Challenges with Operating a Water Recovery System (WRS) in the Microgravity Environment of the International Space Station (ISS)

Layne Carter, NASA
ISS Water Subsystem Manager
Introduction

• The ISS water system produces potable water by the reclamation of crew latent and urine

• The technologies are common to those employed on earth for water purification
  • Distillation
  • Filtration
  • Adsorption and ion exchange
  • Catalytic oxidation

• The design challenge was making these technologies work in the absence of gravity

• Primary issue is dealing with multi-phase fluid scenarios
  • Waste water collection
  • Phase separation
  • Distillation technology
  • Anomalies that create multi-phase fluids
Common Cabin Air Assembly (CCAA)

Condensing Heat Exchanger (CHX) uses air flow across static hydrophilic coating to condense water vapor and feed liquid to air/water separator.

Dynamic pressure from rotary separator delivers condensate to Water Processor.
Waste and Hygiene Compartment (Urinal)

Urine is pulled into funnel by air flow

The residual urine in this separator is a critical factor that requires the urine to be treated for microbial control

Cabin air is then separated in this gas/liquid separator

Critical to provide near-complete gas removal for Urine Processing

Significant controls must also be implemented to insure the “pretreated urine” does not escape into the cabin
Urine Processor Simplified Schematic

Distillation Assembly is a rotary centrifuge that evaporates and condenses the distillate.

Tank bellows must provide a positive pressure to feed the rest of the system.

Gas in tank is difficult to remove, and provides starting point for microbial growth.

Vacuum pump must be capable of pumping two-phase flow.

Gas vented to cabin.

Separation (separates water from purge gases).

Urine distillate to Water Processor.

Wastewater Tank.

Urine from crew.

Brine Filter (removes precipitants).

Advanced Recycle Filter Tank Assy. (accumulates & stores brine for disposal).
Cross Section of Distillation Assembly

This assembly is one of the most complex items on the ISS. The evaporator and condenser spin inside the stationary bowl to maintain an artificial gravity field for the distillation process.

Flight experiment was initially performed on the Shuttle to confirm the behavior of the liquid in microgravity.

Managing condensate in the stationary bowl presented a unique design challenge.
Water Processor Simplified Schematic

As with UPA, free gas in the WPA waste tank is problematic. This bellows must also operate at a positive pressure.

However, free gas is unavoidable and would impact downstream processes - therefore a liquid separator is required.

Catalytic reactor employs three-phase flow, which also required a Shuttle flight experiment to verify performance in microgravity.

A passive hydrophilic membrane separator is used to separate gaseous oxygen and CO2 from process water.
WRS Anomalies on ISS due to Microgravity

- Precipitation of calcium sulfate due to bone loss in microgravity
Excessive free gas from urine container is believed to have overwhelmed Distillation Assembly, resulting in significant quantity of vespel (compressor lobes) dust loading on Separator.
Water Processor Simplified Schematic

- **Wastewater Tank**
- **Ion Exchange Bed** (removes reactor by-products)
- **Reactor** (oxidizes organics and sterilizes)
- **Preheater** (heats water to 267 F)
- **Filter**
- **Gas/Liquid Separator**
- **O2**
- **Microbial Check Valve** (provides isolation)
- **Reject Line** (allows reprocessing)
- **Multifiltration Beds** (removes dissolved contaminants)
- **Regen. HX**
- **Reactor Health Sensor** (verifies reactor is operating w/in limits)
- **Accumulator**
- **Delivery Pump**
- **Ion Exchange Bed** (removes reactor by-products)

**Biomass from waste tank floats downstream and clogs downstream components**

**Free gas from water containers introduced to Product Tank, subsequently clogging filter in potable dispenser**

- **Humidity condensate and urine distillate**
- **Product Water Tank**
- **Wastewater Tank**
- **Filter**
- **Mostly Liquid Separator**
- **0.5 micron Particulate Filter**
- **Ion Exchange Bed** (removes reactor by-products)
In multiple instances on ISS, pressure drop associated with two-phase flow was higher than anticipated. NASA is developing a flight experiment on ISS (PBRE) to investigate.
Lessons Learned

• Design robust solutions for multi-phase flow
• Be prepared for free gas in liquid systems
• Anticipate worst-case scenario for destination of solids