Plasma Pyrolysis Assembly Regeneration Evaluation

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Abstract

In April 2010 the Carbon Dioxide Reduction Assembly (CDRA) was delivered to the International Space Station (ISS). This technology requires hydrogen to recover oxygen from carbon dioxide. This results in the production of water and methane. Water is electrolyzed to provide oxygen to the crew. Methane is vented to space resulting in a loss of valuable hydrogen and unreacted carbon dioxide. This is not critical for ISS because of the water regurgitated from Earth. However, in order to have enough oxygen for long-term missions, it will be necessary to recover the hydrogen to maximize oxygen recovery. Thus, the Plasma Pyrolysis Assembly (PPA) was designed to recover hydrogen from methane. During operation, the PPA produces small amounts of carbon that can ultimately reduce performance by forming on the walls and windows of the reactor chamber. The carbon must be removed, although mechanical methods are highly inefficient, thus chemical methods are of greater interest. The purpose of this effort was to determine the feasibility of chemically removing the carbon from the walls and windows of a PPA reactor using a pure carbon dioxide stream.

Background

The Plasma Pyrolysis Assembly (PPA) is designed to extract hydrogen from methane by partial pyrolysis: 

\[ 2CH_4 \rightarrow 3H_2 + C_2H_2 \]

If full pyrolysis occurs, unwanted carbon is formed: 

\[ CH_4 \rightarrow 3H_2 + C \]

The carbon that is formed can clog the gas ports and foul the microwave window within the reactor. It has been proposed that the reactor can be chemically cleaned with carbon dioxide through the reaction: 

\[ CO_2 + C \rightarrow 2CO \]

The sudden decrease in reflected power indicates when the plasma ignited in the PPA reactor.

Average Input Power vs. Pressure

Testing indicated that CO2 plasma was more easily ignited at lower pressures. It was not possible to ignite the CO2 plasma at 45 torr.

Carbon Collected

Carbon accumulation was found to be fairly consistent between 6-hour repeats.

Regeneration Results

Carbon monoxide was produced in similar quantities and for similar lengths of time for each trial.

Future Work

Future work will include the following efforts:

• All data points must be repeated to ensure statistically significant results.
• Testing should be completed to determine the maximum carbon removal and time necessary for completion.
• Longer accumulation times must be attempted before regeneration.

Conclusion

This testing showed that a CO2 plasma could be ignited at pressure as high as 30 torr and a CO2 flow rate of 200 SmLPM. Carbon deposition from nominal PPA operation is repeatable. Finally, it has been shown that surfaces of the PPA can be regenerated with a CO2 plasma while generating minimal quantities of CO.