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# 有人宇宙活動に必要なエネルギー供給デバイスの検討

# Study of Energy Storage Devices for Manned Space Mission

内藤　均 [1]
**Hitoshi NAITO[1]**
1　宇宙航空研究開発機構，Japan Aerospace Exploration Agency#1,

## 1. Introduction

The research and development of Space Activity such as the moon exploration etc. has been emphasized recently. One of the key technologies to operate missions successively is the energy storage and its supply. The research and development of the super-high energy density lithium-ion battery and the regenerative fuel cell (RFC) is indispensable to realize the long-term mission operation especially manned missions. Gaseous oxygen and hydrogen and liquid water are coexisted inside of RFC, and the separation of these gas and water is the important issue in which RFC is operated in the microgravity condition. In this paper, we will present the outline and the current status of the R&D of these power storage devices and the technical task of RFC operation in space.

## 2. Promising Energy Storage Devices for Manned Space Mission

Table 1 shows the candidates of power sources for space missions. As the primary cell can supply power short time because it cannot recharge, the clean energy storage devices such as rechargeable cell and RFC with Solar cell, and the nuclear power are the candidates for long-term and/or manned missions which are required large amount of energy in space. From the point of safety, clean energy storage devices are preferable. Therefore, Lithium ion battery (LiB) and the RFC are the candidates. In general, the mass of the components should be lightweight, that is, high energy density. LiB for space exploration is under investigating[1)] and 220Wh/kg is achieved up to now. However, LiB is difficult to achieve higher energy density such as 300 Wh/kg with long life performance at the existing state. As RFC has potential to achieve higher energy density when the energy demand become larger, it is suitable for manned space mission.

Table 1 Candidate power sources for space activities

| | Power Source for Space Activities | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | Solar Cell and Energy Storage | | Nuclear Power | | |
| | N/A (Hibemation) | Primary Cell | Li-ion | RFC | RHU | RTG | FPS |
| Application on Lunar Surface (Heritage) | Surveyer | Penetrator | None | None | Lunokhot | ALSEP | None |
| Electric Power | 0 | <1W | 10W ～100W | 100W ～10kW | 1W | 100W ～1kW | 10kW ～100kW |
| Place | All Area | Low-Mid Latitude | All Area | All Area | All Area | All Area | All Area |
| Life(Year) | - | < 1 | > 1 | > 3 | > 10 | > 10 | > 10 |
| Technical Issue | Reliability | None | >200Wh/kg, Wide temp. range | Lightweight >480Wh/kg | Safety | Safety, Converter | Safety, Small Size furnace |

RFC:Regenerative Fuel Cell
Lunokhot: Russian luner surface experiment program
ALSEP : Apollo Lunaer surface Experiment Package
RHU:Radioisotope Heater Unit
RTG:Radioisotope Thermoelectric Generator
FPS:Fission Power Source

## 3. Regenerative Fuel Cell and its Task under microgravity condition

Regenerative fuel cell (RFC) is composed of fuel cell (FC) subsystem and electrolyzer cell (EC) subsystem. An image of RFC is shown in Fig. 1. Oxygen and hydrogen are electrochemically reacted and produces both water and electricity. During power generation, these gases are flown into fuel stack but not all the gases react and part of gases are remained. These remained gases are used as removal of produced water at the FC electrode surface. Therefore, the mixture of oxygen or hydrogen gas and water were flown outside the FC stack. The remained gases should be used effectively, so that the mixture was separated at the gas-water separator and gases are re-used as electrochemical reaction to produce electricity. The gases and water in EC subsystem are flown vice versa as those in FC subsystem. Under the microgravity, gas water separation is one of the most difficult technologies, because usually this is used by gravity on the ground. Several gas water separation methods under the microgravity are considered and tested. Some methods are successfully performed but are required much electricity and/or drawn with contaminants. Therefore, further investigations are necessary for use as devices. In the presentation, the task of the gas/water separation will be introduced.

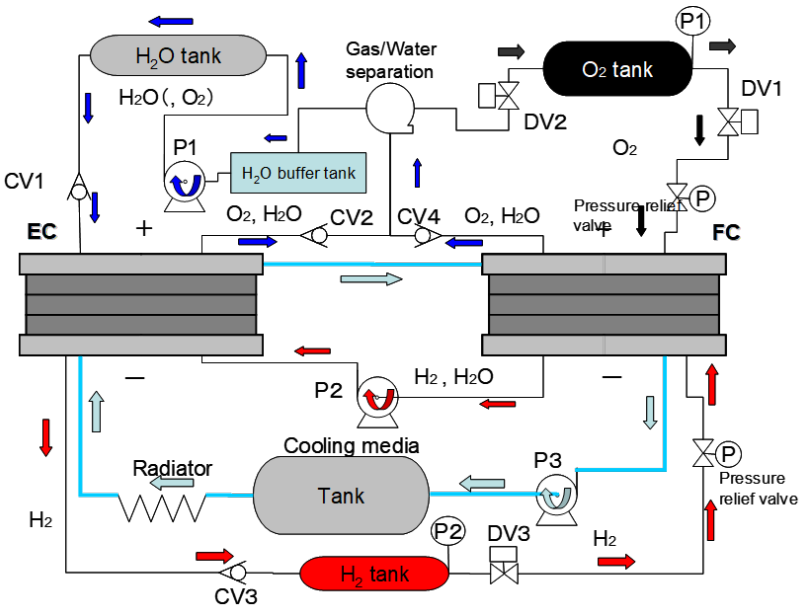


Fig. 1 An image of regenerative fuel cell system

## References

1) A. Mori, et al.: 64th Symp. of Space Science and Technology, 4K02, October 2020.