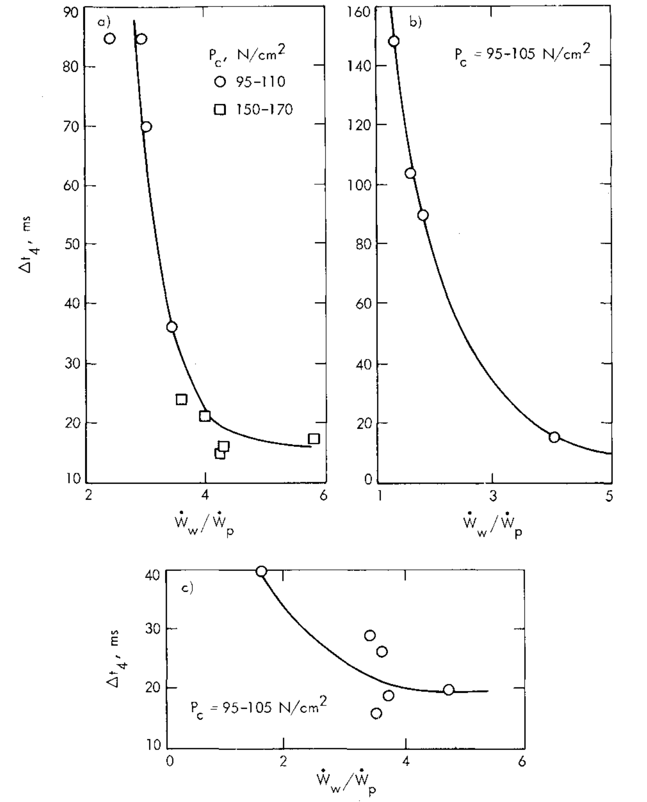

Fig. 5 Photocell inflection-point time delay Δt_4 vs $\dot{W}_w/\dot{W}_p$ for three injector types: a) overhead, solid-cone injectors; b) overhead, solid-jet injectors; and c) head-end fan spray injector.

of water flow and, for no-quenches, begin to recover 10 to 60 ms later, depending on how marginal the test was. Once initiated, quenching, as indicated by darkening of the combustion zone, took place in milliseconds. With the solid-jet injectors, darkening of the burning surface first occurred in the impingement area and then propagated outward.

On a few of the quench tests, quenching of the restricted edge was quite delayed. Also, in marginal no-quench tests, the restricter material continued to decompose and smoke, indicating that it retained its thermal energy or that some burning activity may have persisted at the propellant-restricter interface.

Summary of Results and Conclusions

Tests at $P_c = 100$ N/cm² indicated that 1) For water injection normal to the propellant surface, with a decrease in $\dot{W}_w/\dot{W}_p$, a) minimum water requirements for quench increased slightly for solid-jet and showed a marked increase with solid-cone injectors, and b) quench times increased rapidly for both systems. 2) At the low $\dot{W}_w/\dot{W}_p$ conditions, drag effects on the solid jet were probably still small in this small motor, while the solid-cone plume expansion became insufficient for good water coverage of the propellant surface, providing probable explanations for 1a above. 3) Because of the more efficient water distribution of the overhead systems, minimum water requirements were lower than those of the head-end fan spray injector at the baseline $\dot{W}_w/\dot{W}_p$ test conditions (3 to 4). 4) The measured minimum water quantities agree quite well with the results of laboratory tests[3] conducted in the same pressure range. 5) Marginal or no-quench usually occurred when the water injection time Δt_1 was less than the times from initiation of water injection to the initial drop in motor pressure Δt_2 and photocell output Δt_3. Water quantities required for quench increased with increased pressure.

Attempts to obtain a dP_c/dt quench by rapidly cooling the motor gases with an atomization injector were not successful, although only a few tests were made. Difficulties encountered in quenching at propellant-restricter interfaces could be an important consideration in the design of motors utilizing thrust termination by water injection. Similarly to the findings of Ref. 3, it is concluded that for rapid, positive quenches, $\dot{W}_w/\dot{W}_p$ should not be less than 4 to 5.

It is concluded, from the motion picture data, that thermal quenching of the propellant burning surface and continued cooling of the surface until the hot gases have been exhausted provide a reasonable model for describing the propellant extinguishment characteristics.

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Full-Scale Flight Test Base Pressure Results for a Blunt Planetary Entry Probe Configuration

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Introduction

Base pressure measurements from a planetary entry probe can provide a direct method of deriving the freestream static pressure profile (P_∞) of a planet.[1] However, base pressure data for planetary entry type configurations are limited to the ground test data of Refs. 2–7, and full-scale NASA Ames flight data from Refs. 8 and 9. The purpose of this Note is to present additional, hitherto unpublished, full-scale flight test base pressure data from several flights of a blunt

Received March 11, 1971; revision received May 12, 1971. The present flight test data results are a re-evaluation of flight test data that were originally reduced and analyzed by D. Griffith of General Electric in 1959. The author gratefully acknowledges the assistance of Griffith in preparing the present note and the assistance of C. Dudzinski who reduced and plotted the present flight results.

Index category: Spacecraft Flight Testing; Jets, Wakes, and Viscid-Inviscid Flow Interactions; Entry Vehicles and Landers.

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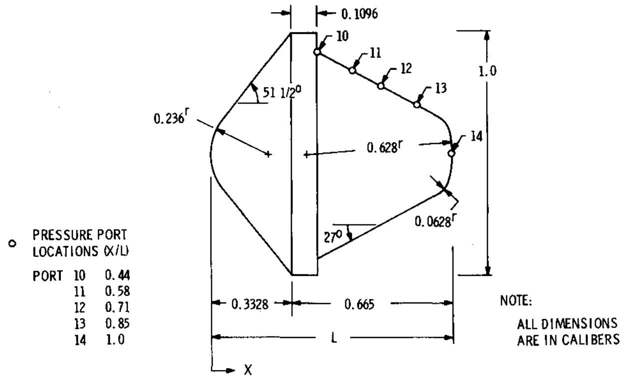

Fig. 1 Re-entry vehicle (*R/V*) flight configuration.

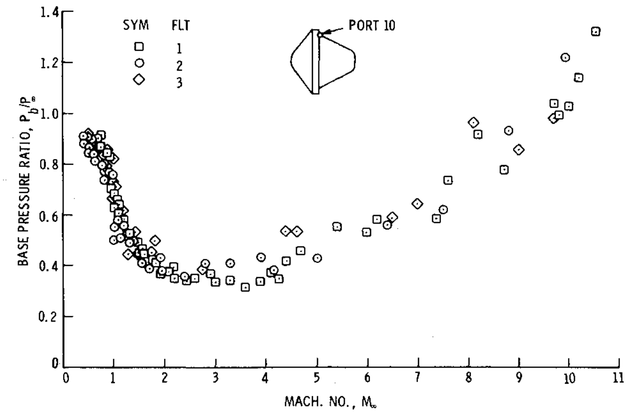

Fig. 3 Flight test base pressure ratio data for several flights, port 10.

body typical of a planetary entry probe configuration. The present data are for a blunt 52° nonablative heat sink/heat shield sphere cone having a bluntness ratio of 0.472 and a reverse frustum afterbody (Fig. 1).

Results

The flight vehicles (*R/V*'s) had a turbulent boundary layer during the data taking period. In addition, the *R/V*'s tended to oscillate about zero angle of attack with the largest amplitude being less than five degrees. It is believed that the flight data presented are indicative of the zero angle-of-attack value based on previous GE base pressure analysis and the free-flight ground test base pressure data of Ref. 2 which indicate that blunt body base pressure is relative insensitive to angle of attack for $\alpha < 10°$. The flight data were reduced only for that portion of the trajectory where the pressure sensors exceeded 5 to 10% of full scale of the sensor range to insure data validity. In addition, the data were nondimensionalized to the form of base to freestream pressure ratio (P_b/P_∞) utilizing the best fit trajectory and a measured atmosphere for each flight.

Base pressure ratio data for a typical flight, for three adjacent pressure port locations, are shown in Fig. 2. Several points are significant. First, the data contain scatter at the higher Mach number ($M_\infty > 7$), but are relatively smooth at the lower Mach numbers where the data are more accurate. Second, the data for all three ports are very close and indicate no significant gradient. Third, the base pressure ratio trend with Mach number is typical of what would qualitatively be predicted[5,10,11] and matches the trend of previously published turbulent flight results.[12]

Base pressure data from the port directly behind the *R/V* shoulder for several flights are presented in Fig. 3. The data for the three flights are in basic agreement and demonstrate repeatability. Base pressure afterbody distributions for two typical flights at several Mach numbers are presented in Fig. 4. The data from both flights indicate no significant gradients. This trend confirms wind-tunnel base pressure results.[11,13,14,15] However, the present flight data trends suggest a slight reduction in base pressure as the center of the base is approached. This is in sharp contrast to laminar flight data[16] which show large radial gradients in which the centerline base pressure can be a factor of two higher than the pressure at the edge.

Future Applications

The present turbulent flow data show that base pressure ratio varies between $P_b/P_\infty \approx 0.35$ and 1.3 from the subsonic to hypersonic flow regimes for a blunt configuration typical of a planetary entry probe. This indicates that base pressure measurements from a planetary entry probe can be used to derive the static freestream pressure profile of a planet subject to the following restrictions: the Mach number history of the probe must be known, a turbulent boundary layer must be established, the probe must have an angle of attack less than five degrees, and mass addition correction factors[17] to account for the effects of an ablative heat shield must be applied as well as correction factors[4] for the effects of differences in γ (ratio of specific heats) for other planetary atmospheres. The

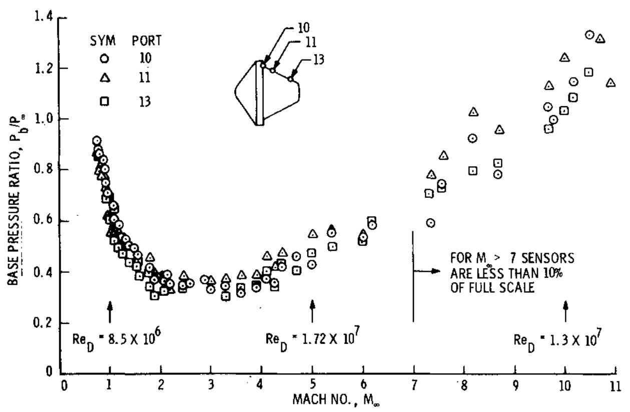

Fig. 2 Flight test base pressure ratio data for several pressure port locations, flight 1.

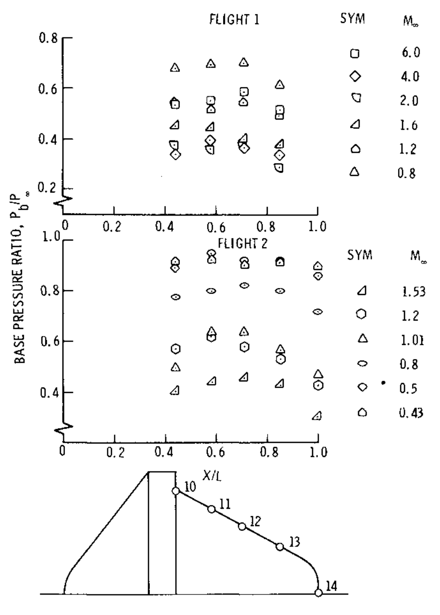

Fig. 4 Afterbody base pressure ratio distribution.

above limitations could be met with the present data for either a Venus or Jupiter entry probe mission. Base pressure measurements are also applicable for a Mars probe mission as a means to derive the static freestream pressure profile of the planet. A Mars probe would most likely have a laminar boundary layer during entry; accordingly, Reynolds number effects on base pressure would also have to be considered in addition to the previously mentioned variables for Venus or Jupiter. However, mass addition effects would be negligible for Mars due to the low heating environment and therefore could be eliminated.

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An Advanced Upper Atmosphere Meteorological Sounding Facility

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IN 1960, at Fort Greely, Alaska, the author demonstrated that a remote meteorological rocket station could be operated to obtain useful wind and temperature data in the 20–65 km (66–213 kft) region on a synoptic basis using an X-band, gun-directing radar in lieu of the powerful range radars for tracking meteorological rocket payloads. Thousands of such tracks have since been obtained by various groups at Cooperative Meteorological Rocket Network (CMRN) stations throughout the world from a wide assortment of comparable tracking equipment. Continuous effort has been expended by the Atmospheric Sciences Laboratory (ASL) to optimize ground station tracking equipment at the U.S. Army stations so that maximum meteorological data can be obtained with a minimum expenditure of equipment and personnel.

A mission requirement to improve the accuracy of data obtained at Fort Greely, Alaska, and Fort Sherman, Canal Zone, and to obtain wind and density data from the surface to 105 km (334 kft) prompted the ASL to reassess the techniques and resources currently available to accomplish these objectives. As a result, advanced upper atmosphere sounding facilities are now being assembled for evaluation at the ASL, White Sands Missile Range (WSMR), New Mexico. When completed, these facilities will be transferred to the Alaskan and Canal Zone sites. Equipment and modifications to be incorporated in the advanced facilities include omnidirectional meteor trail tracking radar (MTR), a modified Nike-Hercules precision tracking radar, and a control and data handling center to integrate the meteorological data collected during operations. The MTR will obtain wind and density data in the 85–105 km (280–344 kft) altitude range, an approximate 40 km (131 kft) increase above normal rocketsonde observation altitudes. The Nike-Hercules precision radar is to be extensively modified to become a Nike-Met radar and will be used to establish calibration tables for the MTR antenna field by simultaneously tracking targets of opportunity. It will also track balloon and rocket payloads used in established sounding programs. The time-shared digital controller (Honeywell 516) will provide real-time output from the MTR, rocketsonde, rawinsonde, and pibal operations along with ballistic computations and launcher setting outputs associated with rocketsonde firings.

Meteor Trail Radar

The MTR to be fielded is a second generation, pulsed doppler model designed by ASL and incorporates certain improvements over the system previously used. The transmitting and receiving antennas are combined and consist of a radome-enclosed, all weather, mechanically stable, stacked, crossed dipole antenna with a vertical whip, centered on and located above a counterpoise. The antenna, with properly phased and amplitude controlled input through a duplexer assembly, transmits an omnidirectional, in the azimuth plane, inverted, approximately cosecant-squared pattern. In the receiving mode, again with proper phasing,

Presented as Paper 70-1392 at the AIAA 2nd Sounding Rocket Technology Conference, Williamsburg, Va., December 7–9, 1970; submitted December 9, 1970; revision received January 26, 1971.

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