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COMBINED ENERGY PRODUCTION AND WASTE MANAGEMENT IN MANNED SPACECRAFT

Abstract

Energy supply and waste management are among the most significant challenges in manned spacecraft. Great efforts are invested in managing solid waste, recycling grey water and urine, cleaning the atmosphere, removing CO2, generating and saving energy, and making further use of components and products. This paper describes and investigates a concept for managing waste water and urine to simultaneously produce electric and heat energy as well as fresh water. An original process has been developed and patented, enabling activation of aluminum powder to react spontaneously with water to produce hydrogen on site and on demand, avoiding the need to store elemental hydrogen. It is based on diffusing a fraction of a lithium-based activator into the aluminum lattice, modifying the protective properties of the existing oxide shell around the particles. The reaction can take place at room temperature with any type of water as well as urine, exhibiting high yield:

(1) Al + 3H2O (grey water, urine) = Al(OH)3 + 3/2H2 + 420 kJ/mole Al (heat energy)

Combining with a hydrogen-oxygen fuel cell one can obtain electric energy and fresh water:

(2) 3/2H2 + 3/4O2 = 3/2H2O (fresh water) + 214 kJ (electric energy) + 214 kJ (heat energy)

Based on the above reactions the research reveals very high specific electric energy of 2.2 kWh/kg Al. Accounting for the oxygen required in the fuel cell reaction as well as the fuel cell, reactor, and peripheral masses, one obtains specific electric energy of 0.9 kWh/kg system for a short (a few hours) operating time and about 1.15 kWh/kg system for a long operating time (e.g., 100 hr), substantially exceeding the specific energy of the best batteries. Additionally, Reaction (1) generates heat energy while utilizing only waste water with no use of oxygen, whereas the fuel cell does not require extra oxygen for the heat produced. One can show that the overall heat produced which can be utilized for heat management and additional applications in the spacecraft, is 23.5 MJ/kg Al. This is about 9 times higher than the specific energy of combustion of HC fuel with air and 2.5 fold better than for HC fuel + oxygen when both components are specifically carried on board. It makes the proposed concept a superior source to any other practical form for the combination of electric and heat energy supply as well as fresh water recovery for spacecraft.