Section 1.0: Introduction

This report provides a final summary of the progress made in research on plasma torch operation with pure hydrocarbon feedstocks at Virginia Tech over the past year. Hypersonic technology is an area where there are strong interests in both military and commercial applications. A critical obstacle to developing reliable scramjet engines is ignition and flameholding in supersonic flow. Efforts have been made to address this problem by researching the effects of combustor cavity shapes, injector configurations and the potential of plasma torches for supersonic combustion applications. The Virginia Tech Plasma Torch was designed in 1988 by Scott Stouffer (1989) and tested with feedstocks of argon, nitrogen and hydrogen. The research conducted at Virginia Tech during the present one-year effort focused primarily on the operation of this plasma torch design with the hydrocarbon feedstocks methane, ethylene and propylene, to observe and document the torch operational characteristics in an ambient environment.

1.1: Goals and Objectives

The goals of the program at Virginia Tech include the following:

- To demonstrate the feasibility of operating a plasma ignitor using pure hydrocarbon feedstocks.
- To maintain stable plasma torch operation for typical system fluctuations.
- To develop a reliable combustion ignition system to meet start/restart requirements.
- To observe and document characteristics such as arc stability, plasma jet phenomena, electrode erosion and startup conditions.
- To discover the presence of any combustion-enhancing radicals using spectroscopic methods.

1.2: Results

During this research effort, extensive data with methane, ethylene and, to some extent, propylene was collected. Experiments designed to provide insight on internal operational characteristics of the torch proved valuable. Increased torch power was observed to improve arc stability, increase the likelihood of operating in a stable mode, and allow for the arc gap to be increased, if necessary. Using a variable high-frequency starter for torch ignition and then running the torch on pure DC eliminated coking problems. Electrode erosion rates, as well as the steady-state torch body temperature, were found to be related to the type of feedstock, torch power and feedstock flowrate. Start/restart tests proved that the torch was a reliable source for continued reignition.

External characteristics caused by internal phenomena were then observed. Analyses of torch startup conditions showed evidence of vortices downstream of the anode constrictor, wave phenomena and electrode emission. High-speed digital photos also showed the presence of plasma jet oscillation, later linked to the output voltage of the power supplies. Finally, spectrographic tests detected the presence of combustion-enhancing radicals and charged species, including C_2, O^+, O_2^+, OH, CH^+, CO^+ and N_2^+.

1.3: Summary

In summary, the reported research efforts and results met each of the aforementioned goals. This report details the background, procedures, equipment and tests results for each objective listed above. Finally, analysis of the torch performance over the past year has provided confidence that it has the potential to be a reliable ignitor and flameholder for supersonic combustion applications.