LASER VELOCIMETRY - A STATE-OF-THE-ART OVERVIEW

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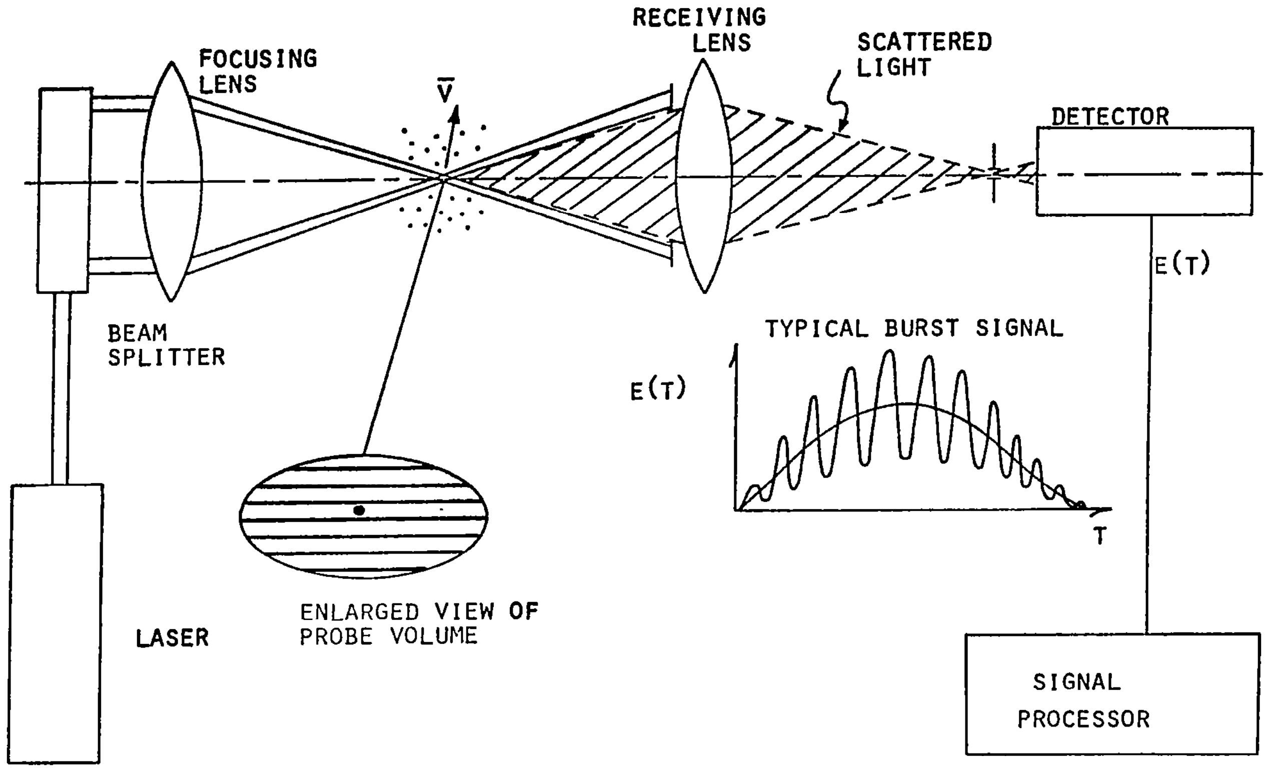
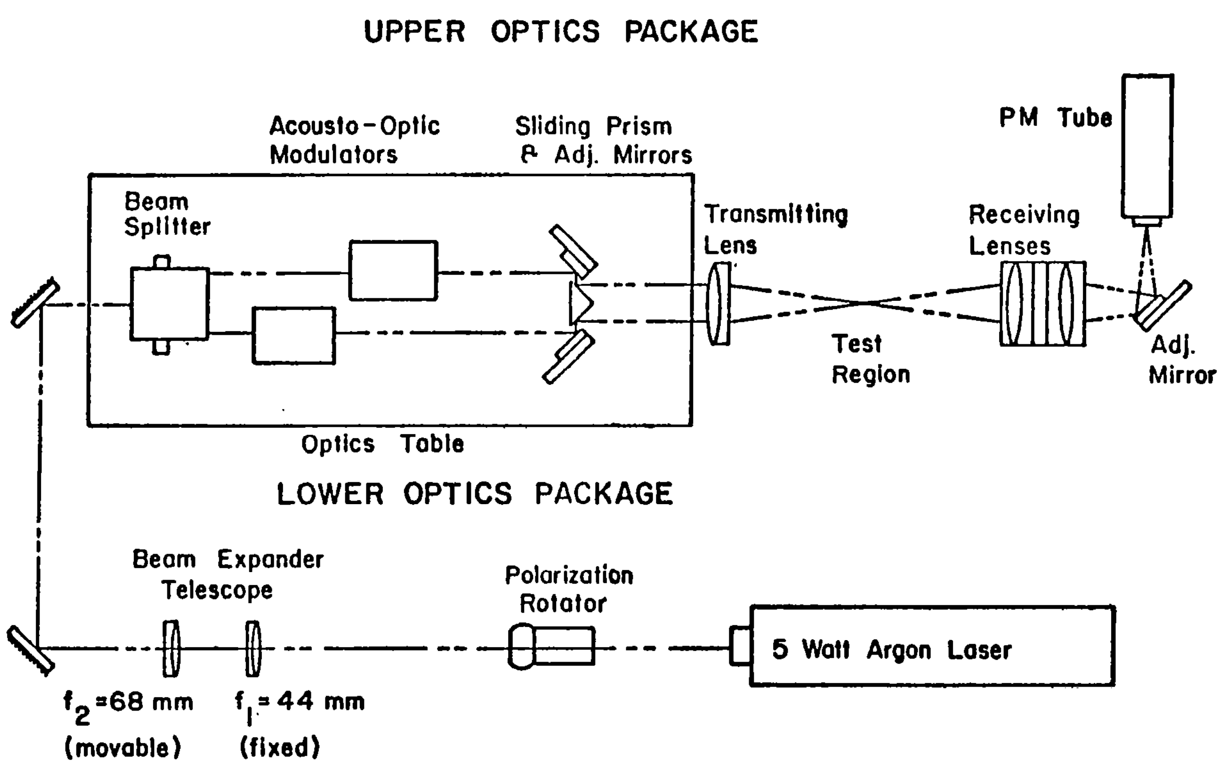
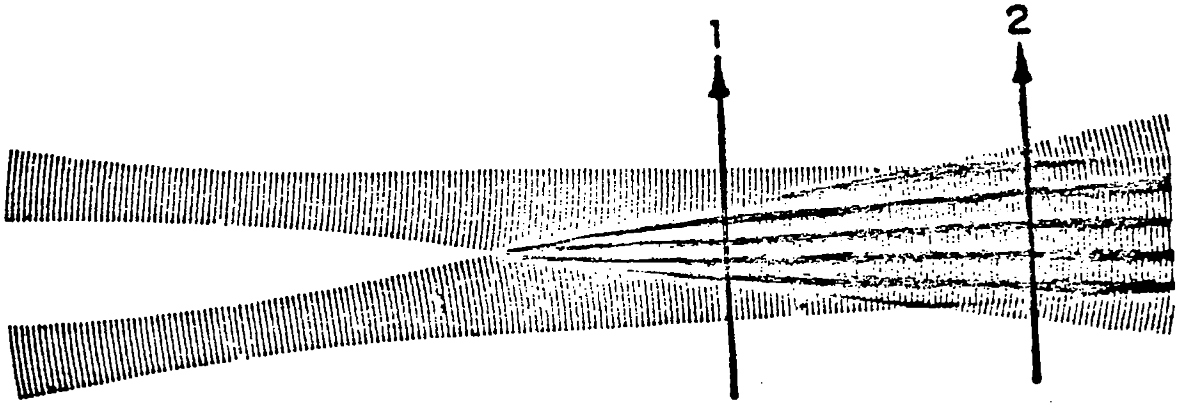
TYPICAL DIFFERENTIAL DOPPLER LDV



VARIABLE PARAMETER LDV SYSTEM



FRINGE MODEL

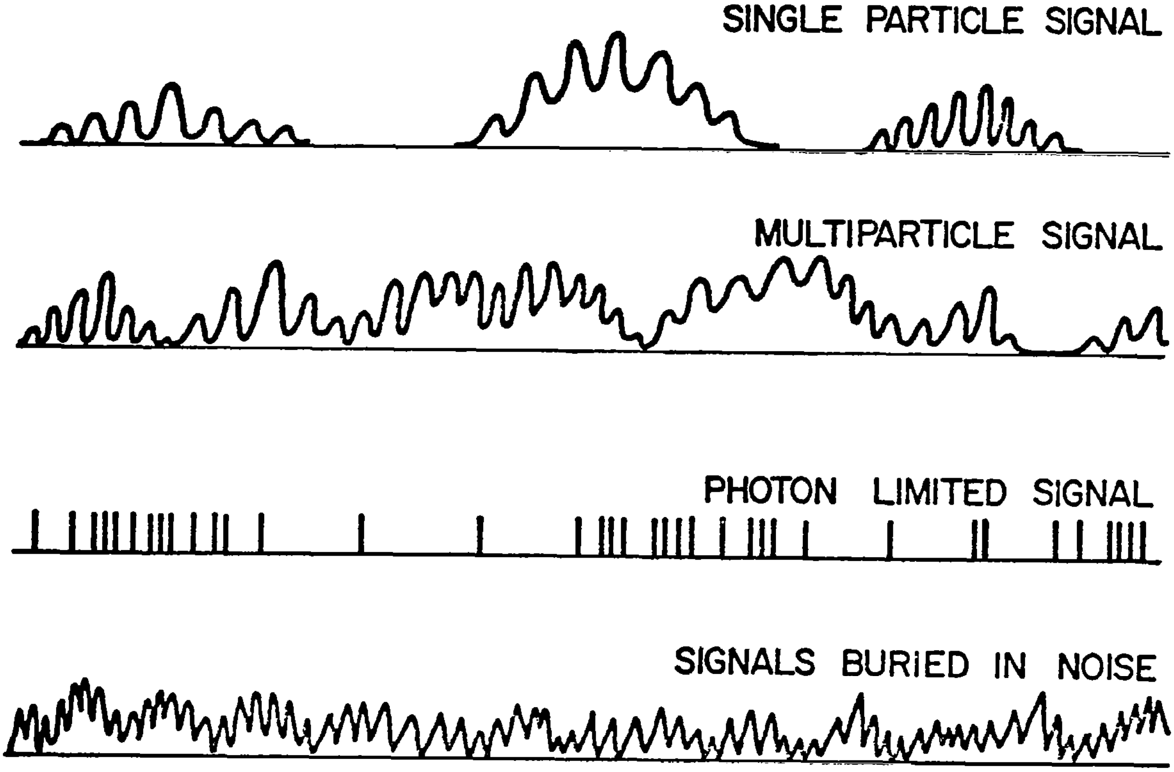


Fringe model indicating variations in Doppler frequency. Beam waists are on same side of focal plane.

When beam intersection does not occur at the waists, the fringe planes in the probe volume will not be parallel and the observed signal frequency will depend on particle trajectory. This effect, though small, can lead to an increase in the measured turbulence intensity. Perhaps of more significance in most cases is that the beam intensity is higher at the waists than in the probe volume. This results in a lower signal-to-noise ratio.

Durst, F. and Stevenson, W. H., "Influence of Gaussian Beam Properties on Laser Doppler Signals," Applied Optics, 18, 516 (1979).

NATURE OF VOLTAGE SIGNAL



The nature of the voltage signal observed at the detector output will depend on several factors including the laser power, scattering efficiency of the particles, and particle seeding density. In high speed wind tunnels either single particle "burst" signals or photon limited signals will be typical.

SIGNAL PROCESSING DEVICES

SPECTRUM ANALYZER

FREQUENCY TRACKER

BURST PROCESSOR (COUNTER)

PHOTON CORRELATOR

TRANSIENT RECORDER

The parameters usually desired from the sampled velocity data are

Mean Velocities	$\bar{u}$, $\bar{v}$, $\bar{w}$?
Turbulence Intensity	$\overline{u'^2}/U$ etc.
Reynolds Stress	$\overline{u'v'}$
Power Spectrum	$E(\omega)$

COMMENTS ON SEEDING

Experience has shown that particles $\lesssim$ 1 μm are needed to make accurate measurements in gas flows. Below 1 μm the scattered intensity drops off rapidly and above 1 μm the particles do not follow the flow. However, smaller particles may be necessary in situations where extremely high accelerations are present.

In tunnels where "zero" seeding is allowed, natural contaminants in the tunnel must be used. This can pose severe requirements on the LDV system, both in terms of the optical design and the signal processing.

Various methods of particle generation are available including liquid atomization, solid particle dispersal, and "chemical" seeding with reacting gases.

Yanta, W. J. "The Use of the Laser Doppler Velocimeter in Aerodynamic Facilities," Paper 80-0435, 10th AIAA Aerodynamics Testing Conference (1980).

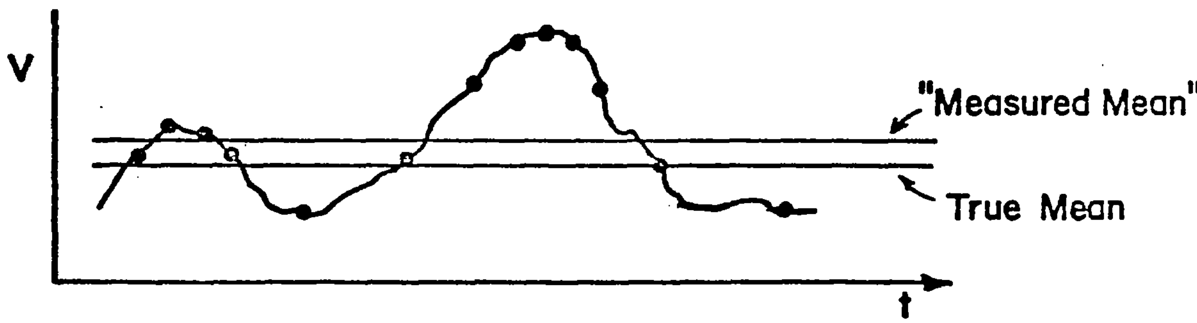
IMPORTANT BIAS ERRORS WHICH OCCUR IN LDV MEASUREMENTS USING BURST (COUNTER) PROCESSORS

BIAS	SOURCE
Particle Lag	Particle Inertia
Directional Ambiguity Bias	Lack of Directional Sensitivity in LDV
Velocity Bias	Particle Controlled Sampling
Incomplete Signal Bias	Signal Validation Based on Fixed Number of Cycles

Both directional ambiguity and incomplete signal bias may be eliminated by frequency shifting.

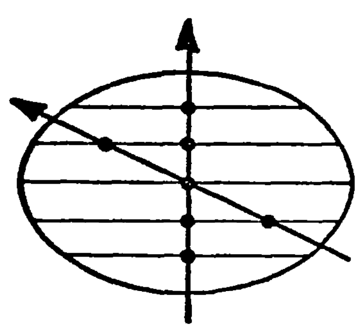
VELOCITY BIAS

ARISES WHEN A PARTICLE (ENSEMBLE) AVERAGE RATHER THAN A TIME AVERAGE OF THE DATA IS USED.

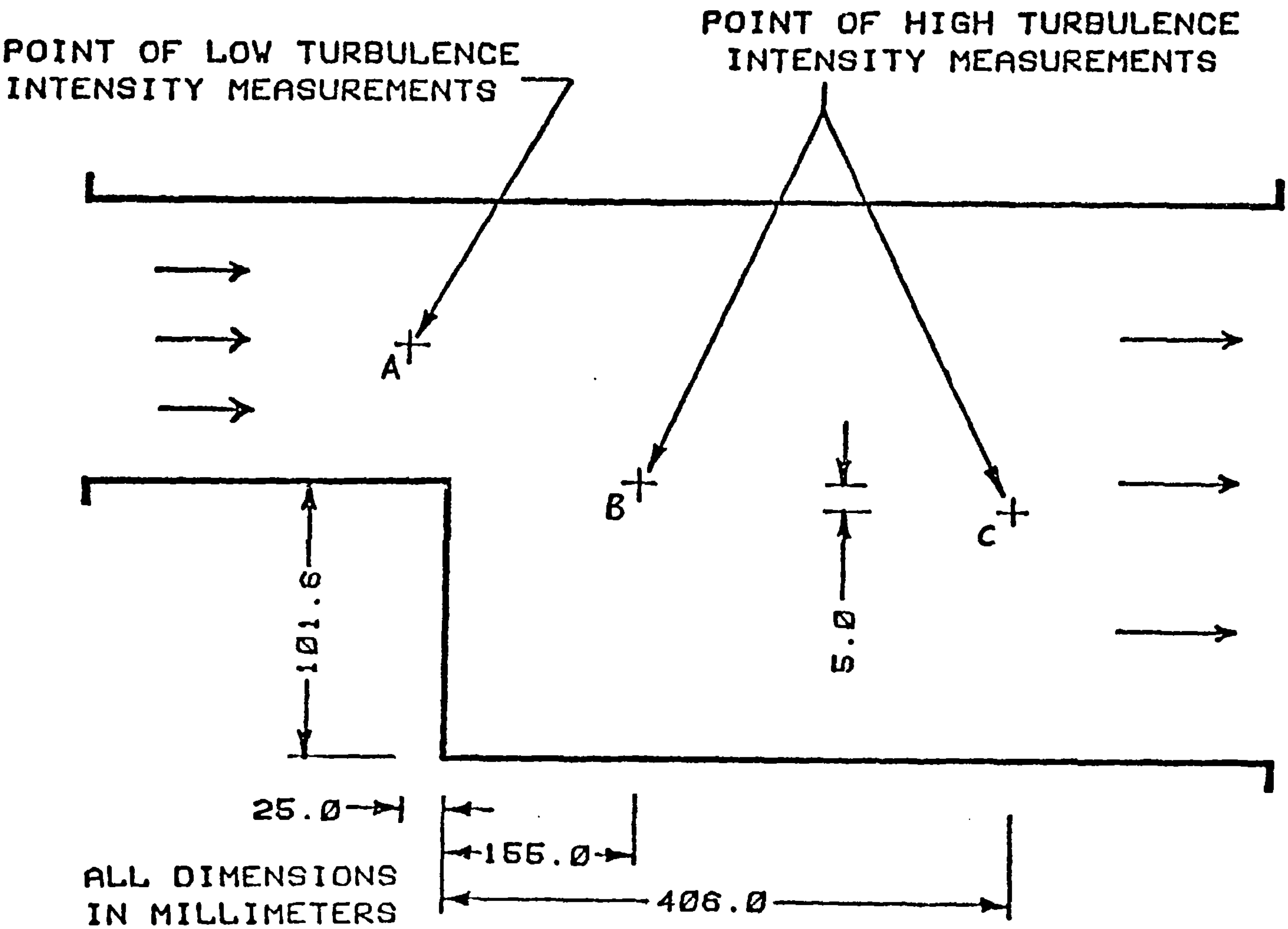


INCOMPLETE SIGNAL BIAS

ARISES IN HIGHLY TURBULENT FLOWS WHEN PARTICLES AT A LARGE "ANGLE OF ATTACK" FAIL TO CROSS THE NUMBER OF FRINGES NEEDED TO TRIGGER AN OUTPUT FROM THE PROCESSOR. THIS LEADS TO AN ERRONEOUSLY HIGH MEASURED MEAN VELOCITY WHEN THE FRINGES ARE ALIGNED PERPENDICULAR TO THE LOCAL MEAN VELOCITY VECTOR.

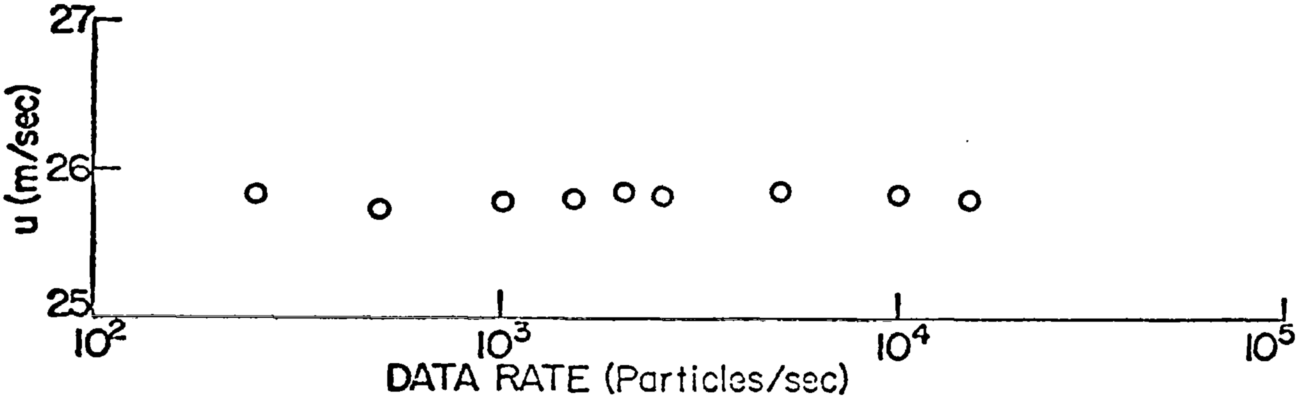


FLOW GEOMETRY OF VELOCITY BIAS STUDY

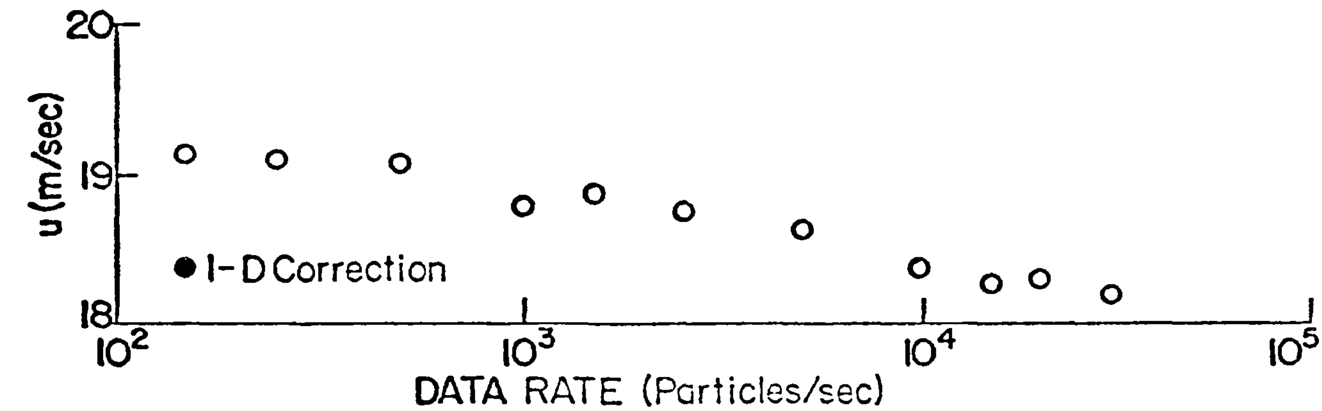


Flow geometry used in Purdue study of velocity bias is shown above. At point A the flow was essentially laminar. At points B and C the turbulence intensity was 20% and 35% respectively.

EFFECT OF DATA RATE ON MEAN VELOCITY



Effect of Data Rate on Mean Velocity at Point A

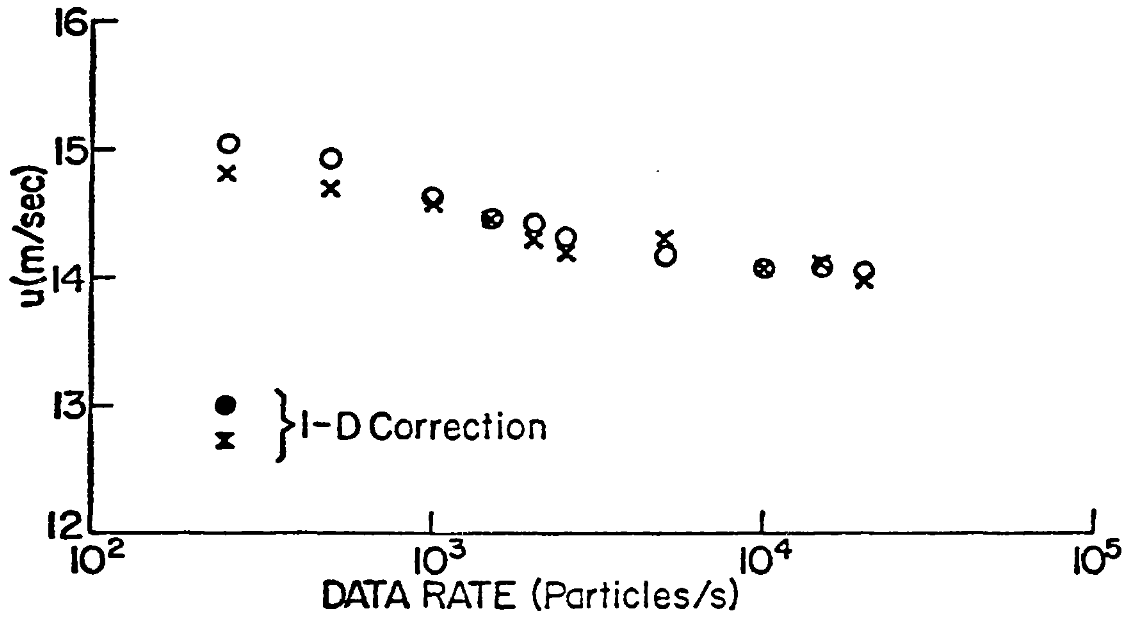


Effect of Data Rate on Mean Velocity at Point B

In the above figures "data rate" refers to the number of validated Doppler signals per second when the processor was uncontrolled. This depends on seeding density. The velocity data shown were taken with the processor controlled by a microcomputer so that a fixed waiting time occurred after a velocity sample was stored before the processor was available to accept a new signal. At the high data rates (high seeding density) this resulted in essentially equal time interval sampling of the velocity at a sample rate of 250 Hz.

The analytically corrected data point shown in the second figure is based on the 1-D correction of McLaughlin and Tiederman.

EFFECT OF DATA RATE ON MEAN VELOCITY (Concluded)



Effect of Data Rate on Mean Velocity at Point C
x = 25 Hz Sampling Rate
o = 250 Hz Sampling Rate

Roesler, T. C., Stevenson, W. H., Thompson, H. D., "Investigation of Bias Errors in Laser Doppler Velocimeter Measurements," AFWAL-TR-80-2105, December 1980.

AREAS REQUIRING FURTHER STUDY

Velocity Bias - "The Final Word"

Improved Designs for 3-D Systems

Measurements Near Surfaces