

# Afterbody Pressure Correlations for Vehicles with Ablated Nose Shapes

Frank J. Barbera\*

Kaman Sciences Corporation, Colorado Springs, Colo.

## Abstract

A CORRELATION method is presented for determining the afterbody pressure distributions over the conical afterbodies of slender re-entry vehicles at small angles of attack that have been severely ablated or eroded in the nosetip region. The technique utilizes flowfield solutions for the pressure distributions over symmetrical sphere-cone re-entry vehicles at zero angle of attack. The method is shown to reduce the afterbody pressure data obtained using seven distinctly different nosetip configurations to a single correlation curve.

## Contents

A comprehensive wind tunnel test program to obtain pressure distribution data was conducted at  $M_\infty = 8$  in tunnel B at the Arnold Engineering Test Center, Arnold Air Force Station, Tenn. The baseline sphere-cone model which was tested was a 6.7-deg half-angle conical afterbody with a bluntness ratio ( $R_N/R_B$ ) of 0.227. The seven nose configurations shown in Fig. 1 were tested and the nose attachment plane was located at body station  $X/L = 0.173$ .

The pressure data from the present experiments were correlated using the axial distance parameter ( $C_P/\sqrt{C_{AN}} \cdot X_s/D_N$ ) suggested by Mirels and Thornton<sup>1</sup> and a pressure parameter,  $C_P/C_{PC}$  where  $C_{PC}$  is the sharp cone pressure,  $D_N$  is the diameter of the nose,  $C_{AN}$  is the nose axial force coefficient referenced to the nose base area, and  $X_s$  is the axial distance from the nosetip sonic point.

The experimental pressure data for each of the ablated nosetips is correlated against the spherical nosetip data in Fig. 2, using the modified distance parameter. The pressure parameter was not utilized in this exercise since experimental data were available for only one cone angle.

It can be seen from the plot that the axial distance correlation parameter has quite effectively collapsed the afterbody pressure data that were obtained with rather diverse nose shapes to the correlation curve obtained for the spherical nose. The pressures in the region less than one nose diameter from the nosetip are not well correlated.

The experimental results previously presented clearly indicate that reasonable afterbody pressure distributions for vehicles with severely ablated nosetips can be obtained from sphere-cone pressure distributions.

The  $\alpha = 0$  pressure distribution along the length of a sphere-cone re-entry vehicle with a cone half-angle of 6.7 deg was calculated for  $M_\infty = 8$ , using the Rakich<sup>2</sup> method of characteristics solution, out to a distance of 160 nose radii

Presented as Paper 80-0312 at the AIAA 18th Aerospace Sciences Meeting, Pasadena, Calif., Jan. 14-16, 1980; submitted Jan. 18, 1980; Synoptic received May 6, 1980. Copyright © American Institute of Aeronautics and Astronautics, Inc., 1979. All rights reserved. Full paper available from AIAA Library, 555 W. 57th St., New York, N.Y. 10019. Price: microfiche, \$3.00; hard copy, \$7.00. Remittance must accompany order.

Index categories: Computational Methods; Supersonic and Hypersonic Flow.

\*Manager, Aerothermal Support Group. Member AIAA.

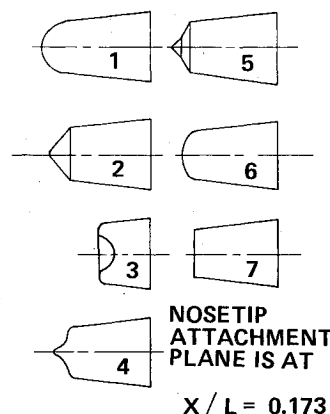


Fig. 1 Nosetip configurations tested.

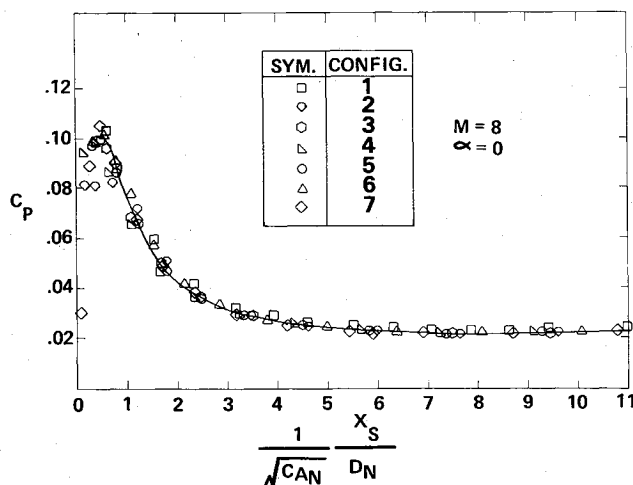


Fig. 2 Correlation curve for test data.

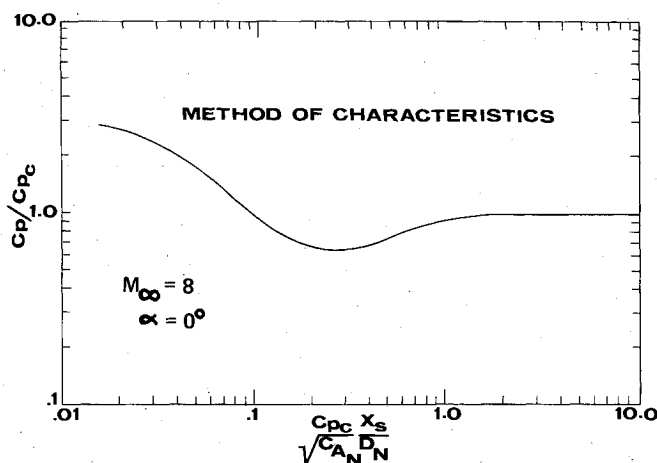


Fig. 3 Theoretical pressure correlation curve.

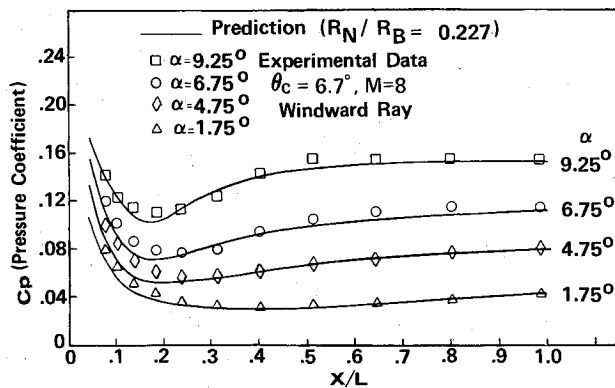


Fig. 4 Comparison of theoretical and experimental pressure distributions.

from the stagnation point. The resulting pressures were normalized by the sharp cone pressure and plotted against the axial distance parameter. The correlation results are presented in Fig. 3.

Pressures along any conical ray of a blunt vehicle at a small angle of attack and at  $M_\infty = 8$  can be obtained using the tangent cone concept and the correlation curve of Fig. 3. The tangent cone is determined using the following relationship:

$$\theta_{TC} = \sin^{-1} (\sin \theta_c \cos \alpha + \cos \theta_c \sin \alpha \cos \phi)$$

where  $\phi$  is the circumferential angle measured from the windward ray,  $\alpha$  is the angle of attack, and  $\theta_c$  is the vehicle cone half-angle.

The method now assumes that there is a new vehicle at  $\alpha = 0$  with an afterbody cone angle of  $\theta_{TC}$ .  $X_s$  is measured from the new sonic point,  $C_{AN}$  is the new nose drag, and  $C_{Pc}$  is for the new cone angle.

A comparison of theoretical and experimental data for the windward ray pressure distribution on a 6.7-deg cone at angles of attack up to 9.25 deg is shown in Fig. 4. The agreement is excellent at all the angles of attack.

The generalized solution presented in this paper can be used to estimate the pressure distributions over slender conical re-entry vehicles at small angles of attack with either spherical or nonspherical nostips. The results compare very well with experimental data except in the region within one nose diameter aft of the nosetip. The nosetip drag must be known to use the method effectively. The method is ideally suited for use in trajectory codes which are attempting to couple the shape change taking place in a severe ablation or erosion environment with the trajectory that is being numerically integrated.

### References

- <sup>1</sup>Mirels, H. and Thornton, P.R., "Effect of Body Perturbations on Hypersonic Flow Over Power Low Bodies," NASA TR R-45, 1959.
- <sup>2</sup>Rakich, J.V., "A Method of Characteristics For Three-Dimensional Supersonic Flow with Applications to Inclined Bodies of Revolution," NASA TN D-5341, 1969.

*From the AIAA Progress in Astronautics and Aeronautics Series...*

## ENTRY HEATING AND THERMAL PROTECTION—v. 69

## HEAT TRANSFER, THERMAL CONTROL, AND HEAT PIPES—v. 70

*Edited by Walter B. Olstad, NASA Headquarters*

The era of space exploration and utilization that we are witnessing today could not have become reality without a host of evolutionary and even revolutionary advances in many technical areas. Thermophysics is certainly no exception. In fact, the interdisciplinary field of thermophysics plays a significant role in the life cycle of all space missions from launch, through operation in the space environment, to entry into the atmosphere of Earth or one of Earth's planetary neighbors. Thermal control has been and remains a prime design concern for all spacecraft. Although many noteworthy advances in thermal control technology can be cited, such as advanced thermal coatings, louvered space radiators, low-temperature phase-change material packages, heat pipes and thermal diodes, and computational thermal analysis techniques, new and more challenging problems continue to arise. The prospects are for increased, not diminished, demands on the skill and ingenuity of the thermal control engineer and for continued advancement in those fundamental discipline areas upon which he relies. It is hoped that these volumes will be useful references for those working in these fields who may wish to bring themselves up-to-date in the applications to spacecraft and a guide and inspiration to those who, in the future, will be faced with new and, as yet, unknown design challenges.

Volume 69—361 pp., 6×9, illus., \$22.00 Mem., \$37.50 List  
Volume 70—393 pp., 6×9, illus., \$22.00 Mem., \$37.50 List

TO ORDER WRITE: Publications Dept., AIAA, 1290 Avenue of the Americas, New York, N.Y. 10104