RAYLEIGH SCATTERING MEASUREMENTS IN NASA LANGLEY'S HYPERSONIC FACILITIES

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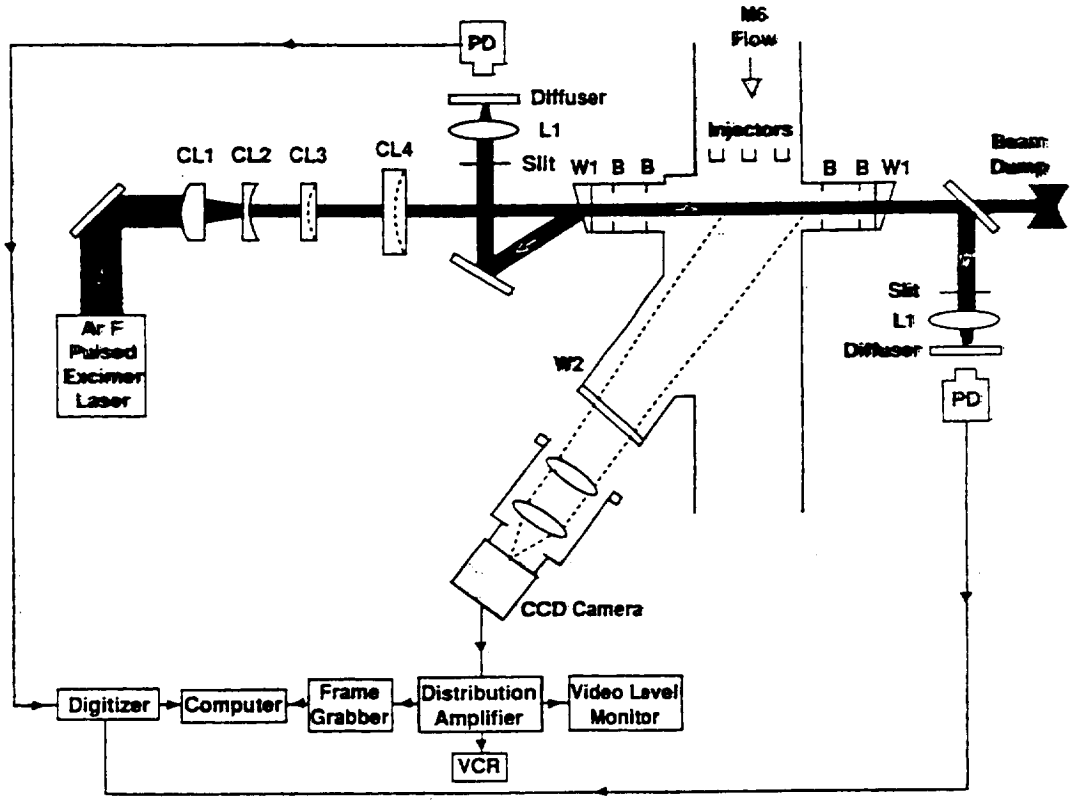
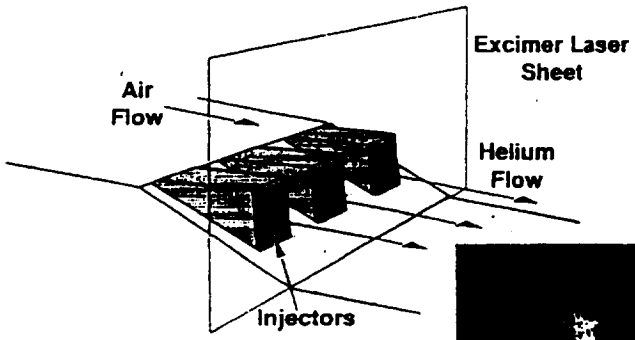
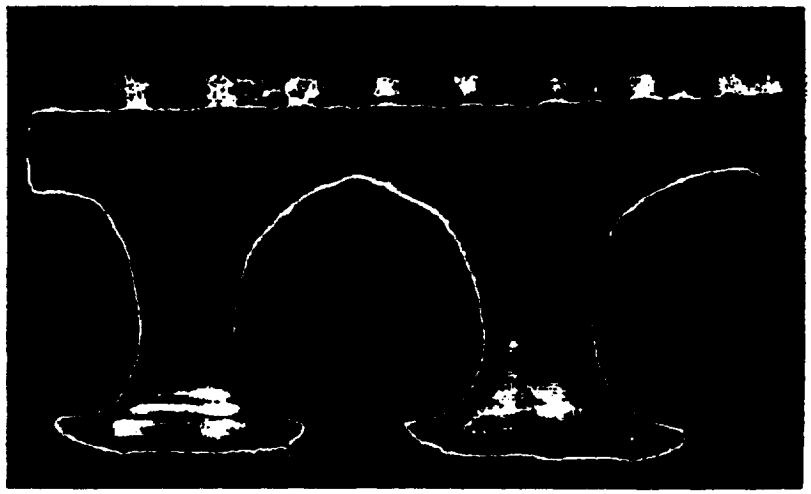
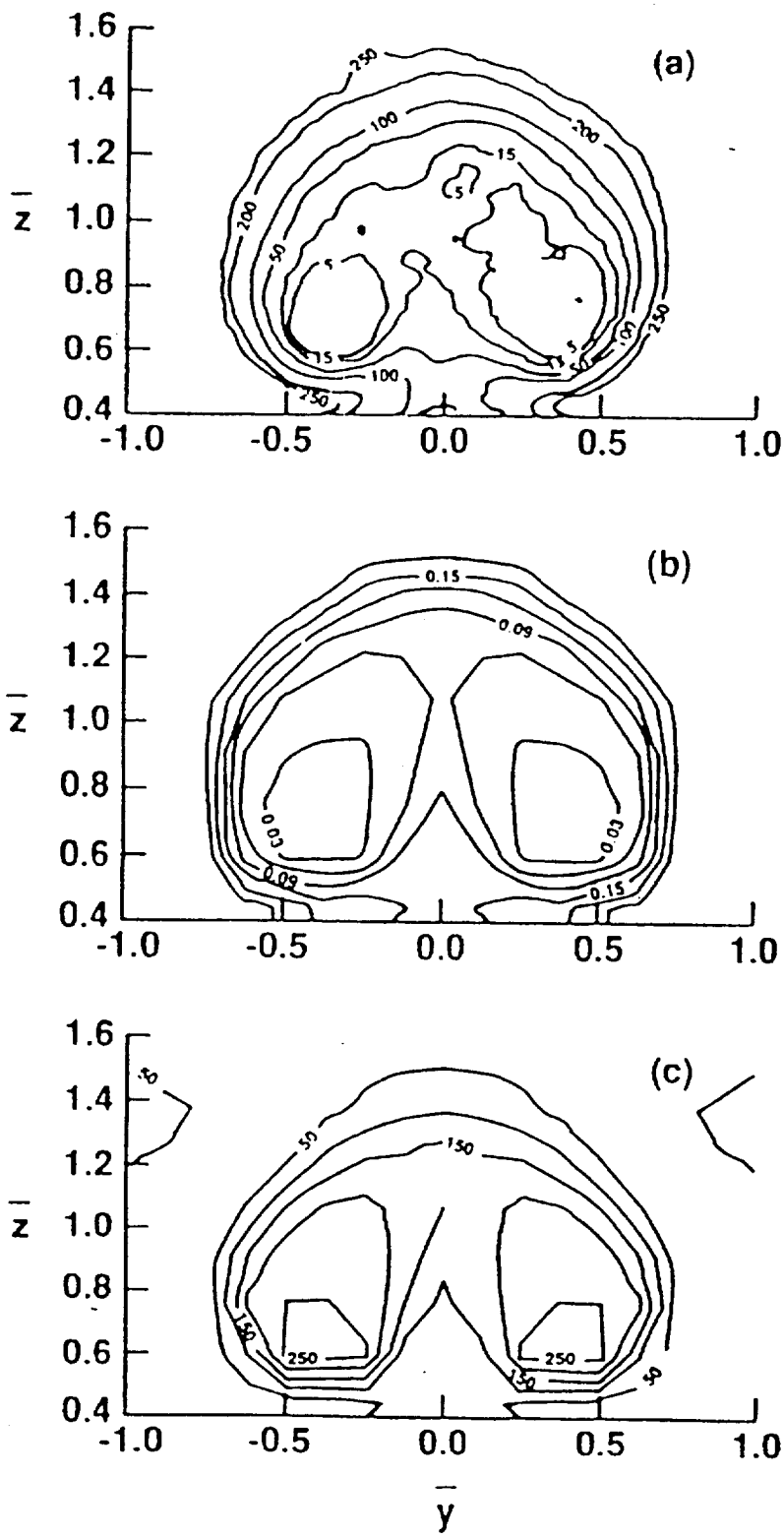


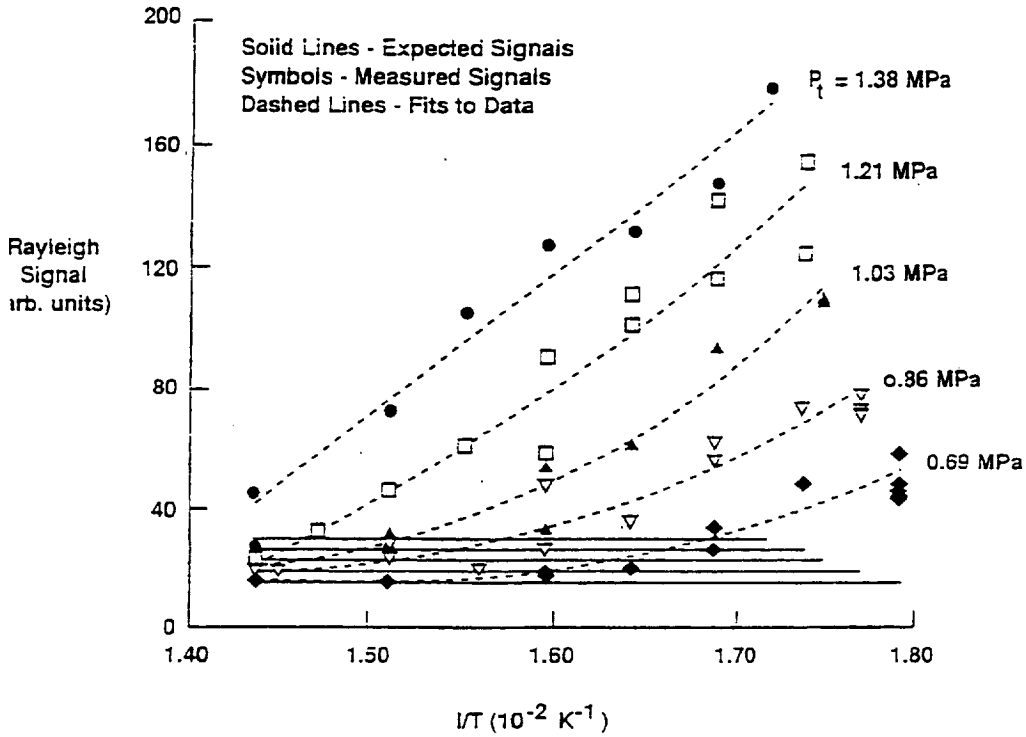
ADVANCED 2-D LASER DIAGNOSTICS

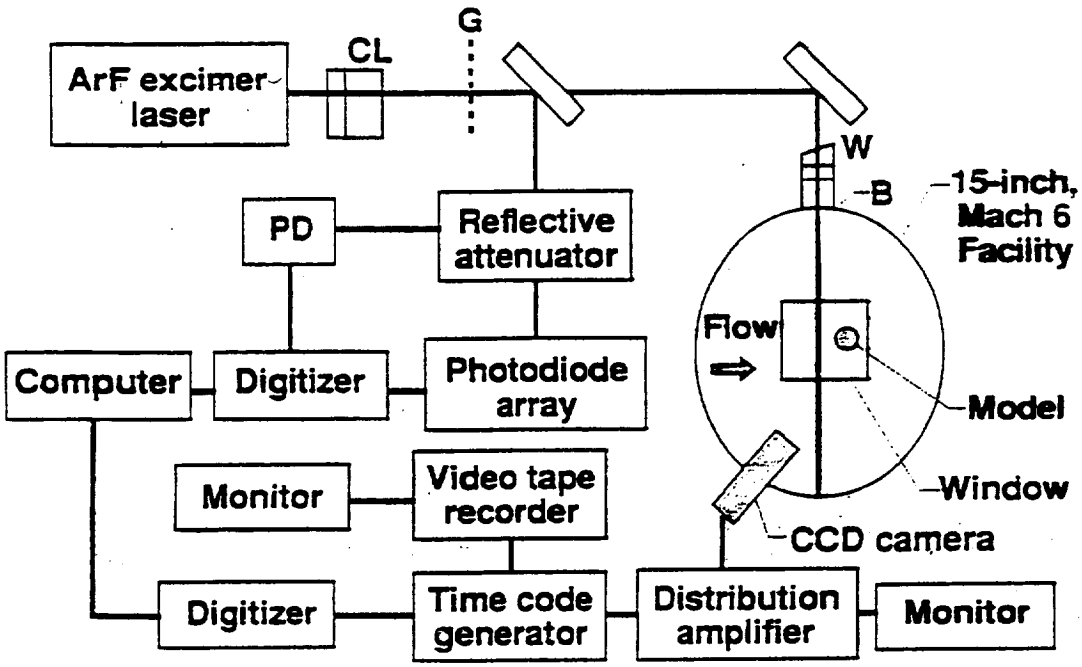


Rayleigh Scattering
Supersonic Mixing Study




(a)
(b)
(c)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
-1.0
-0.5
0.0
0.5
1.0
z̄
ȳ
250
100
200
15
5
50
0.15
0.09
0.03
150


Solid Lines - Expected Signals
Symbols - Measured Signals
Dashed Lines - Fits to Data
P_t = 1.38 MPa
1.21 MPa
1.03 MPa
0.86 MPa
0.69 MPa
Rayleigh Signal (arb. units)
200
160
120
80
40
0
1.40
1.50
1.60
1.70
1.80
1/T (10^{-2} K^{-1})


ArF excimer laser
CL
G
W
B
15-inch, Mach 6 Facility
PD
Reflective attenuator
Flow
Computer
Digitizer
Photodiode array
Model
Monitor
Video tape recorder
Window
CCD camera
Digitizer
Time code generator
Distribution amplifier
Monitor

Laser

- ArF excimer
- 193nm
- 15Hz
- narrowband
- 120mJ/pulse

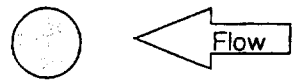
Facility

- 15" test section
- Mach 6 air
- variable temperature up to 700K
- 0.35-2.07 Mpa (50-300psia)

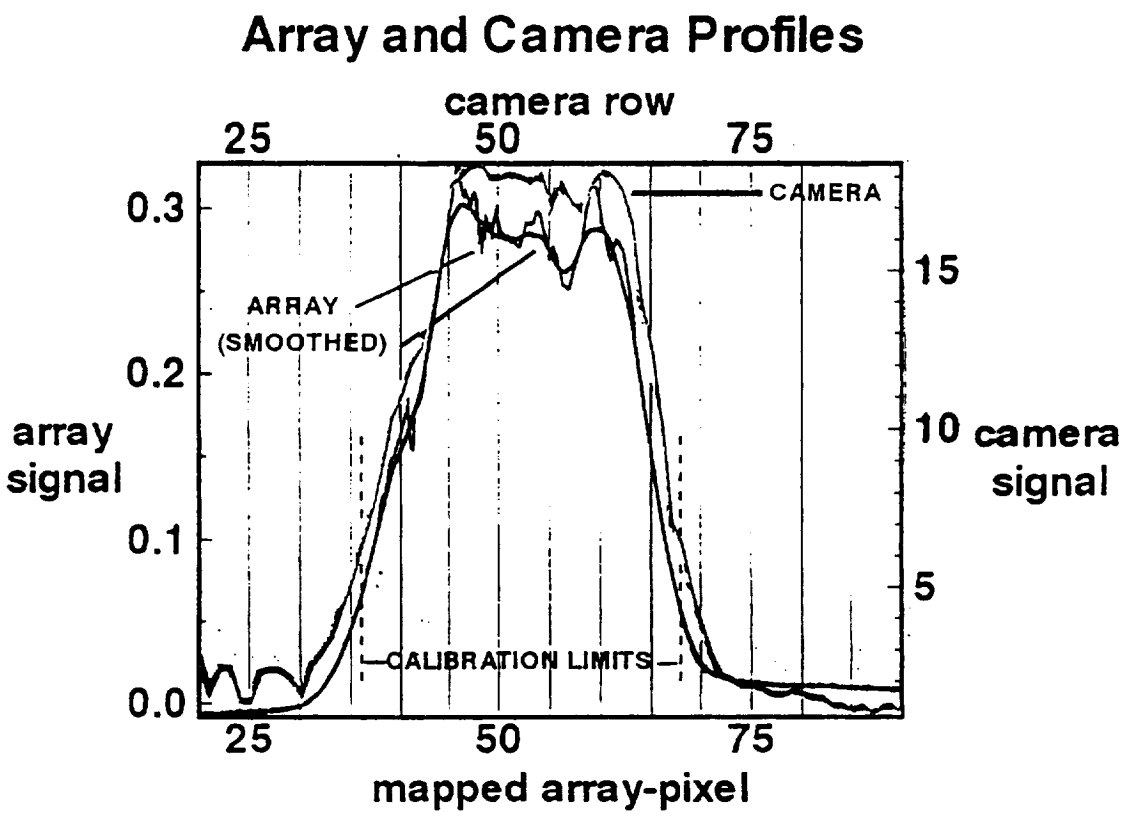
Operating Conditions

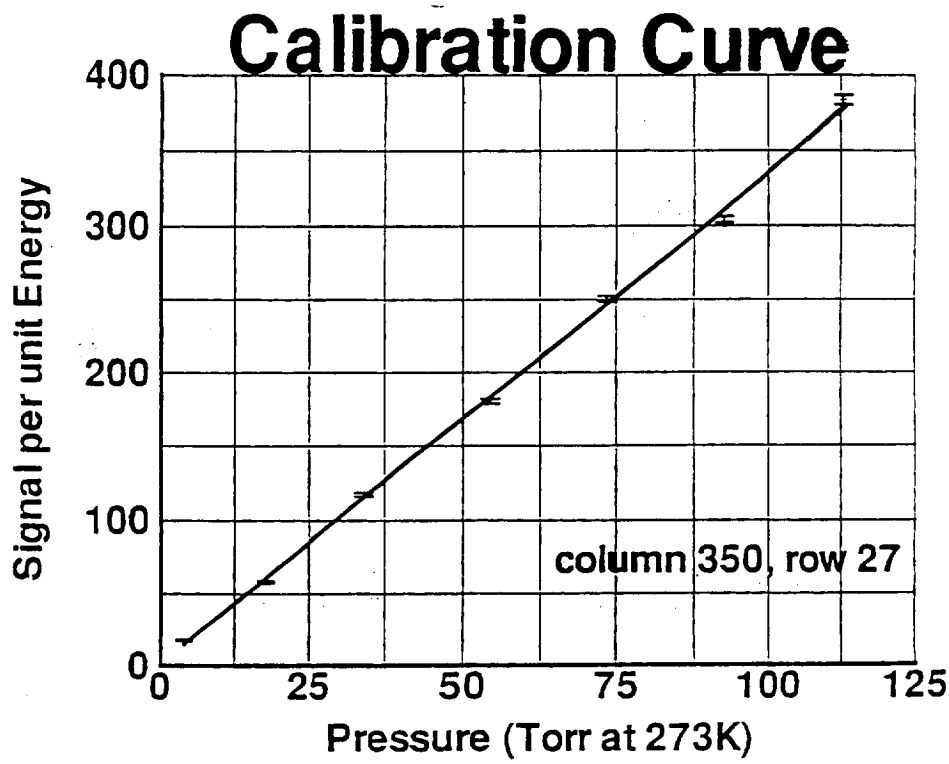
- 672K
- 1.38 Mpa (200psia)

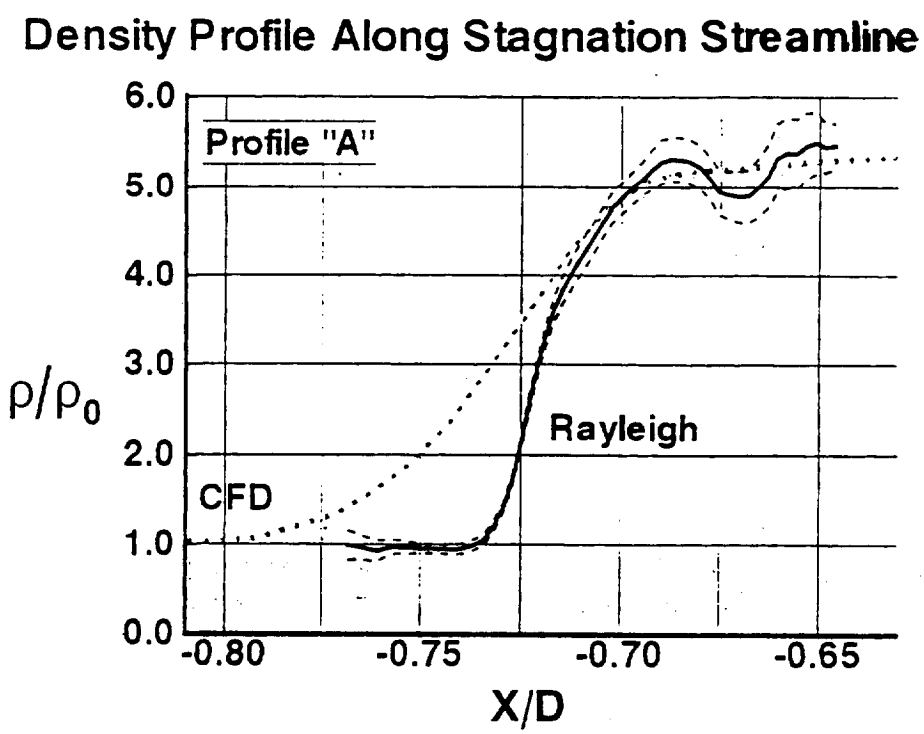
Model



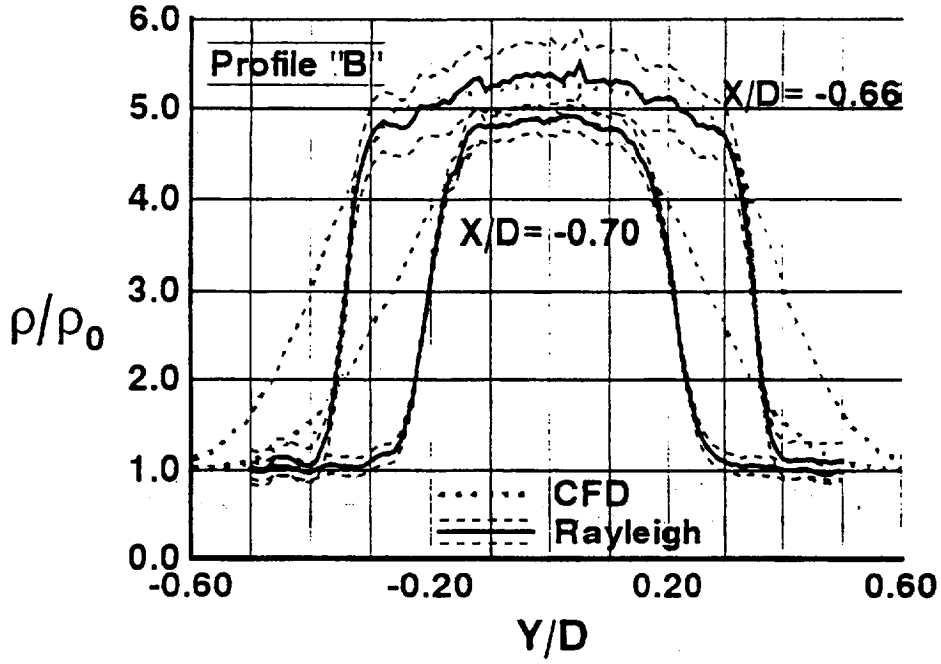
- cylinder
- 38.1 mm diameter
- 15.25 cm length



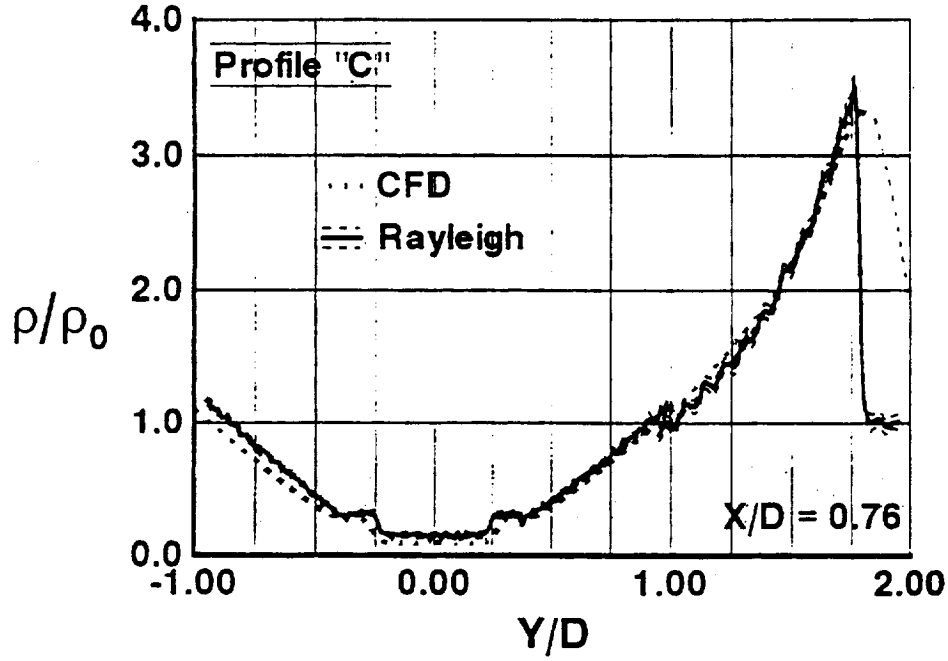

Calibration Curve
Signal per unit Energy
400
300
200
100
0
0
25
50
75
100
125
Pressure (Torr at 273K)
column 350, row 27


Density Profile Along Stagnation Streamline
Profile "A"
ρ/ρ0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Rayleigh
CFD
-0.80
-0.75
-0.70
-0.65
X/D

Density Profile Across Cylinder Bow Shock



Density Profile Across Cylinder Wake



Conclusions

1) The capability of the Rayleigh scattering technique for for quantitative density measurements in a Mach 6 flow has been demonstrated.

2) The densities deduced from the Rayleigh measurements performed on a cylindrical model are in general agreement with the CFD calculations..

3) Further improvements in the accuracy of the measurement may be possible through an increase in the signal-to-noise ratio and removal of the systematic errors.

Future Plans

1) Remove the systematic errors from the data by better design of the apparatus.

2) Test the feasibility of using the Rayleigh scattering technique at 248 nm to improve the signal-to-noise ratio.

3) Repeat the measurements on the cylindrical model in the 15-inch, Mach 6 high temperature facility to obtain a complete data set in the wake region for comparison to the CFD model calculations.

4) Extend the capabilities to different model flow fields.

References

"Quantitative Density Measurements in a Mach 6 Flow Field Using The Rayleigh Scattering Technique," B. Shirinzadeh, R.J. Balla, M. E. Hillard, presented at the 16th International Congress on Instrumentation in Aerospace Simulation Facilities, Wright Patterson Air Force Base, July 18-21, 1995.

"Planar Rayleigh scattering results in helium-air mixing experiments in a Mach-6 wind tunnel," B. Shirinzadeh, M.E. Hillard, R.J. Balla, I.A. Waitz, J.B. Anders, R.J. Exton, Applied Optics 31(30), 20 October, 1992.

"Study of Rayleigh Scattering for Visualization of Helium-Air Mixing at Mach 6", B. Shirinzadeh, R.J. Balla, M.E. Hillard, J.B. Anders, R. J. Exton, I.A. Waitz, proceedings of the International Congress on Instrumentation in Aerospace Simulation Facilities, Rockville, MD, October 27-31, 1991.

"Study of Cluster Formation and its effects on Rayleigh and Raman scattering measurements in a Mach 6 wind tunnel," B. Shirinzadeh, M.E. Hillard, A. B. Blair, R.J. Exton, presented at the AIAA 22nd Fluid Dynamics, Plasma Dynamics & Lasers Conference, AIAA 91-1496, 24-26 June, 1991.

"Condensation Effects on Rayleigh Scattering Measurements in a Supersonic Wind Tunnel," B. Shirinzadeh, M.E. Hillard, R.J. Exton, AIAA Journal 29(2), pp. 242-246, February1991.

"Quantitative Density Measurements in a Mach 6 Flow Field Using The Rayleigh Scattering Technique," B. Shirinzadeh, R.J. Balla, M. E. Hillard, presented at the 16th International Congress on Instrumentation in Aerospace Simulation Facilities, Wright Patterson Air Force Base, July 18-21, 1995.

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