ECLSS Water Recovery: Vapor Compression Distillation and Brine Processing

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Vapor Compression Distillation

In order to conserve liquid hydration resources during extended space missions, Vapor Compression Distillation (VCD) is used to process condensate, hygiene byproducts, and urine waste. In conjunction with proper pre and post-treatments used to remove any extraneous organic or volatile matter, the VCD utilizes a simulated gravity environment in a thermally treated rotating drum in order to remove approximately 85% of water components from waste solutions, producing drinkable water to a purity of approximately 97%. While this technology has been customized for use in micro-gravitational fields, such as those experienced on the International Space Station, the basic water filtration and extraction is to be used in conjunction with a brine processor in attempt to completely dehydrate waste brine in lunar gravity for future use on the lunar outpost.

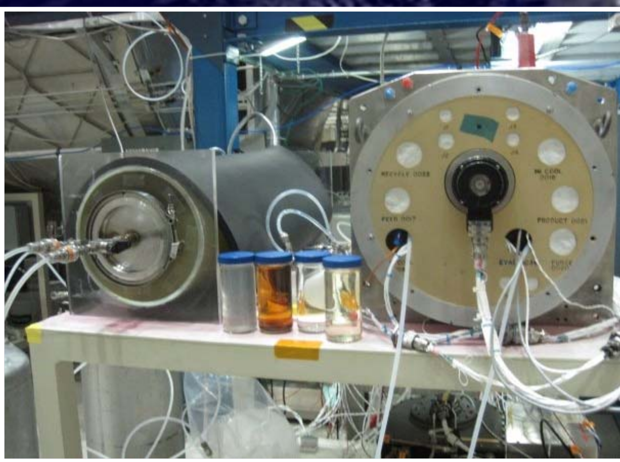

Figure 1: Vapor Compression Distillation Set-up for in-lab experiment processes

How it Works:
-System boils wastewater to produce and collect water vapor
-Changes water from vapor back to liquid phase for collection
-Pressure inside VCD is lowered to 0.7 psi to lower boiling point
-Wastewater fed into rotating drum (220 rpm) to form a thin film coating the walls of drum
-Liquid boils off between 90-105 degrees Fahrenheit
-Water vapor is collected by a "de-mister" in center of drum and fed into a compressor
-Water is then injected onto a thin wall around outside of drum where it condenses
-Water is collected for testing, brine is then removed for brine processing

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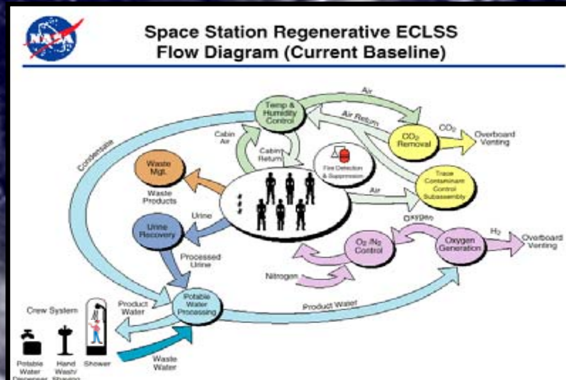

Figure 2: ECLSS flow diagram for International Space Station

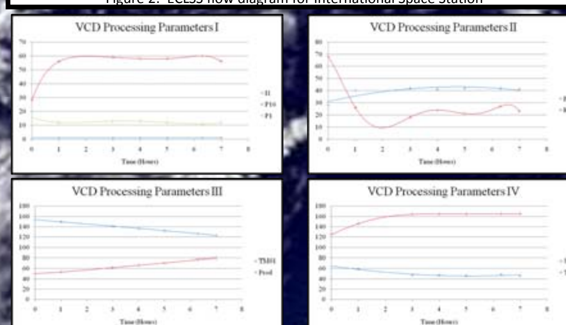

Figure 3: VCD Data trends taken daily for Solution 2 taken 7/16/09. 13.2 lb urine, 65.5 lb hygiene waste, 17.2 lb condensate. I1= Current (Amps); P16=Centrifuge pressure absolute (psi); P1=Delta pressure (psi); P5=Housing pressure of Fluid Control Pump Assembly (psi); TM01=Mass in feed tank (lbs); Prod=Mass of product (lbs); K1=Conductivity of product fluid (μohms); T1=Temp inside centrifuge (°F); SE=Specific Energy (Watt-lbs/hr)

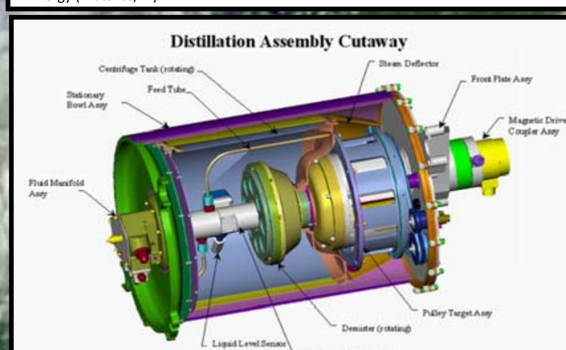

Figure 4: Model of previously used VCD; Reference P. Chien 2005

Brine Processor

The secondary brine processor is in design stages in order to completely remove the remaining water from the VCD processing via an Air Evaporation System (AES). The AES will incorporate similar thermal conditions to that of the VCD, yet will fully utilize the experienced lunar gravity in conjunction with vacuum technology to extract the remaining water without the scaling or fouling experienced by the primary VCD system. The output product is to be tested per standards previously set by the VCD system.

Figure 5: Equipment for Brine Processing System

Solution 1: Condensate & Urine
Solution 2: Condensate, Hygiene Waste (hand wash, shower, oral solution), Urine

Post Processing Tests:
pH/conductivity, TOC, TIC, alcohol, anion/cation, metals, acids, semivolatiles, volatiles, glycol, nonvolatiles, aldehydes, total bacteria, surface tension

Technology	~Current TRL	Influent	Water Recovery	Energy use (w-h / kg processed)	Pros	Cons	Consumables
Microwave	3-4	Solid waste; brine	*Not available*	*Not available*	Uniform heating	No heat recovery	Drying surface
Solar Distillation	2-5	Wastewater; Brine	> 99% (targeted)[45]	*Not available*	Direct use of solar energy	Large surface area	Liners
Thermoelectric Integrated Membrane Evaporation (TIMES)	4-5	Wastewater	>90% [18]	~ 200	Primary processor	Precipitate Fouling	Membranes
Reverse Osmosis (RO)	3-4	Wastewater	> 85% [23]	~10-50 [24]	Development heritage	Precipitate Fouling	Membranes
Air Evaporation System (AES)	6	Brine	> 98% [18]	900 [18]	High recovery	High energy requirement	Wicks
Spray Drying	3-4	Brine	> 99%	893[25]	Industry use	Limited spacecraft history	-

Figure 6: Brine Processing options considered for initial experiment

Future Work: After the Brine Processor assembly has been completed, daily test runs will begin in accordance with VCD product output. Flow rate and tank size may be altered to accommodate daily VCD output and for time/product volume efficiency maximization. Other technology options may be used to compare efficiency and purity of output water product.