

Lessons Learned from the International Space Station (ISS) Environmental Control and Life Support System (ECLSS) Water Subsystem

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ABSTRACT

The International Space Station (ISS) has served as an excellent test bed for the implementation and integration of several life support systems, and has offered many lessons that can be applied to future vehicles and program. This paper focuses on those lessons learned within the Environmental Control and Life Support (ECLS) Water Subsystem, which have dictated on-orbit system performance and forced many operational controls. These include lessons on the need for precise documentation and testing, pros and cons of different types of storage containers, and the need for designing systems to have accessibility and flexibility. This paper describes the issues encountered on ISS and suggests solutions for future systems in the form of recommendations and questions posed to the future designers.

INTRODUCTION

The ISS ECLSS water systems are split between the United States On-Orbit Segment (USOS) and the Russian Segment (RS). At present, the USOS is limited to condensate collection and storage and clean water storage. On the Russian Segment (RS) however, the ECLSS water systems also include a condensate water processor, a stored water distribution system, an oxygen generator, and a toilet. Also on-board is a crew-made hygiene station that uses water. The water used in these systems is supplied and stored by both partners. A detailed overview of the ISS water types and storage containers, as well as information on how and where they are used is discussed in Reference 1.

Integration and operation of these systems, and the various water types available on-orbit, have revealed several on-orbit anomalies and lessons, which are outlined in the following sections. These include: [1] the interaction of various water types and how that relates to maintaining system cleanliness, [2] the pros and cons of

the various water storage mechanisms employed on ISS, [3] accessibility and maintainability of hardware, and [4] the importance of clear requirements definition. Some of these lessons learned were described in Reference 2. This paper expands on additional challenges faced in the last two years, and describes the operational impacts that have been implemented as a result of these issues.

The USOS water systems will grow with the launch of flight ULF-2 in the Fall of 2008, which will bring the Urine Processor Assembly (UPA), Water Processor Assembly (WPA), Waste and Hygiene Compartment (WHC), and Potable Water Dispenser (PWD). Activation of these new systems will also allow full operability of the USOS Oxygen Generation Assembly (OGA) that was launched on ULF-1.1 in 2006. Besides new systems, 2008 will also bring the first flight of the European Automated Transfer Vehicle (ATV), with an additional water supply. In 2009, Japan will launch the Hydrogen-II Transfer Vehicle (HTV), which will also provide a water supply capability. In addition to describing the many lessons learned thus far for the ISS ECLS water system, this paper will also describe how many of these lessons will be applied to this next generation of equipment and water supply.

INTERACTIONS BETWEEN WATER TYPES

ISS Water Types

There are currently several water types on the ISS, which are distinguished primarily by the type of biocide used. The USOS uses an iodine biocide in all of its ECLSS systems, while the Russian segment uses a silver biocide. Presently, iodinated water is used as cooling water in the Extra-Vehicular Mobility Unit (EMU) and as supply water for the USOS Oxygen Generation System (OGS). For both of these systems, iodinated

water is supplied from the Shuttle, which is produced by the Orbiter fuel cells as a by-product of power generation. Following the new hardware activation in the ULF-2 stage, iodinated water will also be available from the WPA, and it will be supplied to the PWD, WHC, and all USOS payloads.

On the Russian segment, silver water is supplied in three different varieties: technical water in Contingency Water Containers (CWCs), potable water in CWCs, and Russian ground supplied water. Both technical and potable water in CWCs is supplied by the Shuttle. The iodine biocide is removed and silver biocide, in the form of silver fluoride, is added in its place. When the WPA is operational, it will be possible to convert the iodinated WPA product water into potable and technical CWC water in the same way. For potable water, mineral salts are also added. Russian ground supplied water is naturally mineralized, and silver ions are added for microbial control.

Finally, the European ATV will also be capable of launching either iodinated water for the USOS or silver water similar to the Russian ground supplied water. The Japanese HTV will only carry USOS iodinated water.

In addition to these "clean" water types, there is also condensate water on the ISS. Both the US and Russian segments have humidity control systems that collect moisture from the atmosphere. Russian condensate is plumbed directly into the Russian condensate water processor (SRV-K). US condensate is transferred through plumbing lines called the USOS waste water bus, and is collected in a large storage tank in the US Lab. It is then transferred to portable containers and carried to the RS, where it is pumped into the SRV-K. When the WPA is operational, the USOS condensate will instead be plumbed directly into the WPA inlet.

Interaction of these five different water types can lead to system failures and affect water quality.

Iodine and Silver

Mixing water with iodine biocide and silver biocide will form a precipitate in the water called silver iodide, a particulate that can then cause clogging of any filters, plumbing, pumps, or other equipment where it is introduced. Another consequence of the mixing is that the overall effectiveness of the biocide is reduced, causing the resultant water at greater risk for microbial contamination. Ensuring that these two water types are not mixed has been a challenge; specifically measures have been taken eliminate iodine from the USOS condensate water plumbing.

Both the OGS and EMU have waste water lines that connect directly into the USOS condensate bus. For the OGS, any water that contains too much gas for electrolysis is rejected into the waste water bus. For the EMU, a small quantity of water is dumped into the waste water bus during EMU servicing following every EVA. In

order to protect the respective systems from any microbial contaminants that are in the condensate, both of these reject lines contain an iodine regulation cartridge, or Microbial Check Valve (MCV), which has the effect of adding iodine to the reject water before it enters the condensate plumbing. In order to stop this iodine from entering the waste water bus, an iodine removal cartridge (ACTEX) has been installed in the OGS reject line. Unfortunately, the EMU servicing plumbing area did not have enough room to install a similar cartridge at that interface, and the EMU servicing system had to be disconnected from the waste water bus. The alternative procedures, which dump the reject water into an external CWC, add approximately 30 minutes to the EMU servicing procedures. When the WPA is operational it will be able to accept and process the iodinated water, and these work-arounds can be removed.

US and Russian Silver Biocide

Ground testing has shown that the US silver fluoride and the Russian electrolytic silver are not compatible. This issue was not actually discovered until 2003, when logistics issues almost required that Russian ground supplied water be stored in CWCs previously used for potable and technical water from the Shuttle. Ground testing performed then to verify compatibility instead showed that when the two water types are mixed, there is an overall reduction in the total silver concentration, increasing the risk of microbial contamination. The mechanism which causes this effect is not completely understood, so no methodology has been found to maintain the stability of mixed water. As a result, the ISS flight rules have been updated to ensure that these two water types are never mixed. The greatest impact this has had is the need to maintain two sets of equipment for the drinking water distribution equipment (the Russian SVO-ZV) for the US and Russian potable water, as well as the crew time needed to change out this equipment when water types are switched.

A similar concern has been raised with the Russian type water that will be delivered on the first ATV flight in March 2008. Like the US CWC water, there is no question that it will meet the Russian water quality standards. However, there has not been any testing showing how it will interact with the other types of silver water on ISS. Because of this concern, the Russian partners have stated that it can not be transferred into the Rodnik system for storage. Additionally, an on-orbit test will be conducted to verify compatibility of the Russian and European water types.

"Dirty" and "Clean" Water

Of the different water types, the condensate water is considered "dirty", while the potable, technical, and Russian ground supplied water are all considered "clean". The main difference being water that is unfit for crew and systems consumption, and water is safe for crew and systems use. While it seems common sense not to mix "clean" and "dirty" water, there are several interfaces on-orbit where these systems and water types