ECLSS for Manned Space Exploration

Masato Sakurai（JAXA）
*JAXA, Chofu, Tokyo, 182-8522, Japan
E-Mail: sakurai.masato@jaxa.jp

To support manned space missions beyond Earth's orbits, recycling life support systems will be necessary to reduce the mass of consumables required. The common and crucial key technology in these manned systems is Environmental Control and Life Support System (ECLSS). It is proposed that these technologies should be focused, to take initiative on promoting a manned based system. The Japan Aerospace Exploration Agency (JAXA) is therefore developing life support technologies for future manned space missions such as water purification, CO_2 reduction and oxygen generation. In order to compare an advantage of non-regenerative and regenerative ECLSS, an Equivalent System of Mass (ESM: volume and energy equivalent to weight) trade study was carried out.

Key words; ECLSS, Air Re-vitalization, Water electrolysis, CO_2 removal, gas/liquid separation

1. Introduction

In recent years, the expansion of manned space activities to the moon and Mars are expected. Along with it, an environment control life support system (ECLSS) with high material regeneration rates. Which will be required to be operated on longer term missions. Therefore, it is necessary for technologies to make the system small, lightweight, and power saving. As has been adopted by ISS, in the current technology,

It is desirable to further reduce the supply of water required for O_2 generation to enable longer periods of human habitation in low Earth orbit, and missions beyond. The theory of the air regeneration system has been well studied, but systems that operate well enough to be of practical use have not yet been developed. Although, early realization of a closed-cycle air regeneration system for space applications is desirable, there are many technical problems to overcome. One of the main problems is the significant limit on the amount of energy available. The maximum power generating capacity of the ISS is about 120 kW, and the available power on manned missions beyond the Earth's orbit will typically be more constrained. Another problem is that water/gas separation is required in many parts of the air regeneration systems, but it is difficult to design a system that operates well in microgravity. This problem is particularly acute in the water electrolysis system, because the water required for electrolysis and the generated gas are constantly in contact.

2. Air re-vitalization

The air regeneration system of Figure 1 is a practically superior system. This could be achieved by a recirculating system. A water electrolysis system produces O_2 and H_2 from water. The crew inhale the O_2 and exhale CO_2, which is concentrated in an absorber by a CO_2 removal system using a pressure swing. The concentrated CO_2 is then reduced by a CO_2 reduction system using the Sabatier reaction ($CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$), producing H_2O and CH_4. The water is then electrolyzed and consumed by the crew again. This proposed air regeneration system can thus significantly reduce the volume of water supply needed, and it's only waste material is CH_4. The supply of crew O_2 on the International Space Station (ISS) is also produced mainly by electrolyzing water.

JAXA is trying to establish the "Closed Loop ECLSS Technology" that requires no water or oxygen supply. The ground demonstration of JAXA's air-recycling system has started in 2014. The system consists of the Contaminant Gas Removal Assembly, the CO_2 Reduction Assembly and the O_2 Generation Assembly. The Contaminant Gas Removal Assembly has the ability to adsorb CO_2. Heating is not needed as the CO_2 adsorption material is regenerated by pressure swing. The ARS applies a low-temperature Sabatier reactor in CO_2 deoxidization. Since the toxic substances such as fluorine compounds are not generated, the catalyst reacts at 250 degrees Celsius. The O_2 Generation Assembly includes the cathode-feed type water electrolysis, which electrolysis voltage is low with high electrolysis current density.

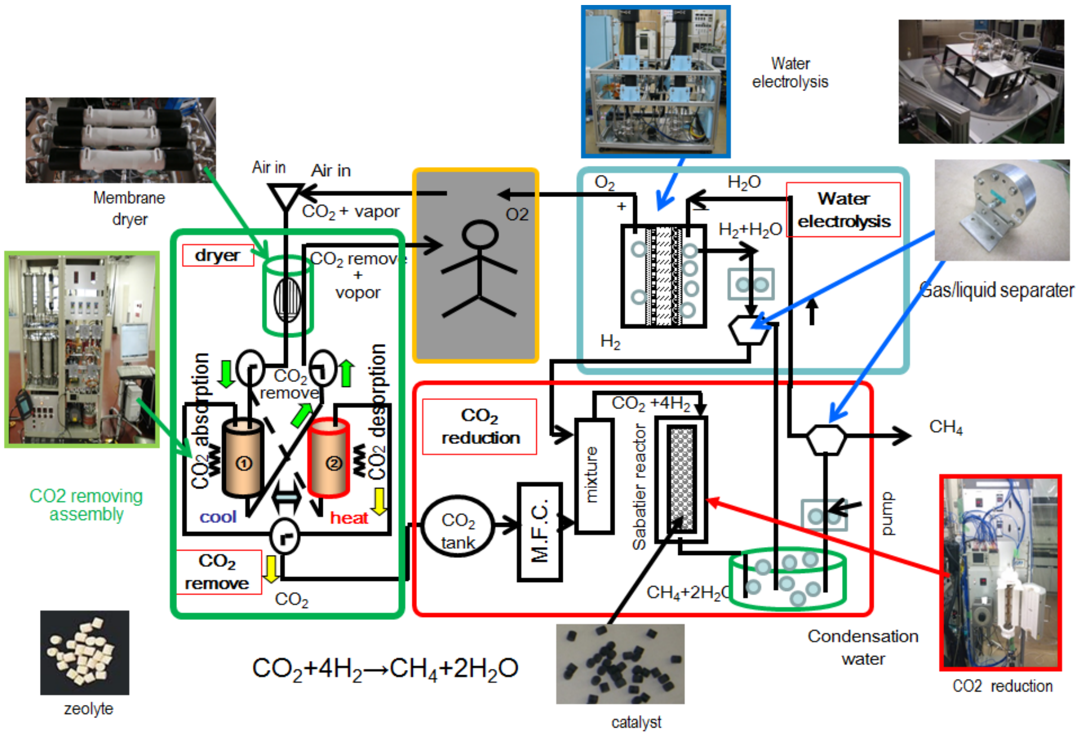

Figure 1 Concept of air revitalization system using CO_2 reduction

3. Equivalent System of Mass

An Equivalent System of Mass (ESM: volume and energy equivalent to weight) trade study[2)] was carried out with the following suppositions:

- Four crew members
- Reduction of CO_2 by Sabatier reaction
- Water reclamation by existing ISS method
- Oxygen production by water electrolysis

The ESM values are shown in Table 1. Values used were volume;100kg/m^3, power;62kg/kWe (solar panels only, excluding batteries), and cooling;53.6 kg / kWth. Consumption rates of 6 kg/day/person for water 0.83 kg/day/person for oxygen was used, and the weights of the non-regenerative ECLSS units installed in the ISS were assumed. As shown in Figure 2, if an 80% recycling rate is established, the equipment weight will become about 1,220 kg. For missions longer than 80 days, regenerative ECLSS is found to be advantageous over a pure consumption ECLSS. If the initial unit weight can be reduced to 800 kg, the breakeven point moves to 60 days.

Table 1 Mass equivalents on the lunar surface

Mission	Volume [kg/m3]	Power [kg/kWe]		Cooling [kg/kWth]
Open Loop (Lunar Surface Access Module)	49.6	179.6		56.0
Low Degree of Closure (Lunar Destination Surface System)	100.0	749 PV + Regenerative Fuel Cell	62 Tracking PV no storage	53.6

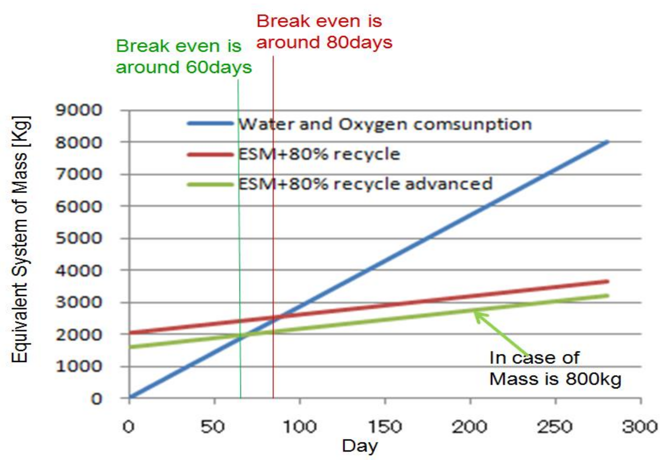

Figure 2 Breakeven point between non-regenerative ECLSS (pure consumption) and regenerative ECLSS

Reference

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