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Author: Mr. Joshua Nelson
International Space University (ISU), France

Prof.Dr. Vadim Rygalov
University of North Dakota, United States

MICRO-CLIMATE CONTROL DEVELOPMENT, LIMITATIONS, AND OPTIMIZATION FOR LOW PRESSURE SPACE GREENHOUSES

Abstract

This paper outlines background research and preliminary results from Reduced Pressure Greenhouse (RPGs) experiments conducted at the Low Pressure Test Bed (LPTB) at Kennedy Space Center in May and June 2011. RPGs have been suggested for growing plants in space environments for long-duration manned missions. As a result of the decreased pressure gradient between greenhouse and outside environment, system mass, and as a result, manufacturing, maintenance, and launch costs, can be significantly reduced. The decreased pressure gradient also leads to a decrease in materials used in manufacturing, a decrease in the leak and replenishment rate, and provides advantages for system maintenance. From 1990 to 2004, NASA's space plant scientists and engineers tested this concept experimentally and ran several projects researching plant growth under low atmospheric pressure (Bucklin et all, 2001; 2004) These preliminary studies showed that the fundamental mechanisms of material and heat exchange are altered under decreased pressure. At present no satisfactory theoretical description of these alterations has been developed. Furthermore plant photosynthetic physiology could be significantly modified by these alterations. Environmental control (temperature and humidity) techniques developed for normal atmospheric pressure (101.3 kPa) are also negatively affected by changes in material and heat exchange due to the lower atmospheric pressure. These negative changes can minimize or even exceed the benefits of decreasing pressure. The theoretical minimum for total atmospheric pressure in RPGs has been suggested by number of research groups (Wheeler et al, 2000) as around 9 kPa (approximately 1/10 of normal Earth atmosphere): 5 kPa of O2, 3 kPa water vapor, and 1 kPa CO2 partial pressure (for plant photosynthesis) and trace gases. Experiments conducted from 2005 - 2009 at the Low Pressure Test Bed (LPTB) determined that: • As the atmospheric pressure decreases, difficulties in maintaining environmental control (temperature and humidity) for maximum plant growth increase non-linearly; • Greenhouse pressures below 20 – 25 kPa could not be justified by system mass savings due to increase of electrical power to provide sufficient air circulation rate and increase of mass for environmental control systems; A second study will be conducted at the LPTB from May to June 2011. The aim of this research is to quantify how energy requirements for environmental control increase with decreasing greenhouse pressures. This will lead to an understanding of the costs and benefits of different operating pressures for a Reduced Pressure Greenhouse. Results will be presented at IAC2011.