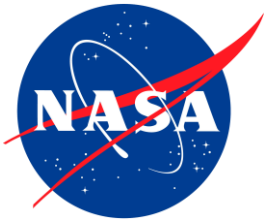


Brine Processor Assembly Ground Testing for ISS Contingency Planning and Exploration Reliability Assessments

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Agenda

- Background & Introduction
- BPA Ground Test Bed Overview
- BPA Ground Test Bed Operations
- Test Campaign
- Conclusions

Background & Introduction

Brine Processor Assembly (BPA)

- The Brine Processor Assembly was launched and installed at the ISS in 2021.
- BPA is a patented technology developed by Paragon Space Development Corporation.
- Objective: expand and increase the total water recovery from urine brine generated by the UPA.
- BPA operates on the ISS as a Technology Demonstration for NASA Exploration missions and processes the brine generated by the UPA to remove water and thereby achieving ~98% water recovery.

Ground Test Bed at NASA MSFC

- A BPA Ground Test Bed was delivered and installed at NASA Marshall Space Flight Center (MSFC) and initial system checks started in 2023.
- Conditions: temperature and humidity-controlled conditions to simulate ISS cabin conditions.
- Flight-like components: detrusor, bladders, brine supply line, all internal components to the system (inlet air filter, heaters, fan), temperature, dewpoint, humidity and leak sensors, exhaust adapter with carbon filter and airflow velocity sensors installed.
- Non-flight components: BPA fill cart with a brine accumulator tank, controls software, scales and brine transfer lines as well as a nitrogen cylinder and pressure system to allow for brine and/or Pretreated Augmented Urine (PTAU) transfer from the tank to the BPA bladder.

BPA Ground Test Bed Overview

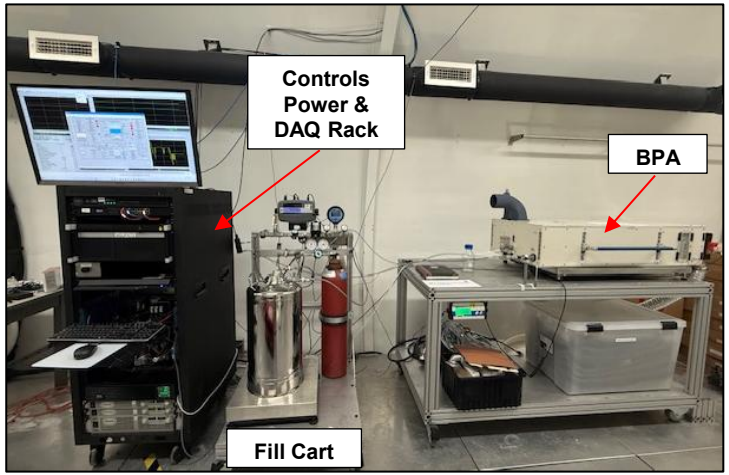


Figure 1. Brine Processor Assembly Ground Test Bed at MSFC.

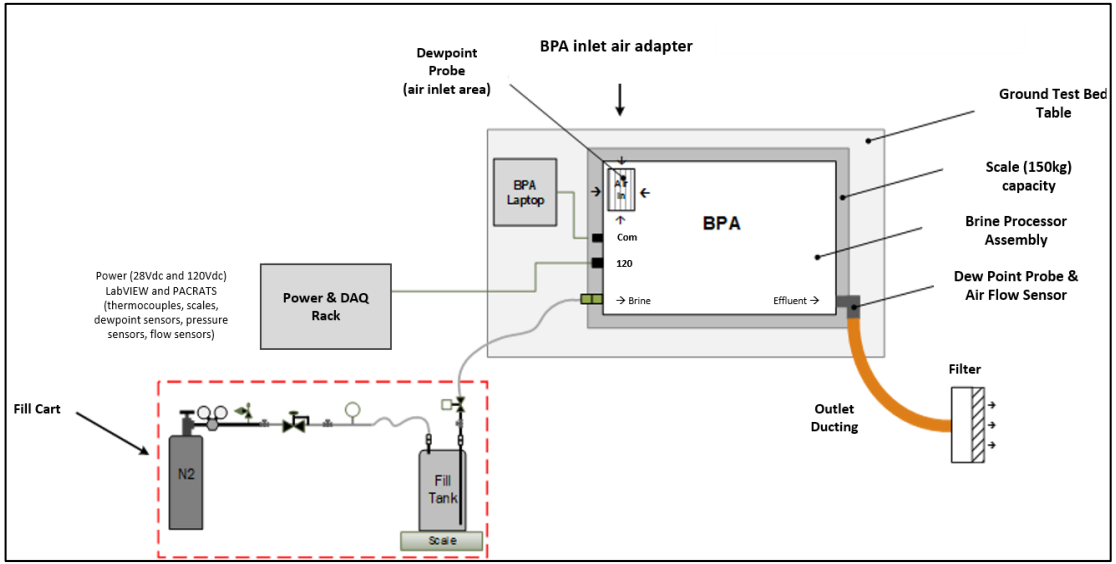


Figure 2. Brine Processor Assembly Ground Test Bed Schematics.

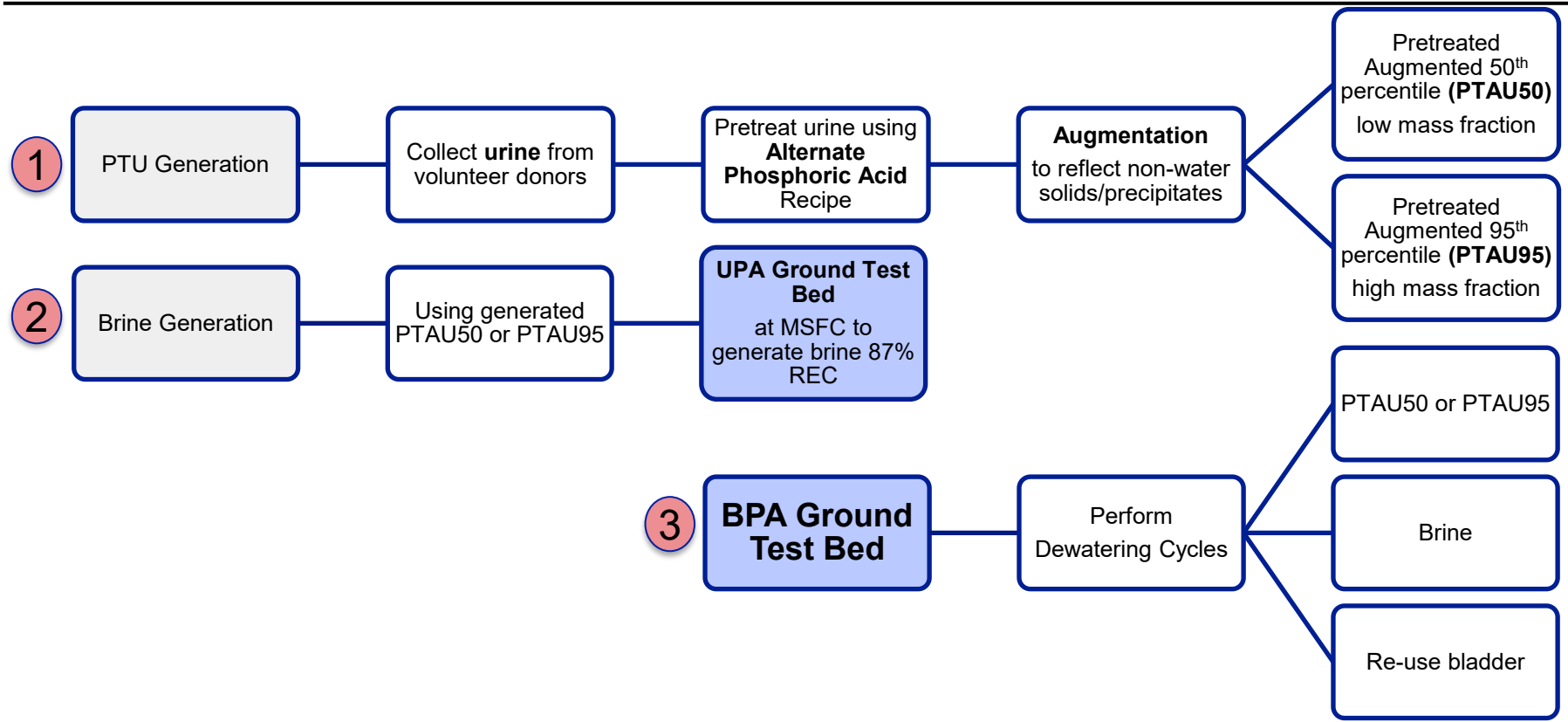
BPA Ground Test Bed Overview

Objectives

- Establish flight-like relevant operations on ground to aid in troubleshooting or further understanding of on-orbit operations.
- Reliability metric based focusing on operational runtime to explore failure modes and enhance statistical understanding for exploration sparing/mass trade studies.
- Allow for upgraded design integration to improve identified performance and/or reliability enhancements.

- ✓ The Ground Test Bed allows for simulation of dewatering cycles utilizing brine and/or PTAU to support ISS troubleshooting needs. It also provides insights for potential ISS contingency planning and reliability assessments to the system.
- ✓ Ultimately, it will be used first to establish baseline operations and understanding within NASA's engineering and Programs to then allow for critical technology advancements as exploration architectures are more realized.

BPA Ground Test Bed Operations



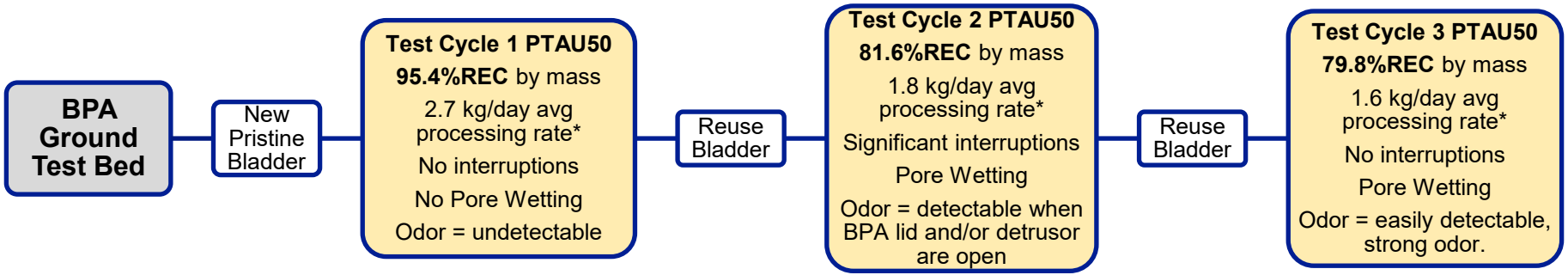
Test Campaign

- **Initial System Checks**
  - Qualify and troubleshoot internal controls software as well as prove full functionality of the brine transfer lines, heaters, fan, and data recording systems.
  - Become familiar with bladder install and fill procedures, and post-processing inspections.
  - Four (4) deionized water test runs performed in the system.
- **Pretreated Augmented Urine (PTAU) Test Series**
  - Explore the use and reuse of the bladder and effects on water recovery.
  - Use of PTAU vs Brine.
  - Evaluate odor and other bladder properties.
- **Pretreated Augmented Urine (PTAU) & Brine Test Series**
  - Explore the use and reuse of the bladder and effects on water recovery/production rates.
  - Use of PTAU, brine and various combinations.
  - Evaluate odor and other bladder properties.
- **Flush & Cleaning Test**
  - Explore the potential cleaning methods for bladder re-utilization focused for on-ground operations.

Test Campaign

1) Pretreated Augmented Urine (PTAU) Test Series

During 2023-2024, the ISS UPA experienced several instances of recovery phases, which limited the rate at which urine was being actively processed. There was a desire to investigate the ability of the ISS BPA as a means to process the pretreated urine rather than the UPA generated brine as a way to get ahead in urine back-log.



*approx. avg rate calculated in the first 4-6 days of the cycle.

Test Campaign

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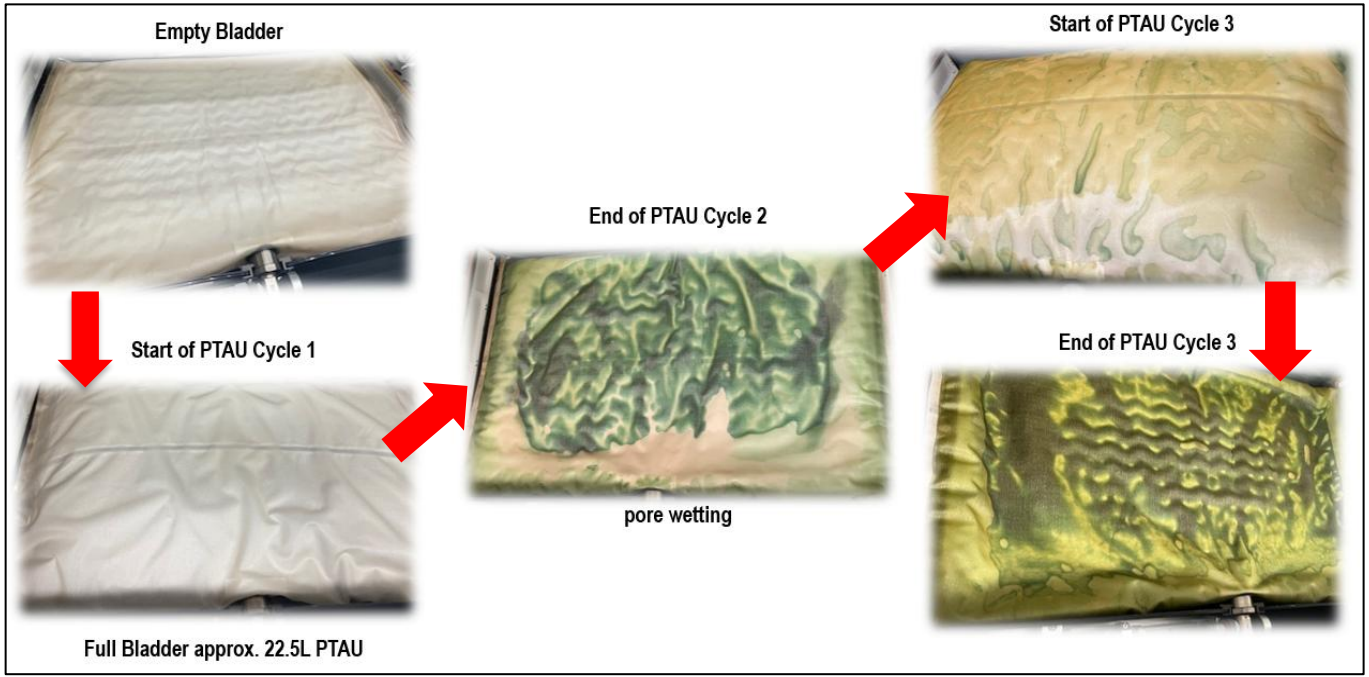
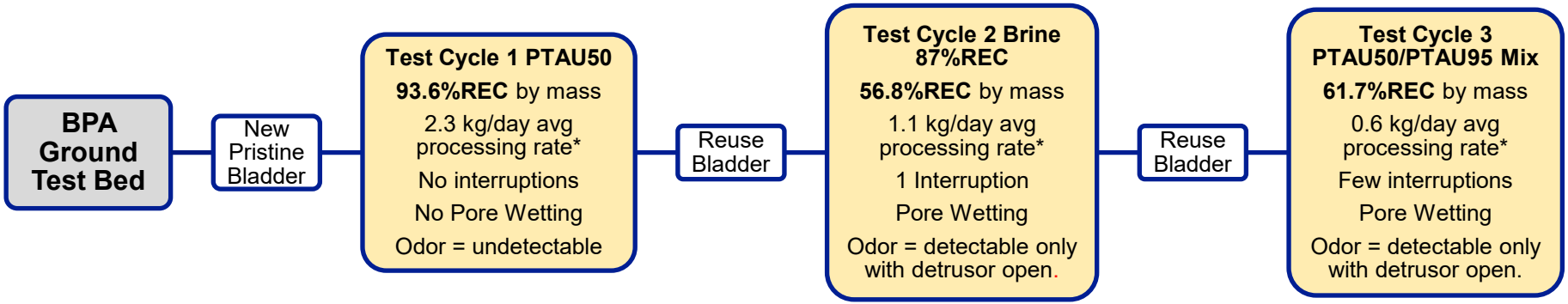


Figure 3. Bladder inside the BPA Ground Test Bed System at various PTAU Test Cycles. Pore wetting observed on Test Cycles 2 & 3.

Test Campaign

2) Pretreated Augmented Urine (PTAU) & Brine Test Series

This test series represents a strategic test matrix to understand the influences of water recovery on-orbit if an ISS BPA processes PTU but then refilled with variable urine-brine quality. The previous test confirmed refilling is possible with some observed decline in production rate but still viable. However, the impacts of refilling the bladder with brine that has even higher solids fractions has not been explored for a reused bladder.

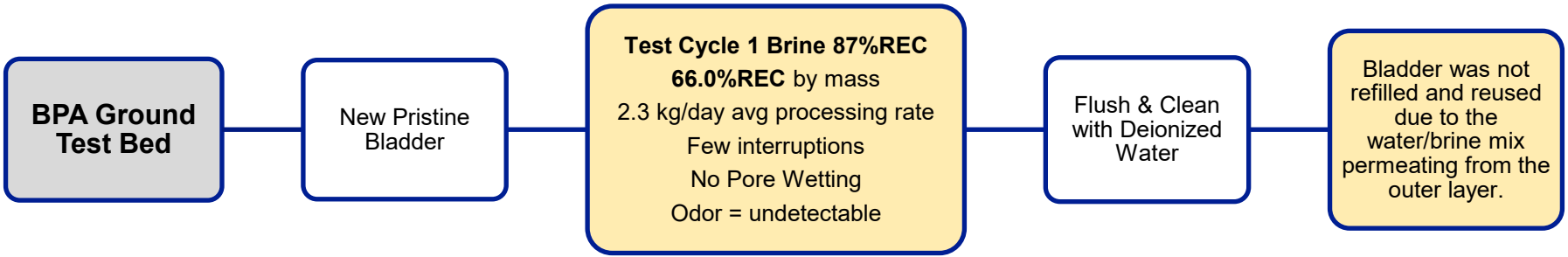


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Test Campaign

3) Flush & Cleaning Test

The intent of this test was to study and understand the efficiencies or gains from applying a cleaning flush procedure in between dewatering cycles and determine an effective cleaning method post-dewatering operations. The goal was to reduce the overall organic minerals contents by >75% and reuse the bladder with the same fluid type. There are limited number of BPA flight-like bladders available on-ground at a given time thus confirming viability to reuse these bladders with an effective cleaning procedure can offer significant cost savings and the opportunity to expand the bladders lifespan.



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Test Campaign

3) Flush & Cleaning Test

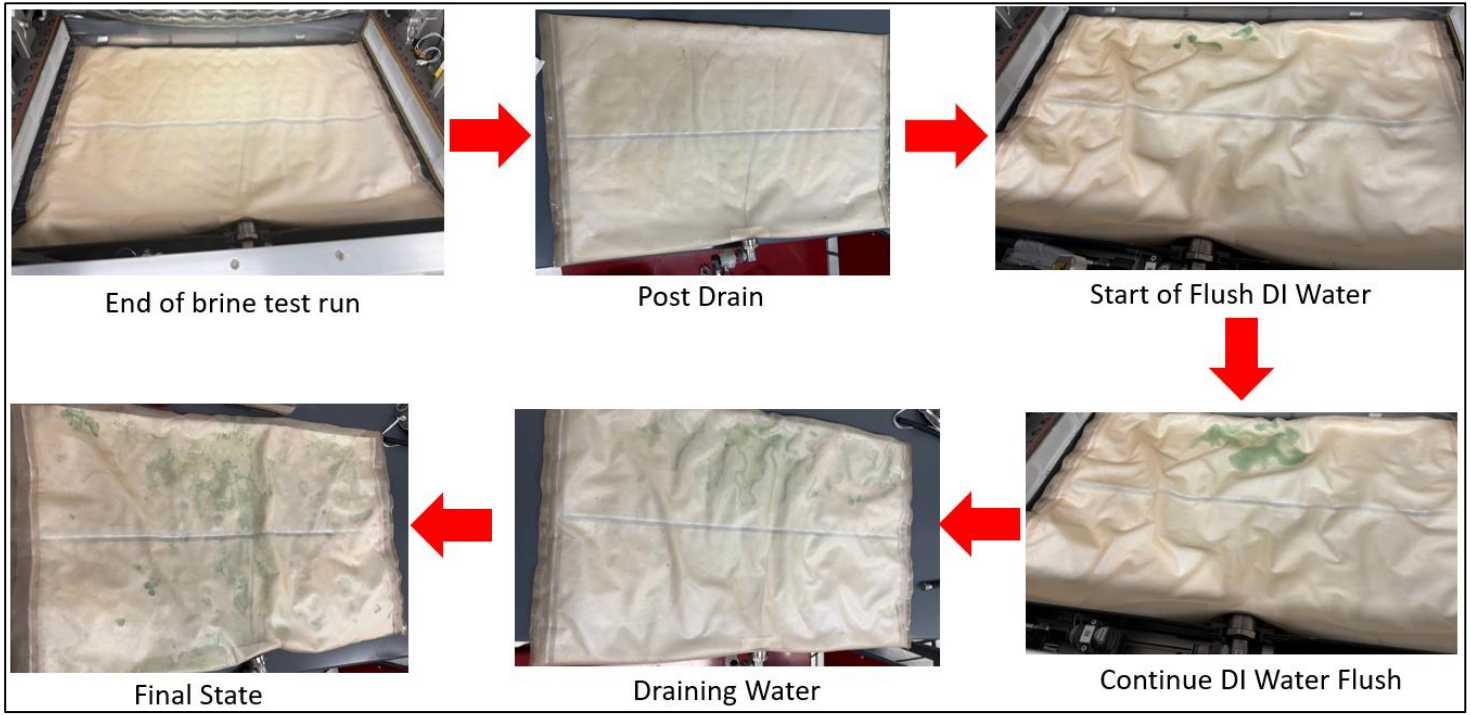


Figure 4. Deionized Water Flush Cleaning Stages.

Test Campaign

Table 1. BPA Ground Test Bed Results Summary

Test	Bladder #	Description	Test Duration (days)	Estimated Initial Total Bladder Volume (L)*	Mass of residual in the bladder at the end of the cycle (kg)	Water Recovery (% total by mass)	Temperature (end of the test)		
							Inlet Temp (°C)	Outlet Temp (°C)	Delta Temp (°C)
1	1	PTAU50	12	22.4	1.0	95.4	42.1	37.2	4.9
2		PTAU50	27	23.5	4.4	81.6	43.4	35.6	7.8
3		PTAU50	25	26.9	5.5	79.8	43.1	35.6	7.5
4	2	PTAU50	10	22.5	1.5	93.6	44.1	36.6	7.5
5		UPA-Brine 87%REC	19	21.1	9.4	56.8	43.9	38.5	5.4
6		PTAU50/ PTAU95 mix	30	29.1	11.2	61.7	44.6	38.0	6.6
7	3	UPA-Brine 87%REC	14	22.7	8.0	66.0	44.3	39.1	5.2

*Total estimated initial volume includes estimated residual volume from previous test cycle.

✓ Inlet and outlet temperatures monitored as an indication of dewatering cycle completion

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4	2	PTAU50	10	22.5	1.5	93.6	44.1	36.6	7.5
5		UPA-Brine 87%REC	19	21.1	9.4	56.8	43.9	38.5	5.4
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Test Campaign

- All the test series maintained the same heater configuration (heater coils 1+2+3) and targeted the same total volume of brine or PTAU for the first initial transfer (22.5L). Subsequent volumes varied as residual brine was left inside the bladder and PTAU or brine availability at the time.
- Dewatering cycles utilizing UPA-brine had lower %REC by mass when compared to PTAU test cycles as expected.
- An approximate 50% reduction in processing rate was observed when reusing bladders.

<u>Pore wetting:</u>

- On ground, larger periods of downtime in the system can negatively affect and contribute to pore wetting in the bladder.
- Bladder reutilization can also contribute to pore wetting.

Conclusions

- The BPA Ground Test Bed at NASA MSFC provided the ability to study and understand the influences of water recovery on-orbit if an ISS BPA processed PTU versus the nominal UPA-brine.
- Refilling bladders is possible with expected decay in production rates as high as 50% specially when processing UPA-brine post a PTU dewatering cycle.
- Pore wetting was a major indicator that was manifested during the entire test campaign even with the elimination of interruptions and downtime within test cycles.
- A brine leak sensor event occurred during the PTAU test series however no visible leak indications were found. The ISS BPA project has already redesigned the Detrusor for an improved brine leak sensor design.

Forward Work:

- Explore the use and reuse of bladders for UPA-brine to understand possibilities and expectations in case of an on-orbit emergency situation where bladders cannot be replaced between cycles or just as a contingency plan for ground support due to the limited availability of flight bladders for ground studies.
- Explore alternative potential flush and cleaning processes between dewatering cycles.
- Install latest designs for continued reliability assessments outside of the ISS operational environment.
- Complete feasibility studies for variable fan control speeds.

Questions?

Thank you for your time!

