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Life Support and EVA Systems (6)

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DEVELOPMENT AND PARABOLIC FLIGHT TESTING OF A CLOSED LOOP PHOTOBIOREACTOR SYSTEM FOR ALGAE BIOMASS PRODUCTION IN HYBRID LIFE SUPPORT SYSTEMS

Abstract

To succeed in long-term manned space missions, the efficiency of conventional physico-chemical life support systems must be enhanced by combination with biological technologies, thus creating hybrid life support systems. A promising approach from the biological side is the cultivation of edible microalgae in a photobioreactor (PBR). Whereas inputs of carbon dioxide, nutrients and light are consumed, edible biomass and oxygen are two delivered outputs with high value for a life support system.

At the Institute of Space Systems of the University of Stuttgart a PBR setup has been developed that allows for the cultivation of Chlorella vulgaris in normal gravity and – preferably – microgravity (μg). The system consists of a main loop which circulates the water-based medium wherein the microalgae are cultivated through a flow chamber. This chamber provides optimal growing conditions to a quantity of alga as large as possible, focusing on optimal illumination, homogeneous distribution of nutrients and carbon dioxide, and a bubble free operation. Different designs of the flow chamber are used: a Kármán vortex design, a helix design and a conical design. The chamber is connected to peripheral units for gas injection, supplying carbon dioxide by a ceramic membrane, and for gas removal from the liquid phase by a vortex separator. Additional pumps in the main loop enable continuous removal of biomass and injection of nutrients. Sensors monitor crucial values like temperature, pressure, carbon dioxide concentrations, and flow speed.

The test setup was prepared for a parabolic flight campaign and tested during 93 parabolas in February 2014. Complementary ground tests have been performed before and after.

This paper presents the overall system design, the different possible designs of the flow chamber and the major peripheral components (pumps, sensors, illumination). A brief description of the test setup and the testing procedures are given. The data obtained from ground and parabolic flight experiments are presented, analyzed, and compared. Focus is set on the functionality of the pumped system, the gas injection and the gas removal, as well as the μg compatibility of the chosen components. From this data, recommendations of changes for a future PBR system in space are derived.