

Performance of the Extravehicular Mobility Unit (EMU) Airlock Coolant Loop Remediation (A/L CLR) Hardware

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ABSTRACT

Following the Columbia accident, the EMUs (Extravehicular Mobility Units) onboard the ISS (International Space Station) went unused for an extended period of time. Upon startup, the units experienced a failure in the coolant systems. The failure resulted in a loss of EVA (Extravehicular Activity) capability from the US segment of the ISS. A failure investigation determined that chemical and biological contaminants and byproducts from the ISS Airlock Heat Exchanger, and the EMU itself, fouled the magnetically coupled pump in the EMU Transport Loop Fan/Pump Separator leading to a lack of coolant flow. Remediation hardware (the Airlock Coolant Loop Remediation water processing kit) and a process to periodically clean the EMU coolant loops on orbit were devised and implemented. The intent of this paper is to report on the successful implementation of the resultant hardware and process, and to highlight the go-forward plan.

INTRODUCTION

The EMU coolant system circulates water used to reject heat from the crewmember and the equipment. See Figure 2 for the Airlock/EMU Coolant Loop Schematic. During EVA, the EMU depends on vacuum for

sublimation cooling. During EVA preparations, the airlock coolant loop provides cooling for the EMU when it is at ambient pressures. The airlock coolant loop contains a heat exchanger and umbilicals to connect to the EMU. The EMU contains the pump and systems to circulate and degas the coolant loop along with the liquid cooling garment to provide cooling to the suited crew member.



FIGURE 1
– EMU
work on
orbit

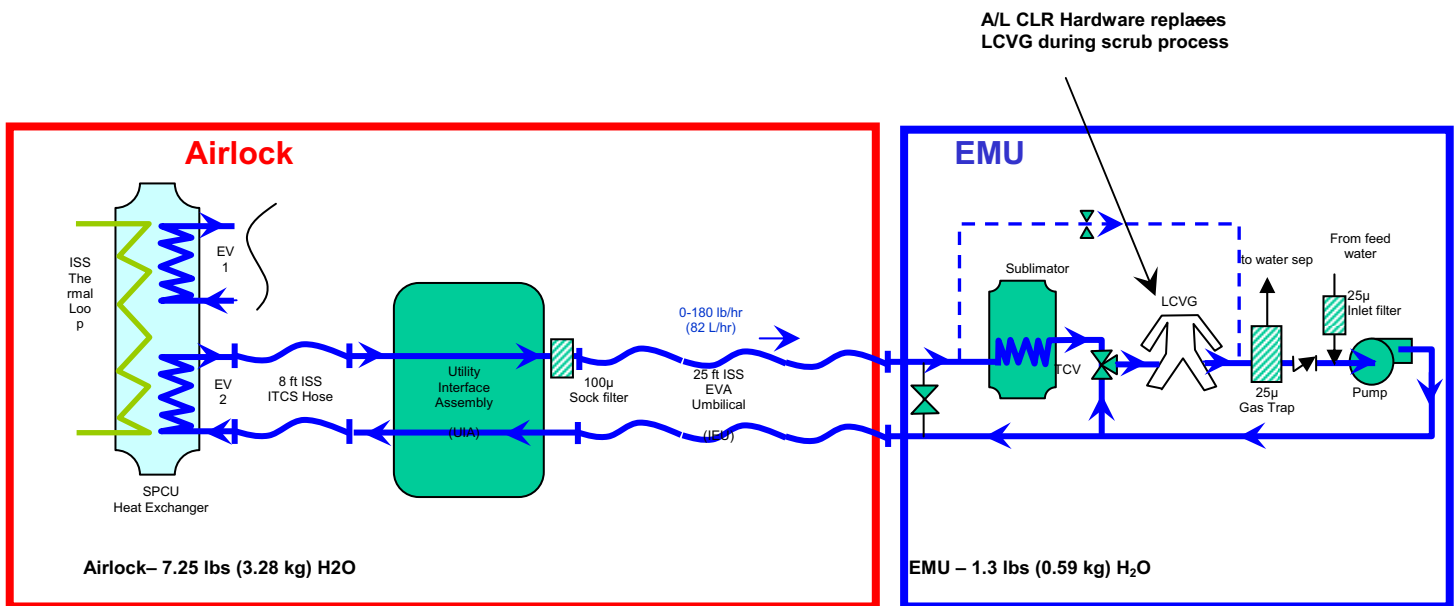


FIGURE 2 – COOLANT LOOP SCHEMATIC AND A/L CLR LOCATION

The A/L CLR water processing kit was developed as a corrective action to the EMU coolant loop flow disruptions experienced on the ISS in May of 2004 and thereafter. The components in the kit are designed to remove the contaminants that caused the prior flow disruptions. A/L CLR water processing kits were utilized on two newly launched EMUs (S/N 3009 and 3010) that were in service for 13-months between 06/2005 – 07/2006. The EMU hardware and spent A/L CLR water processing kit components were returned to the ground in 07/2006. The spent kit components and EMU hardware were evaluated to gauge the success of the A/L CLR kit corrective actions. The primary focus of this paper is to summarize the findings of the evaluation, and to present the devised go-forward plan. (1) (2)

DESCRIPTION OF THE A/L CLR KIT

The A/L CLR water processing kit was devised to scrub and remediate the various chemical and biological contaminants and byproducts that were found to have fouled the magnetically coupled pump in the EMU Transport Loop Fan/Pump Separator (see Figure 3). (3) (4)

The heart of the kit is the EMU Ion Filter, which is a 50:50 by volume packed bed of mixed anion/cation exchange resin and activated carbon. This component is periodically installed into the EMU / Airlock coolant loop and serves the purpose of removing inorganic and organic constituents such as nickel and iron corrosion products and organic acids with the ion exchange resin. Furthermore, uncharged organic contaminants are removed with the activated charcoal. (3)

In service, a 3-micron filter is placed downstream of the EMU Ion Filter to capture fines from the packed bed prior to return of the polished water back into the EMU Transport Loop.

After scrubbing with the EMU Ion Filter, the EMU Biocide Filter is installed to add residual iodine biocide for microbial control. The EMU Biocide Filter is a packed bed of ion exchange resin impregnated with iodine.

The A/L CLR kit also contains a Needle Adaptor to aid in the iodination of the EMU Ion Filter after it is used to reduce microbial activity in the bed in storage between uses.

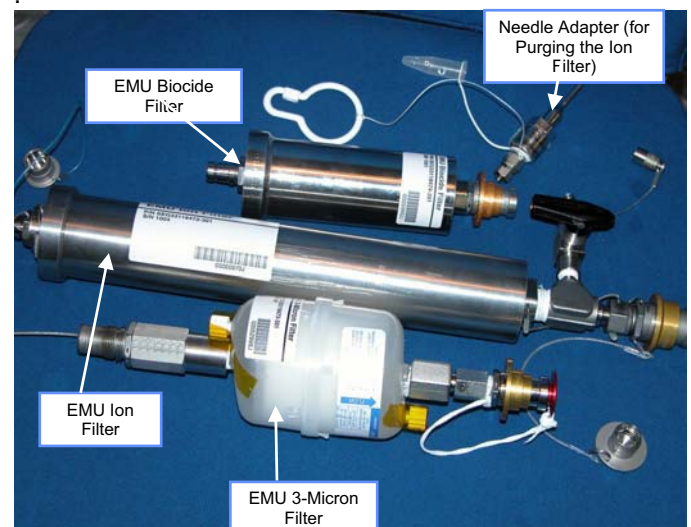


FIGURE 3
A/L CLR WATER PROCESSING KIT COMPONENTS

PRELIMINARY A/L CLR KIT USE SCHEDULE

An initial A/L CLR use schedule was devised based on results from prior EMU Transport Loop water analysis results, the analysis findings from the coolant flow failure investigation, and interaction with the EVA and ISS logistics communities. The preliminary use schedule is summarized in Table 1.

Activity	Item	Requirement
Max stagnation time	EMU	90-days
Pre-EVA scrub	EMU	≤ 2-weeks
Post-EVA scrub	EMU	≤ 2-weeks
Number of uses	Ion bed	4
Shelf life after first use	Ion bed	2-years
Number of uses	3-micron filter	1
Shelf life after first use	3-micron filter	N/A

TABLE 1 - Preliminary A/L CLR Kit Use Schedule

The initial maximum stagnation time for an EMU on-orbit was initially set at 90-days before an A/L CLR scrub cycle was initiated. Furthermore, an A/L CLR scrub requirement was initially set at ≤ 2-weeks before a scheduled EVA. Finally, an A/L CLR scrub requirement was initially set at ≤ 2-weeks after a series of EVA's occurring within 2-weeks of one another.

The number of uses of the Ion Bed was initially set at 4, which was a conservative estimate based on prior EMU Transport Loop coolant water analysis results. Shelf life of the ion bed was set at 2-years after the first use.

The number of uses of the 3-micron filter was initially set at 1, with the item not used thereafter.

The results summarized in this paper have been since utilized to loosen the Table 1 requirements. Efforts are underway to further evaluate returned EMU hardware and spent A/L CLR kit components in an attempt to further loosen the Table 1 requirements due to the anticipated logistics challenges expected after the Shuttle retirement in 2010.

TRANSPORT LOOP WATER ANALYSIS RESULTS

Transport Loop coolant water samples were drawn from each of the subject EMUs (3009 and 3010) through the HUT W LVTA Supply after hardware return. These samples underwent chemical and microbial analyses at Wyle Labs in Houston, TX and Hamilton Sundstrand Labs in Windsor Locks, CT. using standard methods. Results are summarized in Table 2. Select parameters of particular interest that represent the quality of the water in the EMU Transport Loops prior to A/L CLR implementation (pre-2004 maximum and pre-2004

average – including the Post-Columbia accident failed hardware) are provided for comparative purposes. (4) (5)

Parameter	EMU 3009	EMU 3010	Pre-2004
General	-	-	-
pH	5.78	6.36	5.04 (low) 6.63 (ave)
Conductivity (uS/cm)	7.81	7.37	41.1 (max) 19.1 (ave)
Standard Cations	-	-	-
Li (ppm)	< 0.1	< 0.1	-
Na (ppm)	< 0.1	< 0.1	-
NH ₄ (ppm)	< 0.1	< 0.1	-
K (ppm)	< 0.1	< 0.1	-
Mg (ppm)	< 0.1	< 0.1	-
Ca (ppm)	0.38	0.41	-
Standard Anions	-	-	-
F (ppm)	< 0.1	< 0.1	-
Cl (ppm)	< 0.1	< 0.1	-
SO ₄ (ppm)	< 0.1	< 0.1	-
NO ₂ (ppm)	< 0.1	< 0.1	-
NO ₃ (ppm)	< 0.1	< 0.1	-
PO ₄ (ppm)	< 0.1	< 0.1	-
Metals	-	-	-
Fe (ppm)	< 0.05	< 0.05	-
Cr (ppm)	< 0.05	< 0.05	-
Ni (ppm)	0.61	0.60	6.43 (max) 4.16 (ave)
Al (ppm)	0.09	0.07	-
Ti (ppm)	< 0.05	< 0.05	-
Zn (ppm)	< 0.05	< 0.05	--
Si (ppm)	0.26	0.24	5.42 (max) 5.62 (ave)
Mn (ppm)	< 0.05	< 0.05	-
Other	-	-	-
Microbial (CFU/100 ml)	1.3 x 10 ⁴	1.5 x 10 ⁴	3.0 x 10 ⁷ (max) 1.5 x 10 ⁷ (ave)
I ₂ (ppm)	< 0.20	, 0.20	-
Iodide (ppm)	0.82	0.82	-
Total Iodine (ppm)	0.82	0.82	-
Non-volatile Residue (ppm)	0.8	2.4	71.1 (max) 60.8 (ave)
Total Carbon (ppm)	2.29	2.22	-
Total Inorganic Carbon (ppm)	0.76	0.70	-
Total Organic Carbon (ppm)	1.53	1.52	30.5 (max) 23.3 (ave)

TABLE 2 - Transport Loop Water Analysis Results

The analysis of the Transport Loop water from the EMU 3009 and 3010 hardware clearly demonstrates that the