Advanced Life Support System Water Reclamation Using DYNAJET® Cavitating Jets

K. M. Kalumuck, G. L. Chahine, C-T Hsiao, and J-K Choi

DYNAFLOW, INC., 10621-J Iron Bridge Road, Jessup, MD 20794
Email: ken@dynaflow-inc.com

ABSTRACT

Current space water reclamation systems require resupply and expendable use that are too large for long duration remote applications such as Mars expeditions and lunar bases and are expensive for long duration earth orbit missions. In this SBIR project, currently in Phase II, we are developing a novel jet-induced cavitation process for water reclamation that is lightweight, low maintenance, low energy, reliable, and requires little or no expendables. The DYNAJET® cavitating jet technology would accomplish four water reclamation functions: total organic carbon (TOC) reduction, oxidation of specific compounds that are problematic for current systems, microorganism destruction, and oxygenation.

Cavitation is known to produce reactions in water resulting in organic compound oxidation. This is due to the extreme transient pressures and temperatures created during cavitation bubble collapse, resulting in the production of strongly oxidizing hydroxyl radicals and pyrolysis within the cavitation bubble. High-powered ultrasound is also known to disrupt microorganisms. We have demonstrated that jet-induced cavitation can accomplish such oxidation with up to two orders of magnitude greater energy efficiency.

We have thus far demonstrated the feasibility of the DYNAJET® cavitating jet technology to accomplish multiple water reclamation functions including TOC reduction in simulated hygiene waste and in bioreactor effluent provided by NASA, reduction of alcohol and acetone concentrations, and oxygenation. We also have begun a detailed investigation of microorganism destruction beginning with selected bacteria strains and media. Periodic sampling, plating, and counting are used to assess the effectiveness of cavitation in reduction of the number of Colony Forming Units (CFU) to NASA standards. We have also begun expanding the parameter range investigated in order to optimize the system for individual and simultaneous water reclamation functions (i.e., for selected contaminant oxidation, TOC reduction, microorganism destruction, and oxygenation). Controlled experiments are being conducted in several laboratory scale recirculating flow loops employing a variety of cavitating jet configurations and operating conditions. Periodic sampling and measurement of the concentrations of the target contaminants and the dissolved oxygen content are employed to obtain histories of the contaminant concentration reduction versus time. Energy efficiencies are determined based on the energy input required to produce a given level of contaminant or microorganism concentration reduction. These data will be combined with results of a modeling effort to obtain a set of scaling laws to be used for design purposes. Visualization of the cavity characteristics as a function of conditions is being employed utilizing high-speed video and Plexiglas nozzles and reaction chambers. The observed cavity characteristics are being correlated with the measured results of the contaminant reduction experiments in order to provide a mechanistic understanding of desired cavity morphologies and thus guide selection of improved configurations.

The experimental effort is being supported by the parallel development of predictive models. Existing cavitation bubble dynamics models are being expanded to include models for the generation and transport of radicals and contaminants and the subsequent oxidation reactions. Results of parametric studies with these models will be utilized in conjunction with results of the laboratory experiments in order to interpret the data, guide future experiment selection, and develop scaling laws.

A summary of results to date, their implications for development of a high efficiency advanced life support water reclamation system for long duration space flight, and an outline of planned work are presented.