

# Spacesuit Water Membrane Evaporator Integration with the ISS Extravehicular Mobility Unit

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## **Abstract**

**NASA has developed a Solid Water Membrane Evaporation (SWME) to provide cooling for the next generation spacesuit. The current spacesuit team has looked at this technology from the standpoint of using the ISS EMU to demonstrate the SWME technology while EVA, and from the standpoint of augmenting EMU cooling in the case of a fouled EMU cooling system.**

**One approach to increasing the TRL of the system is to incorporate this hardware with the existing EMU. Several integration issues were addressed to support a potential demonstration of the SWME with the existing EMU. Systems analysis was performed to assess the capability of the SWME to maintain crewmember cooling and comfort as a replacement for sublimation. The materials of the SWME were reviewed to address compatibility with the EMU. Conceptual system placement and integration with the EMU via an EVA umbilical system to ensure crew mobility and Airlock egress were performed. A concept of operation for EVA use was identified that is compatible with the existing system. This concept is extensible as a means to provide cooling for the existing EMU. The cooling system of one of the EMUs on orbit has degraded, with the root cause undetermined. Should there be a common cause resident on ISS, this integration could provide a means to recover cooling capability for EMUs on orbit.**

## Nomenclature

|                |   |
|----------------|---|
| <i>CM</i>      | = Crewmember  |
| <i>DCM</i>     | = Display and Control Module  |
| <i>EMU</i>     | = Extravehicular Mobility Unit  |
| <i>EVA</i>     | = Extravehicular Activity   |
| <i>IEU/SCU</i> | = Umbilical that mates the EMU to ISS ISS EMU Umbilical/Service and Cooling Umbilical |
| <i>ISS</i>     | = International Space Station   |
| <i>IV</i>      | = Intravehicular Operation  |
| <i>NASA</i>    | = National Aeronautics and Space Administration                                       |
| <i>PLSS</i>    | = Portable Life Support System  |
| <i>SAFER</i>   | = Simplified Aid For EVA Rescue   |
| <i>STS</i>     | = Space Transportation System   |
| <i>SWME</i>    | = Solid Water Membrane Evaporator   |
| <i>TRL</i>     | = Technology Readiness Level  |

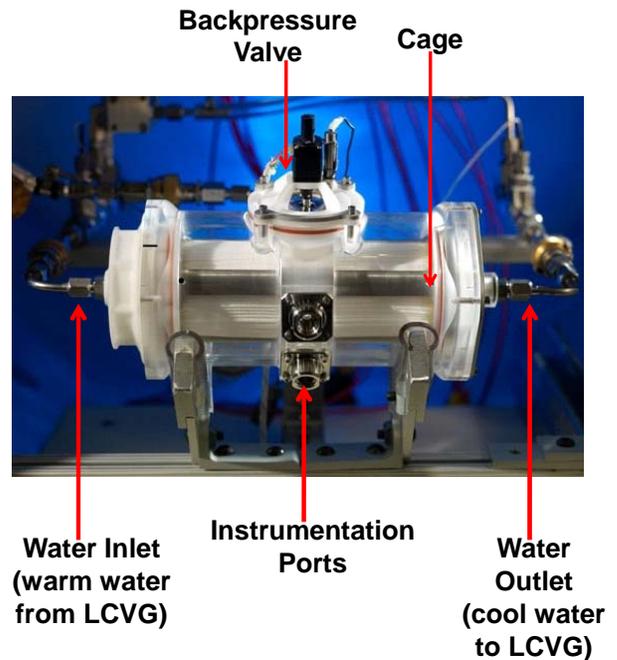
## I. Introduction

### Discussion

NASA has developed a Solid Water Membrane Evaporator (SWME) to provide heat rejection for the next generation of Portable Life Support System (PLSS) on a future spacesuit<sup>1</sup>. The current EVA spacesuit, the ISS EMU, uses a sublimator for heat rejection. The sublimator consists of a porous steel plate, in which pressurized liquid water enters one side, freezes, and then the ice sublimates to space vacuum on the other side of the plate. While this system has provided spacesuit cooling from Apollo through construction of the ISS, it has sensitivities to contamination, and requires water pressurization and regulation systems to operate. The current EMU Portable Life Support System (PLSS) sublimator is certified for 25 EVAs before refurbishment, including cleaning of the porous steel plate, is required. While this is acceptable for operations in low Earth orbit and brief



**Figure 2. Reduced Volume SWME prototype and rectangular SWME showing gate valve implementation**



**Figure 1. Cylindrical SWME construction (Gen 2)**

trips to the Moon, increased robustness will be required for extended exploration missions. Additionally, sublimators do not have the capability of rejecting heat in pressure environments that are above the triple point of water, such as the atmospheric conditions of Mars.

Whereas the EMU sublimator uses the sublimating ice as a heat sink and rejects heat from the circulating coolant water and vent loop with a compact heat exchanger brazed to the sublimation section, the SWME evaporates water directly from the circulating coolant by routing the coolant through porous polypropylene hollow fibers exposed to reduced pressure. The hollow fibers are thin-walled, porous tubes made from polypropylene that are approximately 300 microns in diameter. The hollow fiber fabric allows a large



Since the metabolic rates required for IV operation differ than EVA, determining if a SWME could provide the necessary comfort for the CM was undertaken. The SWME was integrated with the existing EMU systems model. One consideration was the impact to the water flow through the liquid cooling garment as a result of the additional pressure drop for the SWME plus the umbilical. The transport water flow was reduced by 8 percent for the low metabolic rate condition, and by 22 percent at the high metabolic rate condition. Even with this reduction, there was enough flow to maintain crewmember comfort for ISS environmental conditions and metabolic rates.

The next consideration was maintaining the moisture level in the EMU ventilation loop. In nominal EMU operation, the moisture from the CM is condensed in the EMU sublimator and then transferred to the separator where the water rejoins the feedwater loop. The EMU sublimator has a heat sink of 32°F during EVA operation. The transport loop is cooled by this segment of the sublimator which in turn cools the EMU ventilation loop. The ventilation loop is also cooled by the supplemental sublimation area.

A key question in the integration consideration was what performance would be required from the SWME to adequately maintain system ventilation loop temperatures and dewpoints. System model results indicate that a SWME set point temperature of 38°F provides adequate cooling for the CM and acceptable dew point control. This is well above the minimum lower set point temperature of 36°F desired by NASA, yet below the Advanced suit selected set point of ~50°F and previously demonstrated with the SWME controller. Resultant system dew point temperatures into the helmet for high and low metabolic rates are slightly lower with the SWME installed than without: 42.7°F with SWME at low metabolic rate, versus 47.8°F without, and 42.9°F with SWME at high metabolic rate, versus 54°F without.

Another consideration was the change in EMU vent flow into the helmet with the SWME. There was a 7 percent reduction in helmet flow for this condition. This results in helmet flow rates slightly below the present EMU requirement of 6.0 ACFM. The acceptability of this reduction would have to be evaluated by the EMU community.

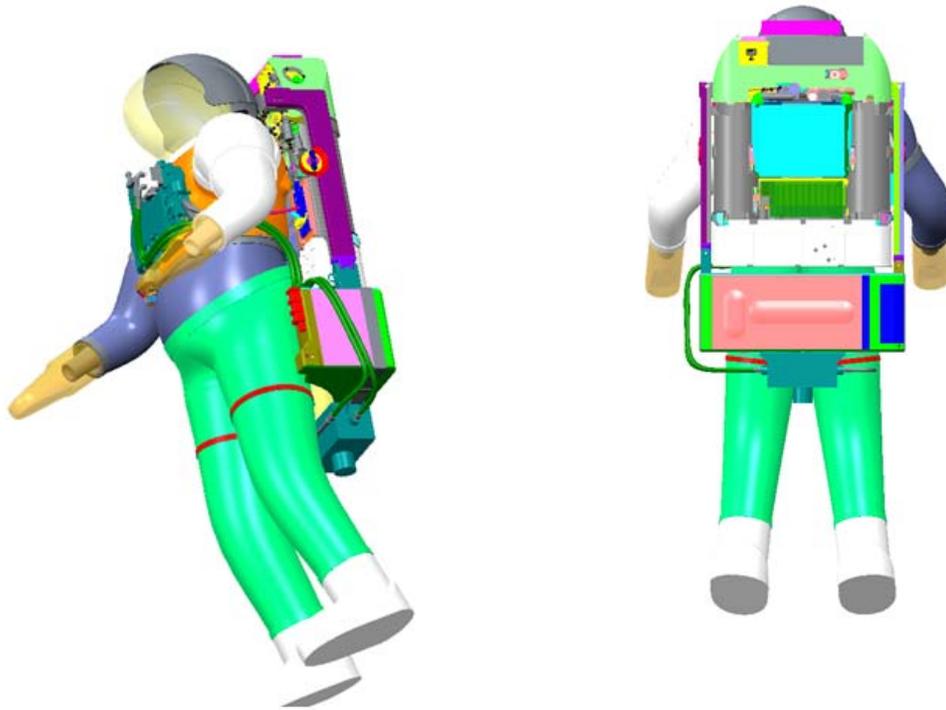
One key difference with the use of SWME for heat rejection is that the consumable water location is changed from the sublimator to the transport water loop. There is an EMU feature because of the EMU water pressurization schema and the ability to transfer condensate back to the feedwater tanks that allows make-up water to be supplied to the transport water instead of the sublimator. The water consumed by the SWME will be replaced by the system at the same rate that it would be consumed in a nominal operation. The supply of water in the EMU feedwater tanks can be used to either supply water for sublimation or for SWME consumption.

The materials of the SWME were reviewed to address compatibility with the EMU, basic hollow fiber membranes should be compatible. The rest of the design could be upgraded from the laboratory demonstrators to meet EMU materials needs.

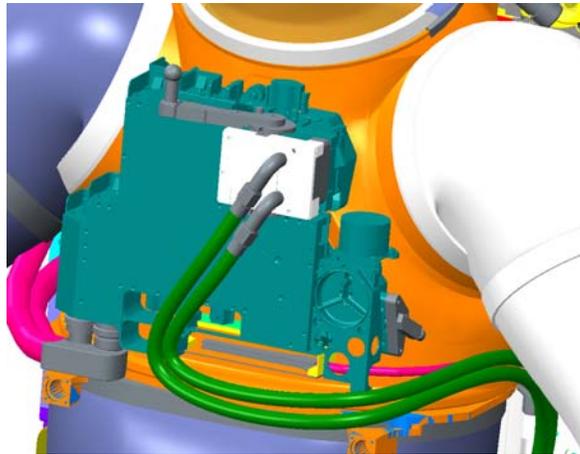
### **Physical Connection of SWME to EMU**

Physically this hardware would consist of an EMU umbilical connector block to access the EMU water systems, hoses to transfer water to and from the SWME, a controller, and self-contained battery power. Conceptual placement of the SWME using the EMU 3-D model was performed. Various locations on the EMU were considered including above the EMU radio at the top of the life support system, attached to the EMU PLSS as a backpack, mated to the back of SAFER and mated below SAFER. Based on past experience with installation of other hardware on the EMU, NASA recommended a location for the SWME below the SAFER. This location increases the size of the EMU in the one dimension that does not impact the ability to move the EMU through ISS hatches. A slightly larger sized payload, the Tile Repair Ablator Dispenser was carried in this location during an EVA on Shuttle Flight STS-123.

Views of the SWME attached to the EMU above the SAFER and the umbilical connection to the DCM are shown in Figures 4 and 5 respectively.



**Figure 4 - SWME Installed below SAFER**



**Figure 5 - SWME Connection to DCM**

#### **EMU SWME Concept of Operations**

A notional concept of operations (con ops) was performed for the conditions where the SWME was utilized in addition to the EMU sublimator as well as for the case where the SWME would provide cooling in lieu of the sublimator. This assessment was performed using the ISS EVA Generic Checklist as a baseline. This assessment resulted in preliminary decisions to attach the SWME to the EMU following SAFER Donning portion of EVA

PREP. The umbilical for the SWME could be mated to the DCM of the EMU following SCU demate while the EMU is at vacuum following crewlock depressurization. This would enable SWME cooling at the same time the EMU sublimator water is nominally turned on so there would not be a change in Crewmember cooling for SWME use with or without sublimator use.

Use of SWME with EMU would result in several EMU caution and warning messages if it was used in lieu of the EMU sublimator.

The EMU sublimator has been demonstrated to be susceptible to trace contaminants since manned chamber testing in 1983<sup>1</sup>. EMU water sources and materials of construction have been closely monitored for acceptability. There was a gradual loss in sublimator performance noted during the STS-120 mission. The cooling system of one of the EMUs used during Increment 32 has degraded in performance over the course of a single EVA from nominal to unacceptable cooling capability, with the root cause undetermined. The source of the contaminants has not yet been identified. If the source(s) of the water quality issues on orbit are not fully identified and this concept is extensible as a means to provide cooling for the existing EMU.

The SWME tendency to concentrate contaminants must be addressed as part of EMU integration. The EMU water supplies are controlled to assure purity, some contaminant and residual biocide will remain. With the EMU using the sublimator, these contaminants are deposited on the porous plate and do not affect water tank or coolant water circuit water quality. With SWME, the pure water evaporating from the coolant circuit may leave behind contaminant, which will slowly concentrate in the loop as pure water is removed. The contaminant control scheme currently used with the EMU to remove water circuit contamination will require review to insure the post EVA scrub will adequately remediate any build up of contaminant.

### **III. Conclusion**

A methodology to increase the TRL of a SWME while providing a means to provide cooling for the existing EMU in the event of water contamination has been identified. Key integration issues of physical integration, system performance, EMU consumables, concept of operations and materials compatibility have all been favorably addressed.

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- <sup>1</sup>. Bue, G.C. et al, "Hollow Fiber Space Water Membrane Evaporator Flight Prototype Design and Testing," AIAA International Conference on Environmental Systems (ICES), July 2011.
  - <sup>2</sup>. Makinen, J. V. et al, "Reduced Volume Prototype Spacesuit Water Membrane Evaporator; A Next Generation Evaporative Cooling System for the Advanced Extravehicular Mobility Unit Portable Life Support System," AIAA International Conference on Environmental Systems (ICES), July 2013
  - <sup>3</sup>. Steele, J. W., et al, "Space Station Water for EMU? Subscale Sublimator Testing," SAE Intersociety Conference on Environmental Systems, July 1993