IAF SPACE POWER SYMPOSIUM (C3)
Advanced Space Power Technologies (3)

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THERMODYNAMIC ANALYSIS OF COMBUSTIBLE SYSTEMS FOR POWER GENERATION IN DEEP SPACE MISSIONS

Abstract

Driven by the limited availability of radioisotope power systems and the diverse electrical power needs of many future deep space mission concepts (including SmallSats), there is an increasing interest in developing a non-nuclear power system that would possess higher energy/power characteristics and a longer life time than primary batteries. Exothermic chemical systems that release heat upon ignition potentially meet these requirements. Additionally, utilizing in-situ resources as reactive components of such systems would decrease the amount of materials that would have to be brought from Earth.

The objective of the present work was to identify the most promising candidates for combustible systems for energy storage and power generation in deep space missions. Such a system can be stored in the solid or liquid state for long time onboard spacecraft and, upon ignition, could provide heat for thermoelectric converters or engines coupled with electric power generators. An important constraint is the condensed (solid or liquid) state of the combustion products. The only exception is hydrogen, which could be fed to a fuel cell for additional power generation.

Dozens of potentially suitable chemical systems were evaluated via thermodynamic calculations of specific energies, volumetric energies, combustion temperatures, product compositions, and volumes of generated gas. Systems that include water, nitrogen, or carbon dioxide were considered as potential users of in-situ resources.

The results have revealed many systems that could generate heat in the range from 10 to 20 MJ/kg with no gaseous products at temperatures that are optimal for thermoelectric conversion. Many of these systems are also characterized by high values of exergy, i.e. most of the generated thermal energy could be converted to work in a reversible engine. Note that combustible systems also promise very high power characteristics. Many of the considered systems could be stored for years with no degradation. For comparison, the best lithium-ion batteries have a specific energy of about 0.9 MJ/kg and have a life time of 2-3 years only; they also have a relatively low specific power. The results also show that utilization of in-situ resources may further increase the energetic characteristics of potential combustible systems.