

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 as of March 2026 and provides a status of the performance and issues related to the operation of the Water Processor Assembly (WPA), Urine Processor Assembly (UPA), and Brine Processor Assembly (BPA).

Nomenclature

1	<i>ARFTA</i>	=	Advanced Recycle Filter Tank Assembly	24	<i>IX</i>	=	Ion Exchange
2	<i>ACV</i>	=	Russian Urinal	25	<i>MCV</i>	=	Microbial Check Valve
3	<i>ACTEX</i>	=	Activated Carbon and Ion Exchange	26	<i>MLS</i>	=	Mostly Liquid Separator
4	Cartridge			27	<i>MF</i>	=	Multifiltration
5	<i>BPA</i>	=	Brine Processor Assembly	28	<i>ORU</i>	=	Orbital Replacement Unit
6	<i>CHX</i>	=	Condensing Heat Exchangers	29	<i>OGA</i>	=	Oxygen Generation Assembly
7	<i>CWC</i>	=	Contingency Water Container	30	<i>PCPA</i>	=	Pressure Control and Pump Assembly
8	<i>CCAA</i>	=	Common Cabin Air Assembly	31	<i>PTU</i>	=	Pre-Treated Urine
9	<i>CV</i>	=	Check Valve	32	<i>PWD</i>	=	Potable Water Dispenser
10	<i>DA</i>	=	Distillation Assembly	33	<i>PWR</i>	=	Potable Water Reservoir
11	<i>ECLS</i>	=	Environment Control and Life Support	34	<i>RST</i>	=	Resupply Tank
12	<i>ECLSS</i>	=	Environment Control and Life Support	35	<i>SPA</i>	=	Separator Plumbing Assembly
13	System			36	<i>UPA</i>	=	Urine Processor Assembly
14	<i>EFA</i>	=	External Filter Assembly	37	<i>UTS</i>	=	Urine Transfer System
15	<i>EMU</i>	=	Extravehicular Mobility Unit	38	<i>UWMS</i>	=	Universal Waste Management System
16	<i>EJB</i>	=	Russian Water Container	39	<i>WHC</i>	=	Waste & Hygiene Compartment
17	<i>FCA</i>	=	Firmware Controller Assembly	40	<i>WRM</i>	=	Water Recovery and Management
18	<i>FCPA</i>	=	Fluids Control and Pump Assembly	41	<i>WPA</i>	=	Water Processor Assembly
19	<i>GLS</i>	=	Gas Liquid Separator	42	<i>WRS</i>	=	Water Recovery System
20	<i>CWC-I</i>	=	Contingency Water Container –	43	<i>WRT</i>	=	Water Resupply Tank
21	Iodinated			44	<i>WSS</i>	=	Water Storage System
22	<i>ISS</i>	=	International Space Station	45	<i>WSTA</i>	=	Wastewater Storage Tank
23	<i>ISPR</i>	=	International Standard Payload Rack	46	<i>WWT</i>	=	Waste Water Tank
				47	<i>xPWD</i>	=	eXploration Potable Water Dispenser

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I. Introduction

The International Space Station (ISS) Water Recovery and Management (WRM) System ensures the availability of potable water for crew drinking and hygiene, oxygen generation, urinal flush water, and payloads as required. To support this function, wastewater is collected in the form of crew urine, humidity condensate, and Sabatier product water, and subsequently processed by the Water Recovery System (WRS) into potable water. This product water is provided to the potable bus for the various users and may be 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 International Standard Payload Racks (ISPR) named WRS#1 and WRS#2. This hardware was delivered to ISS on November 14, 2008, and is located in the ISS Node 3 module.

II. Description of the ISS Water Recovery and Management System

A conceptual schematic of the WRM is provided in Figure 1 and displays the inlets and outlets to both the WRS and OGS since both systems are highly interconnected. Crew urine is collected in the Waste & Hygiene Compartment (WHC) [1], which consists of a Russian Urinal system (referred to as the ACY). To maintain chemical and microbial control of the urine and hardware, the urine is treated with an oxidizer and an inorganic acid. The pretreated urine is delivered to the UPA to produce urine distillate and brine. In addition, pretreated urine collected in the Russian Segment may also be manually transferred in Russian fluid containers (called EDBs) and transferred to the UPA. The installation of the technology demonstration Brine Processor Assembly (BPA) has allowed further processing of the urine brine, achieving >95% water recovered [2].

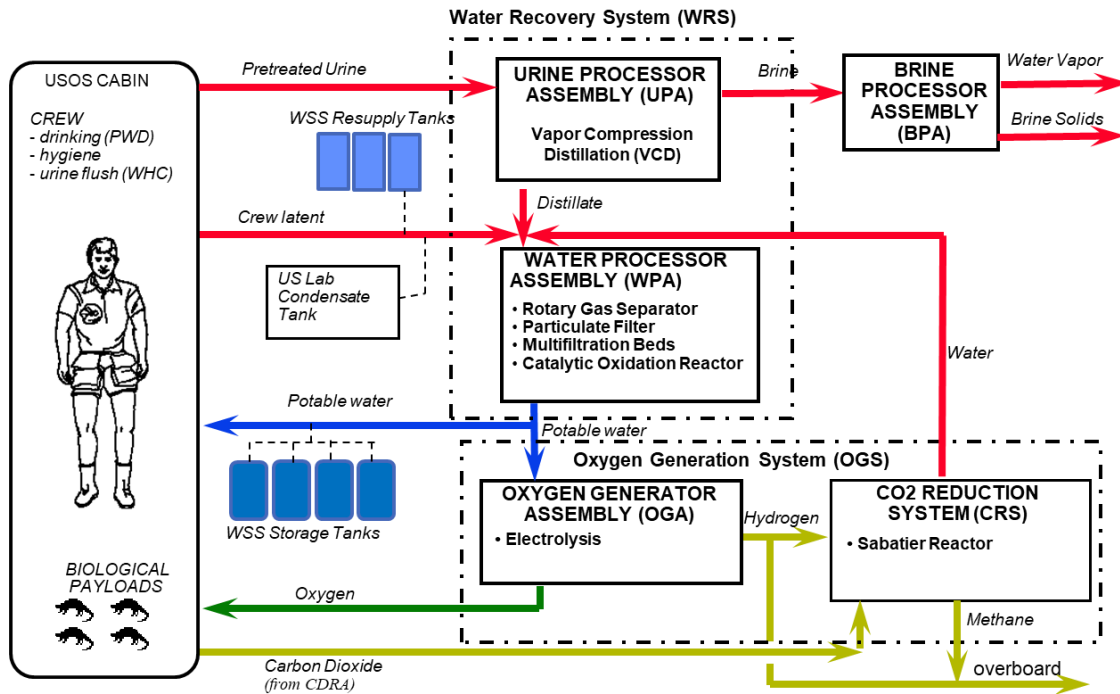


Figure 1. Water Recovery and Management Architecture for the ISS US Segment

Condensate is collected from the cabin air by the Common Cabin Air Assembly (CCAA) Condensing Heat Exchangers (CHXs). Urine distillate, humidity condensate and Sabatier product water are delivered to the WPA Waste Tank for further processing. However, the Sabatier reactor has not been in service since October 2017 due to a failure of the reactor, though replacement hardware is intended to be delivered to return this capability.

Makeup water from Resupply Tanks (RSTs) launched from the ground is added to the WPA waste tank as required to maintain the water balance. A separate Condensate Tank located in the US Laboratory Module is available as a back-up in the event the WPA Waste Tank is unavailable for waste water collection.

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 for the various users. Users of potable water from the bus include the Oxygen Generation Assembly (OGA), the WHC (for flush water), the Potable Water Dispenser (PWD) and eXploration PWD (xPWD) for crew consumption, the Extravehicular Mobility Unit (EMU) sublimator and Payloads. Finally, a reserve of a minimum of 818 L (1803 lbs) of potable water is stored on ISS in Contingency Water Containers - Iodinated (CWC-Is), Water Storage System (WSS) Storage Tanks (plumbed directly into the potable bus) and Water Resupply Tanks (RSTs) to maintain ISS operations in response to contingency scenarios.

Historically, the ISS Water Reserves threshold has been maintained at 818 liters to accommodate potable water to crew, EVA, and oxygen generation during periods of water recovery outages. However, in early 2026, the ISS Program has agreed to increase this reserve to 1413 liter in preparation for enhanced contingency vehicle cooling capabilities arriving later this year. This system is called Supplemental Heat Rejection Evaporative Cooler (SHREC). This new capability would require significant access to water to provide active cooling within the ISS Cabin. Therefore, to reduce risk during an outage of the water management system while this contingency cooling capability is active, the amount of reserved stored water must be increased.

III. Description of the ISS Water Recovery System

The layout of the two WRS racks is shown in Figure 2, along with the OGS Rack. 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.

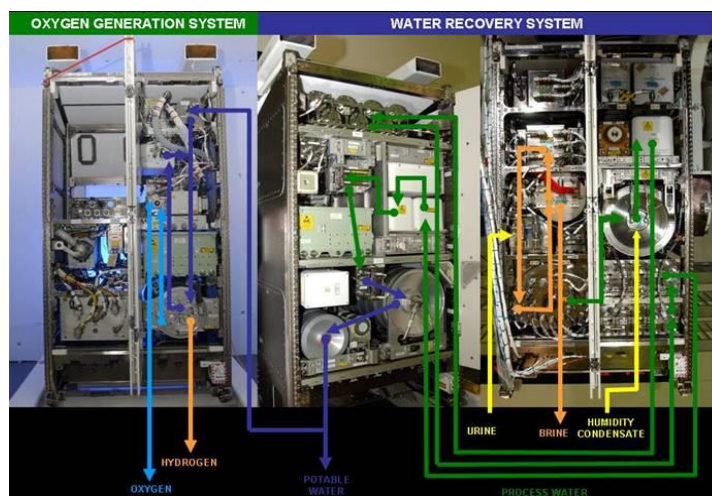


Figure 2. International Space Station Regenerative ECLSS Racks

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 [1,3-6].

A. Urine Processor Assembly

A simplified schematic of the UPA is shown in Figure 3. Pretreated urine is delivered to the UPA either from the US Segment WHC (outfitted with a Russian urinal) or via manual transfer from the Russian E/D. In either case, the composition of the pretreated urine is crew urine, flush water, and a pretreatment formula containing chromium trioxide and an inorganic acid to inhibit microbial growth and the conversion of urea to ammonia. In the Russian segment, the inorganic acid is sulfuric acid. In the US Segment, the inorganic acid has been switched to phosphoric acid to address precipitation issues with calcium sulfate. The pretreated urine is pumped from the Waste Storage Tank Assembly (WSTA) into the UPA recycle loop by the Fluids Control and Pump Assembly (FCPA). In the recycle loop, the pretreated urine is recirculated through the Distillation Assembly (DA), the Advanced Recycle Filter Tank Assembly (ARFTA), a brine filter, and back to the DA. Distillate produced in the DA is pumped to the WPA Waste Water Tank. The DA consists of a rotating centrifuge where the waste urine stream is evaporated at low pressure. The

vapor is compressed and 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. When the brine is concentrated to the required limit, the ARFTA is emptied into an EDB or offloaded into the BPA. The urine brine for disposal is delivered into available expendable containers (ex: empty Resupply Tanks, or expiring EDBs) or into the Russian Rodnik tank on the Progress vehicle for disposal. The ARFTA is refilled with pretreated urine to initiate a new concentration cycle. The Pressure Control and Pump Assembly (PCPA) is four-tube peristaltic purge 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 distillate stream. A Firmware Controller Assembly (FCA) provides the command control, excitation, monitoring, and data downlink for UPA sensors and effectors.

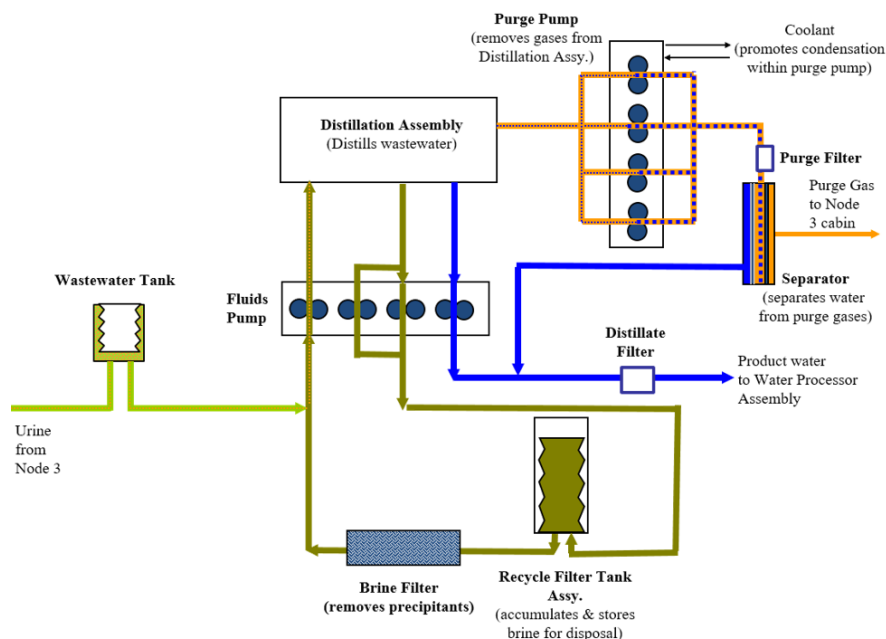


Figure 3. Urine Processor Assembly Schematic

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 expected quantity for a 6-crew load on ISS. The UPA was designed to recover 85% of the water content from the pretreated urine, though issues with urine quality encountered in 2009 required the recovery to be dropped to 75% for the US Segment and 70% for urine collected in the Russian Segment. Implementation of a phosphate-based urine pretreatment [7] in early 2016 allowed the UPA to return to a minimum of 85% recovery of urine collected in the US Segment, though urine recovery from urine collected in the Russian Segment remains at 70% because no changes have been made to the pretreatment in the Russian Segment. Continued assessments of returned brine filter samples have allowed incremental increases of water recovery from US pretreated urine from 85% to 87%. Targeted final percent recovery from US pretreated urine in the UPA is planned for 90%; however, further analysis of returned samples is required.

B. Water Processor Assembly Overview

An updated simplified schematic of the WPA is provided in Figure 4. The WPA feed water includes humidity condensate, distillate from the UPA, and Sabatier product water when available. Wastewater first passes through a 300 micron External Filter Assembly (EFA) to capture any biofilm from the Waste Water Tank (WWT). The water is initially degassed by the Mostly Liquid Separator (MLS), and then pumped through a 0.5 micron particulate filter followed by a Multifiltration (MF) Bed containing adsorbent and ion exchange media. Prior to 2019, the WPA used

two MF beds in series but switched to a single MF bed in July 2019. Volatile organics not effectively removed by the MF bed are oxidized in the Catalytic Reactor at elevated temperature, which also removes microbial contamination. Excess oxygen and gaseous oxidation by-products are removed by the Gas Liquid Separator (GLS). Dissolved and soluble reaction byproducts are removed by the Ion Exchange Bed, which also adds iodine to the product water as a biocide. Product water is stored in the Water Storage Tank prior to delivery to the ISS potable water bus.

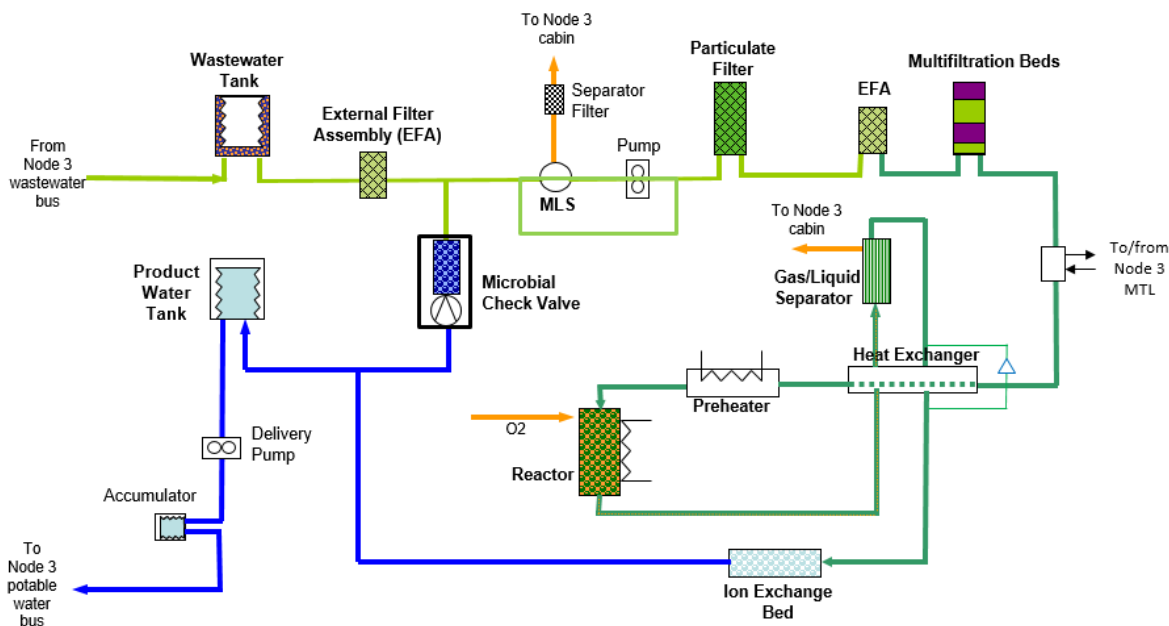


Figure 4. WPA Simplified Schematic

IV. Water Recovery and Management Status

Between February of 2024 and February 2026, WPA has produced approximately 17,900 L (39,000 lbs) of product water. In addition, 2,558 L (5,640 lbs) of total ISS potable water is currently stored on ISS for resupply water and in reserve to protect for contingencies. Management of the water mass balance has improved with the delivery of the Water Storage System (WSS) in the US Segment. This surplus of water in the US Segment is expected to shift with the installation of a replacement distiller for the Russian Segment Urine Processor and a most recent delivery of an additional urine processor in the Multipurpose Laboratory Module (MLM). Installation of the first Urine Processor was completed in 2018, but the distiller failed during initial checkout. Recovery of the system was achieved; however, only for a limited time. Hardware failures and system vacuum leaks have been ongoing challenges for both systems and only recently one of the distillers has shown progress in successful urine processing. Distillate from the Russian Urine Processors are planned to be used for flush water, feed water to the Russian Elektron, and feed water to their condensate processor pending successful results from analysis of distillate samples returned to the ground.

1. Further Water Management Expansions

Several additional modifications to the ISS water system have been delivered and installed, including a Urine Transfer System (UTS), a Universal Waste Management System (UWMS), and a Brine Processor Assembly (BPA). The BPA increases the total water recovery of water from urine brine generated by the UPA to beyond 95%. Thus when combined with the efficiencies of the Water Processor Assembly, the total water recovery aboard the ISS is 98+% when BPA is in operation. The UWMS, also known as “Toilet,” for ISS applications, is a US-designed toilet. With increased crew sizes on the ISS, providing additional waste management has been a critical path to ensure crew comfort as well as management the current Waste and Hygiene Compartment (WHC). These systems play a critical role to understand advanced technologies necessary for next generation exploration missions. The UWMS is a new toilet designed by Collins Aerospace. This hardware is planned for use in the Orion vehicle, and full demonstration of the hardware on ISS is being pursued.

UWMS, “Toilet”

The ISS saw its first US designed toilet arrive and installed in December 2020. As with most new technology installations, there were notable issues seen with the UWMS “Toilet” installation and activation [8]. Since February 2022, the Toilet has seen several more restart attempts and limited check-outs to further realize technology demonstrations and Artemis perspective test objectives. The lack of direct monitoring pretreat dose quality and reported fluid release internal to the Toilet operations have been notable, thus, limiting crew use. Further details are provided in publication [9]. At this time, Toilet is in a stand-down configuration due to a new failed dose pump and unexpected controller failure. The system will remain dormant until hardware replacement can be supplied later in 2026.

Brine Processor Assembly (BPA)

The BPA has been installed on the ISS since March 2021. The BPA has been operating on ISS as a Technology Demonstration for NASA Exploration missions for the first three (3) years of installation. BPA has processed brine generated by the UPA to further remove water to add to that recovered by the Distillation Assembly and thereby achieve ~98% water recovery. The system utilizes a specially designed membrane-based bladder that allows water vapor to pass through (via membrane distillation) with the aid of heated forced convection. The final water reclamation is achieved by established humidity control systems aboard the ISS. The system was delivered to NASA by Paragon Space Development and has since completed 81 dewatering cycles since first activation in early 2021. Since February 2024, the BPA has completed 43 dewatering cycles, yielding approximately 946 liters of urine brine. Of that, it is estimated ~780 liters of water have been returned back to humidity condensate, a significant cost saving in potential resupply mass. In 2024, BPA also processed 1 bladder of pretreated urine (PTU) providing additional data for future potential BPA-like hardware to perform urine processing. Teams also got another opportunity to process another batch of PTU via BPA, leveraging nominal ARFTA flush operations that would have otherwise disposed of this volume. In anticipation of these operations, ground testing at the NASA Marshall Space Flight Center (MSFC) validated successful operations and further insights for bladder reuse configurations [10]. Processing PTU via BPA would allow an alternate option for processing urine directly if the UPA has an extended downtime period. Moreover, the BPA has provided a significant reduction in trash management and logistics by reducing the total volume of brine for disposal (trashing off the ISS vehicle). Further details on BPA operation and accomplishments can be found in separate conference papers [2,12]. A successful demonstration of this technology is considered a critical step prior to future manned missions beyond ISS (i.e., a mission to Mars) because of the necessity to recover as much water as reasonably possible due to the launch costs for water and the absence of resupply capability. With continued success, NASA will continue to use the technology on ISS to reduce the water resupply requirement from earth.

In 2025 the BPA received new outlet exhaust hardware: 1) A new, dedicated ducting 2) A new exhaust outlet, addressing sealing concerns from a previously 3D printed component, and 3) new humidity and flow velocity sensors integrated into the new exhaust ducting. An initial activation of the sensors confirmed viability in giving ground engineering teams direct insights to the humid air exiting a BPA throughout a dewatering cycle. The timing was such that the teams could assess baseline brine dewatering with the PTU run to capture conservative high and conservative low water impartment loads into the cabin.

Some unexpected anomalies were observed in 2024 and 2025 in the thermal responses associated with a specific inlet temperature switch located on the BPA heater assembly. Despite these anomalies, the most significant milestone was achieved in terms of overall water recovery and the progress of the technology demonstration. Refer to publications [13, 14] for more details.

eXploration Potable Water Dispenser (xPWD)

For exploration missions beyond Low Earth Orbit, there are expectations that these missions will enter periods of uncrewed, dormant phases. These exploration missions will also be challenged with minimizing upmass and consumables. The Potable Water Dispenser (PWD) is the point at which crew receives potable water for food, water, and even payload operations. For crew consumption purposes, there needs to be assurance that quality water is maintained. For the PWD operations, the use of a microbial filter at point of use is required to prevent the passage of microbes to the crew. Moreover, the use of the activated carbon and ion exchange cartridge (ACTEX) is deployed to filter out the total iodine (biocide of choice for US water recycling) for crew health concerns. The baseline designs of the PWD had some early challenges due to identified dead-legs within the internal water loops and bypasses that caused microbial disruptions during initial stowage duration. To that end, in the pursuit of exploration mission objectives and enhancing dormancy success on PWD while also upgrading capabilities and functionalities, an eXploration Potable Water Dispenser (xPWD) was funded and activated on the ISS September 2023. The full status of the ISS xPWD can be found in a concurrent publication [15].

2. Water Transfers and ACTEX Throughput

Over the last several years there has been an increase in requests for US water transfers to the Russians due to prioritization of manifest hardware and agreed-to Protocols between the US and RS. This has led the USOS to routinely deliver potable water to RS EDVs. For the foreseeable future, this support is expected to continue. Because RS ECLSS hardware requires de-iodinated water, each USOS-to-RS potable water transfer must include Activated Carbon/Ion Exchange (ACTEX) treatment to remove iodine/iodide for RS compatibility. Historically, there have been two primary delivery methods to fill EDVs from the USOS. The first is to launch RSTs prefilled with iodinated potable water, then transfer via a fluid transfer pump through an ACTEX; however, if no RSTs are available alternate means have been utilized. The second method is to supply from the Water Storage System (WSS) potable tanks, which, by established WSS operations to protect against stagnate potable water in Shuttle style tanks with susceptibility to leachates, requires the use of an internal ACTEX cartridge + MCV resin that re-iodinates the potable water. Therefore, for this particular water transfer mode simultaneously adds throughput through two ACTEX unnecessarily (one on the WSS outlet and one at point of use for the offload) and therefore imposes a heavy burden on ACTEX spares and throughput margins. The currently installed and utilized ACTEXs are with a configuration that uses Ambersorb sorbent. It has a wetted service life of four years or a throughput limit of approximately 6,750 lb (3,062 L) of water. Increased RS water transfer demand has accelerated ACTEX usage, necessitating more frequent Remove and Replace (R&R) actions to remain within these limits. Given finite logistics and the importance of maintaining de-iodination capability for both WHC and RS support, reducing unnecessary ACTEX throughput is a priority. To address these constraints, water transfers to the RS with de-iodinated water from the PWD method was implemented to support RS EDV fills using WPA product water with a single external ACTEX. This approach bypasses the WSS potable tank pathway and eliminates the need to run two ACTEX cartridges in parallel. By relying on one external ACTEX to de-iodinate WPA product water before transfer, the method significantly reduces overall ACTEX throughput demand while meeting RS water quality requirements. The rationale for adopting this method is threefold. First, it leverages an established procedure, offering operational simplicity and straightforward execution. Second, it minimizes RS crew training burden, which is expected to be limited and manageable. Third, it avoids wasteful simultaneous exhaustion of two ACTEX cartridges inherent in WSS method, preserving scarce On-Orbit spares. This conservation is critical: if ACTEX logistic is not able to meet such high throughput demand, the USOS would be unable to provide de-iodinated water to the RSOS. Consequently, curbing unnecessary usage, particularly on the WSS outlet ACTEX, is warranted.

This PWD configuration, although is convenient from the items above, a third option is actively being looked into to re-assess the established WSS procedures for use of its internal ACTEX + MCV cartridges as the potable water in these tanks are being cycled much more frequently than originally designed; therefore, risk of leachates are significantly reduced. Moreover, as the success of the xPWD continues, there could be Programmatic decision points to allow the legacy PWD to retire, thus omitting access to a by-pass port for these particular water transfer activities.

V. Urine Processor Assembly Current Status

1. Highlights

The UPA produced 8,907 L (19,637 lbs) of distillate at 70% (Russian urine treated with baseline pretreatment) to 87% recovery (US urine treated with alternate pretreatment) from February 2024 to February 2026, completing 87

ARFTA concentration cycles during that time. A graphical summary of UPA water produced and upmass required for ISS operations is provided in Figure 5. As of February 2026, UPA surpassed 100,000 lbs of distillate produced since operations began in 2008. From 2023 to 2024, several PCPA units had to be installed to recover UPA operations. The circumstances, challenges and recoveries behind these events are further explored in a concurrent publication [16]. In the past two years, 17 brine filters (concurrent with expected loading estimates) have been replaced to maintain nominal UPA operations.

To the credit of upgraded hardware successfully incorporated into UPA, most significantly within the DA [11], the UPA has maintained a high level of performance during the increase of crew size and continued processing of Russian urine. UPA has seen significantly more operational run time (>30% increase) in a given year since 2020. A comparison of UPA operations from 2020 through 2025 is presented in Table 1. Despite this increase duty cycle on UPA, there have been limited issues to report at this time. Moreover, in 2025, the longest operating FCPA reached 10,054 operational hours. This was just over 250% of the predicted operational life of 4,000 hours for a 1st generation planetary drive. The FCPA was replaced due to a failed pump motor drive train, with a new FCPA with a 1st generation planetary drive. The DA has also reached over a phenomenal 15,000 operational hours, at over 300% of its predicted operational life of 4,387 hours and 3 times longer than the previous fleet leader in runtime hours. The SPA and Purge Filter have operated nominally throughout the past 2 years after having been replaced when the PPSA tech demo hardware was removed in November 2023.

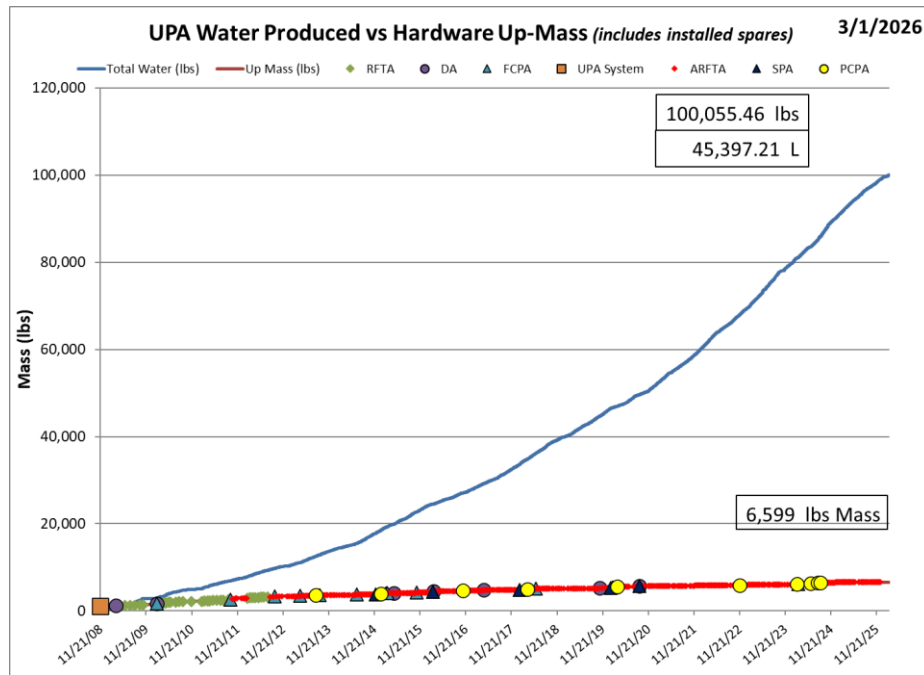


Figure 5. UPA Production and Upmass on ISS

Table 1. UPA Metrics Comparing Last Six Years of Operations

Year	Avg ISS Crew Size	Process Runs	Concentration Cycles	Processing Hours	Total Urine Pounds Processed (lbs)	Total Pounds Brine Generated (lbs)
2020	5 (max: 6)	245	25	1657	5355	1197
2021	7 (max: 11)	326	34	2544	8296	1627
2022	7 (max: 11)	345	44	2786	9,278	2105
2023	7 (max: 11)	359	47	2964	10,486	2249
2024	8(max: 12)	382	46	3160	10,752	2201
2025	7(max:11)	343	43	2700	8,945	2085

2. FrankenPump

As alluded above, end of 2023 into 2024 was a challenging period for PCPA performance. In November 2023, the first 2nd generation planetary drive PCPA was installed. This ORU experienced a premature failure of the pump motor drive train. In Feb 2024, this PCPA was replaced with an older, legacy design harmonic drive PCPA, with expected limited remaining operational life for peristaltic tube install. This PCPA operated for 4 additional months before failing due to ruptured peristaltic tubing. At this point, on orbit, there was a PCPA with failed motor, viable pump ‘body’, and a failed ‘body’ but working motor. Ground teams devised a plan to perform Intermediate-level (I-level) maintenance to take components from the two (2) non-functioning ORUs. A working motor was removed from the PCPA with the failed peristaltic tubing and was installed into the PCPA with a failed motor. This level of maintenance was never designed to be performed on ISS in microgravity but was performed flawlessly by crewmembers. This newly created PCPA was named “FrankenPump”. The circumstances, challenges and recoveries behind these events are further explored in a concurrent publication [17]. This FrankenPump PCPA operated for a couple of weeks and provided enough time for a pristine spare to arrive on ISS, installed after FrankenPump experienced a motor failure. The new, pristine spare PCPA is a 1st generation planetary drive. This ORU (the fifth since November 2023) is still installed and performing nominally with a current runtime of 2,381 hours, 99% of the predicted operational life.

3. Urine Back-Log Management

The Purge Pump issues and failures seen this year during UPA operations created multiple down times with the UPA in a non-functional state. During these down times, extra PTU was collected that could not be processed. In order to not throw away potential good potable water, this PTU was stowed in containers and saved to be processed when UPA was back operating nominally. Approximately 300 L of PTU was collected during the various times UPA was not operating. This stored PTU required a Flight Rule waiver so that its storage time would not expire while waiting to be processed. As PTU ages, the formation of solids increases and pH increases (while still remaining in the acidic range) can also occur within the storage containers. The waiver allowed additional time for the PTU to remain in a stowage container and stipulated that before being processed it will be filtered through the urine filter hose nominally used only for Russian Segment PTU. Historically, when the UPA has processed bad PTU with excessive biological growth, there has been degraded performance and failures within the system. Once the UPA was fully operational again, all of the backlog of PTU was successfully processed and no PTU had to be disposed. Roughly 180 L of PTU exceeded the original expiration date and required the additional time allowed by the Flight Rule waiver on expiration time. UPA data reviews were able to determine that this PTU processed through the UPA nominally. Having this additional data regarding aged PTU provides additional insight to compare with the under-treated PTU problems experienced last year that led to issues with UPA processing ability.

VI. Water Processor Assembly Current Status

The WPA has processed increasing amounts of wastewater as average crew sizes continue to increase on the ISS. Despite the increased throughput, the WPA continues to operate well. Since February of 2024, the WPA saw several major ORU replacements where all but one were replaced due to expected end of life performance. Since last reporting, the WPA required replacement of the Wastewater Filter (informally known as the EFA), Particulate Filter, two catalytic reactors, and the Ion Exchange (IX) Bed ORU. In addition, since last reporting the installed MF Bed has since reached the first ionic breakthrough at 8,000 lbs. Teams will continue to monitor for the second and third ionic breakthrough, estimated around 12,500 lbs and 27,000 lbs respectively, but the intent is to keep this MF bed installed until such breakthrough occurs even if throughput surpasses 27,000 lbs.

1. Particulate Filter ORU

The overall size of this filter allows for extended installed operation within an ISS architecture. The baselined design life was listed at 3 years of operation before requiring a replacement ORU. There have only been two replacements of this filter: one in 2013 after 4 years of operation, and the second this year after an incredible 4251 days (11.6 years). For some background, the first particulate filter was replaced in 2013 after available telemetry suggested this filter to be the cause of some highly variable differential pressure (dP) readings across the filter. When the filter was replaced with a pristine filter, the variability slightly improved but did not resolve. It was later determined that a faulty check valve (CV) upstream of the filter was the primary culprit. After removal of this CV, the high variability dP response fully resolved, thus indicating the original particulate filter did not need to be removed in 2013.

Given that the original particulate filter was already well past its 3-year design life when the initial issue occurred, the filter did not need to be reinstalled and was allowed to be returned to ground for refurbishment. Fast forward to Fall 2024 – dP readings across the particulate filter began to rise with secondary performance impacts to the upstream Pump Separator, which was having to push harder (operate more) against this filter loading. It was recommended that this particular filter be replaced. Not only had it been installed for close to 12 years, it had also processed a total of 141,500 lbs of wastewater. Figure 6 below shows the dP profile across all particulate filters and highlights the system response once the filters or the upstream CV was replaced.

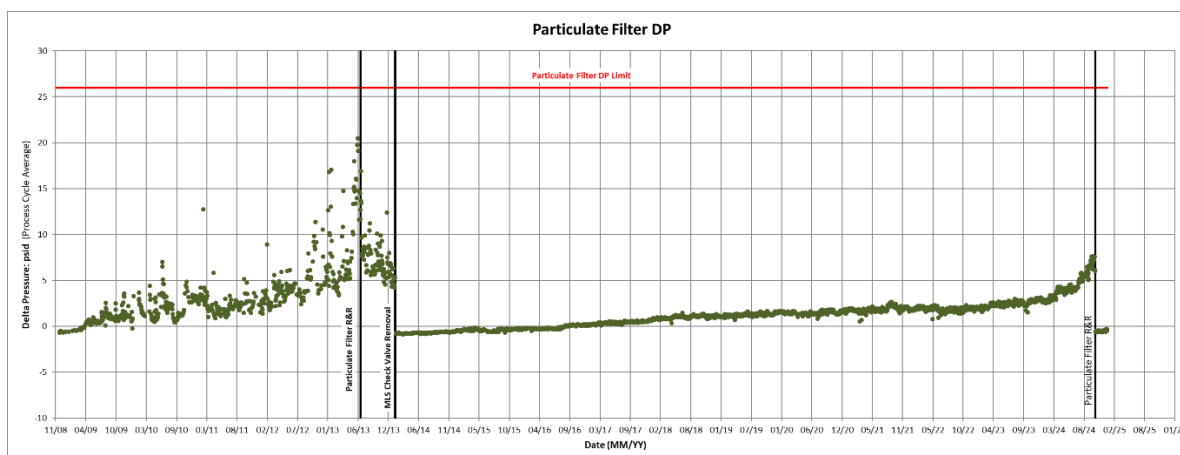


Figure 6. The delta Pressure profile across all three installed particulate filters.

2. Catalytic Reactor ORUs

Over the last two years since previous reporting, the WPA saw multiple catalytic reactor replacements. The first was for Catalytic Reactor SN007, a legacy design with elastomeric seals. This failure was a result of expected end-of-life external water leakage, common for a legacy design catalytic reactor. All legacy design catalytic reactors exhibit a degree of external leakage isolated to the end cap seals of the catalyst cylinders, causing the WPA to fault due to water accumulation on critical electronics. At the time of the SN007 failure (May 2024), the Upgraded Catalytic Reactor SN001 was on board and ready to be installed. Also onboard were two legacy cat reactors, (legacy) SN001 and SN006, but they were not the ideal replacement units, as there was a desire among the ISS engineering teams to install the upgraded unit and obtain valuable runtime data for exploration assessments.

Although Program and Project agreement was in place to install the Upgraded Catalytic Reactor SN001, unfortunately, Catalytic Reactor SN006 was installed by mistake. Furthermore, the unit was already powered up, had reached required system temperatures, and was in the process of completing a flush with wastewater through the unit before teams realized this installation error. Engineering requested that the Upgraded Catalytic Reactor SN001 be installed immediately so that the engineering teams would not need to wait for ~2 years for SN006 to fail, and would not have to limit the Tech Demo period and assessment of the upgraded refurbishment processes (which have not yet demonstrated an ability to prevent a recurrence of a previous failure of the Demo Catalytic Reactor).

It was agreed to do the swap of SN006 to the Upgraded Catalytic Reactor SN001. Before that could be completed, preparation of the SN006 was required as unsterilized wastewater had entered the unit and there was a risk that biofouling could have occurred while in storage. To best prepare the catalytic reactor for stowage and against the effects of exposure to unsterilized wastewater, the unit had been allowed to reach its thermal stabilization temperature to achieve sterility and allowed to cool before its removal from the ISS rack. This was a procedure developed from prior experience: it had been established that thermal cycles and time at high temperature contribute significantly to the degradation of elastomeric seals that led to the legacy catalytic reactor failure modes. This procedure may have adversely affected its time of expected end of life but the magnitude of the impact, if any, the limited accidental installed time has done to the SN006 lifespan is unclear.

The Upgraded Catalytic Reactor SN001 was finally installed and successfully activated. There were some expected operational misbehaviors due to a known and accepted (prior to launch) failed thermocouple but overall, the unit was holding pressure and temperature and was generating appropriate quality water. Unfortunately, approximately two weeks into operations, the catalytic reactor exhibited severe external water leakage. Telemetry suggested the water leakage was located within the catalytic reactor cylinders; thus it is assumed that this was yet another recurrence to

the previous development test objective (DTO) leakage with the new metal seal upgrades. To recover WPA operation, the unit was removed and replaced with the already wetted SN006 and the system was able to recover back to nominal operations. The failed upgraded catalytic reactor has since been returned to the ground testing teams and is awaiting ground investigation to determine cause of failure.

The SN006 catalytic reactor operated for 419 days and processed over 23,000 lbs of water, showing intermittent loss of pressures throughout the install, failing once sustained loss of pressure due to external water leakage occurred. The (legacy) Catalytic Reactor SN001 was then installed in July 2025, showing occasional decay in pressure management but not impacting nominal operations. These intermittent decay in pressure profiles that do not fault WPA are suspected to be internal water leakage through downstream regulators and not due to external water leakage.

3. Ion Exchange Bed ORU

As discussed in a previous report, the removed and replaced Ion Exchange (IX) Bed had become the fleet leader for the amount of water processed while active in WPA. As a reminder, this bed is the final scrubber for the WPA that removes the remaining byproducts from the catalytic reactor and imparts iodine to the clean water. The IX bed has been sized such that the predicted end of life signature can be monitored in real time from a downstream conductivity sensor, the data from which can indicate ionic breakthrough. However, the amount and levels of the iodine cannot be monitored in real time and requires taking water samples for offline monitoring. The increased crew size and the activation of the Brine Processor Assembly have added more available water to be reclaimed and recycled through the WPA in an accelerated rate compared to historical WPA production rates. The amount of water processed in the IX bed has correspondingly increased but remains within the originally planned preventative maintenance of three years of service life. Therefore, engineering teams requested additional iodine samples to increase the data resolution of measured iodine depletion in order to update the estimated projected life in a way that can reflect the increased throughput. The updated estimates provided the much-needed confidence to allow the IX bed to continue operation past the average throughput limit. In May 2024, the IX bed was preemptively removed and replaced before seeing an ionic breakthrough, but after the IX bed reached just over 50,000 lbs of throughput.

VII. Conclusion and Future Work

Since the 2024 reporting period, the WRS has continued to provide the ISS crew with potable water, the Oxygen Generation System with water to electrolyze, the Waste & Hygiene Compartment with flush water, water for crew hygiene, and water for use on payloads. During this time, the WPA required the MF bed to be replaced after reaching its anticipated end of life signature and has seen a new milestone in IX bed operation with processing the most water in a given installation with no issues in imparting proper iodine levels. With the use of the legacy catalytic reactors, it was expected that every 1.5+ years the external water leakage through the elastomeric seals would recur. To that end, over the course of this current reporting periods, two catalytic reactors were replaced due to the legacy failure mode and one additional failure, prematurely, on the Upgraded Catalytic Reactor – likely stemming from continued metal seal design and integration challenges. The root cause will be unclear until the unit enters its ground investigation. Until then, the next line of catalytic reactor spares will selectively target other available upgrades to strike a balance between exploration checkouts on orbit and critical sparing posture risks.

The UPA has seen historical operational runtime hours on the Distillation Assembly and Fluids Control and Pump Assembly, reaching well over 300% of predicted runtime each. This is a testament to years of dedicated upgrades work that addressed a series of challenges within each ORU. In contrast, the UPA has also seen several purge pump failures from a variety of failure causes [16]. Despite the higher number for purge pump ORU R&Rs, only one premature failure mode was exhibited on “Criticality 1” level hardware. The UPA continues to see increases in operational runtime hours overall due to increased crew sizes and continued processing of Russian urine. Despite this increased duty cycle, the UPA has continued operating with no apparent issues related to throughput increase.

The increase in water transfers from the US to the RS found increased throughput of the on-orbit ACTEXs driving changes in planned activities, transitioning RS water transfers to the PWD-based procedure with a single external ACTEX. This maintains de-iodination performance while materially reducing ACTEX throughput and sparing consumption. This strategy sustains ongoing cross-segment water support, aligns with hardware life constraints, and strengthens logistics resilience for continued RS transfer operations.

The ELCSS communities continue to look to future exploration missions. Critical paths of challenging the next generation ELCSS technologies in the relevant space environment are finally being realized. The upgraded MF beds, BPA, UTS, and UPA’s DA and planetary gears (as found in the fluids and purge pumps) have all been integrated on the ISS and are showing exceptional performance. The xPWD ISS operation and runtime with enhanced UV light

technology are actively showing success. The added flexibility xPWD brings for ground commanding and enhanced telemetry insight is further cause for celebration.

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