Flight Test Comparison of Two Electron Attachment Techniques

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Theme

TEFLON ablation as a mechanism for altering the electron concentration in the flow surrounding a vehicle, was examined during re-entry. This was a companion flight to a liquid injection test which used Freon 114B2.[1] Data are presented on the effect of the ablation products on the flow. These results are compared with those of the injection flight. Measurements, obtained by microwave techniques and paired electrostatic probe measurements of positive ion and electron densities, show significant electron reduction with the dominant mechanism being negative ion formation.

Contents

Ablation is a widely accepted technique for providing thermal protection during re-entry. However, a systematic study of its use as a mechanism for chemically altering the electron concentrations in the ionized flow about a re-entry vehicle has not been conducted under flight test conditions. In this application the shielding is not of major interest; the ablation is considered essentially as a control on the level of electron-reducing products introduced into the flow. If sufficient mass is ablated into the boundary layer, the resultant cooling alone can enhance recombination thereby reducing the electron density. More efficient electron removal can result however, when the ablator products are electrophilic. This is the case for Teflon. (From the electromagnetic viewpoint, formation of negative ions is equivalent to recombination since the relatively massive ions react only weakly with microwave radiation.)

In the case of the liquid injection experiment, similar considerations applied. There the alleviant was locally introduced in a series of pulses into the flow which would pass over the test antenna. Since the liquid injectant, Freon 114B2, undergoes rapid pyrolytic decomposition into a teflon-like monomer, the two flights represent conceptually different alleviation techniques which have similar downstream flow chemistries.

Onboard diagnostic instrumentation demonstrated that flow conditions were essentially identical for both flights. Three previous flights[2,3] established the nature of the unmodified re-entry effects.

The re-entry vehicles with the location of the electrostatic probes and microwave antennas are shown in Fig. 1. The vehicles were blunt 9° cones with 6 in. nose radii. Peak velocities were about 16,500 fps. The hemispherical cap of the ablation flight was covered with Teflon, having a low alkali

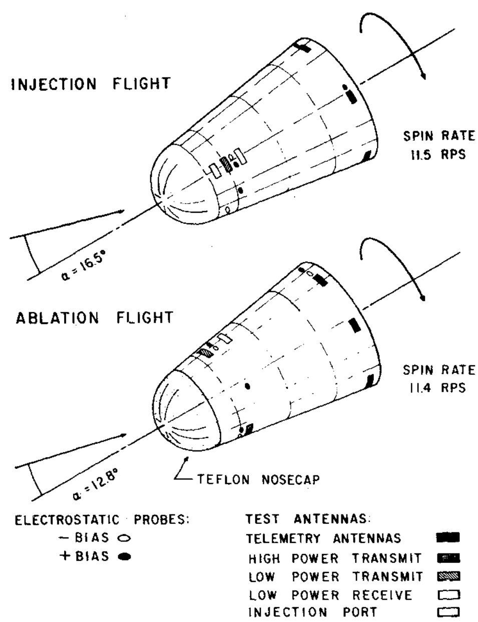

Fig. 1 Sketch of nose cones showing location of probes and antennas.

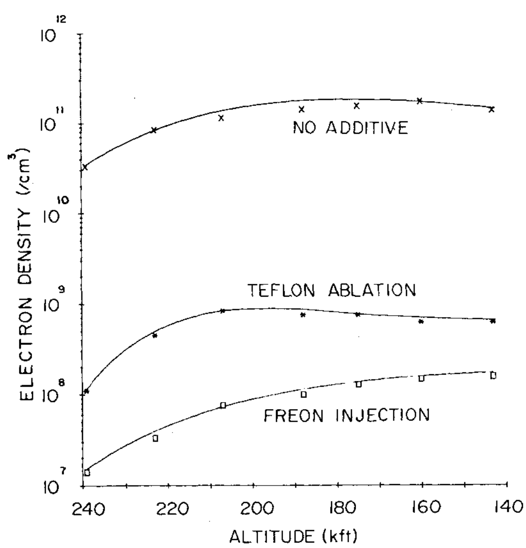

Fig. 2 Effect of alleviants on electron density.

content. On the injection flight, as shown in the figure, liquid was introduced from orifices located directly in front of the test antennas. The basic microwave test systems and diagnostic probes were located at identical vehicular positions on both flights to allow direct comparison of the effect of the two alleviation techniques. The paired probes provided information on the electron and ion concentrations both at the shoulder (the actual site of the microwave experiment) and at the rear of the vehicle, after an extended chemical reaction

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Index categories: Plasma Dynamics and MHD; Supersonic and Hypersonic Flow; Thermochemistry and Chemical Kinetics.

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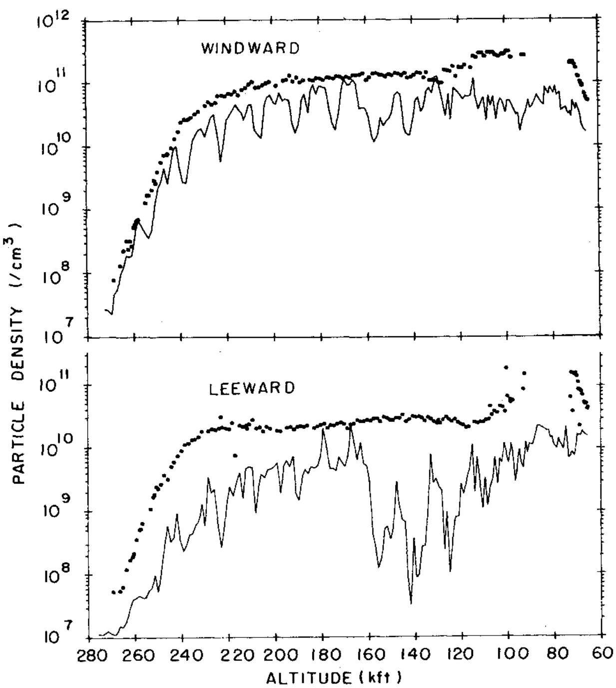

Fig. 3 **Windward and leeward positive ion density measured on both flights at $S/R_N=2.4$(—, injection flight data; ....., ablation flight data).**

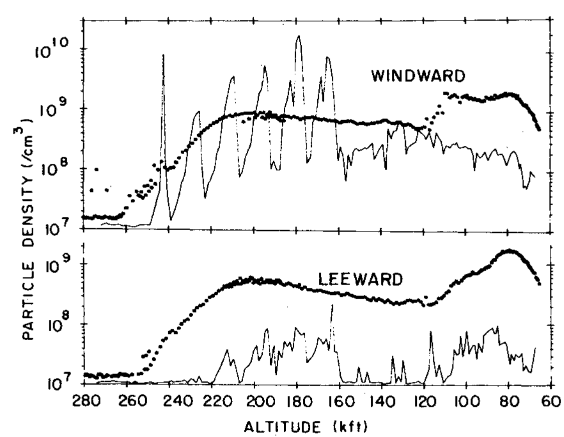

Fig. 4 **Windward and leeward electron density measured on both flights at $S/R_N 2.4$ (—, injection flight data; ....., ablation flight data).**

time. A number of important plasma modification results were obtained from the combined sensors.

A conclusive result of the measurements is that, for these flight conditions, the main additive effect was the formation of negative ions. Although some cooling was observed in the case of Freon injection, there was no such indication in the Teflon flight results.

On the Teflon flight, (Fig. 2) probe data indicates that the electron density was at least two orders of magnitude lower than the positive ion density at all probe locations. On the Freon flight, the electron density was lowered by as much as three orders of magnitude in certain cases. This, however, was partially due to cooling effects produced by the greater mass addition of liquid additive.

Figure 3 shows the windward and leeward ion density and Fig. 4 the corresponding electron density for both flights measured by a typical probe pair. The marked contrast between the Freon and Teflon data is due to the difference in the additive techniques. In the ablation case, the alleviant effect is continuous whereas the Freon pulses result in sequential dips in the curves. A larger decrease is seen at 160 kft after initiation of higher flow pulses. The presence of cooling is shown by the decrease in the ion density during each pulse. In the interpulse period the ion curves return to the no-additive value. The cooling becomes less pronounced as the altitude decreases. Allowing for the cooling during the Freon pulse periods, the overall trend of the windward data on both flights was similar. This was not the case, however, for the leeward data.

The increase in ion and electron densities shown by all probes at about 120 kft in the Teflon-ablation flight has been attributed to the transition to a turbulent boundary layer. However, the probes affected by the liquid-Freon injection did not show any increase in either the electron or ion density in this altitude regime.

Both the Teflon ablation and the Freon injection reduced the mismatch of each of the onboard transmitting antennas. There was a marked decrease in signal attenuation for both the test and the telemetry antennas as a result of the additives. The change in interantenna coupling during re-entry was similarly reduced.

The data comparisons for the two additive flights indicate that injection resulted in greater alleviation than ablation. However, it is apparent that either method represents a viable choice to improve the re-entry performance of onboard antennas.

References

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[2]Poirier, J. L., Rotman, W., Hayes, D. T., and Lennon, J. F., "Effects of the Re-entry Plasma Sheath on Microwave Antenna Performance: Trailblazer II Rocket Results of 18 June 1967," AFCRL-TR-69-0354, Aug. 1969, Air Force Cambridge Research Laboratories, Hanscom AFB, Mass.

[3]Hayes, D. T. and Rotman, W., "Microwave and Electrostatic Probe Measurements on a Blunt Re-Entry Vehicle," *AIAA Journal*, Vol. 11, May 1973, pp. 675-682.