until model passage. In cases where the effects of either turbulence or the vertical temperature distribution were of interest, this hot gas injection method was unsuitable. Both types of seeding particles provided adequate flow visualization but are sensitive to vertical temperature distributions.

SOLID PARTICLE SIZE DISTRIBUTION

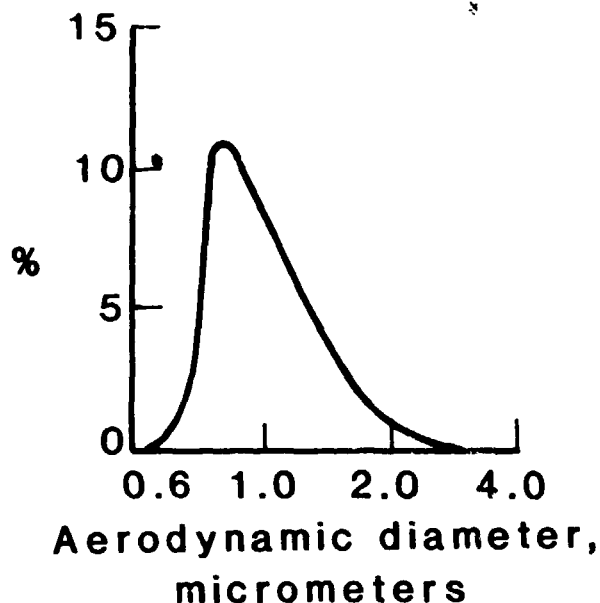


Figure 4

TEST SECTION TEMPERATURE DISTRIBUTION

Although the test section is enclosed within the facility, the environment within the test section is still influenced by the outdoor meteorological conditions. In particular the temperature near the ceiling tends to track the daily variation in outdoor temperature while the temperature near the floor, which is thick concrete and below ground level, is relatively constant. This results in a vertical temperature gradient which varies with the time of day and season. Thirteen thermocouples were mounted off the test section floor and side walls to measure the test section temperature distribution during test runs. To verify that the wall measurements were providing an accurate indication of the temperature gradient at the tunnel centerline, detailed measurements were made with 24 uniformly distributed thermocouples. A contour plot of a typical test section temperature distribution is shown in figure 5. All but the wall mounted thermocouples were removed from the test section during runs. Testing on a typical summer day covered the range from near zero gradient conditions in the early morning to a maximum gradient between 0.5 and 1.0 degree F per foot in the afternoon.

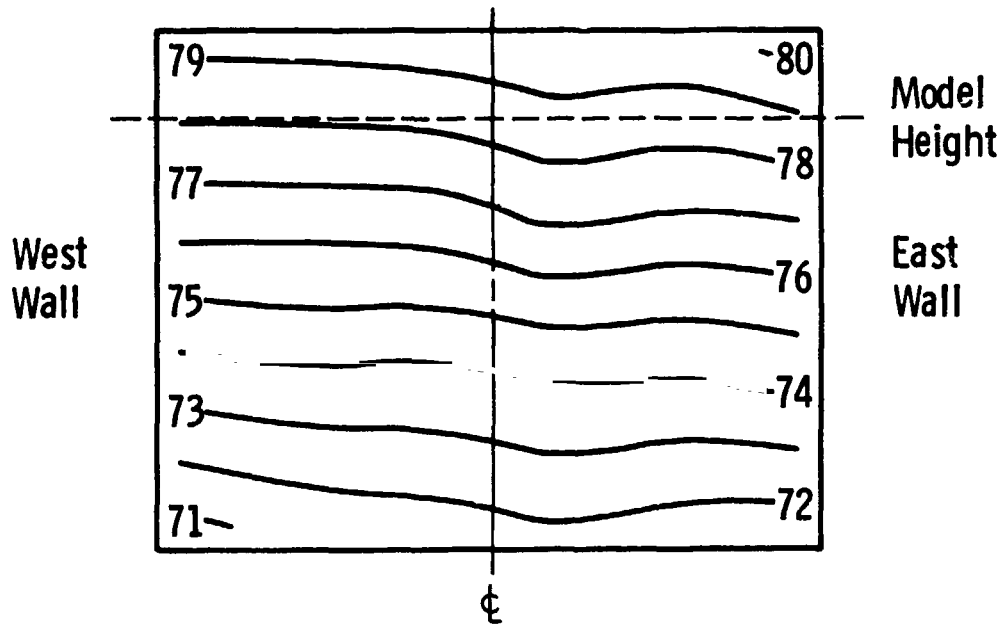


Figure 5

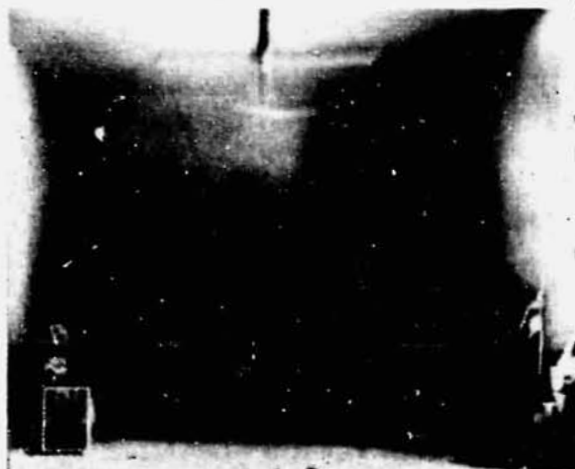
TEMPERATURE DISTRIBUTION EFFECTS ON SEEDING

In the Vortex Research Facility, the test section temperature distribution can be a primary factor in achieving a satisfactory seeding distribution. If the seeding particles are at a different temperature than the air being seeded, the particles will drift from the desired height. When the height of the particles differs significantly with the model's height, a poor seeding distribution occurs. The mild stratification case has a 0.2°F per foot temperature distribution. For the heavy stratification case, the temperature distribution was 1.4°F per foot. The large temperature distribution caused the seeding particles to sink below the model which resulted in a poorer seeding distribution. The seeding levels shown are for flow visualization although similar results occur for the lower LV seeding levels. (See figure 6.)

AR = 7 Rectangular wing

Mild stratification

Heavy stratification



T = 0 sec



T = 2 sec

Figure 6

CONCLUSIONS

Two types of seeding particles have been used in the Vortex Research Facility. Hot kerosene vapor does not maintain uniform particle size when it cools and has been shown to influence vortex wake persistence. Solid particle seeding seems to provide a better indication of vortex wake behavior. Seeding distributions for both types of seeding particles are affected by vertical temperature distributions.

- O VRF has used two types of particles
- O Kerosene vapor becomes non uniform in size when vapor cools
- O Kerosene vapor has been shown to influence vortex wake persistence
- O Solid particle seeding seems to provide a better indication of vortex wake behavior
- O Seeding distributions affected by vertical temperature distributions

REFERENCES

1. Satran, Dale R.; Neuhart, Dan; Holbrook, G. Thomas; and Greene, George C.: Vortex Research Facility Improvements and Preliminary Density Stratification Effects on Vortex Wakes. AIAA Paper No. 85-0050, January 1985.
2. Gartrell, Luther R.; and Rhodes, David B.: A Scanning Laser-Velocimeter Technique for Measuring Two-Dimensional Wake-Vortex Velocity Distributions. NASA TP 1661, May 1980.