# Hypersonic Flow Field around a Hemisphere in a $CO_2$-$N_2$-A Gas Mixture

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PRESENTED here are sample solutions of the subsonic-transonic flow region around a hemispherical cap moving at hypersonic speeds through atmospheres consisting of carbon dioxide, nitrogen, and argon These data are preliminary results of a systematic effort to develop equilibrium solutions for blunted axially symmetric or two-dimensional bodies at supersonic speeds in any arbitrarily specified mixture of $CO_2$-$N_2$-A The particular atmosphere chosen for this presentation is 0 5$CO_2$-0 25$N_2$-0 25A, considered as being representative of those atmospheres now being considered for Mars Constant temperature, pressure, and radiation intensity lines are mapped in the shock layer for a typical case; shock shape and surface pressure distribution correlations are presented; and shock standoff distance is compared with available hypersonic approximations

In order to assess adequately the capabilities of space vehicles designed to penetrate the atmospheres of Mars and Venus, it is necessary to define as accurately as possible the aerothermodynamic environment likely to be encountered during such missions Also, in view of the existing uncertainties concerning the character of planetary atmospheres, it is necessary to be able to define the environment for as broad a range of ambient conditions (i e , composition, density, velocity, etc ) as possible

To fulfill these requirements, it is necessary to resort to numerical techniques and digital computer methods; indeed, it is necessary to make use of a system of computer programs Such a system, now under development, will ultimately provide aerothermodynamic environment data for any desired configuration at any desired ambient condition At the present time, the system development has progressed to the point of providing equilibrium solutions for blunted axially symmetric or two-dimensional bodies, traveling at supersonic or hypersonic speeds in any $CO_2$-$N_2$-A gas mixture desired

The current system consists of two programs: a blunt-body flow-field program and a thermodynamic and radiation properties program The flow-field program was originally written for flow in air,[1] based on the inverse method [2,3] Modification of the flow-field program was carried out so that tabular inputs of equilibrium thermodynamic and radiative properties of a general atmosphere can be used instead of the specialized air subroutines Thermodynamic and radiative property tables are obtained from the second program This program[4] provides the equilibrium chemical radiative emissivities of arbitrarily specified carbon dioxide-nitrogen-argon mixtures The chemical state is obtained by the minimization of the Gibbs free energy (based on the first method of Ref 5), whereas emissivity per unit length per particle is calculated from the data in Ref 6 Therefore, optically thin radiation coupling is included

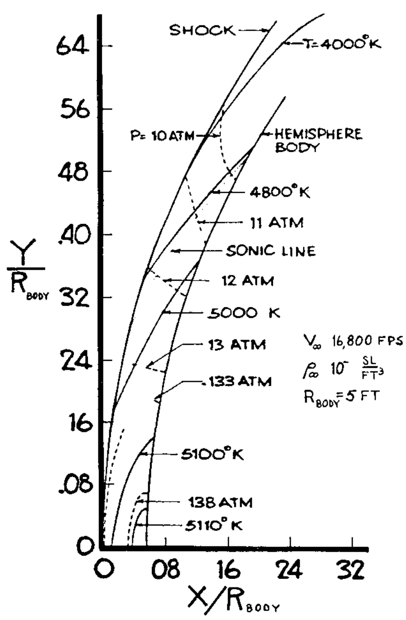


**Fig 1 Hypersonic shock layer in 0 5$CO_2$-0 25$N_2$-0 25A, constant temperature and pressure lines**

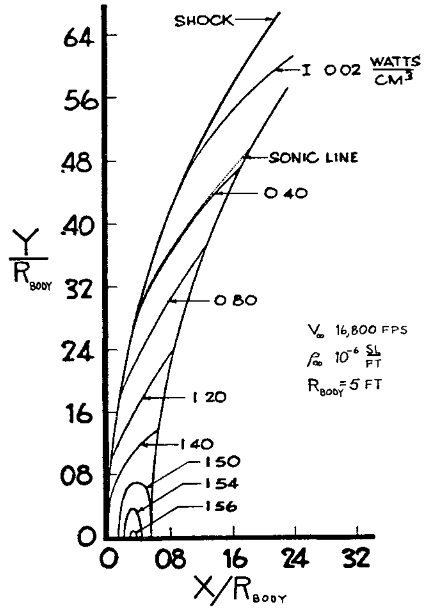


**Fig 2 Hypersonic shock layer in 0 5$CO_2$-0 25$N_2$-0 25A, constant emission lines**

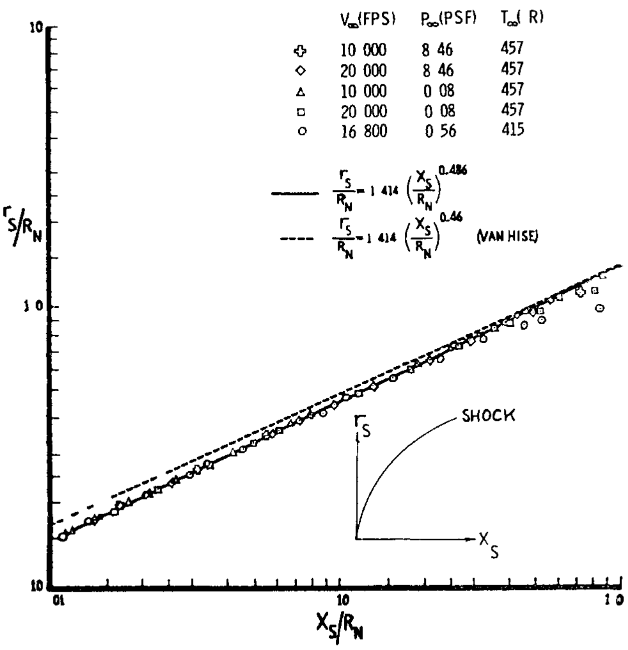


**Fig 3 Hypersonic bow shock correlation in 0 5$CO_2$-0 25$N_2$ 0 25A**

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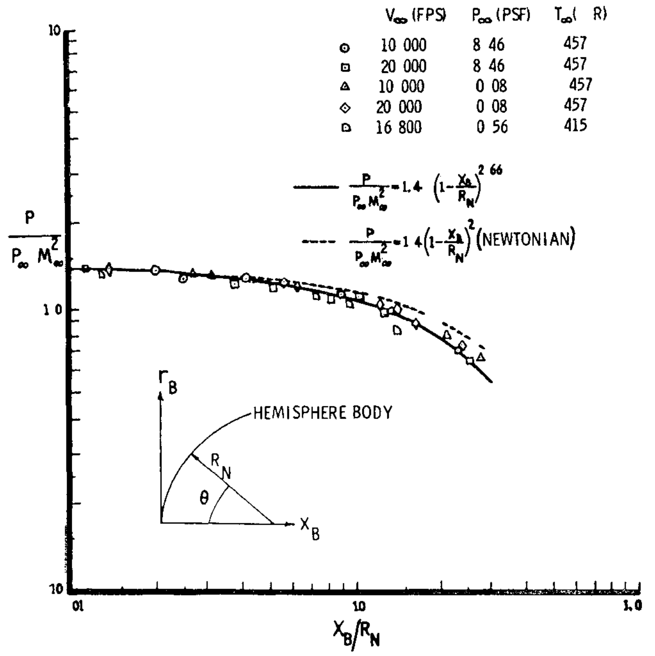


**Fig 4 Hypersonic surface pressure distribution correlation in 0 5$CO_2$-0 25$N_2$-0 25A**

For a particular Mars entry situation, typical of those currently being considered, the shock layer is presented in Figs 1 and 2 It is interesting to note that a radiation intensity peak occurs between the shock wave and the body Several cases, with various freestream velocities and densities, have been run In Fig 3, the shock-shape results from these calculations are correlated and compared with the Van Hise correlation[7] The surface pressure distributions are correlated in Fig 4 and compared with the Newtonian pressure distribution For the conditions considered here, quite good correlations are possible for the atmosphere 0 5 $CO_2$-0 25$N_2$-0 25A Some deviation is observed from the Van Hise air correlation in the case of shock shape and from the Newtonian pressure It remains to be seen what correlations are possible for other atmospheres The hypersonic approximation for shock standoff distance

$$\frac{\Delta}{R} = 1 - \frac{R_N}{R} = \frac{\epsilon}{1 + (\frac{8}{3}\epsilon)^{1/2}}$$

is plotted in Fig 5 ($R$ = shock radius, $R_N$ = body radius, $\Delta$ = standoff distance, and $\epsilon$ = density ratio across a normal shock) Results of the blunt-body calculations are also shown here As is expected, good agreement occurs for the higher velocities

More comprehensive calculations for a wide range of flight conditions and atmospheres are now being carried out and will be reported

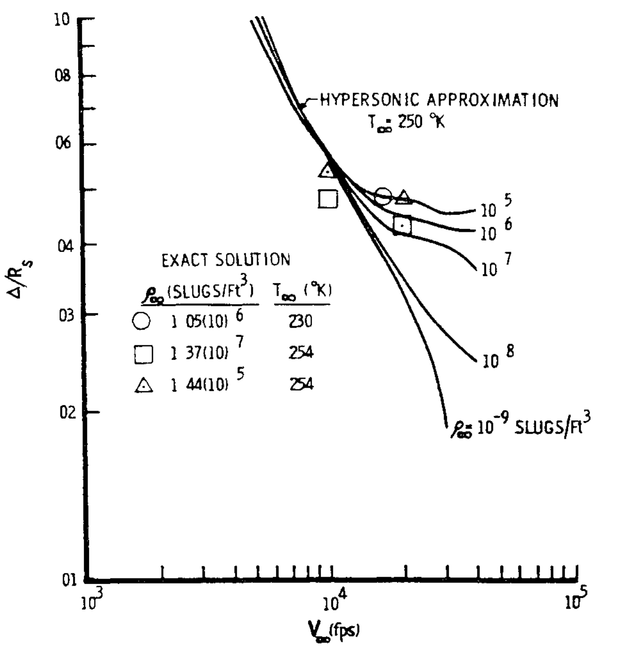


**Fig 5 Hypersonic shock standoff distance in 0 5$CO_2$-0 25$N_2$-0 25A**

## References

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# Temperature-Entropy Diagram of Monomethylhydrazine

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### Nomenclature

$C_p$ = heat capacity at constant pressure, Btu/lbm-°R
$d$ = differential operator
$\partial$ = partial differential operator
$\Delta$ = delta change in property
$H$ = enthalpy, Btu/lbm
ln = natural logarithm
$MW$ = molecular weight, lbm/lb-mole
$P$ = pressure, psia
$P_r$ = reduced pressure $P/P$
$Q$ = quality of vapor-liquid or vapor solid mixture, weight fraction vapor
$R$ = gas constant, 1 9865/$MW$, Btu/lbm-°R
$S$ = entropy, Btu/lbm-°R
$T$ = temperature °R
$T_r$ = reduced temperature $T/T$
$V$ = specific volume, ft$^3$/lbm
$Z$ = compressibility factor

*Subscripts*

1 = reference condition
2 = final condition
$c$ = critical
$f$ = fusion
$i$ = ideal gas
$l$ = liquid

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