N90-12528

RECENT FLOW VISUALIZATION STUDIES IN THE 0.3-m TCT

Walter L. Snow, Alpheus W. Burner, and William K. Goad
Langley Research Center
Hampton, Virginia

SCHEMATIC OF TYPICAL FLOW VISUALIZATION SETUP IN 0.3-M TCT

Light beams are altered by refractive index changes and indeed flow induced refractive index changes provides the impetus for conventional visualization techniques such as schlieren and shadowgraph. Unfortunately effects related to the flow can be masked by refractive index inhomogeneities external to the test section. For high-pressure cryogenic facilities this is especially true in the interface between the region of test and the more benign environment where equipment is housed. Since the refractive index is directly proportional to density, it depends upon pressure and temperature through the ideal gas law. Even mild temperature inhomogeneities can be detrimental when coupled with high pressures as occurs in the plenum. The simple shadowgraph scheme depicted in figure 1 was used to assess the flow quality of the Langley 0.3-Meter Transonic Cryogenic Tunnel. The light source was a pulsed (15 microsecond) 75-watt xenon arc lamp focused onto a 0.51 mm diameter pinhole. Light was collimated with an f/8 mirror with a 1.22-m focal length. Data were recorded on film with a 70mm format reflex camera.

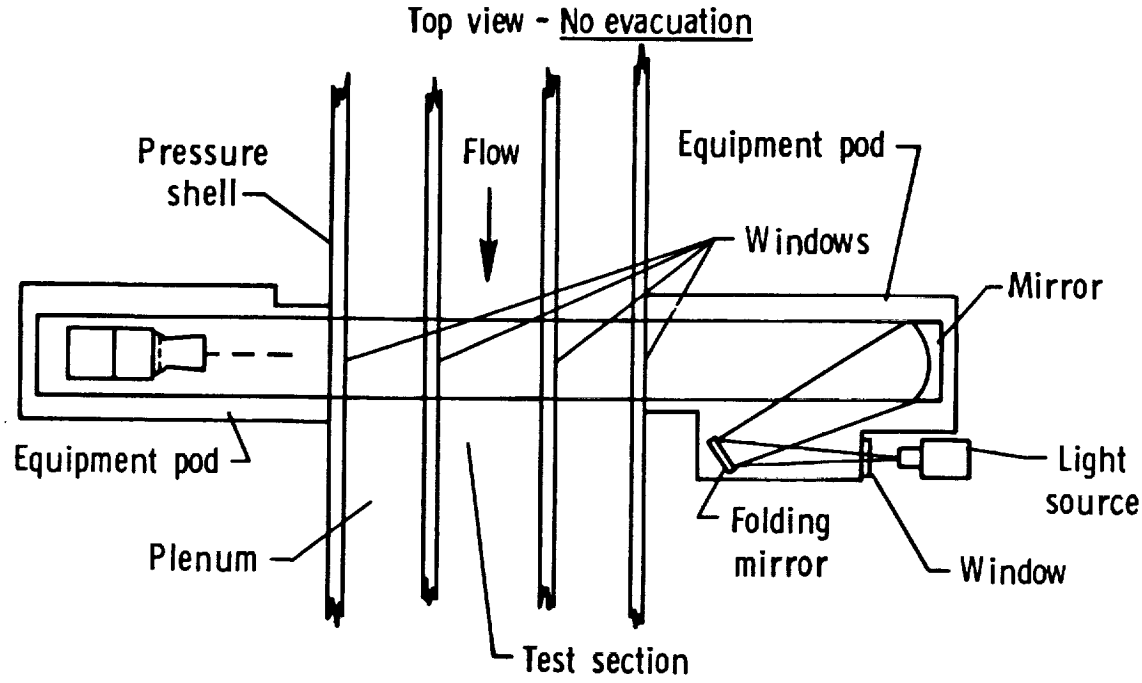

Figure 1

REPRESENTATIVE SHADOWGRAPH RESULTS PRIOR TO IMPROVEMENTS

The simple shadowgraph scheme depicted in figure 1 was used to characterize the flow quality of the Langley 0.3-Meter TCT with results shown in figure 2. This collage of photos was taken at Mach 0.65 conditions with stagnation pressure and temperature as indicated. The completely uniform light field which characterizes the pretest condition becomes increasingly mottled and jumbled as temperature decreases and pressure increases. This behavior is typical of earlier optical experiments conducted in this facility (see refs. 41, 42, and 43).

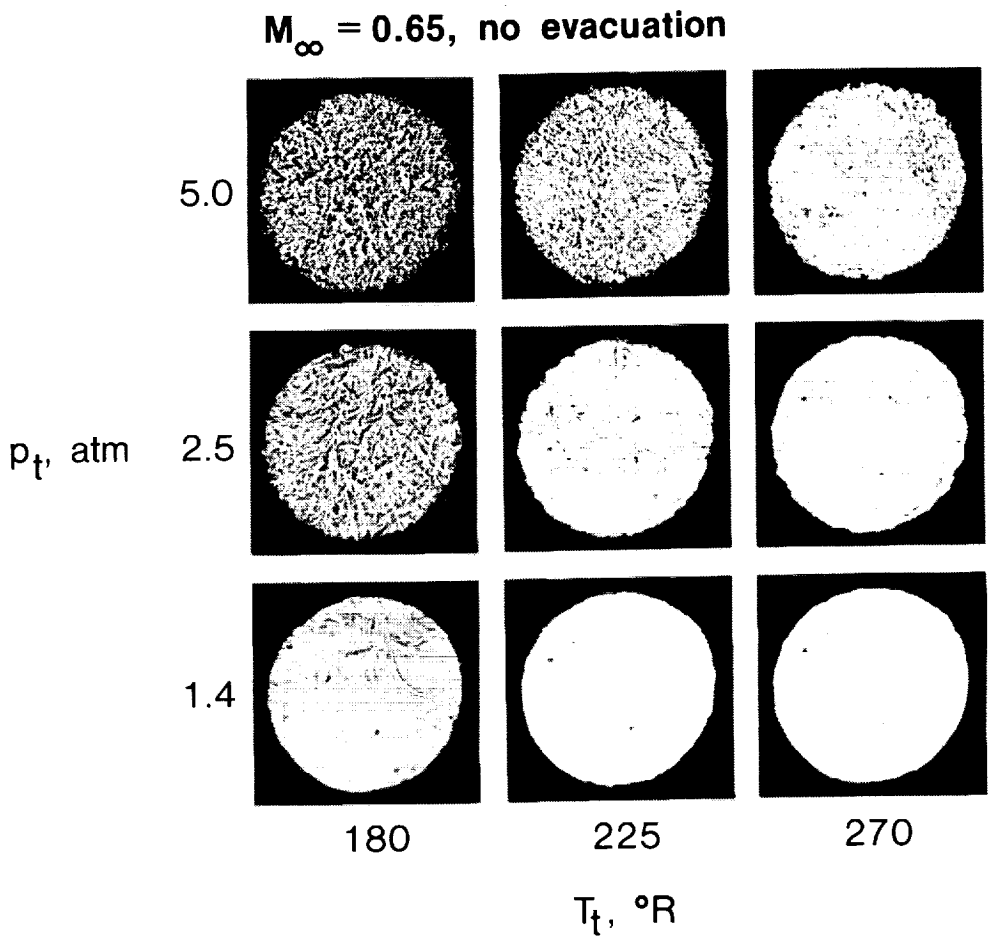

Figure 2

MODIFIED SHADOWGRAPH SYSTEM TO EXCLUDE PLENUM EFFECTS

Several of the tests devised to determine the source of the image degradation are described in reference 19. The crucial test involved installation of tubes to penetrate the plenum. The tubes could be purged or evacuated to allow direct viewing of the test section. Figure 3 shows the same layout as figure 1 with the hatched area designating the region impacted by the isolation tubes. A bellows type of arrangement was required to accommodate the large differential expansion experienced in the structure of the facility. Details of the assembly are found in the reference.

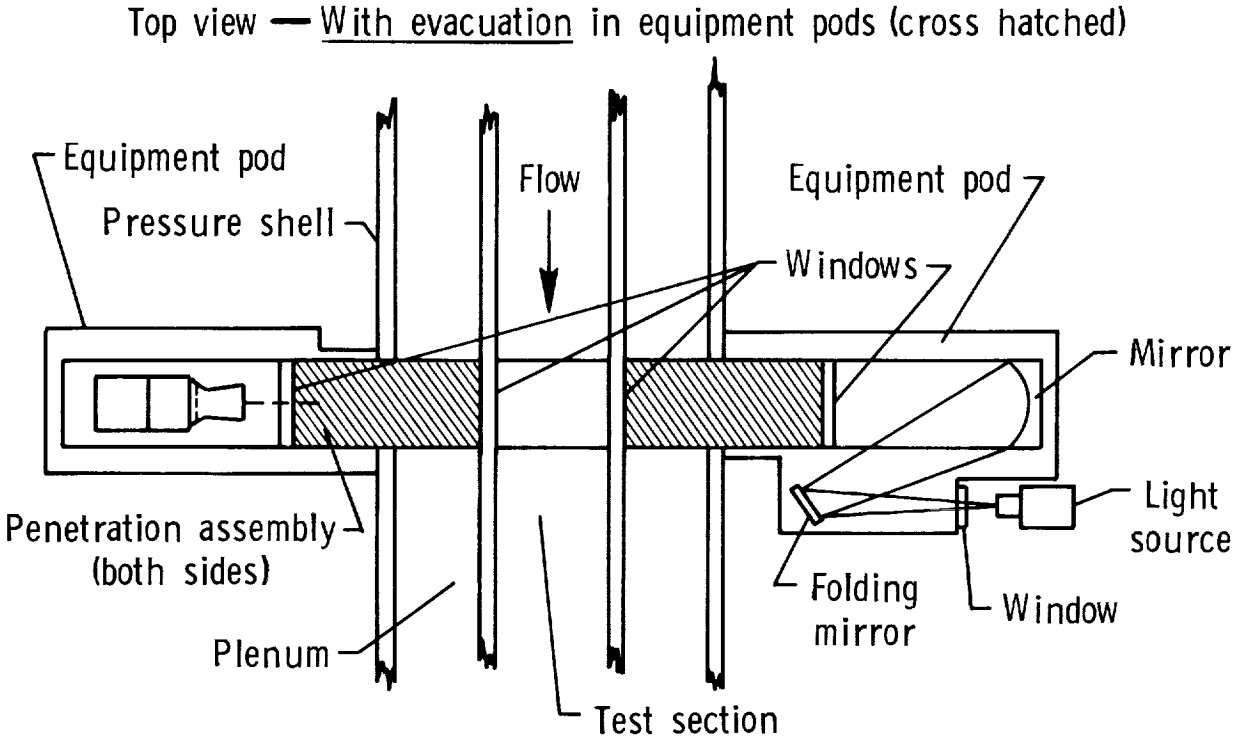

Figure 3

EFFECT OF PLENUM EVACUATION ON SHADOWGRAPH RESULTS

When the penetration tubes were evacuated the quality of the shadowgraphs improved dramatically. Results for the worst test condition of figure 2 (T_t = 180 R, p_t = 5 atm, Mach 0.65) are shown in figure 4. Residual "graininess" in the evacuated case is believed to be due to the flow field itself. Earlier difficulties were brought about by density inhomogeneities in the regions of strong temperature gradients especially in those areas under high pressure. Provisions for evacuated paths to and from the test section should be seriously considered in future flow visualization efforts for facilities of this type. In scaled up cryogenic facilities such as the National Transonic Facility equipment is completely housed within the plenum area (ref. 42). Much of the critical optical path would be in the controlled environment of the equipment enclosures. Nevertheless, regions near windows where extreme temperature gradients occur should be evacuated if possible to lessen the effects of convection induced mixing.

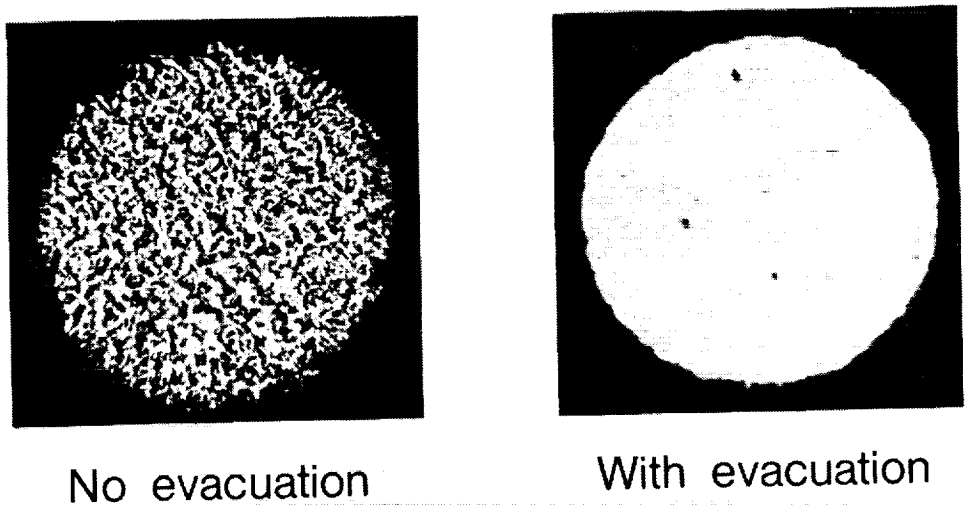

Figure 4

REFERENCES

1. Stainback, P. C.; and Johnson, C. B.: "A Probe and Data Reduction Technique for Obtaining Hot Wire Data at Transonic Speeds" in the Flow Quality Measurements in Transonic Wind Tunnels and Planned Calibration of the National Transonic Facility Appendix. NASA CP-2183, pp. 113-121, High Reynolds Number Research - 1980, December 1980.
2. Stainback, P. C.; Johnson, C. B.; and Basnett, C. B.: Preliminary Measurements of Velocity, Density and Total Temperature Fluctuations in Compressible Subsonic Flow. AIAA-83-0384, presented at the AIAA 21st Aerospace Sciences Meeting, Reno, Nevada, January 10-14, 1983.
3. Stainback, P. C.; Johnson, C. B.; Holmes, B. J.; Obara, C. J.; Carraway, D. L.; et al.: Flow Diagnostics and Visualization in Wind Tunnels and Flight. NASA CP 2397, Volume I, presented at the Langley Symposium on Aerodynamics, April 1985.
4. Johnson, C. B.; Johnson, W. G., Jr.; and Stainback, P. C.: A Summary of Reynolds Number Effects On Some Recent Tests in the Langley 0.3-Meter Transonic Cryogenic Tunnel. SAE Technical paper 861765, presented at Aerospace Technology Conference and Exposition, Long Beach, California, October 13-16, 1986.
5. Lynch, F. T.; and Patel, D. R.: Some Important New Instrumentation Needs and Testing Requirements for Testing in a Cryogenic Wind Tunnel Such as the NTF. AIAA-82-0605, presented at the AIAA 12th Aerodynamic Testing Conference, Williamsburg, Virginia, March 22-24, 1982.
6. Fancher, M. F.: Aspects of Cryogenic Wind Tunnel Testing Technology at Douglas. AIAA-82-0606, presented at the AIAA 12th Aerodynamic Testing Conference, Williamsburg, Virginia, March 22-24, 1982.
7. Bobbitt, P. J.; Waggoner, E. G.; Harvey, W. D.; and Dagenhart, J. R.: A Faster ''Transition'' to Laminar Flow. SAE Technical Paper 851855, presented at the Aerospace Technology Conference and Exposition, Long Beach, California, October 14-17, 1985.
8. Johnson, C. B.; Carraway, D. L.; Stainback, P. C.; and Fancher, M. F.: A Transition Detection Study Using a Cryogenic Hot Film System in the Langley 0.3-Meter Transonic Cryogenic Tunnel. AIAA-87-0049, presented at the AIAA 25th Aerospace Sciences Meeting, Reno, Nevada, January 12-15, 1987.
9. Johnson, C. B.; Carraway, D. L.; Hopson, P., Jr.; and Tran, S. Q.: Status of a Specialized Boundary Layer Transition Detection System for Use in the U.S. National Transonic Facility. Presented at the 12th International Congress on Instrumentation in Aerospace Simulation Facilities, Williamsburg, Virginia, June 22-25, 1987.
10. Stack, J. P.; Mangalam, S. M.; and Berry, S. A.: A Nonintrusive Study of Laminar Separation Bubble Using Surface-Film Gages. AIAA-87-1271, presented at the AIAA 19th Fluid Dynamics, Plasma Dynamics, and Lasers Conference, Honolulu, Hawaii, June 8-10, 1987.
11. Azzazy, M.; Modarress, D.; and Trolinger, J. D.: Feasibility Study of Optical Boundary Layer Transition Detection Method. NASA CR-178109, June 1986.
12. Meyers, James F.; and Hepner, Timothy E.: Velocity Vector Analysis of a Juncture Flow Using a Three Component Laser Velocimeter. Presented at the Second International Symposium on Applications of Laser Anemometry to Fluid Mechanics, Lisbon, Portugal, July 2-4, 1984.
13. Scheiman, J.; and Kubendran, L. R.: Juncture Flow Measurements Using Laser Velocimetry. AIAA-85-1612, presented at the AIAA 18th Fluid Dynamics and Plasmadynamics and Lasers Conference, Cincinnati, Ohio, July 16-18, 1985.

14. Scheiman, J.; and Kubendran, L. R.: "LDV Seeding System for the Langley Low Turbulence Pressure Tunnel," in NASA CP-2393, presented at the Workshop on Wind Tunnel Seeding Systems for Laser Velocimeters, NASA Langley Research Center, Hampton, Virginia, March 1985.
15. Jones, G. S.; Gartrell, L. R.; Sewall, W. G.; and Stainback, P. C.: Designing Transonic Wind Tunnels for Flow Diagnostics and Laser Velocimeter Applications. AIAA-87-1434, presented at the AIAA 19th Fluid Dynamics, Plasma Dynamics, and Lasers Conference, Honolulu, Hawaii, June 8-10, 1987.
16. Vakili, A. D.; and Wu, J. M.: A New Instrument for Direct Measurement of Wall Shear Stress. Proceedings of the 28th International Instrumentation Symposium, Instrument Society of America Proceedings, vol. 19, part 1, pp. 147-152, May 1982.
17. Vakili, A. D.; and Wu, J. M.: Development of a New Instrument for Direct Skin Friction Measurements. NASA CR 176818, March 1986.
18. Vakili, A. D.; Wu., J. M.; and Lawing P. L.: Wall Shear Stress Measurements Using a New Transducer. AIAA-86-1092, presented at the AIAA/ASME 4th Joint Fluid Mechanics and Plasma Dynamics and Laser Conference, Atlanta, Georgia, May 12-14, 1986.
19. Snow, Walter L.; Burner, Alpheus W.; and Goad, William K.: Improvement in the Quality of Flow Visualization in the Langley 0.3-Meter Transonic Cryogenic Tunnel. NASA TM 87730, 1986.
20. Stainback, P. C.: A Review of Hot Wire Anemometry In Transonic Flows. ICIASF 85 Record, Stanford, California, pp. 67-78.
21. Stainback, P. C.: Some Influences of Approximate Values for Velocity, Density, and Total Temperature Sensitivities on Hot Wire Anemometer Results. AIAA-86-0506, presented at the AIAA 24th Aerospace Sciences Meeting, Reno, Nevada, January 6-9, 1986.
22. Rose, W. C.; and Otten, L. J., III: Airborne Measurement of Atmospheric Turbulence. Presented at the USAF/NASA Aero-Optics Synposium, NASA Ames Research Center, California, August 14-15, 1979.
23. Otten, L. J., III; Pavel, A. L.; Finley, W. E.; and Rose, W. C.: A Survey of Recent Atmospheric Turbulence Measurements from a Subsonic Aircraft. AIAA-81-0298, presented at the AIAA 19th Aerospace Sciences Meeting, St. Louis, Missouri, January 12-15, 1981.
24. Ehernberger, L. J.: The YF-12 Gust Velocity Measuring System. NASA Conference Publication 2054 - Volume 1, presented at YF-12 Experiments Symposium, Dryden Flight Research Center, Edwards, California, September 13-15, 1978.
25. Nagel, A. L.: Aerodynamic Research Applications at Boeing. In: Internal Council of the Aeronautical Sciences, Congress, 13th and AIAA Aircraft Systems and Technology Conference, Seattle, Washington, August 22-27, 1982, Proceedings, volume 2, pp. 1235-1242.
26. Fancher, M. F. A Transonic Cryogenic Wind Tunnel Test of a Supercritical Airfoil Model. Background and Progress. AIAA-80-0418, presented at the AIAA 11th Aerodynamic Testing Conference, Colorado Springs, Colorado, March 1980.
27. Fancher, M. F.: A Hot-Film System for Boundary-Layer Transition Detection in Cryogenic Wind Tunnels, presented to Euromech Colloquium 142 on Hot-Wire, Hot-Film Anemometry and Condition Measurement, July 1980.
28. Schlichting, Hermann: Boundary Layer Theory. McGraw-Hill, 1960.
29. Viken, J. K.: Aerodynamic Design Considerations and Theoretical Results for a High Reynolds Number Natural Laminar Flow Airfoil. M.S. Thesis, George Washington University, January 1983.
30. Srokowski, A. J.; and Orszag, S. A.: Mass Flow Requirements for LFC Wing Design. AIAA-77-1222, August 1977.

31. Owen, F. K.: Transition Experiments on a Flat Plate at Subsonic and Supersonic Speeds. AIAA-69-9 presented at the AIAA 7th Aerospace Sciences Meeting, New York, January 20-22, 1969.
32. McGhee, R. J.; Viken, J. K.; Pfenninger, W.; Beasley, W. D.; and Harvey, W. D.: Experimental Results for a Flapped Natural-Laminar-Flow Airfoil with High Lift/Drag Ratio. NASA TM-85788, May 1984.
33. Stainback, P. C.; McGhee, R. J.; Beasley, W. D.; and Morgan, H. L., Jr.: The Langley Research Center's Low Turbulence Pressure Tunnel. AIAA-86-0762, presented at the AIAA 14th Aerodynamic Testing Conference, West Palm Beach, Florida, March 5-7, 1986.
34. Klebanoff, P. S.: Characteristics of Turbulence in a Boundary Layer with Zero Pressure Gradient, NACA Report 1247, 1955.
35. Braden, J. A.; Whipkey, R. R.; Jones, G. S.; and Lilley, D. E.: Experimental Study of the Separating Confluent Boundary-Layer -- Volume II - Experimental Data. NASA Contractor Report 166018, March 1983.
36. Braden, J. A.; Whipkey, R. R.; Jones, G. S.; and Lilley, D. E.: Experimental Study of the Separating Confluent Boundary-Layer -- Volume I - Summary. NASA Contractor Report 3655, June 1983.
37. Allen, Jerry M.: Systematic Study of Error Sources In Supersonic Skin-friction Balance Measurements. NASA TN D-8291, October 1976.
38. Allen, Jerry M.: An Improved Sensing Element for Skin-friction Balance Measurements. AIAA-80-0049 presented at the AIAA 18th Aerospace Sciences Meeting, Pasadena, California, January 14-16, 1980.
39. Allen, Jerry M.: Evaluation of Compressible-flow Preston Tube Calibrations. NASA TN D-7190, May 1973.
40. White, Frank M.: Fluid Mechanics, McGraw-Hill Book Company, 1974.
41. Burner, A. W.; and Goad, W. K.: Flow Visualization in a Cryogenic Wind Tunnel Using Holography. NASA TM-84556, 1982.
42. Rhodes, D. B.; and Jones, S. B.: Flow Visualization in the Langley 0.3-Meter Transonic Cryogenic Tunnel and Preliminary Plans for the National Transonic Facility. Flow Visualization and Laser Velocimetry for Wind Tunnels, NASA CP-2243, 1982, pp. 117-132.
43. Snow, W. L.; Burner, A. W.; and Goad, W. K.: Image Degradation in Langley 0.3-Meter Transonic Cryogenic Tunnel. NASA TM-84550, 1982.