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CO_2 除去システム軌道上実証計画と装置設計のための地上試験

Ground testing for the ISS demonstration and system development of the CO_2 removal system

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1. Introduction

JAXA is conducting basic research on environmental control and life support systems (ECLSS), which are indispensable as one of the human spaceflight technologies, and is advancing to research applying them to system development. CO_2 removal system is one of the ECLSS subsystems to remove astronaut metabolic CO_2 from the cabin air. JAXA will provide CO_2 removal system to the Gateway's International Habitation module (I-HAB), which is the core system supporting human space activities orbiting the Moon. As a precursor mission, JAXA has a plan to demonstrate the CO_2 removal technology in Kibo of the International Space Station (ISS) that is an experimental facility providing a long and favorable microgravity environment so as to proof the concept and to acquire on-orbit operation experiences and lessons learned to be fed back to the Gateway program[1)]. Ground tests performed in advance of the ISS demonstration and development of the CO_2 removal system are introduced in this paper.

2. Ground testing of the CO_2 removal system

2.1. Test equipment

Figure 1 shows the schematic diagram of a pressure-temperature swing CO_2 removal process for the ground test equipment. It consists of two series of CO_2 removal processor, A and B, which are operated alternately for continuous processing. Therefore, two CO_2 sorbent beds and two desiccant beds are equipped. Solid amine-based particle (R11) is selected as the CO_2 sorbent[2)], and solid silica gel particle as the desiccant. While one side is absorbing CO_2 and dehumidifying, another is regenerating CO_2 sorbent and desiccant. In the next cycle, series A and B is switched. In one side, air flow is generated by a blower. In another, CO_2 is desorbed due to temperature rise by the heaters built in the canister and pressure drop by the vacuum pump, and then exhausted from the canister. An overview photo of the test equipment is shown as Figure 2.

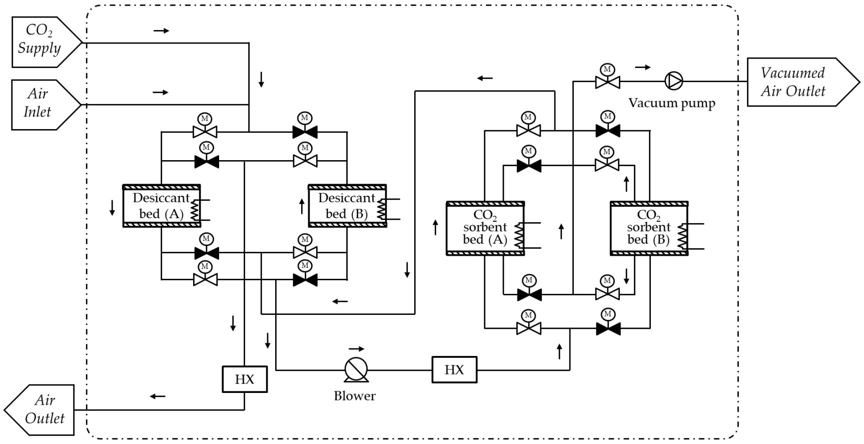

Figure 1. Schematic diagram of the test equipment

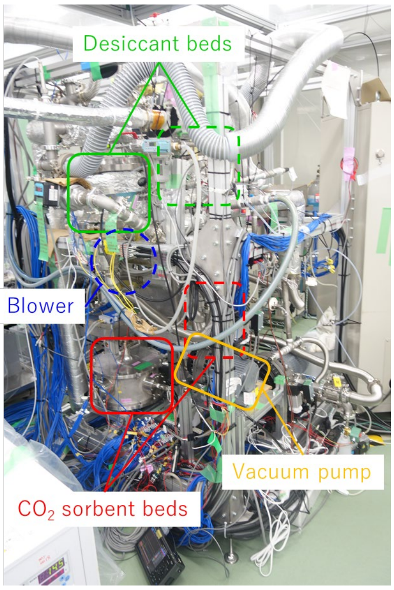

Figure 2. Overview of the test equipment

2.2. Cyclic operation test

JAXA performed cyclic operation tests on the ground with the equipment described above and the prototype CO_2 solid sorbent canister, simulating the ISS cabin condition of inlet CO_2 concentration, air temperature, humidity and coolant water temperature. Effects of operation parameters on CO_2 removal performance and phenomenon were evaluated through lots of test data reviews, and then the performance goal of 1.36 g/min or over was achieved. Figure 3 through 5 show the typical test data where performance of approximately 1.41 g/min was obtained with the test condition of cycle time of 50 minutes, air flow rate of 15 Nm³/h, heater temperature control target of 73 °C for regeneration.

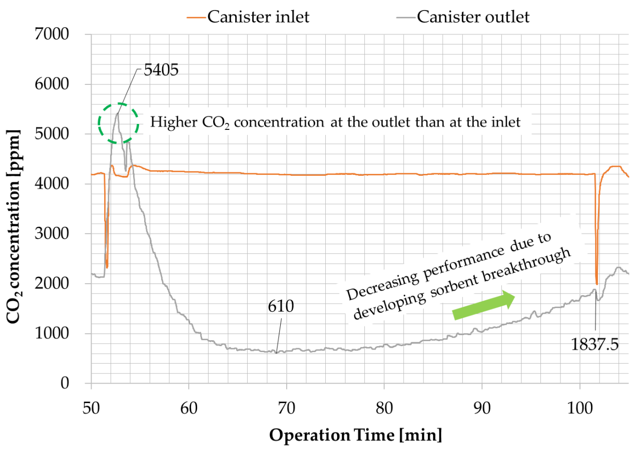

Figure 3. CO_2 concentration profile in the absorption cycle

At the beginning of the CO_2 absorption cycle, CO_2 with concentration higher than that of inlet is exhausted from the canister because sorbent temperature was still high at the end of the previous regeneration cycle (See Figure 3 and 4). Temperature at the bottom, mid and top area in the CO_2 sorbent was measured, where air flows upward. It is known from the isotherm that the CO_2 solid sorbent indicates higher CO_2 absorption capability at lower

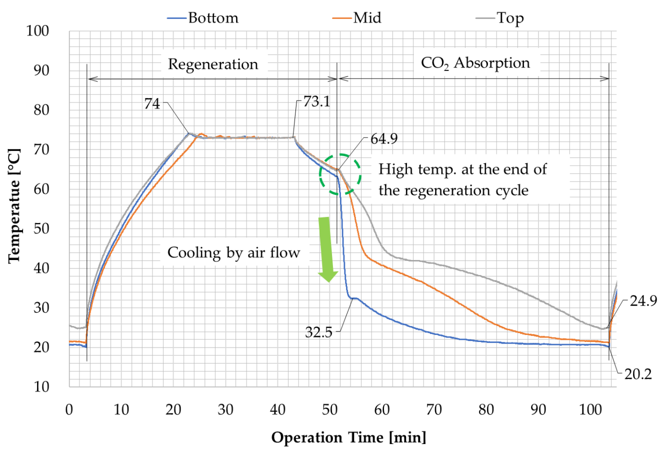

Figure 4. Temperature profile inside the CO_2 canister

temperature and higher $ppCO_2$. In 15 minutes, sorbent was cooled enough by air flow, and the highest performance was recorded, where approximately 85 % of CO_2 in the air flow is absorbed. Then sorbent breakthrough develops, and the performance keeps decreasing gradually until the end of the absorption cycle (Figure 3).

In the regeneration cycle, inside of the canister is vacuumed and heated to desorb CO_2 from the sorbent. Temperature rise causes CO_2 desorption from sorbent, which results in pressure rise inside the canister. It reaches the highest of approximately 2.1 kPa in 20 minutes as shown in Figure 5. Thereafter desorption velocity decreases and inside pressure keeps dropping until the end of the regeneration cycle because the vacuum pump keeps constant vacuuming velocity. The heaters are operated for 40 minutes and then turned off for the last 8 minutes to allow the CO_2 solid sorbent to cool before the next absorption cycle because air flow with high temperature makes the CO_2 solid sorbent oxidized, which causes gradual deterioration of the sorbent and degradation of CO_2 absorption capability[2].

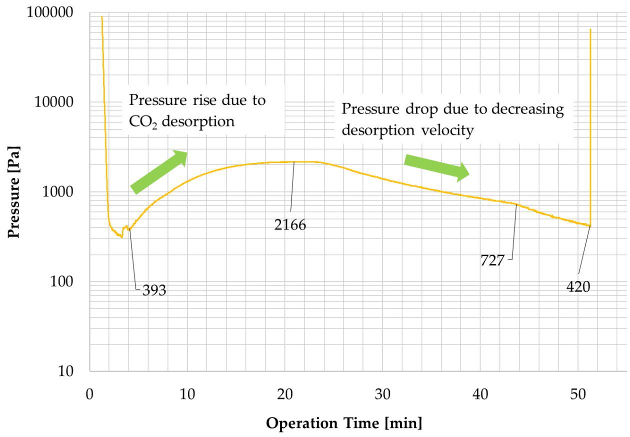

Figure 5. Pressure profile inside the CO_2 canister in the regeneration cycle

3. Conclusions

Ground tests were performed with the prototype CO_2 solid sorbent canister for studying absorption and regeneration phenomena, optimization of parameters of cyclic operation and for fundamental evaluation of canister capability. Results and lessons learned through the ground tests are successively being fed back and reflected to the ongoing ISS demonstration program[1] and the Gateway program.

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