Rotating Reverse Osmosis for Water Recovery on Long-term Space Missions

Karen Pickering, *Johnson Space Center*

Water is essential to sustain human life. The large quantities necessary for consumption and hygiene make the supply of this resource on space missions costly. Although periodic resupply is feasible for short-term missions, water recovery from wastewater will be essential to operate a lunar base or to carry out missions to Mars.

A number of physical-chemical technologies are candidates for use on a lunar outpost. Northwestern University, Evanston, Ill., via a NASA Research Announcement grant, developed one of these technologies – rotating reverse osmosis (RRO). To understand how RRO works, we must first understand the process of reverse osmosis (RO).

RO is a separation process by which, through applying a pressure in excess of the osmotic pressure, water is forced across a semipermeable membrane from a solution of high concentration to a solution of low concentration. This water passes through the membrane at a much higher rate than that of the solutes, which leads to separation of the water and the solutes.

The small size of the system and its low energy cost compared to thermal systems make RO a good candidate water purification method for space flight. NASA is also considering the technology for its advantages in recovering potable water from hygiene water. However, there are issues with the use of RO. Because the feed solution is concentrated as water passes through the membrane, solutes build up on the membrane over time in a phenomenon known as fouling. To reduce fouling, RO systems are typically operated at low recovery rates and in a crossflow configuration in which the fluid is run parallel to the surface of the membrane. This combination increases shear force across the membrane surface and effectively washes away the concentrated solutes, extending the life of the membrane.

We designed the RRO system to minimize fouling to allow for increased recovery rates. In this system, an inner cylinder supporting the RO membrane is rotated within a fixed outer cylinder. This configuration alters the flow characteristics of the fluid within the annulus, which further increases shear across the membrane and reduces the buildup of solutes on the membrane surface.

Scientists delivered a second-generation RRO prototype to the Johnson Space Center Advanced Water Recovery Systems Development Facility for evaluation (figure 1). A number of analyses were subsequently performed on the system to answer three key questions: (1) Does a rotating RO configuration reduce membrane fouling? (2) Can an RRO system successfully remove a surfactant from an influent stream? and (3) Can an RRO system successfully recover water from a mixed stream of early lunar base wastewater?

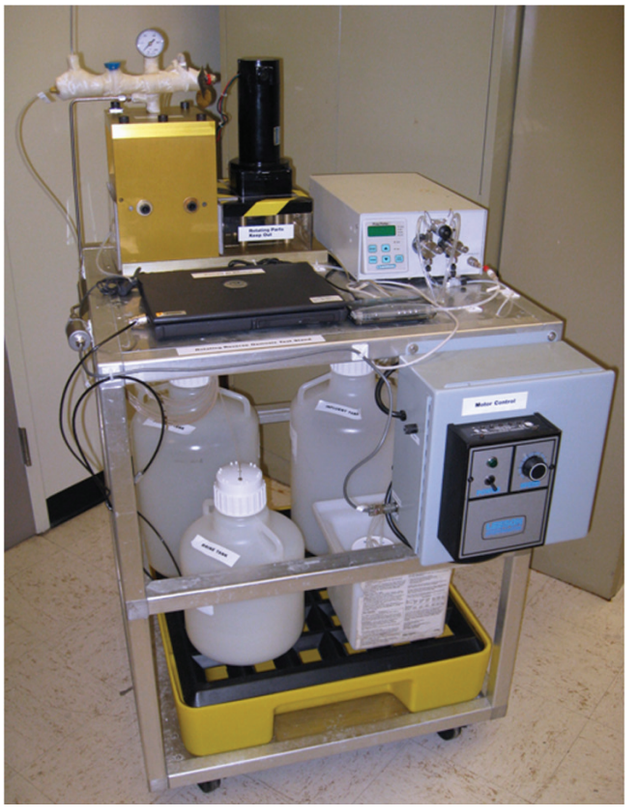

Fig. 1. *Second-generation RRO system.*

Results of various feasibility tests demonstrated that the flux, or fluid flow across a membrane area, of the RRO was affected by the rotating configuration. The rotating test points had a higher flux at 500 psig than the non-

rotating test points. This suggests that the RRO does reduce membrane fouling; however, the flux declined within the first 12 hours of operation, after which the rotation no longer provided an advantage (figure 2). While the recovery showed similar trends, it was highly dependent on the flow rate of the brine, which varied during each test point.

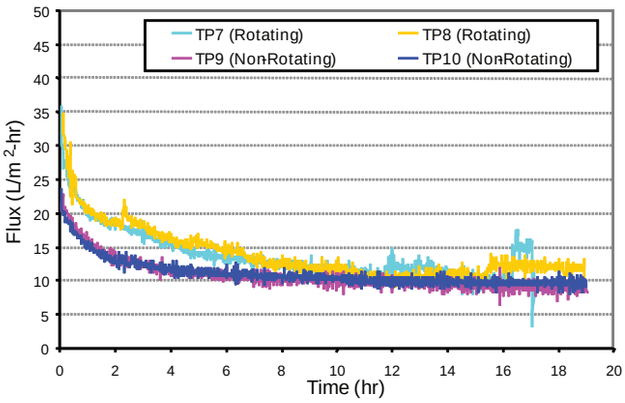

Fig. 2. *Flux over time for two rotating and two non-rotating mixed waste stream test points.*

The RRO was capable of excluding a number of contaminants, including surfactants, but did not appear to provide an advantage over a non-rotating RO system in product water quality.

Further RRO development will need to address several mechanical issues. For example, because of the rotating nature of the system and the membrane geometry, a number of components are susceptible to failure. More importantly, the rotating and non-rotating seals need to be redesigned to reduce leakage and to facilitate membrane replacement. The integrity of the membrane also requires improvement to reduce failures at its seams.

In summary, although the RRO system has several advantages compared to operation of a static RO system, additional development work is needed before this technology can be baselined as part of a water recovery system for Exploration missions.

Click here for next report