A WARM GARAGE FOR A LUNAR ROVER. E. Shafirovich[1] and S. L. Rickman[2], [1]Department of Aerospace and Mechanical Engineering, The University of Texas at El Paso, 500 W. University Ave., El Paso, TX 79968, eshafirovich2@utep.edu, [2]NASA Engineering and Safety Center, Mail Stop WE, 2101 NASA Parkway, Houston, TX 77058, steven.l.rickman@nasa.gov.

Approach: One approach to heating a rover during the lunar night is the so-called thermal wadis concept [1]. This involves heating the regolith with solar concentrators and placing the rover on the heated surface for the night. Since the regolith is heated by a relatively weak heat flux, a high thermal conductivity is required for heating a sufficiently large mass of regolith. However, lunar regolith has a low thermal conductivity. Therefore, the concept involves increasing the conductivity by sintering the regolith, which requires a significant energy input and complex procedures.

Here we propose an alternative approach where the low thermal conductivity of regolith is an advantage. Specifically, we propose to use a highly exothermic combustible mixture for heat generation. The mixture pellets are placed in the surface layer of regolith and ignited. The combustion forms condensed products and releases heat, which then slowly spreads to the surrounding regolith. Heat can also be transferred, for example, by heat pipes, into radiant heating surfaces installed on the ground. A greenhouse that transmits sunlight during the day and decreases the radiative heat losses during the night can also be installed.

Selection of the Heat-generating Mixture: The reactive mixture should have a high specific energy and generate only condensed products since gases could disturb the regolith layer, carry enthalpy out of the system, and lead to an explosion. There are mixtures, (sometimes called pyrolants) that possess very high specific energies. One example is magnesium-Teflon-Viton mixtures used in flares. However, they produce gases and may cause explosions. Other mixtures that include magnesium cannot be used either because of the high vapor pressure of Mg at temperatures well below the combustion temperature. Recently, mixtures that involve lithium peroxide (Li_2O_2) have been proposed for using in space power systems [2]. However, they produce lithium oxide (Li_2O), which boils at 2800 K at 1 atm and hence at a lower temperature in vacuum.

Fortunately, there exist many mixtures that release a lot of heat and form only condensed products during the combustion. Many such mixtures have been used for self-propagating high-temperature synthesis (SHS) of various materials [3, 4]. For the application discussed here, titanium/boron (1:2 mole ratio) mixture appears to be particularly promising. The specific energy is 4.0 MJ/kg (1.1 kWh/kg), the adiabatic flame temperature is about 3200 K, and the reaction forms solid titanium diboride (TiB_2, melting point: 3500 K). The mixture can be ignited easily with a heated tungsten wire, and it has been used widely as a booster to ignite the main mixture in the SHS process.

Estimates: Assuming that specific heat of regolith is 500 J/(kg·K) [5] and all generated heat is transferred to regolith, 12.5 kg of the Ti/B mixture would increase the temperature of 1000 kg of regolith by 100 K.

To evaluate the rate of heat transfer in the regolith, a spherical model was analyzed where the heat released by a 12.5 kg Ti/B core propagates by thermal conduction through a 1000 kg regolith shell with no heat loss from its outer surface. At a bulk density of 1500 kg/m^3 [5], the radius of the shell was 54 cm, while the radius of the core was about 11 cm. The calculations were conducted using Thermal Desktop SINDA/FLUINT (Cullimore and Ring Technologies) software at two constant values of bulk thermal conductivity k of the regolith: 0.001 and 0.01 W/(m·K). The results show that after 14.5 days the core lost 31% of the released heat at the lower k and 77% at the higher k. At a distance of 20 cm from the core surface, the temperature of the regolith increased by only 1 K at the lower k and by 132 K at the higher k. In reality, the regolith near the heat source will be melted, so its thermal conductivity will increase significantly. Nevertheless, the conducted estimates indicate that combustion-based heat generators, placed directly in the regolith, could provide heat during a rather long period such as the lunar night.

Conclusion: Heat generators based on gasless combustion of highly energetic reactive mixtures could be installed directly in the surface layer of lunar regolith. Because of the low thermal conductivity of the regolith, such generators would keep thermal energy for days and gradually supply heat to a rover/lander.

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