

Testing of an Arcjet Thruster with Capability of Direct-Drive Operation

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I. Abstract

ELECTRIC thrusters typically require a power processing unit (PPU) to convert the spacecraft provided power to the voltage-current that a thruster needs for operation. Testing has been initiated to study whether an arcjet thruster can be operated directly with the power produced by solar arrays without any additional conversion. Elimination of the PPU significantly reduces system-level complexity of the propulsion system, and lowers developmental cost and risk. The work aims to identify and address technical questions related to power conditioning and noise suppression in the system and heating of the thruster in long-duration operation. The apparatus under investigation has a target power level from 400-1,000 W. However, the proposed direct-drive arcjet is potentially a highly scalable concept, applicable to solar-electric spacecraft with up to 100's of kW and beyond.

A direct-drive electric propulsion system would be comprised of a thruster that operates with the power supplied directly from the power source (typically solar arrays) with no further power conditioning needed between those two components. Arcjet thrusters are electric propulsion devices, with the power supplied as a high current at low voltage; of all the different types of electric thruster, they are best suited for direct drive from solar arrays. One advantage of an arcjet over Hall or gridded ion thrusters is that for comparable power the arcjet is a much smaller device and can provide more thrust and orders of magnitude higher thrust density ($\sim 1-10 \text{ N/m}^2$), albeit at lower I_{sp} ($\sim 800-1000 \text{ s}$). In addition, arcjets are capable of operating on a wide range of propellant options, having been demonstrated on H_2 , ammonia, N_2 , Ar, Kr, Xe, while present SOA Hall and ion thrusters are primarily limited to Xe propellant. Direct-drive is often discussed in terms of Hall thrusters, but they require 250-300 V for operation, which is difficult even with high-voltage solar arrays. The arcjet requires under 100 V, which is more in-line with what is easily possible with a solar array.

Direct-drive of an electric propulsion system confers the advantage of reducing or eliminating the power processing unit (PPU) that is typically needed to convert the spacecraft-provided power to the voltage and current needed for thruster operation. Since the PPU is typically the most expensive piece of an electric thruster system, from both a fabrication and qualification standpoint, its elimination offers the potential for major reductions in system cost and risk.

The design of the arcjet built for this effort was based on previous low power (1 kW class) arcjets.¹⁻³ It has a precision machined 99.95% pure tungsten anode which also serves as the nozzle. The anode constrictor region is 1 mm (0.040-in) diameter and 1 mm (0.040-in) long. The cathode is a tungsten welding electrode doped with LaO_2 ; its tip was precision ground to a 30° angle ending in a blunt end. The two electrodes are separated by a boron-nitride insulator which also serves as the propellant injection manifold; it ends in six small holes which introduce the propellant gas in the diverging section of the nozzle, directly adjacent to the cathode. The electrodes and insulator are housed in a stainless-steel outer-body, with a Macor insulator at the mid-plane to provide thermal isolation between the front and back halves of the device. The gas seals were made using Grafoil gaskets. Figure 1A shows the assembled thruster in the vacuum chamber; figure 1B shows the thruster in operation on argon at a flow rate of 676 sccm (20 mg/s).

Initial testing was conducted in a 3.5-ft diameter vacuum chamber; the ultimate pressure reached during quasi-steady operation of the thruster was about 330 millitorr. The thruster was powered with a high-current, 0-100A, 15 kW power supply. The discharge was initiated with a high-voltage ($\sim 10 \text{ kV}$) spark initiator that was isolated from the

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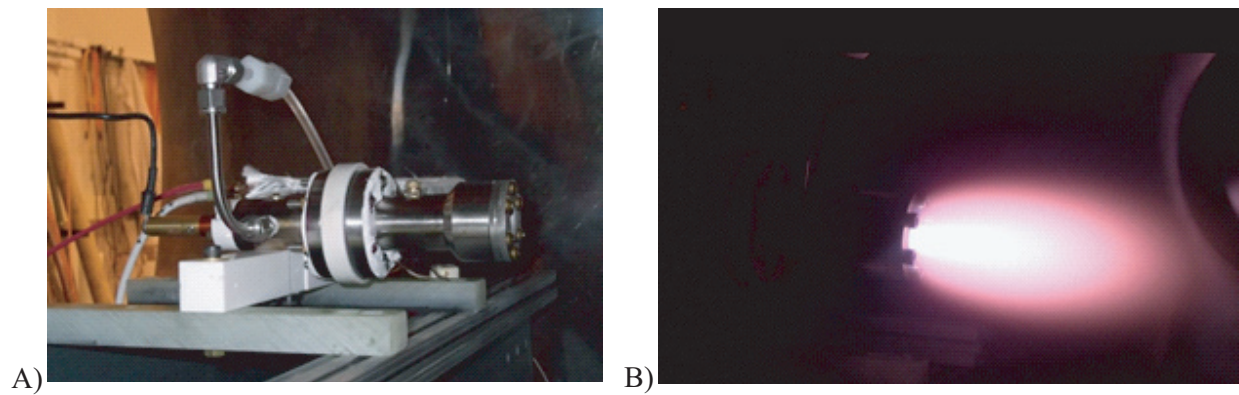


Figure 1. A) Assembled arcjet thruster. B) Arcjet in operation on argon propellant.

supply by a stack of diodes. The testing indicated that an operating point exists within the I-V characteristics that is compatible with direct-drive solar-electric operation; for a flow rate of 20 mg/s (argon) the arc could be sustained at a voltage of about 20 V and a current of 25 A (500W).

Acknowledgments

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