Mini-Membrane Evaporator for Contingency Spacesuit Cooling

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A new Portable Life Support System is being developed at NASA JSC.

Includes new technology development hardware;
- Spacesuit Water Membrane Evaporator for heat rejection
- High-speed ventilation fan
- Primary and Secondary oxygen regulators
- Rapid-Cycle Amine (CO2 removal)

Integrated PLSS testing completed at a breadboard level in 2011 (PLSS 1.0)
Packaging the PLSS into ‘backpack’ began in 2013 (PLSS 2.0)
The current Extravehicular Mobility Unit (EMU) utilizes a secondary oxygen vessel (SOV) for contingency breathing oxygen and cooling of the crewmember during an EVA anomaly.

- Sublimator failure
- Power failure

The SOV flows high pressure oxygen through the LCVG to cool the crewmember.

Some drawbacks of the SOV include:

- Very high pressure charge: 6000 psi
  - Primary oxygen vessel (POV) is charged only to 3000 psi and is smaller
- Cannot be recharged on orbit after use—must be returned for service
- Provides only 30 minutes of get-back time
During packaging analyses for PLSS 2.0, it became clear that more space was needed to package all of the components.

A proposed solution was to eliminate the SOV and replace it with a smaller tank, identical to the POV.
  - Rely on new, smaller SOV for contingency breathing oxygen only
  - Create an Auxiliary Cooling Loop (ACL), which relies on a small membrane evaporator for heat rejection.

Advantages to identical Primary and Secondary oxygen tanks include;
  - More available volume inside of PLSS package
  - Component similarity
  - Rechargeable on-orbit
Auxiliary Cooling Loop Overview

Auxiliary Cooling Loop consists of;
- Small Membrane Evaporator, Mini-ME, utilizing same technology as the primary heat rejection device for the PLSS, the Spacesuit Water Membrane Evaporator (SWME)
  - Independent pump
  - Independent power supply
  - Independent LCVG tubing in the vest area only
  - Independent feedwater assembly
  - Independent controller

Advantages of the ACL
- Can be recharged on orbit
- Can provide more get-back time
- Completely independent system
Mini-ME is an evaporative cooler
- 8000 porous microfibers
  - 300 microns in diameter

**Process**
- Water in LCVG absorbs body heat while circulating
- Warm water pumped through Mini-ME
- Valve is opened
- Mini-ME evaporates water vapor, while maintaining liquid water
  - Cools water
- Cooled water is then recirculated through LCVG.
- LCVG water lost due to evaporation (cooling) is replaced from feedwater
Proposed operation of ACL
- During a contingency event, the crewmember will turn-on the ACL via a switch on the Display Control Module (DCM)
- The switch will turn on the independent controller
- The pump will start
- The valve will fully open, exposing fibers to vacuum, rejecting heat

Goals for first generation of hardware:
- Accommodate a 1200 BTU/hr crewmember metabolic rate
- Provide 60 minutes of heat rejection
- Package into PLSS 2.0—rectangular cross section preferred

The dimensions for the first Mini-ME were dictated by available volume in the PLSS.
A rectangular membrane evaporator was designed and constructed in-house.

A clear, acrylic housing was chosen in order to evaluate membrane integrity.

The fiber cartridge was constructed with 8000 fibers, utilizing a new, layered technique.

Gate valve with small stepper motor
  - Gate valve chosen due to volumetric constraints within the PLSS volume.
- Two units were constructed.
- Preliminary testing results showed heat rejection performance of 95-110W (325-375 BTU/hr) at 50kg/hr flow rate with a 10 degree Celsius outlet temperature.
- Approximately ~10 W of heat leak was observed across the closed gate valve
  - This could cause fiber freezing and loss of feedwater during system standby
- Following preliminary testing, one Mini-ME was installed into the PLSS 2.0 backpack.

Completed Mini-ME unit
PLSS 2.0

Mini-ME (left), RVP SWME (right)
Subsequent Mini-ME Testing

- Following the preliminary testing of Mini-ME, a study was conducted to:
  - investigate ideal fiber density and packaging in terms of heat rejection
  - Determine smallest valve throat area needed to reject at full capability
- 9 Fiber Density Test Articles (FDTA’s) were constructed with different fiber densities and with replaceable valve throat areas.
- Each unit was tested for a total of 24 hours.
- Data from these tests allowed analysts to correlate models to data
- Ideal configuration: 16 bundles of 6 layers (9413 fibers), which produced 165W of heat rejection with a 55kg/hr flow rate

<table>
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<th>Fiber Density Test Article (FDTA)</th>
<th>Bundle Count</th>
<th>Layers</th>
<th>Nominal Fiber Count</th>
<th>Day 4, 0.75 in² Orifice Plate, 10°C Outlet Heat Rejection (W)</th>
<th>FDTA Outlet Water Mass Flow (kg/hr)</th>
<th>Normalized (10°C Tout, 55 kg/hr mdot FDTA Day 4, 0.75 in² Orifice Plate Heat Rejection (W))</th>
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Nominal bundle width (in) 1.85
Nominal fiber density (fibers/inch) 53
Nominal fiber exposed length (in) 2.25
FDTA Analysis

- Valve throats of 0.75in\(^2\), 1 in\(^2\) and 4in\(^2\) were investigated.
  - No difference between 0.75in\(^2\) and 4 in\(^2\)

- Fiber density and packaging:
  - Most data points show that fewer layers yield greater heat rejection for same fiber count
  - Strongly suggests optimum packaging is higher bundle count and fewer layers
  - Limits of this approach would require additional testing

![Graph showing heat rejection vs. total fiber count](attachment:graph.png)
Fiber Density Test Article (FDTA)
The Mini-ME and ACL will be tested as an integrated system in PLSS 2.0, beginning in September.

The next generation of Mini-ME hardware (Mini-ME2) is currently being designed.

- Goals:
  - New valve with 0W heat leak
  - More heat rejection (350W)

Mini-ME2 will be tested independently, and ultimately integrated into the next round of PLSS testing (PLSS 2.5).
Acknowledgments

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