METAL FUELS AND CHEMICAL OXYGEN GENERATORS FOR LUNAR NIGHT SURVIVAL.

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Introduction: During the lunar night, landers and rovers could be heated and powered using combustible systems with high energy density. Currently, one such system is under development at JPL [1, 2]. The reactants are lithium, melted before the operation, and sulfur hexafluoride (SF_6), stored as a saturated liquid at 21 bar. The specific energy is about 14 MJ/kg (4 kWh/kg) [1, 3]. The combustion generates condensed products LiF and Li_2S. Unfortunately, the development has faced challenges such as corrosion of the materials and accumulation of the products in the reaction zone [2].

Here we evaluate a different system, which is based on combustion of lithium or magnesium powders with oxygen. In this concept, a cylindrical reactor is filled with the powder, and oxygen gas is fed from one end. Ignition at either the same or opposite end triggers a self-sustained combustion, supported by the infiltration of oxygen through either the initial metal powder or the combustion products. For oxygen storage, chemical oxygen generators, such as those used in aircraft, submarines, and space stations [4], can be used. They usually contain sodium chlorate ($NaClO_3$) or lithium perchlorate ($LiClO_4$) as the oxygen source. The objective of the present paper is to estimate the effectiveness of using of such a system for lunar night survival in comparison with the Li-SF_6 combustion.

Results and Discussion: Based on the enthalpies of formation at standard conditions, the stoichiometric combustion reactions of Li and Mg with O_2 release 20.0 and 14.9 MJ/kg, respectively. A multi-purpose oxygen generator (MPOG, Molecular Products) has a mass of about 12 kg and produces 2600 L (3.459 kg) of O_2. The stoichiometric reaction with this amount of O_2 needs 3.001 kg of Li or 5.253 kg of Mg. Since Mg is 3.25 times denser than Li, it would occupy a smaller volume (at the same porosity). In both cases, about 130 MJ (36 kWh) of heat is released. In addition, the MPOG itself releases about 2.5 MJ of heat.

Recently, combustion of Mg and Li powders with infiltrating O_2 has been studied [5, 6]. The linear burning rate in these experiments was rather low, of the order of 0.1 mm/s. At this rate, for the combustion time being equal to the MPOG operation time, 75 min, a cylindrical reactor with 5.253 kg of Mg at 71% porosity (the average porosity of the Mg powder in [5]), should be 45 cm long and 17.2 cm in diameter, i.e., it would be similar in size to the MPOG (13.3cm x 13.3cm x 40cm).

The challenge in the proposed concept is the relatively short operation time, which results in a rather high thermal power, about 29 kW. One option for the heat removal is the use of an alkali metal fed by an electromagnetic pump. This option has been used, for example, in TOPAZ-II space nuclear reactor, which generated a thermal power of 115 kW [7]. Another option is to use heat pipes with an alkali metal as the working fluid. Such heat pipes are used in space nuclear reactors with a thermal power of 4−40 kW [8].

The proposed design involves a 12 kg MPOG and 5.253 kg Mg (or 3.001 kg Li) and generates 132 MJ (37 kWh) of heat. The JPL design includes a 15.84 kg SF_6 tank and 4.58 kg of Li to generate 157 MJ (44 kWh) of heat [1]. Thus, the two designs may generate similar heats per unit mass.

It should be noted that the MPOG uses $NaClO_3$, which contains 45 wt% of oxygen. $LiClO_4$ contains 60 wt% of oxygen, and it has been used in backup generators for space stations [4]. Thus, for the proposed system, a generator with a higher oxygen content could be developed.

One more design option includes multiple cartridges with chemical oxygen generators and metal combustors. The cartridges could be used consecutively to address a greater energy demand. Further, in a less demanding mission, multiple cartridges with smaller oxygen generators and combustors could be used to generate a small amount of heat many times during the mission.

Conclusion: Lithium and magnesium fuels in combination with commercially available chemical oxygen generators could provide heat during the lunar night with the effectiveness comparable with that of the Li-SF_6 system.

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References: [1] Hendricks T.J. et al. (2020) *Conf. Advanced Power Systems for Deep Space Exploration*. [2] Hunter M. et al. (2022) *Conf. Advanced Power Systems for Deep Space Exploration*. [3] Greer, C.J. et al. (2018) *Acta Astronaut., 151*, 68–79. [4] Graf J. et al. (2000) SAE Tech. Paper 2000-01-2348. [5] Cordova, S. et al. (2022) *Combust. Flame, 238*, 111950. [6] Estala-Rodriguez K. et al. (2022) *Proc. Combust. Inst., 39*, in press, doi: 10.1016/j.proci.2022.07.051. [7] Zhang W. et al. (2016) *Nucl. Eng. Des., 307*, 218–233. [8] Gibson M.A. et al. (2020) *Nucl. Technol., 206*, 31–42.