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宇宙ステーションにおける水再生

Water Recovery Systems on the Space Station

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1. Abstract

We developed a urine recycle system, the JEM Water Recovery System (JWRS), which was designed as a sub-scale system for technology in-orbit demonstration. The JWRS is designed to operate without consumables and achieve 85% water recovery. The treatment process uses cation exchange resins to prevent scale problems, followed by electrolysis and electrodialysis to purify the water to drinking water standards. The technology demonstration was a very important mission to demonstrate the principles of our unique water recovery system and identify challenges in operating it in orbit. In the electrolysis process, bubbles are generated by the electrolysis of water and the oxidative decomposition of organic matter. On the ground, the bubbles quickly move away from the electrode surface due to buoyancy, stabilizing the electrolysis voltage. However, in microgravity, the bubbles may remain on the electrode surface due to surface tension, resulting in poor electrical resistance. In particular, in electrolysis processes with low flow rates, the force that separates the bubbles from the electrode surface is weak, increasing the risk of voltage fluctuation. Therefore, the electrolysis cell is designed to minimize dependence on gravity. We consider the electrolysis is carried out under plug flow, and the water flowing from the electrolysis cell side sweeps away bubbles, which has the effect of preventing the electrode surface from being covered by bubbles. However, the processes of bubble generation and dislodgement are very complex. The article introduced microgravity effects on the electrolysis process.

Fig1. JWRS

2. Water Recovery System Overview

Urine contains various components, and urine collected in a microgravity environment is characterized by high concentrations of cations such as calcium and magnesium. This can lead to equipment failure due to precipitation within the urine regeneration system. On the International Space Station (ISS), urine is recycled through a process that combines vacuum distillation, catalytic reactions, and adsorption technologies[1]. However, the dependence on consumables for residue removal makes this system unsuitable for future human deep space missions where resupply supplies from Earth will become increasingly limited. To address this, we developed four water treatment processes that were integrated. To eliminate consumables, a regeneration process for the ion exchange resin was also incorporated. These four processes include (1) ion exchange, (2) electrolysis, (3) electrodialysis, and (4) ion exchange resin regeneration, as shown in Figure 2.

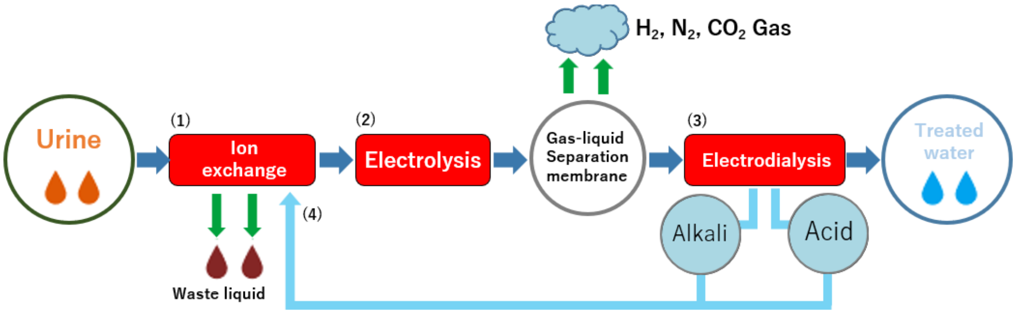

Fig.2 Concept of water treatment process.

3. Technology demonstration in microgravity

We conducted an in-orbit demonstration of our unique water recovery system and forcusd on the peformance of in-orbit electrolysis cells. It was confirmed that the first cell near the inlet received continuous and stable electricity. In contrast, the second cell near the outlet, where bubbles discharged from first cell accumulated, exhibited increased fluctuations in current and voltage due to bubble behavior under microgravity. However, the increase in average voltage was slight, and continuous current flow was maintained. These results demonstrate that stable electrolysis is achievable even under microgravity.

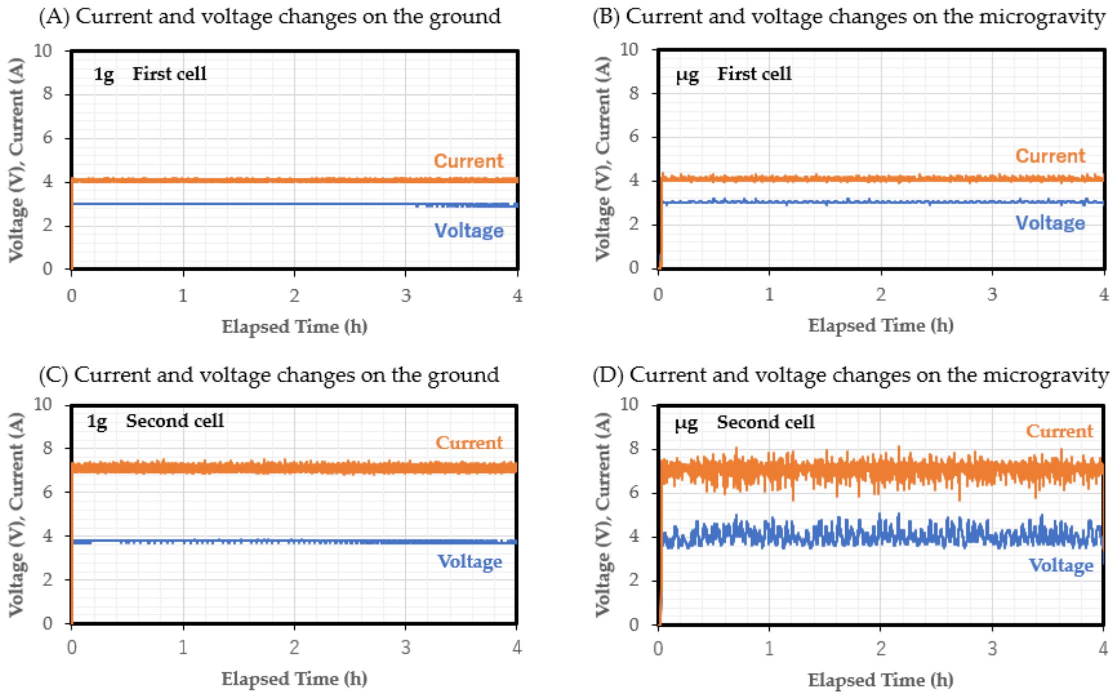

Figure 3. Gravity dependence of the electrolysis process: (A)/(B) are First cell - Applied current is 4.1 A , Flow rate is 1.7 ml/min. (C)/(D) are Second cell – Applied current is 7.1 A, Flow rate is 1.7 ml/min.

Under standard operating conditions, water electrolysis was possible in a region unaffected by microgravity, confirming the validity of the design[1].

References

1) Matsumoto, S., Akashi, M., Shido Y., Saruwatari, H., Matsumoto, Y., Izawa S., and Ishiwata, K., "Technology Demonstration of New Water Recovery System onboard ISS" , 53rd ICES, Kentucky,ICES-2024-151, 2024