Status of ISS Water Management and Recovery

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Water management on ISS is responsible for the provision of water to the crew for drinking water, food preparation, and hygiene, to the Oxygen Generation System (OGS) for oxygen production via electrolysis, to the Waste & Hygiene Compartment (WHC) for flush water, and for experiments on ISS. This paper summarizes water management activities on the ISS US Segment, and provides a status of the performance and issues related to the operation of the Water Processor Assembly (WPA) and Urine Processor Assembly (UPA). This paper summarizes the on-orbit status as of June 2013, and describes the technical challenges encountered and lessons learned over the past year.

I. Introduction

The International Space Station (ISS) Water Recovery and Management (WRM) System insures availability of potable water for crew drinking and hygiene, oxygen generation, urinal flush water, and payloads as required. To support this function, waste water is collected in the form of crew urine, humidity condensate, and Sabatier product water, and subsequently processed by the Water Recovery System (WRS) to potable water. This product water is provided to the potable bus for the various users, and is stored in water bags for future use when the potable bus needs supplementing. The WRS is comprised of the Urine Processor Assembly (UPA) and Water Processor Assembly (WPA), which are located in two ISPR racks, named WRS#1 and WRS#2. This hardware was delivered to ISS on STS-126 on November 14, 2008 and initially installed in the US Lab module. On February 18, 2010, the racks were transferred to their permanent home in the Node 3 module.

II. Description of the ISS Water Recovery and Management System

The ISS WRM provides the capability to receive the waste water on ISS (crew urine, humidity condensate, and Sabatier product water), process the waste water to potable standards via the WRS, and distribute potable water to users on the potable bus. A conceptual schematic of the WRM is provided in Figure 1. The waste water bus receives humidity condensate from the Common Cabin Air Assemblies (CCAAs) on ISS, which condenses water vapor and other condensable contaminants and delivers the condensate to the bus via a water separator. In addition, waste water is also received from the Carbon Dioxide Reduction System. This hardware uses Sabatier technology to produce water from carbon dioxide (from the Carbon Dioxide Removal Assembly (CDRA)) and hydrogen (from the electrolysis process in the Oxygen Generation System). Waste water is typically delivered to the WPA Waste Tank, though the Condensate Tank located in the US Laboratory Module is available in the event the WPA Waste Tank is

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disconnected from the waste bus. If this is required, the crew must manually connect the Condensate Tank to the waste water bus. Once the WPA Waste Tank is online again, the crew will disconnect the Condensate Tank from the waste water bus. Condensate collected in this scenario must subsequently be offloaded into a Contingency Water Container (CWC). The CWC can then be emptied into the WPA waste tank via a pump, transferred to the Russian Segment for processing by the Russian Condensate Processor (referred to as the SRV-K) or vented overboard (though venting is highly discouraged due to the loss of water consumables and use of propellant required to maneuver the ISS into an acceptable attitude).

Crew urine is collected in the Waste & Hygiene Compartment (WHC), which includes a Russian Urinal (referred to as the ACY) integrated for operation in the US Segment. To maintain chemical and microbial control of the urine and hardware, the urine is treated with chemicals and flush water. The pretreated urine is then delivered to the Urine Processor Assembly (UPA) for subsequent processing. The UPA produces urine distillate, which is pumped directly to the WPA Waste Water Tank, where it is combined with the humidity condensate from the cabin and Sabatier product water, and subsequently processed by the WPA. A detailed description of the UPA and WPA treatment process is provided in Section III.

After the waste water is processed by the WRS, it is delivered to the potable bus. The potable bus is maintained at a pressure of approximately 230 to 280 kPa (19 to 26.5 psig) so that water is available on demand from the various users. Users of potable water on the bus include the Oxygen Generation System (OGS), the WHC (for flush water), the Potable Water Dispenser (PWD) for crew consumption, and Payloads.

Management of the water mass balance on ISS is achieved through various means depending on the specific scenario and availability of crew time. Excess water is typically offloaded as potable water by emptying the WPA product tank into a CWC-I. A CWC-I is a CWC compatible with the iodine used as a biocide in the US potable water. Potable water can be returned to the system using the WPA tee hose. As described previously[2], a tee hose and manual shutoff valve were installed on ISS in 2010 to allow potable water to be transferred from a CWC-I back to the WPA Water Storage tank. This capability provided greater operational flexibility for maintaining the ISS water balance in the US Segment. In 2012, a Microbial Removal Filter (MRF) was also introduced to the potable transfer procedure to prevent free gas from being transferred to the potable bus[1].

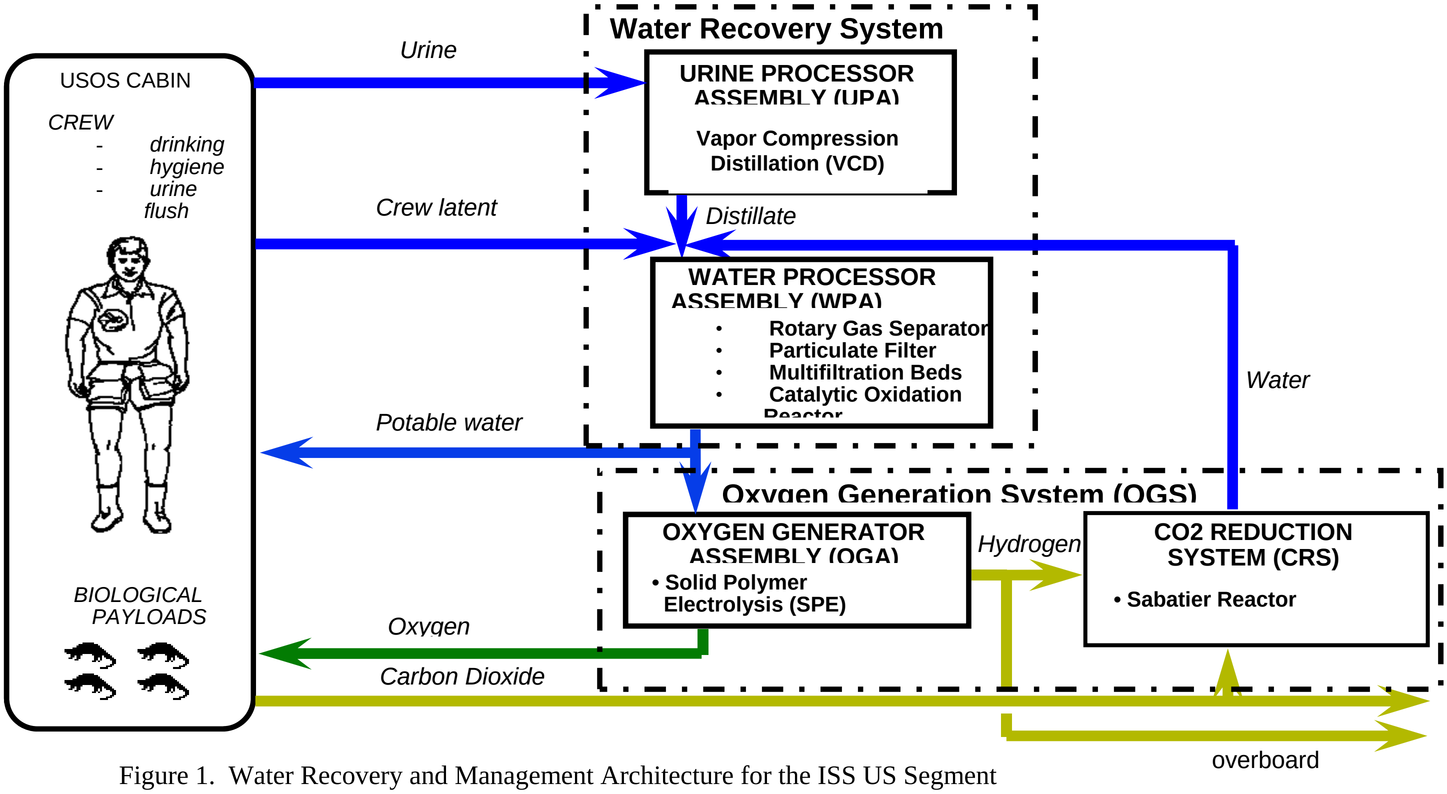

Figure 1. Water Recovery and Management Architecture for the ISS US Segment

III. Description of the ISS Water Recovery System

The layout of the two WRS racks is shown in Figure 2, along with the OGS. The WPA is packaged in WRS Rack #1 and partially in WRS Rack #2, linked by process water lines running between the two racks. The remaining portion of WRS Rack #2 houses the UPA.

The following section provides a description of the WRS, current operational status, and describes issues and lessons learned during the past year. For the prior years' status, see references 1-4.

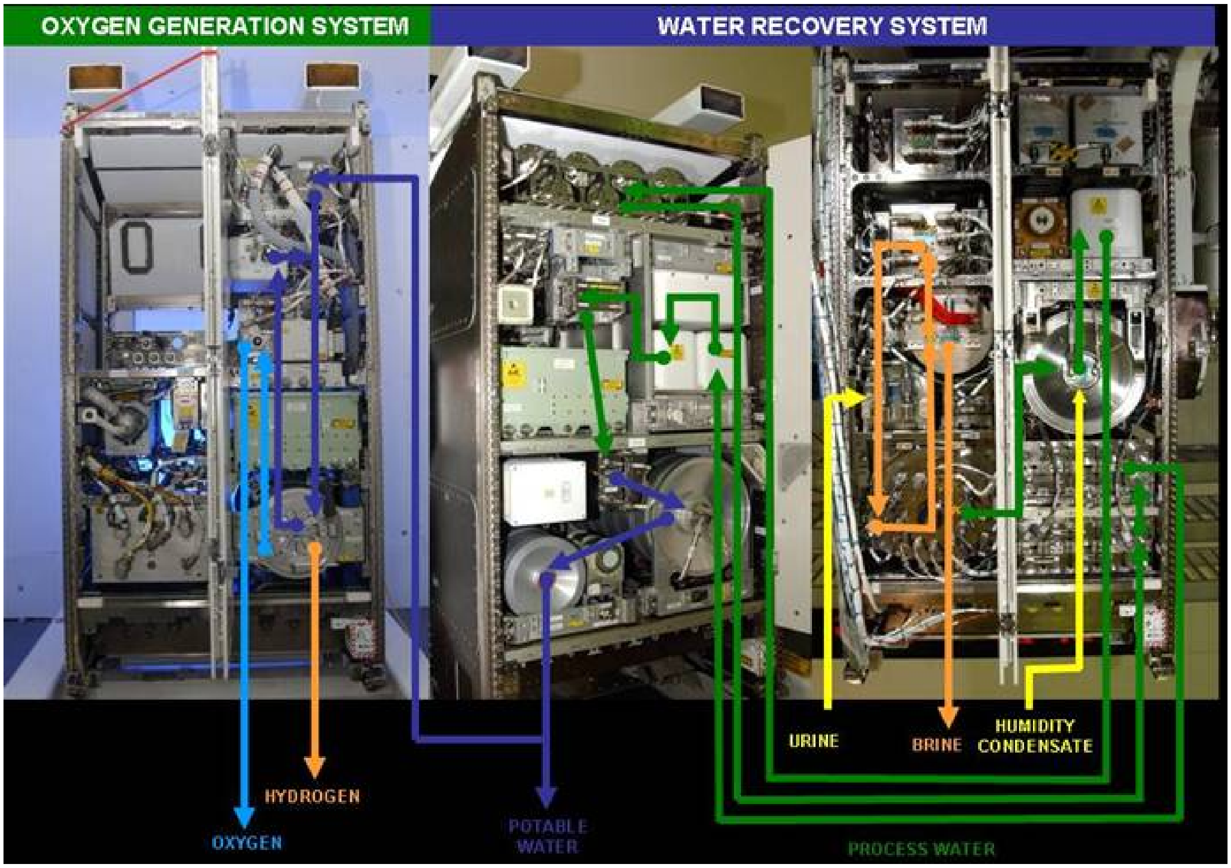

Figure 2. International Space Station Regenerative ECLSS Racks

A. Water Processor Assembly Overview

A simplified schematic of the WPA is provided in Figure 3. The WPA is packaged into 16 Orbital Replacement Units (ORU), and occupies WRS#1 and the right half of WRS#2. Wastewater delivered to the WPA includes condensate from the Temperature and Humidity Control System, distillate from the UPA, and Sabatier product water. This wastewater is temporarily stored in the Waste Water Tank ORU. The Waste Water Tank includes a bellows that maintains a pressure of approximately 5.2 – 15.5 kPa (0.75 to 2.25 psig) over the tank cycle, which serves to push water and gas into the Mostly Liquid Separator (MLS). Gas is removed from the wastewater by the MLS (part of the Pump/Separator ORU), and passes through the Separator Filter ORU where odor-causing contaminants are removed from entrained air before returning the air to the cabin. Next, the water is pumped through the Particulate Filter ORU followed by two Multifiltration (MF) Beds where inorganic and non-volatile organic contaminants are removed. Once breakthrough of the first bed is detected, the second bed is relocated into the first bed position, and a new second bed is installed. The Sensor ORU located between the two MF beds helps to determine when the first bed is saturated based on conductivity. Following the MF Beds, the process water stream enters the Catalytic Reactor ORU, where low molecular weight organics not removed by the adsorption process are oxidized in the presence of oxygen, elevated temperature, and a catalyst. A regenerative heat exchanger recovers heat from the catalytic reactor effluent water to make this process more efficient. The Gas Separator ORU removes excess oxygen and gaseous oxidation by-products from the process water and returns it to the cabin. The Reactor Health Sensor ORU monitors the conductivity of the reactor effluent as an indication of whether the organic load coming into the reactor is within the reactor's oxidative capacity. Finally, the Ion Exchange Bed ORU removes dissolved products of oxidation and adds iodine for residual microbial control. The water is subsequently stored in the Water Storage Tank prior to delivery to the ISS potable water bus. The Water Delivery ORU contains a pump and small accumulator tank to deliver potable water on demand to users. The WPA is controlled by a firmware controller that provides the command control, excitation, monitoring, and data downlink for WPA sensors and effectors.

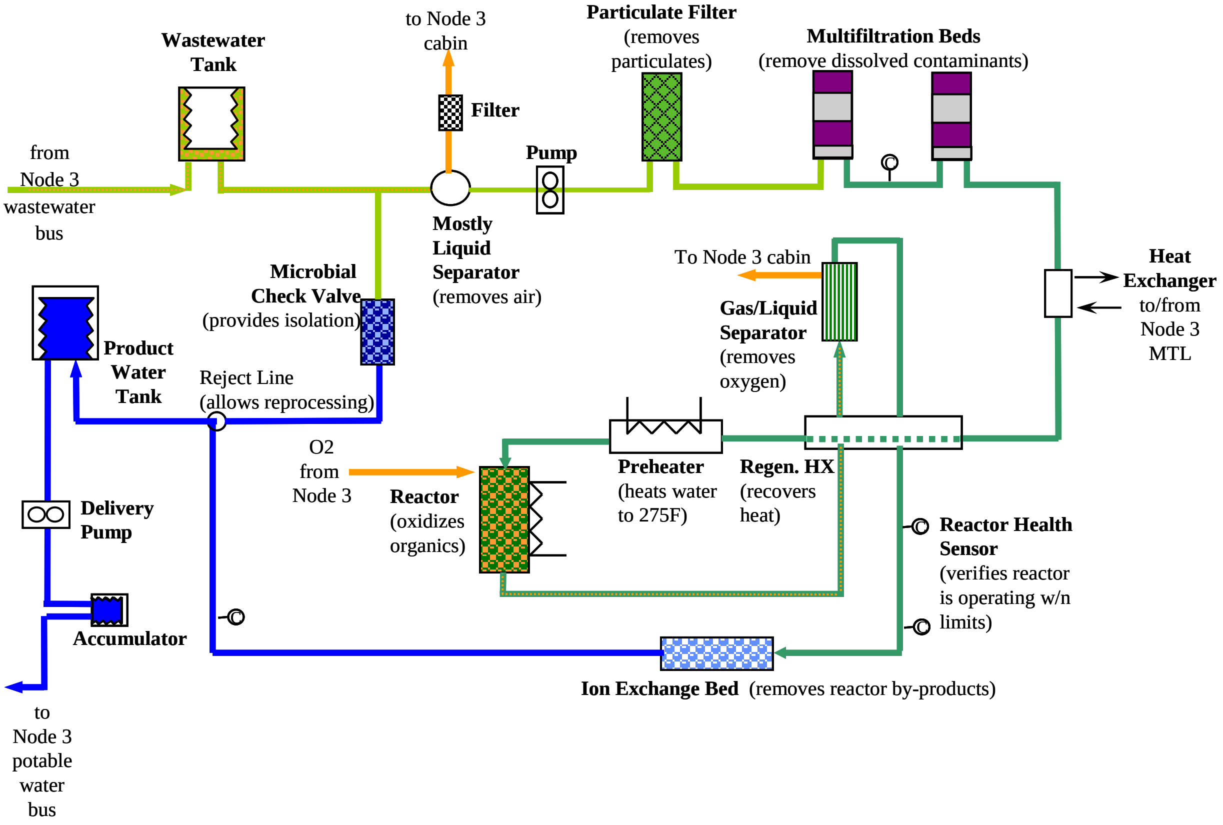

Figure 3. WPA Simplified Schematic

B. Urine Processor Assembly Overview

A simplified schematic of the UPA is shown in Figure 4. The UPA is packaged into 7 ORUs, which take up slightly more than half of the WRS Rack #2. Pretreated urine is delivered to the UPA either from the USOS Waste and Hygiene Compartment (outfitted with a Russian urinal) or via manual transfer from the Russian urine container (called an EDV). In either case, the composition of the pretreated urine is the same, including urine, flush water, and a pretreatment formula containing chromium trioxide and sulfuric acid to control microbial growth and the reaction of urea to ammonia. The urine is temporarily stored in the Wastewater Storage Tank Assembly (WSTA). When a sufficient quantity of feed has been collected in the WSTA, a process cycle is automatically initiated. The Fluids Control and Pump Assembly (FCPA) is a four-tube peristaltic pump that moves urine from the WSTA into the Distillation Assembly (DA), recycles the concentrated waste from the DA into the Advanced Recycle Filter Tank Assembly (ARFTA) and back to the DA, and pumps product distillate from the DA to the wastewater interface with the WPA. The DA is the heart of the UPA, and consists of a rotating centrifuge where the waste urine stream is evaporated at low pressure. The vapor is compressed and subsequently condensed on the opposite side of the evaporator surface to conserve latent energy. A rotary lobe compressor provides the driving force for the evaporation and compression of water vapor. Waste brine resulting from the distillation process is stored in the

ARFTA, which is a bellows tank that can be filled and drained on ISS. The ARFTA has less capacity (approximately 22 L) than the RFTA (41 L), but the capability to fill and drain the ARFTA on ISS avoids the costly resupply penalty associated with launching each RFTA. When the brine is concentrated to the required limit, the ARFTA is emptied into an EDV, a Russian Rodnik tank on the Progress vehicle, or into the water tanks on the ATV vehicle. Next, it is refilled with pretreated urine, which allows the process to repeat. The Pressure Control and Pump Assembly (PCPA) is another four-tube peristaltic pump which provides for the removal of non-condensable gases and water vapor from the DA. Liquid cooling of the pump housing promotes condensation, thus reducing the required volumetric capacity of the peristaltic pump. Gases and condensed water are pumped to the Separator Plumbing Assembly (SPA), which recovers and returns water from the purge gases to the product water stream. A Firmware Controller Assembly (FCA) provides the command control, excitation, monitoring, and data downlink for UPA sensors and effectors.

The UPA was designed to process a nominal load of 9 kg/day (19.8 lbs/day) of wastewater consisting of urine and flush water. This is the equivalent of a 6-crew load on ISS, though in reality the UPA typically processes only the urine generated in the US Segment. Product water from the UPA has been evaluated on the ground to verify it meets the requirements for conductivity, pH, ammonia, particles, and total organic carbon. The UPA was designed to recover 85% of the water content from the pretreated urine, though issues with urine quality encountered in 2009 have required the recovery to be dropped to 74%. These issues and the effort to return to 85% recovery are addressed in the discussion on UPA Status.

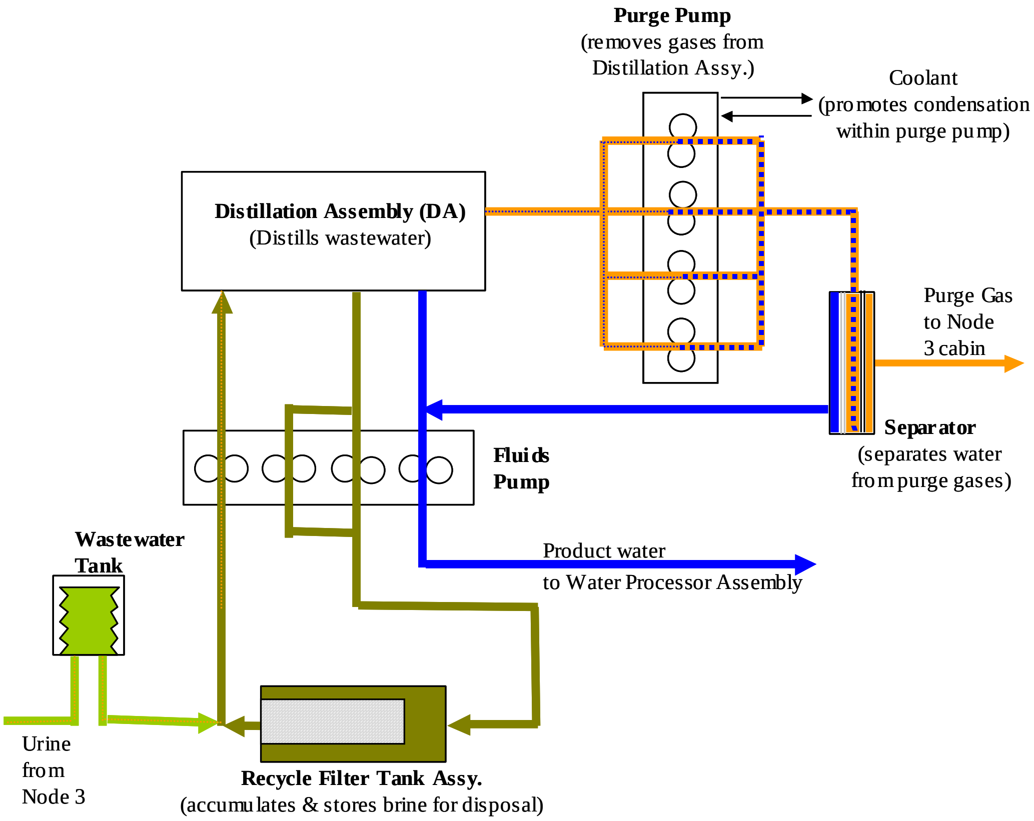

Figure 4. Urine Processor Assembly Schematic

IV. Water Recovery and Management Status

In the last year, 3340 L of potable water have been supplied to the US Segment potable bus for crew use and for the OGS. Management of the water mass balance has continued to be a challenge due to the need to maintain 1002 L of potable water on ISS for crew reserve, limited storage life of potable water in CWC-Is, and the need to minimize the introduction of free gas onto the potable bus.

Free gas is a significant issue in micro-gravity, since it cannot be removed from the water without a gas separator. As mentioned previously, the MRF addresses the free gas issue by using the 0.2 micron filtration to stop free gas during a CWC-I transfer to the WPA product tank. Free gas is vented from the housing by the crew as it accumulates. This procedure reduces crew time required for CWC-I transfer, but not without issue. First, enough free gas accumulates in the MRF housing during the transfer that it became necessary for the crew to still perform a short degassing procedure on each CWC-I prior to a transfer, thus reducing the crew time savings. To degas a CWC-I, the crew spins the CWC-I to coalesce the gas in one location, and then manipulates the bag to move the free gas to the CWC-I outlet port, where it can be vented into the cabin. Second, MRFs were only certified for two months of use, impacting their resupply and availability for use on ISS. A test is currently underway to extend the certified life of the MRF.

Finally, the water mass balance in the US Segment has created an issue due to an excess of water. The US Segment currently has approximately 1600 liters of stored potable water in CWC-Is on ISS. In the event of a failure to the ISS water system, 1002 L must be maintained on ISS as reserve. Though this is a positive benefit in terms of supporting various failure scenarios on ISS, it creates stowage problems in the crowded US Segment. Furthermore, CWC-Is are currently only certified to contain potable water for 3 years. After 3 years, if the water has not been removed from the CWC-I, the bag is downgraded to waste water (condensate) grade. To extend the life of these CWC-Is, a shelf life test is being performed on the ground in parallel with ISS operations. During this test, samples are taken every 6 months to certify the CWC-I for a longer storage life. This has been an operational challenge over the last year as shelf life testing to extend the CWC-I certification was ongoing. Numerous CWC-Is would expire under their current certified life, only to be recertified as the shelf life testing results on the ground showed acceptable water quality. These bags became known as "zombie" bags as they would regularly expire, and then return to life based on the shelf life test results. The operations team had a challenge to use these zombie bags during the short window when they were recertified prior to reaching the next expiration date (which would then be extended yet again as testing continued).

Various solutions are currently being developed to address these issues. Two CWC-Is have been returned from ISS, and are being sampled periodically to extended the certified life of the CWC-Is on ISS. This process has extended the certified life to 44 months, and has the potential to extend the life to 5 years (60 months). Also, hardware is currently being delivered that would allow potable CWC-Is to be emptied into the waste water bus without downgrading the CWC-Is. This is accomplished by pumping the potable water through a Microbial Check Valve, which is filled with MCV resin and prevents any back flow of contamination from the waste bus to the potable CWC-I. Finally, engineering personnel are also evaluated the viability of adding additional water storage on ISS. This would be accomplishing by launching a rack filled with multiple tanks that can be connected to the potable bus. Water could be automatically transferred to and from this water storage facility as needed for the water balance, thereby reducing crew time impacts for handing CWC-Is.

V. Urine Processor Assembly Current Status

The UPA was initially activated on November 20, 2008. In the last year, the UPA has produced 1300 L (2870 lb) of distillate at 70 to 75% recovery, cycling through 10 RFTAs and 8 ARFTA cycles during that time. As of June 21, 2012, the total UPA production on ISS is at 4130 L (9110 lb) of distillate. A graphical summary of UPA production rate and upmass required for ISS operations is provided in Figure 5. The UPA experienced no significant anomalies on ISS in the last year.

As reported previously[2], Distillation Assembly (DA) S/N 02 failed on October 24, 2009 due to accumulation of solids in the Distillation Assembly. The root cause of the anomaly was due to the precipitation of calcium sulfate in the urine brine at the target recovery of 85%. Calcium is present in the urine primarily due to bone loss from the crew, whereas sulfate is present primarily due to the use of sulfuric acid in the urine pretreatment. Calcium levels on ISS are elevated compared to ground urine due to the absence of gravity. During ground testing, the UPA was proven to have no issues with recovering 85% of the water from pretreated urine. However, at 85% recovery on ISS, the higher concentration of calcium resulted in calcium sulfate exceeding its solubility limit. The initial response to this failure was to reduce the recovery to 70%. In parallel, ISS crew member have been instructed to drink more water primarily to improve overall health, but also to reduce the calcium concentration in the raw urine. Based on approximately two years of data, analysis of crew urine has determined that the average calcium concentration has dropped to a level that will support 74 to 75% recovery by the UPA.

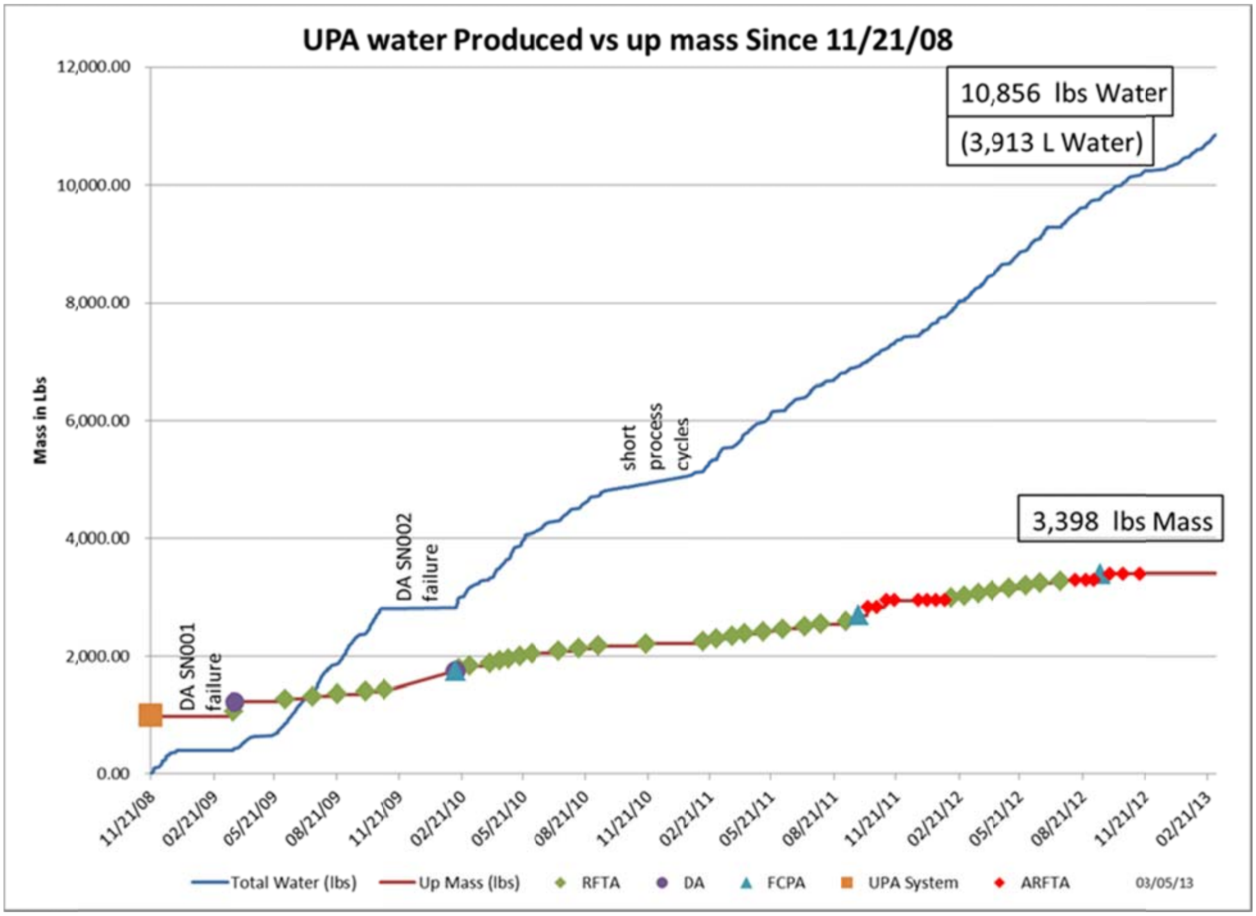

Figure 5. UPA Production and Upmass on ISS

In parallel with this modification to on-orbit operations, NASA personnel have continued with the effort to return UPA to 85% recovery. A significant research effort was performed at JSC to evaluate various technology options, ultimately identifying several viable concepts for achieving 85% recovery, including ion exchange resin and alternate pretreatment. A review of these two options in 2012 identified alternate pretreatment as the preferred option, though development of Ion Exchange has continued in parallel at a reduced level in the event the alternate pretreatment concept doesn't prove viable.

Alternate pretreatment has focused on replacing sulfuric acid with phosphoric acid in the pretreatment[5]. This approach also has significant risk, as the pretreatment formula is critical for maintaining microbial and chemical control in the pretreated urine. The primary objective has been on maintaining a pH of 2.0 in the pretreated urine while maintaining microbial control. An initial effort to reduce the concentration of the oxidizer in the pretreatment proved unsuccessful due to fungal growth in the pretreated urine. Subsequent efforts maintained the oxidizer dose consistent with the concentration in the current baseline. The UPA development unit has been successfully tested with the alternate pretreatment, showing no indication of precipitation or microbial growth. Materials compatibility tests are also underway to verify this pretreatment formula is compatible with the UPA and with the Russian urinal in the US Waste & Hygiene Compartment (WHC).

A significant operational change for the UPA in 2011 was the integration of the Advanced RFTA (ARFTA). This hardware replaces the current RFTA with a bellows assembly that can be drained and emptied on ISS[1]. Though ARFTA operation requires more crew time to fill and drain each tank, it provides a significant savings in launch mass (avoiding approximately 200 kg annually for launching RFTAs). After using the remaining RFTAs on ISS, the UPA was configured for ARFTA in June 2012. There have been no operational issues with the ARFTA since that time. However, the crew time for ARFTA operation is significant. To address that issue, a final modification to the UPA/ARFTA concept is currently in development. This modification will allow the crew to fill and drain the ARFTA without removing the tank from the rack. This modification is desirable because approximately 45 minutes of crew time is required to removal/install the ARFTA following each concentration cycle. Therefore, this modification would save approximately 12 hours of crew time each year, which is desirable due to the limited crew time available for maintenance tasks on ISS. This hardware primarily consists of a valve manifold that can be manually configured by the crew for nominal UPA operation, and for draining and filling the ARFTA. This new hardware is scheduled to be available on ISS in late 2014.

The UPA Fluids Control and Pump Assembly (FCPA) has failed three times in the last two years. FCPA S/N 02 failed in September 2011 after 1134 operating hours, and S/N 01 failed in September 2012 after 1662 operating hours. Both of these units have been returned to the ground for a failure investigation. Engineering personnel have determined the two failures were unrelated. S/N 02 failed due to insufficient lubrication of the outboard motor bearing. Other motors provided by the vendor are also at risk for a similar failure, though procurements since 2009 have required documentation on the quantity of lubricant applied to each bearing to insure compliance. Inspection of S/N 01 determined the bearings were adequately lubricated. Instead, this unit appeared to have failed due to a misalignment of the motor adaptor, which is an assembly error after a match machining process. This assembly issue was previously identified and controls are already in place to prevent a recurrence. However, several ORUs were delivered before the assembly error was identified and corrected. FCPA S/N 03 was one of these ORUs. This ORU failed on ISS after 410 operating hours. This ORU has not been returned, so the root cause is currently unknown. However, the on-orbit data indicates the motor physically disconnected from the pump, which is a failure consistent with the misalignment of the motor adaptor.

Finally, the UPA software was upgraded in early 2013 to address various operational issues identified once the UPA began operating on ISS. In addition, this software was revised to be consistent with operational changes associated with the transition from the RFTA to the ARFTA in 2012. Prior to the software revision, engineering personnel at the Johnson Space Center were required to enter overrides and implement unique procedural commands to operate the UPA.

VI. Water Processor Assembly Current Status

The WPA was initially activated on November 22, 2008. As of April 21, 2013, the WPA has produced approximately 13,400 kg (29,545 lb) of product water, including 3340 kg (7360 lb) in the last year.

Three anomalies have occurred to the WPA in the past year on ISS. First, the WPA process pump failed, apparently seizing during initial operation. The spare pump failed when it was turned on after installation, due to a known design issue in which the ceramic gears seize due to the formation of alumina oxide during storage. This issue has been resolved by replacing alumina parts with zirconia. The subsequent pump has operated nominally since installation.

Second, the WPA experienced another increasing trend in the Total Organic Carbon (TOC) concentration in early 2012 (see Figure 7), similar to the anomaly observed in 2010[1,2]. This trend began after approximately 4200 L of MF Bed throughput, which was also consistent with the trend observed in 2010. Before on-orbit troubleshooting could be pursued, the Catalytic Reactor failed due to a leaking o-ring. This failure had the same root cause as the leak in 2010[2], and was not unexpected after two years of operation on ISS. The current reactor includes new o-rings that are compatible with the operating environment, and are designed to support the 5-year life of this hardware. Along with replacing the reactor, both MF Beds were also replaced to insure the new reactor was not degraded with any organic contaminants. After this maintenance activity, the product water TOC continued to rise, consistent with the trend after replacement of both MF Beds (but not the Catalytic Reactor) in 2010. To provide additional understanding of the root cause for the TOC trend, the Ion Exchange Bed was replaced in April 2012 while the product water TOC was still increasing. Subsequently, the product water TOC returned to nominal levels. Samples were taken of the condensate, waste water, MF Bed effluent (before and after the new MF Beds were installed), and product water for return on the Soyuz and subsequent ground analysis. Analysis of the product water confirmed that the source of the TOC rise is dimethylsilanediol (DMSD), consistent with the TOC trend in 2010. DMSD is a common by-product of the degradation of polydimethylsiloxanes (PDMS), which are common compounds present in various products, including caulks, adhesives, lubricants, and hygiene products. Various PDMS compounds are prevalent on ISS, and analysis of the current and previous condensate samples from ISS also indicates that DMSD has been present in the WPA waste water since WPA operations began on ISS. In addition, 41.9 mg/L of DMSD was detected in a sample of the MF Bed effluent taken before the beds were replaced on July 29. This result is consistent with the sample of the MF Bed effluent in 2010 prior to bed changeout, in which the DMSD was detected at 37 mg/L. An additional sample of the MF Bed effluent was taken approximately two weeks after replacement of the MF Bed. Analysis of this sample showed no DMSD detected above the detection limit of 0.4 mg/L. This is also consistent with the sample in 2010 taken after MF Bed changeout, in which DMSD was reported as <0.4 mg/L. These results indicate the MF Beds are initially removing the DMSD, but eventually the DMSD saturates the adsorbent and ion exchange resin in each bed and is in the reactor influent at a concentration of approximately 40 mg/L. To determine the effect of DMSD on reactor performance, a flight-like reactor was challenged with the contaminant level expected on ISS (including DMSD). Test results indicate the reactor is consistently removing approximately 70% of the DMSD, resulting in approximately 10 mg/L of DMSD in the reactor effluent. If this ground test accurately represents reactor performance on ISS, the DMSD in the reactor effluent is being initially removed by the Ion Exchange Bed, given the fact that DMSD has a slight ionic charge. Eventually, the Ion Exchange Bed is saturated with the DMSD, which results in a breakthrough curve consistent with the TOC trend observed from the ISS TOC Analyzer (see Figure 7). Additional tests at Hamilton Sundstrand have corroborated the capacity of the Ion Exchange Bed for DMSD, and have shown that increased concentrations of DMSD can be produced in the Ion Exchange Bed effluent by displacement of the DMSD with bicarbonate. Based on this data, engineering personnel have determined that the DMSD eventually saturates the MF Bed and is subsequently fed to the Catalytic Reactor. Since the reactor cannot oxidize the entire load, DMSD in the reactor effluent eventually saturates the IX Bed and is detected in the product water by the TOC Analyzer. A more detailed explanation of this investigation and the plan to prevent DMSD from contaminating the product water can be found elsewhere[7].

To gain a better understanding of the MF Bed performance on ISS, the MF Beds removed from the WPA in 2010 were returned to the ground and analyzed in late 2011 (MF Bed in first position) and late 2012 (MF Bed in second position). A detailed review of this investigation and results can be found elsewhere[8, 9]. However, a key finding was that several polydimethylsiloxanes (PDMS) had saturated the adsorbent and ion exchange resin. This is inconsistent with the MF Bed design concept, which was to insure that ionic breakthrough of the MF Bed occurred before organics saturated the adsorbents. Fortunately, the various PDMSs had not saturated the MF Bed in the second position. Based on this analysis and the aforementioned Ion Exchange Bed test with DMSD, engineering personnel will develop a new design of the MF Bed that removes problematic organics and therefore insures effective operation of the Catalytic Reactor.

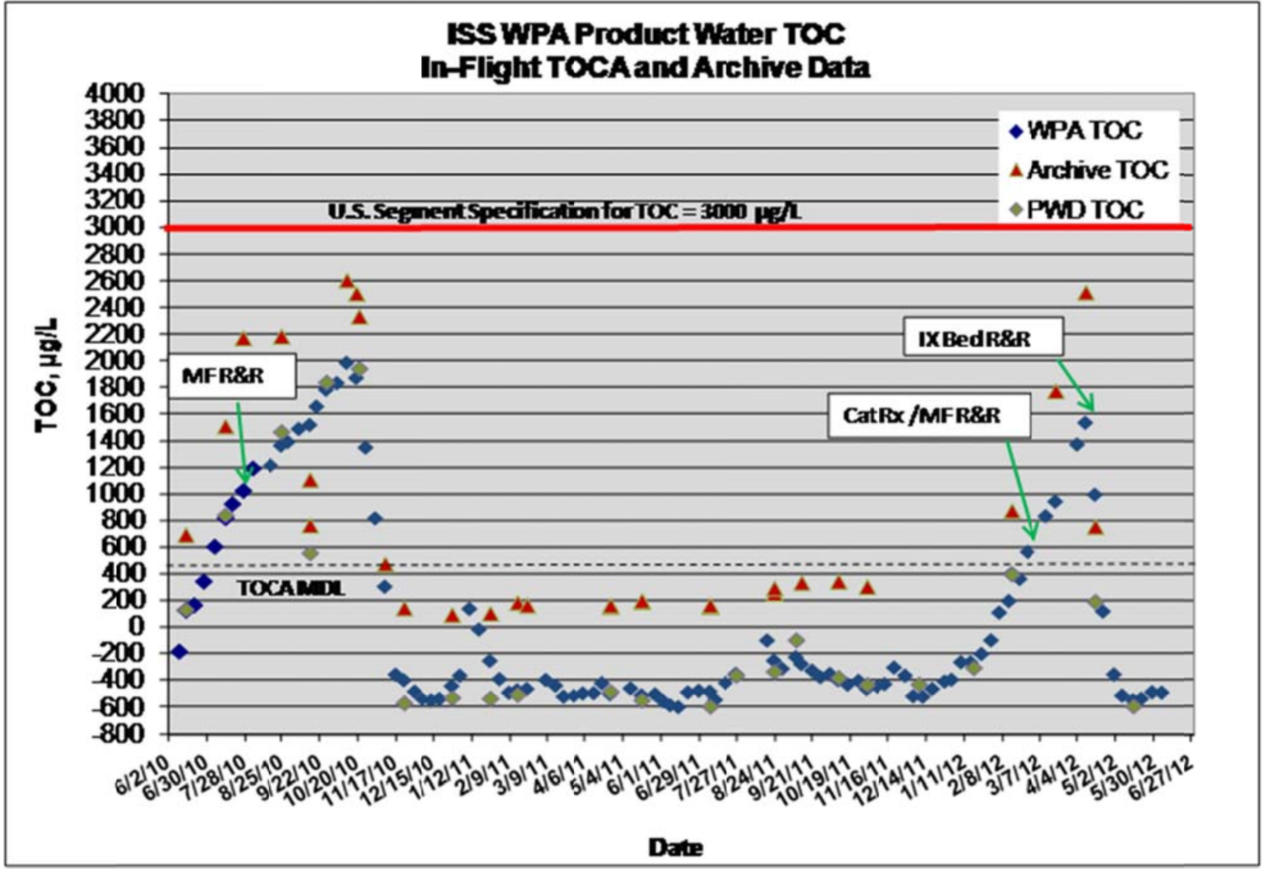

Figure 7. WPA TOC Trend[10]

Previous papers[2,3] have addressed the issue with increased pressure drop between the waste tank and the Mostly Liquid Separator (MLS). This anomaly occurred due to growth of biomass in the plumbing between the waste tank and the MLS, specifically in the two solenoid valves that have smaller clearances than the rest of the nominal plumbing. In 2010, after the Pump/Separator ORU was replaced, a filter was installed upstream of the MLS's inlet solenoid valve. In March 2011, the Waste Tank solenoid valve and the waste water filter (installed to protect the MLS inlet solenoid valve) both required maintenance. The crew removed the Waste Tank solenoid valve and capped the line (allowing flow through the passageway), and replaced the waste water filter with a new filter. During this time, WPA operations were also modified to control the growth and release of biomass in the waste tank, which is considered to be the primary source of solids contributing to the loading of the waste water filter and solenoid valve. This was primarily accomplished by managing cycles on the waste tank bellows, such that the bellows was cycled over its nominal range each month to prevent significant accumulation of biomass growth on the bellows. Since March 2011, no significant increase in the pressure drop in this plumbing has been observed. In addition to the tank management scheme, a software modification was implemented in April 2013 by which the waste water filter and MLS inlet are flushed with iodinated water at the end of each process cycle, thus providing additional mitigation against biological growth. This software modification also revised automated leak tests of the product water plumbing that were not working properly with the original software. Software limits for the delivery of potable water were modified to support offloading water into CWC-Is on ISS, and automatic feedback is now provided to support commanding the WPA by operations personnel. Also, controls were put in place that will protect the Mostly Liquid Separator from exceeding its maximum design pressure in the event of a WPA power outage.

As noted previously, the Multifiltration Beds were replaced in February 2012 as part of the TOC trend investigation. The MF Beds had a total throughput of 4613 L when they were removed. The Ion Exchange Bed was removed on April 30, 2012, after 3.5 years of use on ISS and a throughput of 9416 L. This bed was initially scheduled for replacement in November 2011 based on the expected life of the MCV resin in the bed effluent, but its life was extended based on ground analysis that showed the MCV resin was still imparting an iodine concentration of 2.2 mg/L. At the time this ORU was removed, there were no indications of ionic breakthrough. As of April 2013, there are no indications that the Particulate Filter is loading after approximately 4.5 years of operation on ISS. Similarly, the Gas Separator has shown no indication of performance degradation after 4.5 years of use.

VII. Conclusion

In the past year, the WRS has continued to provide the ISS crew with potable water for drinking, electrolysis via the Oxygen Generation System, flush water for the Waste & Hygiene Compartment, and hygiene water. The UPA has operated at a reduced water recovery of 74% to prevent precipitation of calcium sulfate in the brine. Though progress has been made toward the goal of returning to 85% recovery, ongoing technology development will not be ready for implementation on ISS for at least another year. Furthermore, the current water balance on ISS does not require 85% recovery to meet current ISS needs, due to the availability of the UPA/WPA and the resupply capability of the Progress, HTV, and ATV vehicles.

After a failure to the FCPA in 2011, the UPA experienced two more failures to this ORU in 2012. The root cause for the first two failures has been addressed with previous changes to vendor inspection process and the assembly process of the pump at MSFC. It is suspected that the third failure is also due to an assembly error, but this cannot be confirmed until the hardware is returned to the ground. Likewise, the WPA experienced two pump failures in the last year. The first is currently unexplained, whereas the second is due to formation of alumina oxide during storage. All future process pumps incorporate an improve gear material that has been shown to not be sensitive to storage conditions. Finally, efforts are ongoing to identify a means to remove DMSD and PDMSs from WPA waste water.

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