Available online at www.sciencedirect.com
ScienceDirect
PERGAMON
Acta Astronautica 61 (2007) 8–15
ACTA ASTRONAUTICA
www.elsevier.com/locate/actaastro

Regenerative water supply for an interplanetary space station: The experience gained on the space stations "Salut", "Mir", ISS and development prospects

Leonid Bobe[a,*], Nikoly Samsonov[a,1], Lev Gavrilov[a], Vladimir Novikov[a], Mihail Tomashpolskiy[a], Peter Andreychuk[b], Nikoly Protasov[b], Yury Synjak[c], Vladimir Skuratov[c]

[a] *NIICHIMMASH, Moscow, Russia*
[b] *RSC "Energia", Korolev, Russia*
[c] *IMBP RAN, Moscow, Russia*

Available online 13 March 2007

Abstract

Based on the experience in operation of Russian space stations Salut, Mir and International space station ISS the station's water balance data, parameters and characteristics of the systems for water recovery have been obtained. Using the data design analysis an integrated water supply system for an interplanetary space station has been performed. A packaged physical/chemical system for water supply is composed of an integrated system for water recovery from humidity condensate, green house condensate, water from carbon dioxide reduction system and condensate from urine system; a system for water reclamation from urine; hygiene water processing system and a water storage system. The take off mass of the packaged water supply system (including expendables, redundancy hardware, equivalent mass of power consumption and of thermal control) is appropriate for Mars missions. The international space station is indispensable for verifying innovative processes and new water recovery systems intended for missions to Mars.
© 2007 Elsevier Ltd. All rights reserved.

1. Introduction

Implementation of promising orbital and interplanetary missions is associated with improvements in crew life support systems (LSSs). One of the LSS key components is water supply systems. The systems have to provide maximum recovery of water from water-containing products of life and from bioengineering systems meeting the needs of the crew in water with minimum water consumption from supplies. The sources of water and oxygen aboard the space station are human products of life: sweat and moisture breathed out and collected in air-conditioning system, i.e. humidity condensate; urine; carbon dioxide; plant evaporated moisture; hygiene water and water produced by

* Corresponding author. Tel.: +495 685 02 33; fax: +49 5685 18 13.
E-mail addresses: l_bobe@niichimmash.ru (L. Bobe), lssd@niichimmash.ru (N. Samsonov), l_gavrilov@niichimmash.ru (L. Gavrilov), lssd@niichimmash.ru (V. Novikov), mtomash@niichimmash.ru (M. Tomashpolskiy), post@rsce.ru (P. Andreychuk), post@rsce.ru (N. Protasov), info@imbp.ru (Y. Synjak), skuratov@imbp.ru (V. Skuratov).
[1] Chief designer of regenerative life support systems.
Abbreviations: ISS, International space station; LSS, life support system; SRV, water recovery system; SRV-K, system for water recovery from humidity condensate; SPK-U, urine feed and pretreatment subsystem; SRV-U, system for water reclamation from urine; SRV-HG, hygiene water processing system

0094-5765/$ - see front matter © 2007 Elsevier Ltd. All rights reserved.
doi:10.1016/j.actaastro.2007.01.003

engineering systems, for example, by fuel cells of an electrochemical generator. Due to energy, space and mass limitations physical/chemical processes would be used in water recovery systems of space stations in the near future. Biology processes and food production are future problems and would be realized on planetary bases.

In Russia (former USSR) design, production and testing of physical/chemical water recovery systems were done by the All Union Research and Design Institute of Chemical Engineering (NIICHIMMASH, Moscow) in cooperation with the General customer RSC Energia and the Institute of Biomedical Problems (IMBP).

Experience in the design and operation of Salut, Mir and ISS water supply systems based on water recovery from humidity condensate (on Salut, Mir and ISS) and from urine (on Mir) as well as the use of delivered supplies made it possible to obtain the data on human water balance on the space station and the operational parameters of the recovery systems. These data are used by the authors to perform design analysis of water supply systems for promising space stations.

LSS and water systems based on physical/chemical means are reviewed in the paper. It is also suggested that a vitamin green house would be included in LSS.

2. Experience in development and operation of water recovery systems

2.1. Ground tests by using an integrated LSS

In 1967–1968 a physical/chemical regenerative LSS integrated with systems developed and built by NIICHIMMASH was tested at IMBP [1]. Physical/chemical systems provided life support of three test men in the pressurized module of a space station for one year. The systems for water recovery from humidity condensate, urine and hygiene water were operated. The principle possibility of men's long-term life support and water supply in confined space by means of water recovery was approved experimentally [1,2]. Based on this investigation and further work on flight systems' design and operation basic methods of water recovery were set up. The following methods are being realized at the present time. A sorption-catalytic method with subsequent mineralizing, preservation with ionic silver and pasteurization of the product water is used for water recovery from humidity condensate. Water reclamation from urine is provided via distillation with sorption-catalytic purification of the condensate. Purification of hygiene water would be provided by ultra-filtration with subsequent sorption and ionic exchange purification. Oxygen generation is carried out by electrolysis of alkali water solution by using water reclaimed from urine. Specially designed hardware operable in microgravity conditions was designed. Hardware for hydrodynamic and heat- and mass transfer processes in gas–liquid fluids should be specifically pointed out.

2.2. Water recovery from humidity condensate on Salut space stations

The flight systems for water recovery from humidity condensate SRV-K were designed initially for long duration orbital space stations Salut. In January 1975 for the first time in space flights the crew of the space station "Salut-4" A.A. Gubarev and G.M. Grechko used the water recovered from humidity condensate for drinking and food and beverage preparation. The system was operational for all station's flight period.

Similar systems of SRV-K types had operated on space stations Salut-6 (1977–1981 for 570 days) and Salut-7 (1982–1986 for 743 days). The SRV-K system together with the supplies system provided water for the crew. In addition, the water recovery system purified water of supplies with an exceeded storage time limit, heated and provided hot water for hygiene procedures [3].

2.3. Space station "Mir" water supply

Practically a completely integrated physical/chemical recovery LSS (excluding carbon dioxide concentration and reduction systems) for water recovery and oxygen generation was installed for the first time in world practice on the space station Mir. This system supported long duration and effective operation of the station in manned flight mode of operation [4,5]. Principal schematic of water supply is presented in Fig. 1. There are separate systems for potable water recovery from humidity condensate, for service water reclamation from urine and for hygiene water purification. Oxygen for breathing is provided by electrolysis of water reclaimed from urine. Water supplies were delivered by Progress cargo space ships in Rodnik and EDV tanks. Since beginning Russian—US cooperation water provided in fuel cells has been transferred to the station for drinking and water electrolysis. The water recovery systems supplied the station with good quality water for the entire flight period. Some parameters of the space station Mir's water recovery systems are presented in Table 1.

As it is seen the mass consumptions for water recovery are sufficiently lower than the mass consumptions

Download English Version:

https://daneshyari.com/en/article/1717007

Download Persian Version:

https://daneshyari.com/article/1717007

Daneshyari.com