

Gas and Water Recycling System  
for IOC Vivarium Experiments

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Abstract

The animal and plant experiments for the Japanese life science mission at the initial operational capability of space station and the associated gas and water recycling units for supporting these experiments were investigated.

Based on these investigations, preliminary design was conducted. The interfaces between animal experiment facility, large scale phytotron and these units and the scale of these units such as estimated power requirements, capacity and so on are described.

1. Japanese life science missions

Many life science experiments are proposed by Japanese researchers to be conducted in the Japanese experiment module (JEM) which will be attached to the space station common module. These experiments are classified into three time phased missions such as the IOC phase, mid phase and growth phase. In the IOC phase 28 experiments (1),(2) are proposed so far and they are also classified

into four fields such as biology, space medicine, CELSS and biotechnology. The gas and water recycling units are used to support biology, CELSS and medicine experiments which use small animals, plants and algae in the IOC phase. Table 1 shows the missions proposed in Japan.

Main experiment items using small animals are as follows.

- . Mechanism of space motion sickness and its countermeasure.
- . Musculoskeletal degradation mechanism and its countermeasure.
- . Change of kidney function and its countermeasure.
- . Blood and immunological change and its countermeasure.

Table 1. Proposed Missions

	Species	Research Field
Small Animal	Rat, Mouse, Squirrel Monkey, etc.	Medicine/Biology
Higher Plant	Lettuce, Spinach, Soy bean, Potato, Tomato, etc.	Biology/CELSS
Algae	Spirulina Chlorella	CELSS

Main experiment items using plants and algae are as follows.

- . Development, maturity, flowering, fructification and geotropism of plants.
- . Morphological and metabolic change of algae and plants necessary for controlled ecological life support system (CELSS).
- . Optimum cultivation technology in space for CELSS.

## 2. System Requirements

According to the concept study of Japanese experiment module so far, a single rack space will be provided for the experiments using small animals and plants respectively and a half rack space for the experiments of algae.

This module concept design will perhaps be changed in the phase B study, but seems not to be changed drastically. Therefore, the study for the required ability of water and gas recycling units depends on the concept design of Japanese module. In a single rack six squirrel monkeys can be bred and 45cm x 60cm cultivation area can be used for plants and also for a half rack space 2 liter volume cultivation can be used for algae<sup>(3),(4)</sup>.

Estimated amounts of metabolism of these animals, plants

C-3

Table 2. Metabolism of Proposed Missions

(unit: Kg)

			Rat (10)	Squarrel Monkey (6)	Plant (45x60cm <sup>2</sup> )	Algae ( 2 lit. )	Total
Intake Quantity	Water	1 day	0.3	0.48	0.2	0.1	1.08
		90 days	27.0	43.2	18.0	9.0	97.2
	O <sub>2</sub> Gas	1 day	0.09	0.15	-	-	0.24
		90 days	8.1	13.5	-	-	21.6
	CO <sub>2</sub> gas	1 day	-	-	-	0.1	0.1
		90 days	-	-	0.6-1.0	9.0	9.6-10.0
Exhaust Quantity	Feces	1 day	0.14		-	-	
		90 days	12.6		-	-	
	Urine/ Waste Water	1 day	0.15	0.25	-	-	0.4
		90 days	13.5	22.5	30.0-50.0	2.0-4.0	68.0-90.0
	Trans- piration	1 day	0.15	0.23	0.2	0.1	0.68
		90 days	13.5	20.7	18.0	9.0	61.2
	CO <sub>2</sub>	1 day	0.1	0.18	-	-	0.28
		90 days	9.0	16.2	-	-	25.2
	O <sub>2</sub>	1 day	-	-	-	0.07	0.07
		90 days	-	-	0.4-0.7	6.3	6.7-7.0

and algae are shown in Table 2.

### 3. Composition and function of the system

The system consists of two main processing units, one of which is the gas recycling system and the other is the water recycling system. The block diagram is shown in Fig. 1. Only the interface between these units is a water pipe line, through which condensed water from the dehumidifier of the gas recycling unit is fed to the storage tank in the water recycling unit. Therefore, these units can be operated separately.

#### (1) Gas recycling system<sup>(3)</sup>

The required function of the gas recycling system is to take off  $\text{CO}_2$  gas from the outlet air of the animal vivarium and also take off  $\text{O}_2$  gas from the outlet air of the phytotron and the algae cultivator.

The separated  $\text{CO}_2$  gas is stored in the tank to supply for controlling air circumstances in the phytotron and the algae cultivator. The separated  $\text{O}_2$  gas is also stored in another tank for supplying to the animal vivarium.

The function diagram is shown in Fig. 2. As  $\text{CO}_2$  gas in the outlet air from the animal vivarium is gradually increasing, a part of the outlet air is directly returned to the animal vivarium and the residual air is led to the

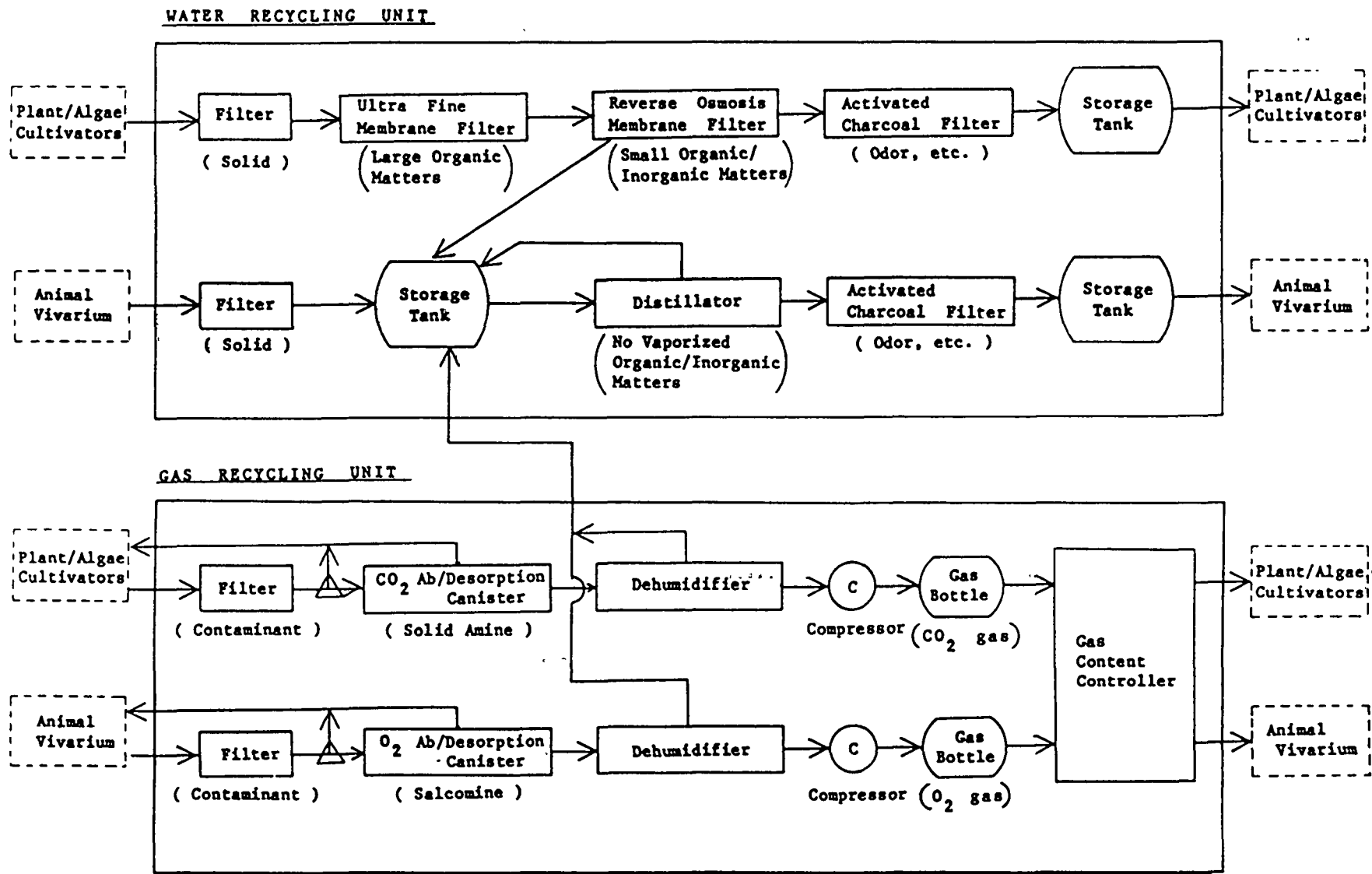


Figure 1 Functional Diagram of Gas and Water Recycling System

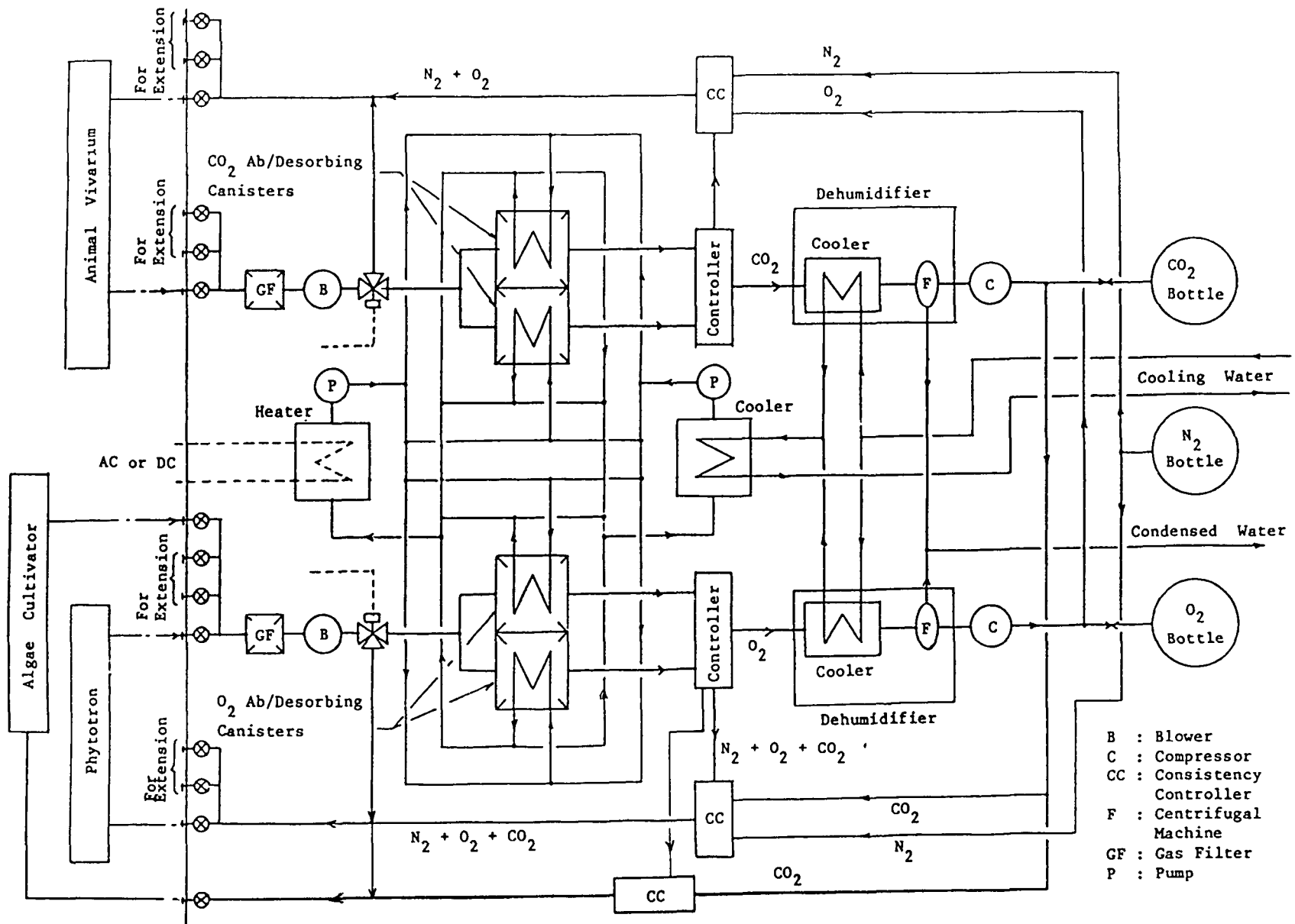


Figure 2 Block Diagram of Gas Recycling Unit

canister filled with solid amine which has the characteristics to absorb and desorb  $\text{CO}_2$  gas according to the change of temperature. One of the typical characteristics of solid amine is shown in Fig. 3. The dividing rate of the outlet air flow is controlled by the flow controller according to the required  $\text{CO}_2$  gas content which is planning to set below 0.5%.

To operate the process continuously, two canisters filled with solid amine are provided. When one of them works in  $\text{CO}_2$  absorbing phase, the other works in  $\text{CO}_2$  desorbing phase. Switching is automatically controlled by the event program.

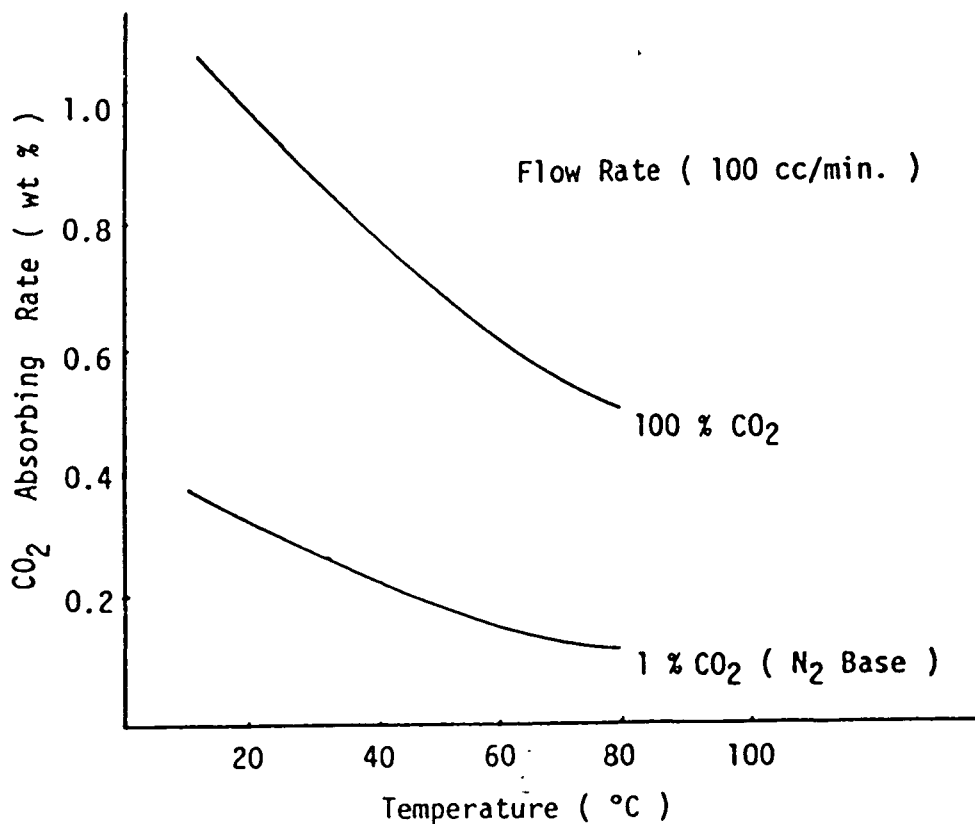


Figure 3 Solid Amine  $\text{CO}_2$  Absorb/Desorbing Characteristics



As  $O_2$  gas in the outlet air from the phytotron and the algae cultivator is also slowly increasing, a part of the outlet air flow from those experiment facilities is directly returned to the phytotron and the algae cultivator, and the residual air is led to the canister filled with salcomine which has the characteristics to absorb and desorb  $O_2$  gas according to the change of temperature.

One of typical characteristics is shown in Fig. 4. The dividing rate of the outlet air flow is controlled by the flow controller according to the required  $O_2$  gas content which is not determined now.

To operate the process continuously, two canisters filled with salcomine are provided. They work as same as the  $CO_2$  gas processing system.

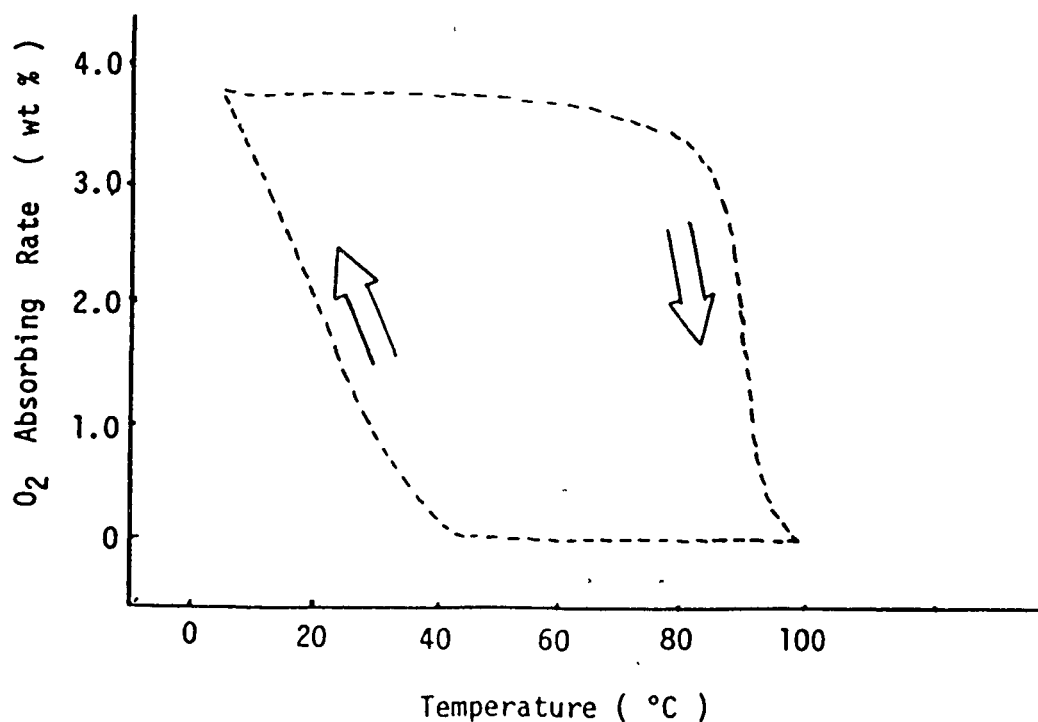


Figure 4 Salcomine  $O_2$  Absorb/Desorbing Characteristics

To use these two kinds of canisters continuously during at least three months, some improvements on the characteristics of solid amine and salcomine are supposed to be necessary. This gas recycling system does not include the control system for temperature and humidity of the supplying air to the experiment facilities. In each experiment facility, suitable air conditioning is independently demanded for providing the different air condition in each phase of the experiments. On the other hand, to control the gas contents in each facility separately makes the system and operation very complex and is causative of miss operation. Therefore, the concentrated method for gas contents control to each experiment facility seems to be better than the separated individual control method.

(2) Water recycling system<sup>(3)</sup>.

The required function of the water recycling system used in the IOC phase is to process urine from the animal vivarium and wasted nutrient solution from the phytotron and the algae cultivator and also to make the clean water enough to use as drinking water for animals and as the water to make refreshment of solution for plants and algae.

The waste liquid from the experiment facilities contains many kinds of organic matters, inorganic matters and

little solids such as pieces of roots, therefore, those materials must be removed. The functional diagram of the water recycling system is shown in Fig. 5.

As the drinking water for animals requires high purification level comparing to the water to make nutrient solution for plants and algae, the system consisted of two processing lines shown in Fig. 5 is chosen in order to make process effectively. Only the condensed liquid at the reverse osmosis membrane filter unit is fed to the distillator unit in order to recovery water much more.

The role of the ultra fine membrane filter is to remove large proteins. The reverse osmosis membrane filter is used to take off small molecular weight organic and inorganic matters such as NaCl and so on which pass through the ultra fine membrane filter. The purified water passed through the reverse osmoisis membrane filter is stored and used for plant and algae experiments. The residual condensed liquid is fed to the storage tank and mixed in the liquid coming from the animal vivarium. The mixed liquid is fed to the distillator to take off consistencies which are not vaporized. The residual organic matters and odor contained in the purified water from the distillator are finally taken off by the activated charcoal.

The residual liquid at the distillator is sent to the crystalizer and taken off crystalloid consistencies and fed back to the storage tank again.

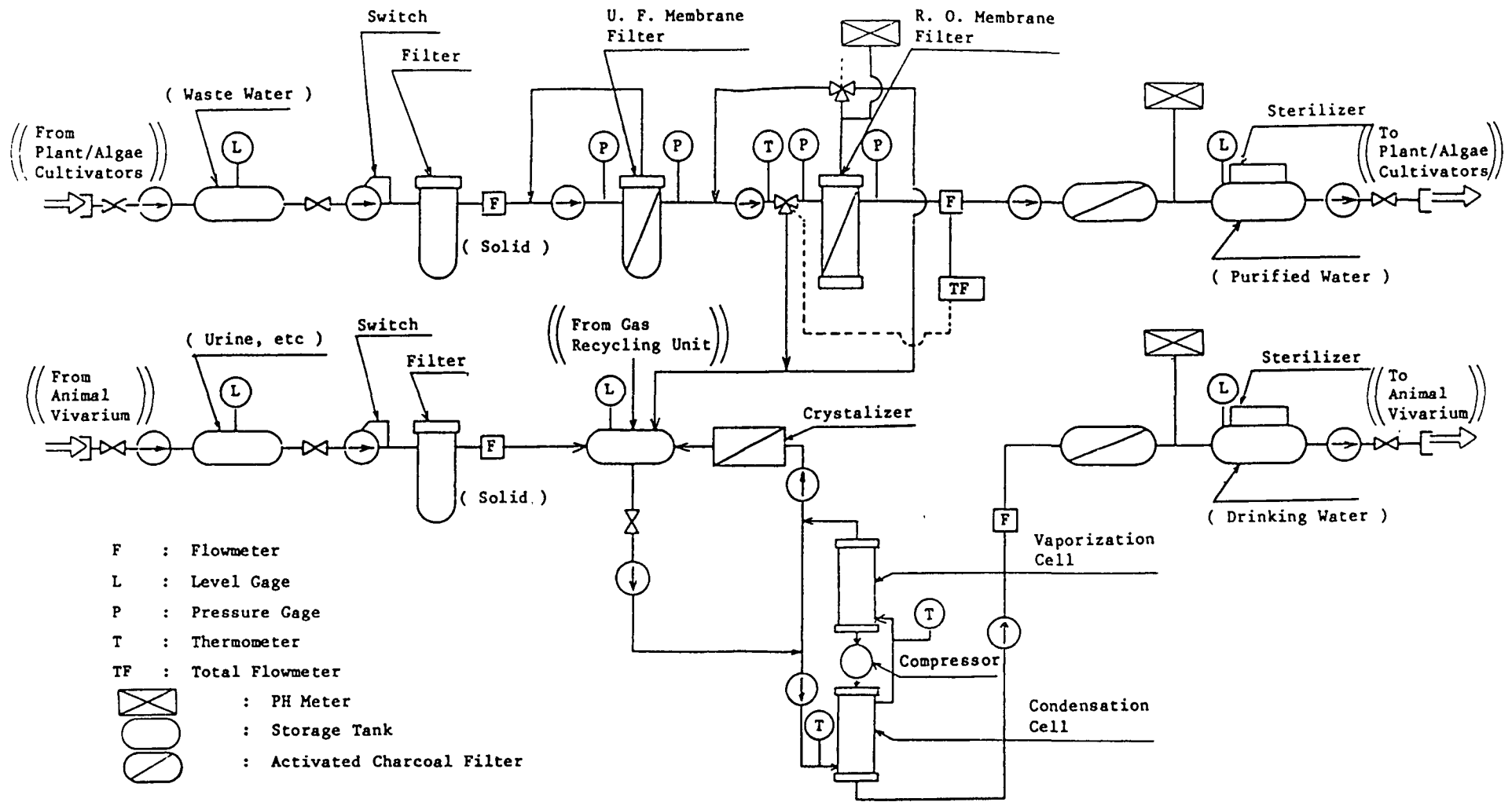


Figure 5 Block Diagram of Water Recycling Unit

The estimated volume of waste water from the plant and algae experiment facilities is about 26 liters and it is fed to the water recycling system every 15 days and processed in about six hours. On the one hand, as the estimated volume of liquid from the animal vivarium is about one liter every day, it is stored in the storage tank and processed every five days.

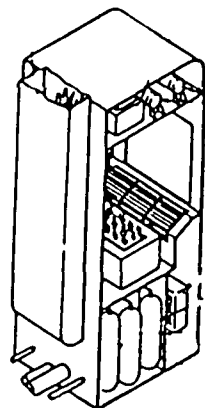
#### 4. Specifications of the system

The specifications of the water and gas recycling units are shown in Table 3 and the configuration is shown in Fig. 6.

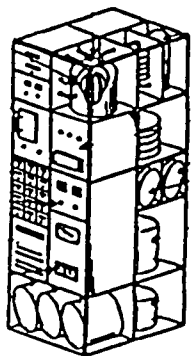
In order to use as a common experiment support facility of the life science missions, as shown in Fig. 7 it is

Table 3. Specification of Each Unit

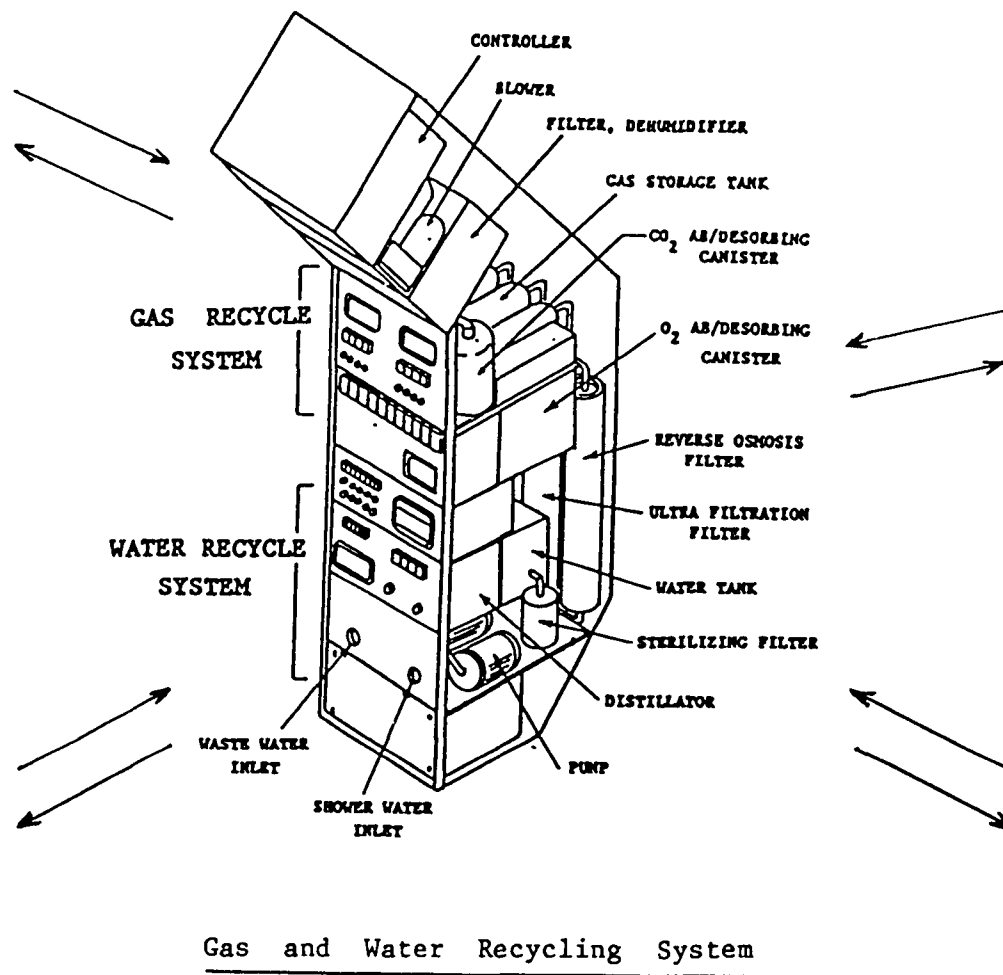
		Water Recycle Unit	Gas Recycle Unit
Volume		1/2 Single Rack	1/2 Single Rack
Weight (Kg)		250	200
Processing Capacity		5 lit./every 5 days 26 lit./every 15 days	CO <sub>2</sub> :0.33 Kg/day O <sub>2</sub> : 0.22 Kg/day
	Monthly (Kw/day)	4.22	12.13
	Average (Kw/hr)	0.18	0.51
	Monthly Total (Kwh)	127	364
	Peak (Kw)	0.52	0.56



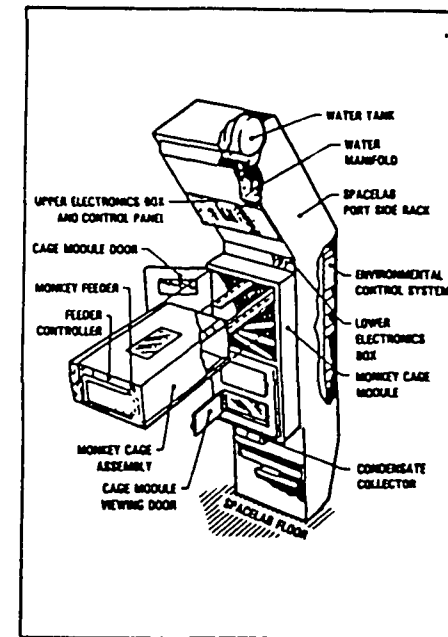
Phytotron



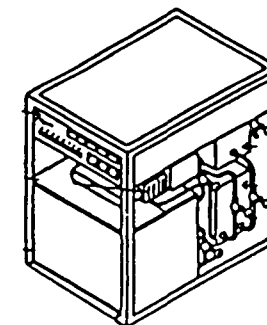
Algae Cultivator



Gas and Water Recycling System



Animal Holding Facility (RAHF)



Fish Breeding Equipment

Figure 7 Gas and Water Recycling System and Related Life Science Experiment Equipments

designed that the interfaces to the experiment facilities are only pipes and signal lines.

To make easily exchange the degraded canisters and filters, the cassette styles are adopted. As the minimum exchange interval, three months are planned.

## 5. Conclusion

These water and gas recycling units is designed as one of the common experiment support system for the life science experiment facilities used in the Japanese Experiment Module, and to use these units will save transportation and operation costs for the life science experiments in the space station.

These units are also designed to have so simple interfaces that the connection to another life science experiment facilities such as the Research Animal Holding Facility (RAHF)<sup>(5)</sup> developed by the Rockheed Missiles & Space Company shown in Fig. 7 can be easily done with small modifications.

## References

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