WL-TM-93-300

OPTICALLY SMART SURFACES SURVIVABILITY TESTING AT MACH 3

Linda G. Smith
Glenn W. Williams

January 1993

Approved for public release; distribution is unlimited

WL/FIME, Bldg 24C
2145 Fifth St, Ste 1
Flight Dynamics Directorate
Wright Laboratory
Air Force Materiel Command
Wright-Patterson Air Force Base, Ohio 45433-7005

NOTICE

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely Government-related procurement, the United States Government incurs no responsibility or any obligation whatsoever. The fact that the government may have formulated or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication, or otherwise in any manner construed, as licensing the holder, or any other person or corporation; or as conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

This report is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nationals.

This technical memo has been reviewed and is approved for publication.

Linda G Smith
LINDA G. SMITH
Aerospace Engineer
Experimental Facilities Research Branch

GEORGE L. SEIBERT, Chief
Experimental Facilities Research Branch
Aeromechanics Division

David R Selegan
DAVID R. SELEGAN, Chief
Aeromechanics Division
Flight Dynamics Directorate

If your address has changed, if you wish to be removed from our mailing list, or if the addressee is not longer employed by your organization please notify Linda Smith, WPAFB, OH 45433-7005 to help us maintain a current mailing list.

Copies of this report should not be returned unless return is required by security considerations, contractual obligations, or notice on a specific document.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
Jan 93

3. REPORT TYPE AND DATES COVERED
Final

4. TITLE AND SUBTITLE
Optically Smart Surfaces Survivability Testing at Mach 3

5. FUNDING NUMBERS
30054118

6. AUTHOR(S)
Linda G. Smith, Glenn W. Williams

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Flight Dynamics Directorate, WL, AFMC
WL/FIME
WPAFB OH 45433-7005

8. PERFORMING ORGANIZATION REPORT NUMBER
WL-TM-93-300

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for Public Release; Distribution is Unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Optically smart surfaces are being developed as wind tunnel diagnostic techniques for the Wright Laboratory. The optically smart surfaces are holographic optical elements constructed by flow coating an aluminum plate with photoresist as the emulsion material. Survivability of these optically smart surfaces was tested in the Mach 3 High Reynolds Number Facility. The surfaces did not survive at angle of attack to the freestream flow for higher Reynolds numbers and did survive when the surface was parallel to the freestream flow.

14. SUBJECT TERMS
Holographic Optical Elements, Wind Tunnel Test, Survivability

15. NUMBER OF PAGES
9

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

NSN 7540-01-280-5500

Standard Form 298 (Rev 2-89)
Prescribed by ANSI Std Z39-18
298-102

ABSTRACT

Optically smart surfaces are being developed as wind tunnel diagnostic techniques for the Wright Laboratory. The optically smart surfaces are holographic optical elements constructed by flow coating an aluminum plate with photoresist as the emulsion material. Survivability of these optically smart surfaces was tested in the Mach 3 High Reynolds Number Facility. The surfaces did not survive at angle of attack to the freestream flow for higher Reynolds numbers and did survive when the surface was parallel to the freestream flow.

PREFACE AND ACKNOWLEDGEMENTS

Optically Smart Surfaces for Wind Tunnel Testing is a Small Business Innovative Research (SBIR) Phase II contract that the Aero-Diagnostics Research Section, Experimental Facilities Research Branch, Aeromechanics Division, Flight Dynamics Directorate, Wright Laboratory has with MetroLaser of Irvine, California. This contract requires MetroLaser to develop optically smart sensors for laser velocimetry and boundary layer transition detection that will be demonstrated in a Aeromechanics Division wind tunnel. Due to tunnel scheduling constraints and optical accessibility in the Mach 3 High Reynolds Number Facility a decision was made to test in the Mach 3 HRNF. The question of survivability of optically smart surfaces in the facility needed to be answered early in sensor development so that methods could be changed early if necessary. The Aero-Diagnostics Research Section designed and built a simple wedge model that two optically smart surface plates could be screwed onto for survivability testing. This report is the result of this testing.

Design of the wedge model was completed by Hsue-Fu Lee. The authors wish to acknowledge the facility support provided by Max Hillsamer, Tom Norris, Rick Allen, SSgt John Williams, and Joe Scheuring. Mr. Ed Fields of the Technical Photo Division provided superb support in photographing the model and smart surfaces. Dr. James Trolinger, Dr. James Millerd, and Mr. Fred Unterseher are the principle players in the project at MetroLaser.

INTRODUCTION

Optically Smart Surfaces for Wind Tunnel Testing is a program for development of the technology to embed holographic optical elements on the surface of a wind tunnel model which will be used for laser velocimetry, strain, or boundary-layer transition detection. Further details on this technology have been reported by Trolinger and Rosenthal (1992a and 1992b). A holographic optical element is a hologram that is used to simulate a conventional optical element. The emulsion used on the aluminum plates was photoresist as described by Trolinger and Rosenthal (1992a).

However, if optically smart surfaces are to be utilized in supersonic high-Reynolds number flows, the emulsion they are constructed on must be able to survive the harsh environments that can be encountered in these facilities. Hence, the purpose of these survivability tests was to determine if photoresist could withstand the environment of the Mach 3 High Reynolds Number Facility (HRNF) at the Wright Laboratory.

TEST DESCRIPTION AND RESULTS

The optically smart surfaces wedge shown in Figs. 1 and 2 was tested in the Wright Laboratory Mach 3 HRNF. The 15 degree wedge was designed with two indented areas for mounting 4 inch by 5 inch aluminum plates with optically smart surfaces. The plates are mounted such that one plate is parallel to the freestream velocity and the other plate is mounted at a 15 degree angle of attack relative to the freestream velocity. Operating conditions for the Mach 3 HRNF were published by Fiore, et al (1975).

For this set of experiments the tunnel was operated at stagnation pressures of 85, 150, and 300 psia which corresponds to a Reynolds number range of 14.9 to 52.6 million/ft at a stagnation temperature of 500°R. The static temperature at these conditions is around 150°R and thus the tunnel and model begin collecting frost upon tunnel shutdown. A summary of the test runs and their conditions is shown in Table I. It should be noted that for run 1 the tunnel had not been operated for a period of approximately 12 months and a thin layer of rust had formed of the tunnel sidewalls. This resulted in the first run having a large content of abrasive particles present in the freestream flowfield. This was considered the worst case scenario that might be encountered by the optically smart surfaces. The holographic optical elements on the optically smart surfaces prior to wind tunnel exposure are shown in Fig. 3.

During run 1, the optically smart surfaces parallel to the freestream flow survived the abrasive flowfield satisfactorily. However, the surface at the 15 degree angle of attack was essentially sand-blasted to the base aluminum surface in a period of approximately 2 seconds. The streamlines for 3.6 μm alcohol particles over a 10 degree half-angle wedge in the Mach 3 facility as computed by Maurice (1992) are shown in Fig. 4. It is believed that the particles impinging on the optically smart surfaces were on the order of 10 μm in diameter and thus would impact the model further from the leading edge and be entrained in the boundary layer.

Prior to the second run, the model was heated to the point where water vapor was no longer freezing on the model surface and the plate that survived run 1 was moved to the 15° angle of attack position for the remaining runs. Run 2 was begun at a stagnation pressure of 85 psia for 45 seconds. Little or no visible deterioration of the smart surfaces took place at that condition. Then the tunnel stagnation pressure was increased on-line to 150 psia and held at that condition for approximately 30 seconds. Again no visible deterioration took place. Finally, the stagnation pressure was increased to 300 psia. At this condition the surface began deteriorating immediately and after 15 seconds the surface had been essentially sand-blasted to the base aluminum.

Table I: Test Conditions

Run No.	Plate	Plate Angle of Attack (degrees)	Stagnation Pressure (psia)	Reynolds Number	Run Duration (seconds)
1	1	15	150	26.3×10^6/ft	55
1	2	0	150	26.3×10^6/ft	55
2a	2	15	85	14.9×10^6/ft	45
2b	2	15	150	26.3×10^6/ft	30
2c	2	15	300	52.6×10^6/ft	15

CONCLUSIONS AND RECOMMENDATIONS

The conclusion of this series of testing is that the survivability of holograms in the Mach 3 facility depends upon the Reynolds number and the angle of attack. The optically smart surface holograms survive at 0° angle of attack for Reynolds numbers up to at least 26.3×10^6/ft and additional testing would be required to determine if they survive at higher Reynolds numbers. However, it is the opinion of the authors that the specific type of surfaces tested would survive at any Reynolds number at 0° angle of attack . At 15° angle of attack, these surfaces survived the "clean" flow up to Reynolds number of 26.3×10^6/ft. At higher Reynolds numbers the particle impingement on the surface essentially sand blasted these surfaces making them unusable for measurements. These particular surfaces at angle of attack will not survive the "dirty" flowfield of a wind tunnel that has not been operated for any significant period of time.

The results of these tests lead to the recommendations that this optically smart surface material would only be usable in high-Reynolds-number flowfields at 0° angle of attack . In the interest of demonstrating the functionality of optically smart surfaces, it is recommended that initial testing at the Wright Laboratory take place in the Trisonic Gasdynamics Facility at a Mach number in the range 0.3-0.8. Additional research and development of rugged optically smart surfaces will continue.

REFERENCES

Fiore, A.W., Moore, D.G., Murray, D.H., and West, J.E., 1975, "Design and Calibration of the ARL Mach 3 High Reynolds Number Facility," Aerospace Research Laboratories, ARL TR 75-0012, January 1975.

Maurice, M.S., 1992, "A Method to Quantify and Correct Particle Velocity Bias in Laser Velocimetry Measurements," AIAA Paper 92-0764, January 1992.

Trolinger, J.D. and Rosenthal, D.M., 1992a, "Optically Smart Surfaces for Wind Tunnel Measurements," Wright Laboratory Technical Report, WL-TR-92-3037, Wright-Patterson Air Force Base, April 1992.

Trolinger, J.D. and Rosenthal, D.M., 1992b, "Optically Smart Surfaces For Aerodynamic Measurements," AIAA Paper 92-3895, July 1992.

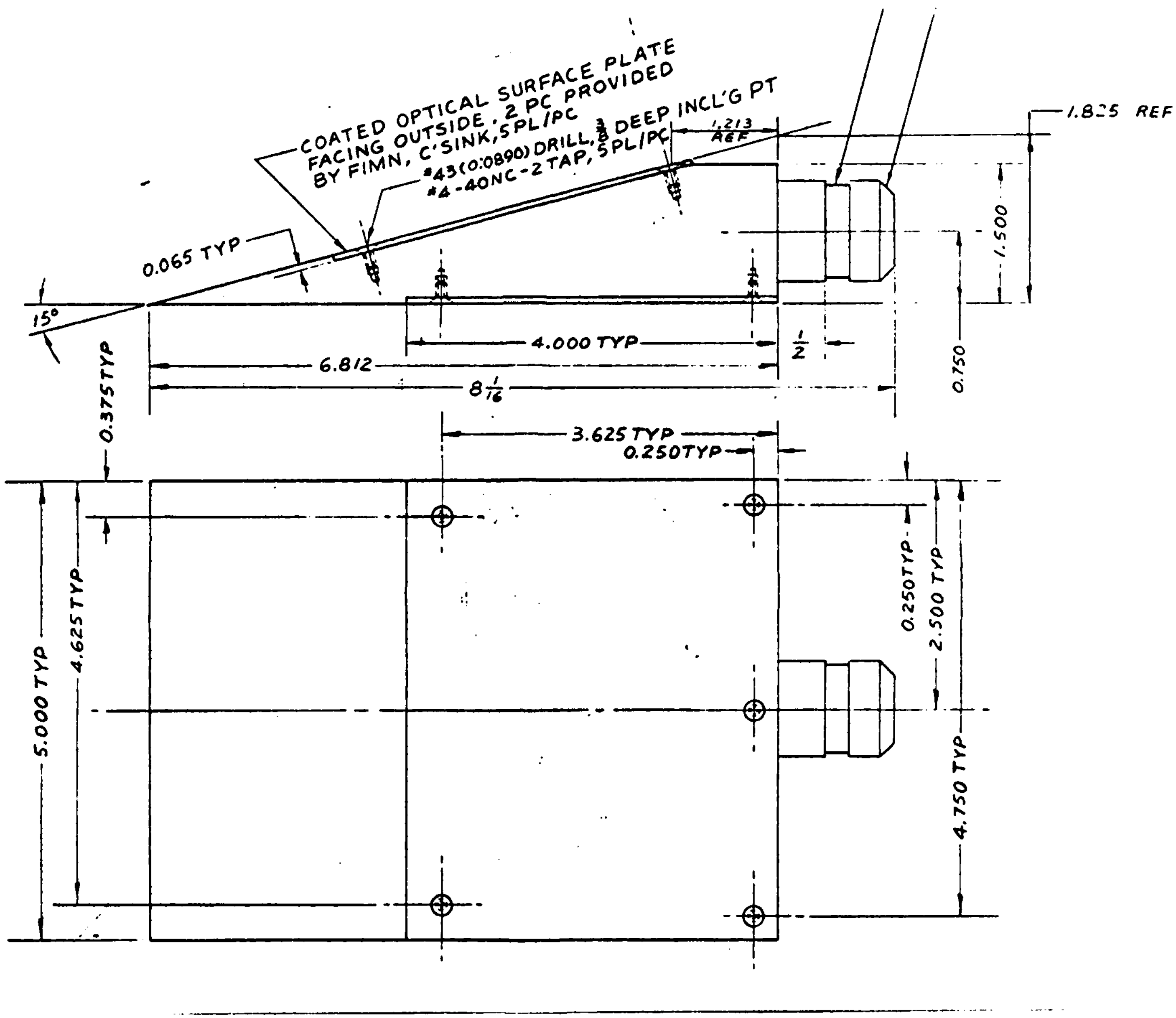

Fig. 1. Optically Smart Surfaces Wedge Technical Drawing.

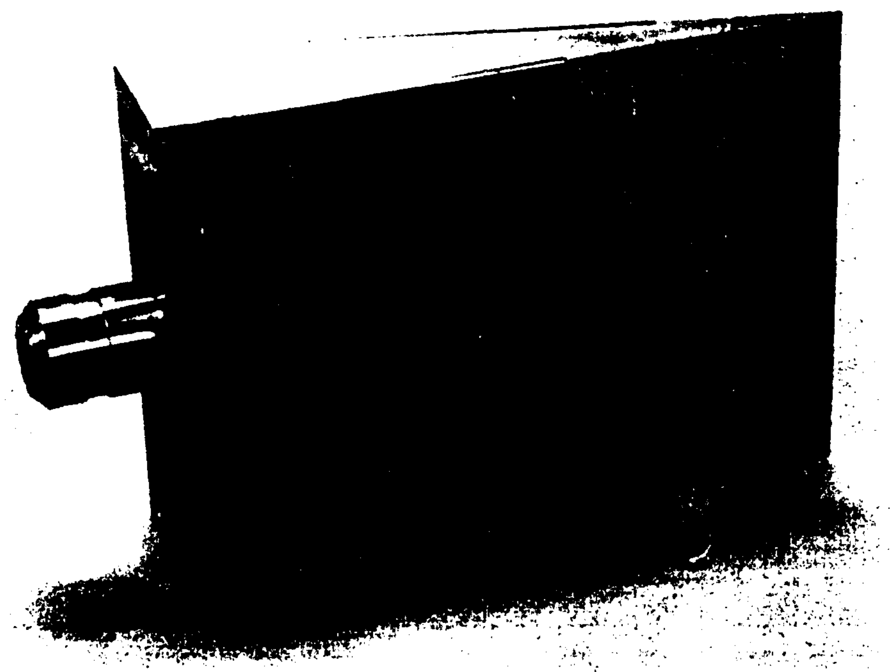

Fig. 2. Optically Smart Surfaces Wedge.

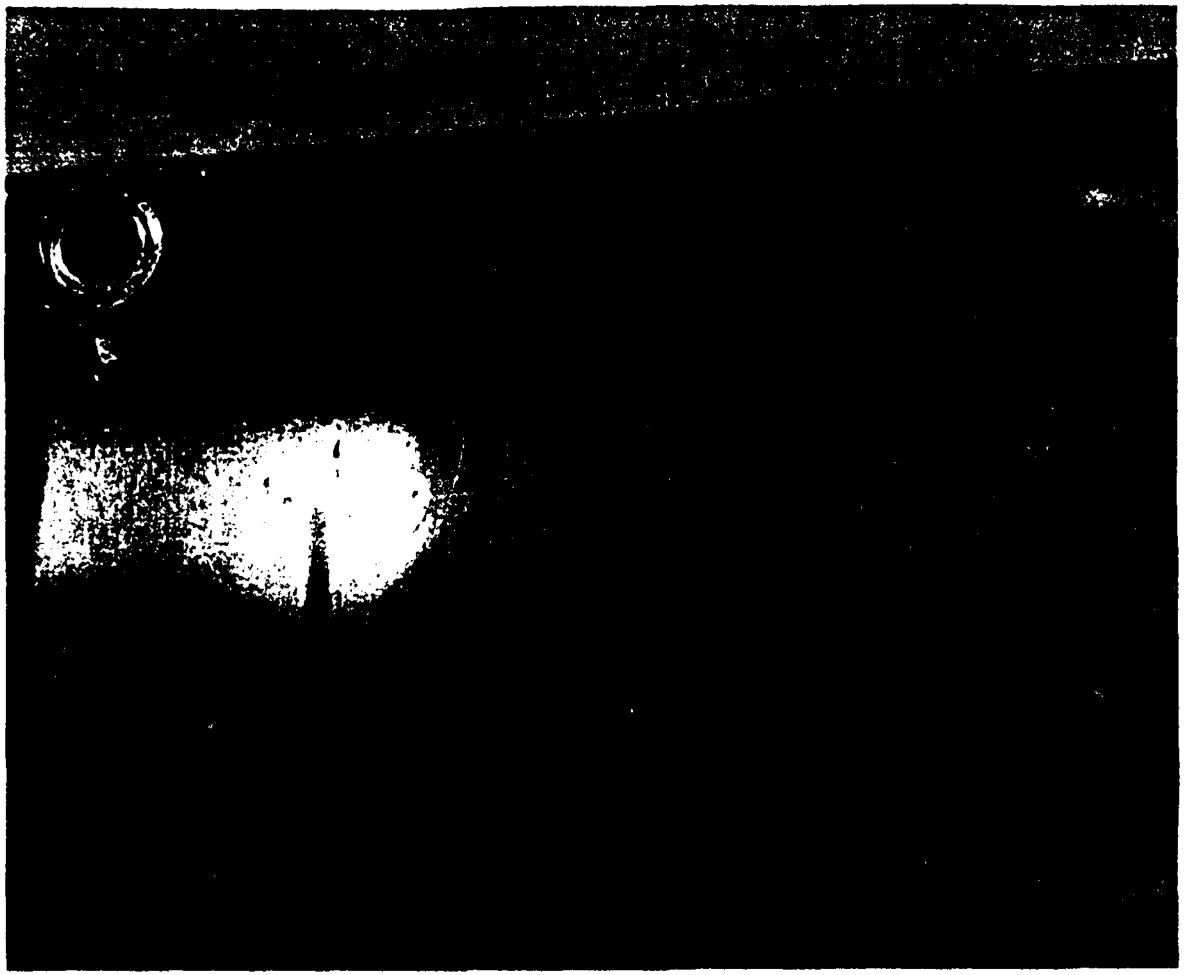

Fig. 3. Optically Smart Surfaces Prior to Wind Tunnel Testing.

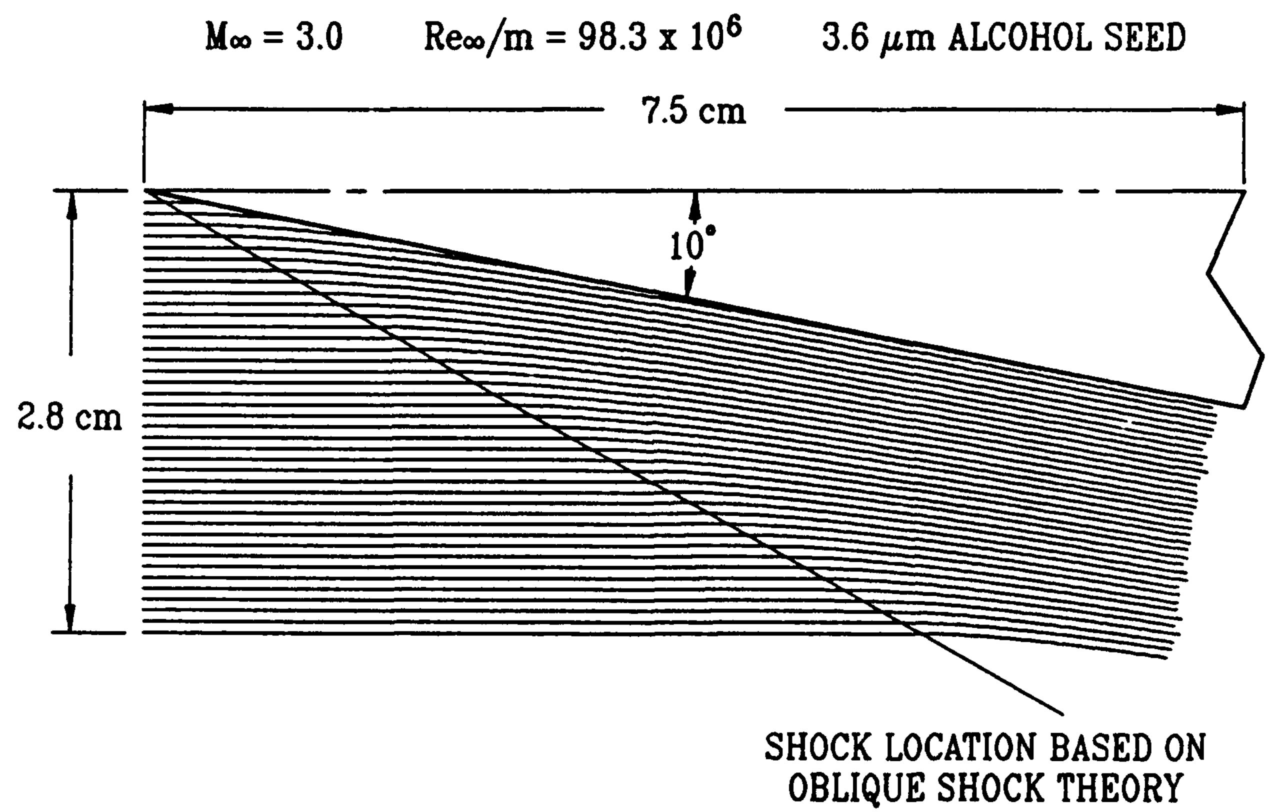

Fig. 4. Particle Streamlines on a 10° Half-Angle Wedge at Mach 3.