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Radioisotope Thermoelectric Power Systems: Enabling Technology for European Space Exploration Missions

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Abstract

Radioisotope power systems (RPS) have proved critical enablers for many of the most demanding space and planetary science missions. US systems, fuelled by ^{238}Pu, have returned extraordinary science from missions such as the Pioneer and Voyager probes, Galileo (Jupiter) and Cassini (Saturn). At the time of writing, New Horizons and Mars Science Laboratory are en route to Pluto and Mars respectively and are equipped with Radioisotope Thermoelectric Generators (RTG). RPSs can provide electrical power to spacecraft systems independently of solar energy, permitting more capable and productive spacecraft and missions. Europe is focused on developing ^{241}Am powered RPSs.

1. Introduction

The ability to produce spacecraft radioisotope power systems would significantly enhance the independent European capability for space exploration. As a result the European Space Agency (ESA) initiated development of such systems around 2005 [1]. A strong team of academic and industrial partners has been built in the UK and Europe. This paper will summarise the UK-led studies covering fuel selection and production, safety requirements, RTG technologies and prototype laboratory testing conducted as part of these ongoing activities. This paper will not discuss parallel French-led RTG studies or UK-led Stirling conversion studies.

2. Isotope Selection

The ESA isotope selection study concluded that there were two leading candidate fuel isotopes, ^{241}Am and ^{238}Pu, suitable for use in RPSs. In Europe isotope selection studies have identified ^{241}Am as the isotope of choice (as Am_2O_3) for a European programme due its production of 100% pure isotope from the decay of ^{241}Pu in separated civil plutonium from reprocessing. This is in spite of its power density being only approximately 25% that of ^{238}Pu, and is largely due to the economically attractive chemical separation. An initial design and assessment of the end-to-end costs of a ^{241}Am production facility has been undertaken, and small-scale material production to verify the flow sheets will commence this year [2].

3. Isotope Containment

A further study has explored the containment of radioisotope material in the event of a number of deterministic design basis accidents, including launcher explosion, re-entry from orbit and ground impact. Concept designs generated consist of a multilayer containment system with an outer aeroshell for re-entry heating and impact threats, and an inner containment for severe impacts. For the inner containment, conventional [3] and novel [4] metal-matrix composite approaches have been evaluated.

4. RTG

Thermoelectric conversion has the advantage of requiring no moving parts; an inherent asset for long-term, reliable operation. Concept RTG designs were produced for electrical power outputs of 1-50 W [5,6]. An electrically heated laboratory prototype was designed and constructed to test system performance around the 5 W design point. The volume of the heater element was the same as the volume of Am_2O_3 producing 83 W of thermal power, which was used as the electrical heater set point. The electrical output was measured at 3.5 W, an overall efficiency of 4.2%, a very encouraging result compared to prior US systems.

5. Conclusions

These activities combined represent the first systematic study of ^{241}Am fuelled RTG systems - and to the best of the authors' knowledge – the first time representative RTG component manufacture and prototype laboratory testing has been undertaken outside the USA or Russia.

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