AIAA Journal

VOLUME 8 | SEPTEMBER 1970 | NUMBER 9

Journal Users—Send Your Comments on SYNOPTICS

Several sample *Synoptics* have appeared in the August, September, and September-October issues of the Journals. The Publications Committee will discuss the implementation of *Synoptics* into the Journal structure at its October meeting. *Please send your suggestions or comments (positive or negative)* to Dr. Jerry Grey, Vice-President, Publications, at AIAA, 1290 Sixth Avenue, New York, N. Y. 10019 *prior to October 5* so that the Publications Committee will be able to consider your views in its deliberations.

SYNOPTIC: Correlation of Propellant Density Gradients and Capacitance with the Efficiency of a Plasma Gun, C. S. Cook, P. Gloersen, B. Gorowitz, and T. W. Karras, General Electric Space Sciences Laboratory, King of Prussia, Pa.; *AIAA Journal*, Vol. 8, No. 9, pp. 1537-1543.

Electric and Advanced Space Propulsion

Theme

This paper presents experimental data that correlate high accelerator capacitance and gentle propellant prefire density gradients with high efficiency in a pulsed coaxial plasma accelerator. The validity of the thrust based efficiency, about 60% at 5000 sec specific impulse, was supported by independent measurements.

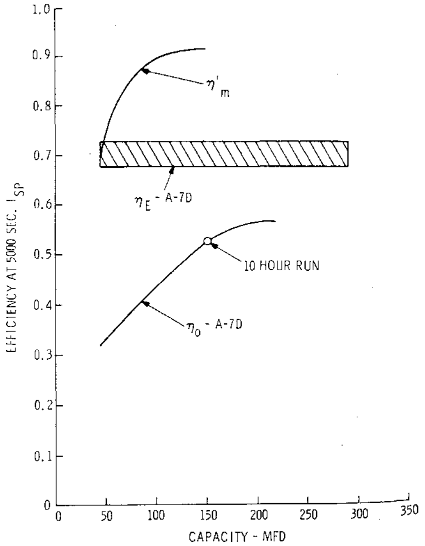

Fig. 1 Available mass fraction η_m', fraction of input energy collected in a downstream calorimeter n_E, and over-all efficiency η_0 at operating conditions resulting in a specific impulse of 5000 secs as functions of the capacitance of the energy storage bank. These data were obtained with low axial propellant density gradients.

Content

The over-all efficiency of repetitively pulsed coaxial plasma accelerators has previously been enhanced through a systematic design optimization. Accelerator capacitance optimization has since been added, giving a further increase in over-all efficiency, η_0. Figure 1 shows this, as well as the calorimetric efficiency η_E and the fraction of the injected propellant available for acceleration η_m', accompanying the increase in capacitance.

This increase in performance is partially attributed to the higher mass loading at a given energy-per-shot value permitted by lowering the voltage while increasing the capacitance. This leads directly to a higher efficiency at a given specific impulse, as shown on Fig. 2. Other effects, such as

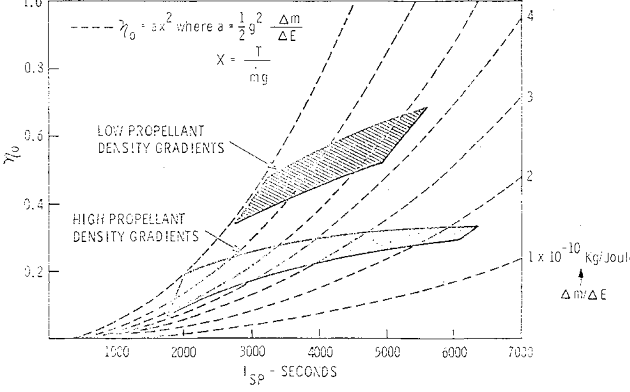

Fig. 2 Illustration of the variable operation of the A-7XD accelerator. The two bands represent operating extremes observed in the same A-7XD configuration, having changed only the characteristics of the propellant inlet valve.

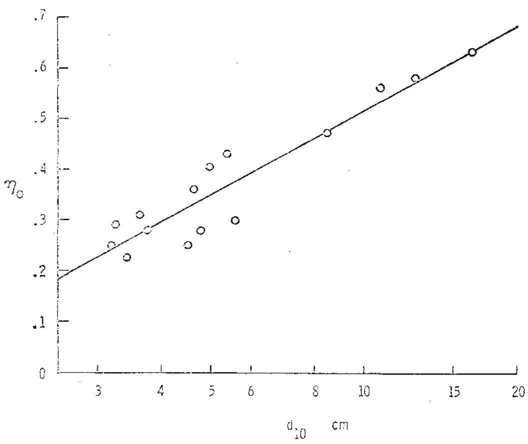

Fig. 3 Over-all efficiency as a function of the characteristic length for decrease of propellant density by a factor of ten, (d_{10}), A7 and A8 electrodes, and 220 μf capacitance were used with a variety of valves.

the increased capacitance extending the discharge period to match the ion acceleration time, or the increased propellant flow rate increasing propellant availability as shown on Fig. 1, also contributed. Measurement techniques and basic accelerator design have been covered in detail elsewhere and so will not be reported here.

Despite optimal settings of all gross parameters, wide variations in performance, discharge current wave forms, and even visual appearance of the discharge could still be observed. While a wide variety of factors play some role in this, a strong correlation of accelerator over-all efficiency with the prefire propellant distribution supports the view that the details of valve design are dominant.

The axial propellant density gradients were the specific characteristics studied and it was found that the more gentle these were, the higher the resulting efficiency. Figure 3 shows the over-all efficiency at 5000 sec specific impulse as a function of the characteristic distance over which the axial propellant density would decrease by a factor of ten (d_{10}). These data were obtained by standard fast ionization gage techniques with a wide variety of valve designs.

The combined requirements of gentle gradients and a high available propellant fraction η_m' can be interpreted as support for a short propellant pulse with a width comparable to the active length of the accelerator. Accelerator triggering can then be timed to occur when the density peak has propagated to a position midway between the electrodes and spread so that the gradients are small. The best performance has been obtained with just such a propellant distribution.

The validity of the measurements leading to this high performance has been supported by independent measurements. The specific impulse determined from thrust and mass flow has been validated by electrostatic gridded probe analyses. The values found by either method were essentially the same. The over-all efficiency itself was obtained from the calorimetric efficiency, the propellant mass utilization and the ion velocity distribution as well as the more conventional thrust, mass flow, and power input determination. The values determined in this way differed by about 6%, well within the uncertainty of the individual measurements.

Correlation of Propellant Density Gradients and Capacitance with the Efficiency of a Plasma Gun

C. S. Cook,* P. Gloersen,† B. Gorowitz,‡ and T. W. Karras§
General Electric Space Sciences Laboratory, King of Prussia, Pa.

Additional studies have been made of a repetitively pulsed coaxial plasma gun. Gross performance characteristics were found to depend most heavily on axial propellant density gradients and circuit capacitance; and over-all efficiency averaged over many runs was higher than that previously reported, i.e., about 60% at 5000 sec specific impulse. Diagnostic techniques were applied to the gun; the data were used to corroborate the gross performance measurements and to help understand differences in operation.

I. Introduction

Considerable effort has been applied towards improvement of the performance of coaxial plasma accelerators with regard to those characteristics deemed important for eventual application to space flight.[1-10] Some of the more recent results are reported here. As support for this work, there has also been a concerted effort at understanding the acceleration processes through the use of detailed diagnostics. The results of some of these techniques have been discussed separately in varying degrees elsewhere[2-12]; however, additional information and interpretations have become available and are also included here.

The earliest systematic studies directed toward improving the performance of these devices used exhaust stream calorimetry for monitoring the trends as accelerator electrode shape, discharge circuit parameters, and mass loading techniques were changed.[5] Later studies made use of mass flow measurements, input power measurements, and a thrust balance on which the accelerator was mounted.[6] In both these studies, successive design changes resulted in a continuing increase in the efficiency of the plasma gun to the point where long-term runs and detailed diagnostics became warranted in order to confirm the measurements obtained by the earlier techniques. After an extended period of successful

Received July 14, 1969; revision received January 19, 1970. We wish to acknowledge useful discussions with our colleague F. W. Mezger.

* Research Engineer, Laser Applications.
† Consulting Scientist, Experimental Physics. Associate Fellow AIAA.
‡ Research Chemist, Structural Materials Programs. Member AIAA.
§ Principal Scientist, Plasma Physics. Member AIAA.