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Interactive Presentations - 22nd IAA SYMPOSIUM ON HUMAN EXPLORATION OF THE SOLAR SYSTEM (IP)

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OXYGEN PRODUCTION ON MARS WITH IN-SITU RESOURCE UTILIZATION

Abstract

Many challenges remain to be solved to enable human exploration of Mars. One of the challenges is the lack of oxygen (O2), which makes up only 0.14% of the Martian atmosphere. Not only is this resource necessary for breathing, but it is also needed as a propellant to launch from Mars. Over 2 years, as much as 800 tonnes of O2 would be needed for propellant and to support six astronauts. Considering high transportation costs, shipping the required amount of O2 to Mars would be unfeasible. To address this challenge, our group has designed a process to produce 50 kg/hr of O2 on Mars using in-situ resources, while eliminating toxic by-products. The developed process produces O2 from carbon dioxide (CO2), which makes up 95% of Martian atmosphere, and recycles harmful carbon monoxide (CO) by-product into CO2. In the first step of the process, CO2 is separated from Martian air via cryogenic cooling. The CO2 is then sent to an electrolyser unit, where it is electrochemically split into O2 and CO. The CO and CO2 mixture is sent to a membrane separator, where CO2 is separated and recycled to the process. The remaining gas is sent to a fluidized bed reactor, where the CO is treated by reacting with the regolith (Martian soil) to form CO2. Economic analysis was conducted using NASA's Equivalent System Mass (ESM) Analysis. This method accounts for the infrastructure that would need to be shipped in addition to the process itself. To optimize project costs, emphasis was placed on reducing the mass, volume, and power of each piece of equipment, leading to novel designs and solutions. After optimization, the ESM of the process was 60 tonnes, which is 6.8% of the amount of O2 that would need to be shipped to Mars, resulting in over $3 billion saved in shipping costs. A detailed process design including equipment sizing, mass, materials, and power requirements, process flow diagram, piping and instrumentation diagrams, control strategies, and plant layout were delivered as a result of this project. Process optimization resulted in novel designs and heat integration strategies. Environmental impact, maintenance and safety were also analyzed for each step. An implementation plan was proposed based on mass constraints imposed by the developing interplanetary transportation technologies. Lastly, utilization of process by-products was also considered. To conclude, the proposed in-situ O2 production would significantly reduce shipping costs while meeting the O2 demand.