Carbon Dioxide Reduction Technology Trade Study

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For long-term human missions, a closed-loop atmosphere revitalization system (ARS) is essential to minimize consumables. A carbon dioxide (CO_2) reduction technology is used to reclaim oxygen (O_2) from metabolic CO_2 and is vital to reduce the delivery mass of metabolic O_2. A key step in closing the loop for ARS will include a proper CO_2 reduction subsystem that is reliable and with low equivalent system mass (ESM).

Sabatier and Bosch CO_2 reduction are two traditional CO_2 reduction subsystems (CRS). Although a Sabatier CRS has been delivered to International Space Station (ISS) and is an important step toward closing the ISS ARS loop, it recovers only 50% of the available O_2 in CO_2. A Bosch CRS is able to reclaim all O_2 in CO_2. However, due to continuous carbon deposition on the catalyst surface, the penalties of replacing spent catalysts and reactors and crew time in a Bosch CRS are significant.

Recently, technologies have been developed for recovering hydrogen (H_2) from Sabatier-product methane (CH_4). These include methane pyrolysis using a microwave plasma, catalytic thermal pyrolysis of CH_4 and thermal pyrolysis of CH_4. Further, development in Sabatier reactor designs based on microchannel and microlith technology could open up opportunities in reducing system mass and enhancing system control. Improvements in Bosch CRS conversion have also been reported. In addition, co-electrolysis of steam and CO_2 is a new technology that integrates oxygen generation and CO_2 reduction functions in a single system. A co-electrolysis unit followed by either a Sabatier or a carbon formation reactor based on Bosch chemistry could improve the overall competitiveness of an integrated O_2 generation and CO_2 reduction subsystem.

This study evaluates all these CO_2 reduction technologies, conducts water mass balances for required external supply of water for 1-, 5- and 10-yr missions, evaluates mass, volume, power, cooling and resupply requirements of various technologies. A system analysis and comparison among the technologies was made based on ESM, technology readiness level and reliability. Those technologies with potential were recommended for development.