

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

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ABSTRACT

An EMU water processing kit (Airlock Coolant Loop Recovery – A/L CLR) was developed as a corrective action to Extravehicular Mobility Unit (EMU) coolant flow disruptions experienced on the International Space Station (ISS) in May of 2004 and thereafter. Conservative schedules for A/L CLR use and component life were initially developed and implemented based on prior analysis results and analytical modeling.

The examination of post-flight samples and EMU hardware in November of 2006 indicated that the A/L CLR kits were functioning well and had excess capacity that would allow a relaxation of the initially conservative schedules of use and component life. A relaxed use schedule and list of component lives were implemented thereafter.

Since the adoption of the relaxed A/L CLR schedules of use and component lives, several A/L CLR kit items, transport loop water samples and sensitive EMU transport loop components have been examined to gauge the impact of the relaxed requirements. The intent of this paper is to summarize the findings of that evaluation, and to outline updated schedules for A/L CLR use and component life.

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.

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 have been utilized since 2004 as standard operating procedure, with periodic examination of EMU coolant loop water and hardware as a means to determine adequate functionality, optimized processing cycles, and maximized A/L CLR component shelf-life. The primary focus of this paper is to summarize the findings of recent A/L CLR performance data that have lead to revised recommendations on frequency of processing cycles and hardware shelf life. (1) (2)

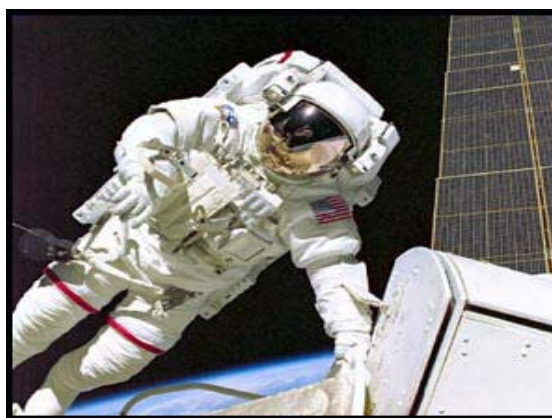


Figure 1 – EMU On-orbit

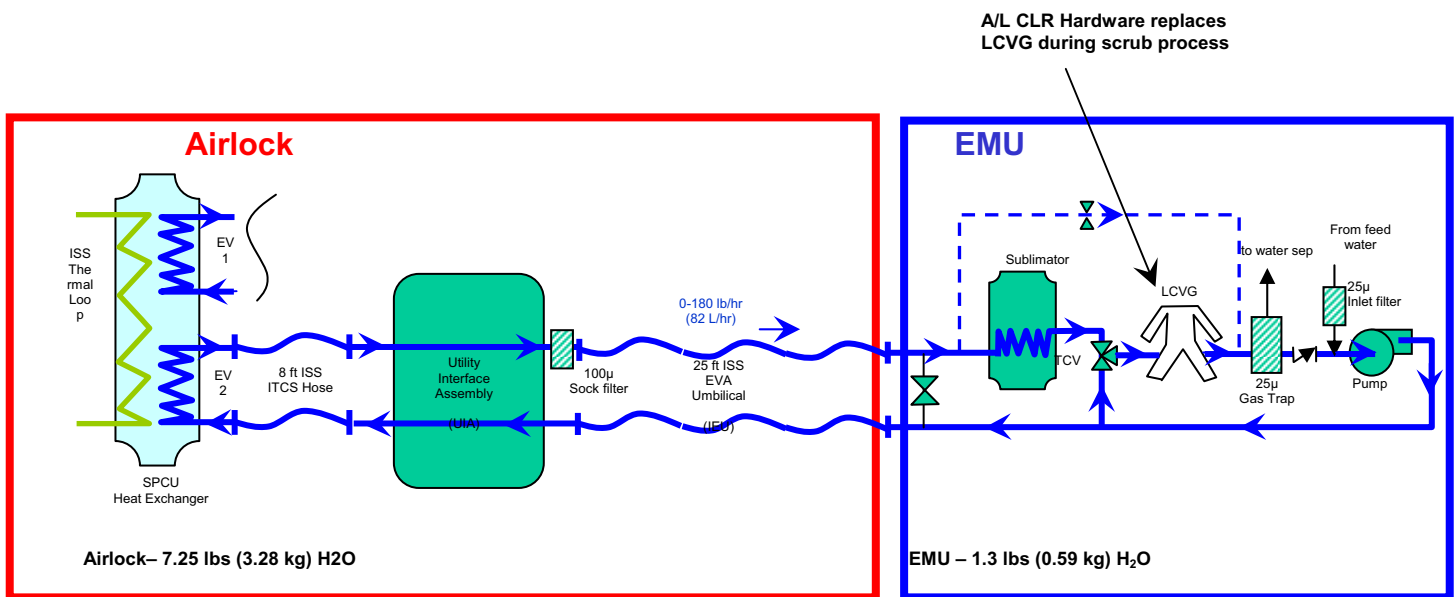


Figure 2 – Coolant Loop Schematic And A/L CLR Location

DESCRIPTION OF THE A/L CLR KIT

The A/L CLR water processing kit (see Figure 3) 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. (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.

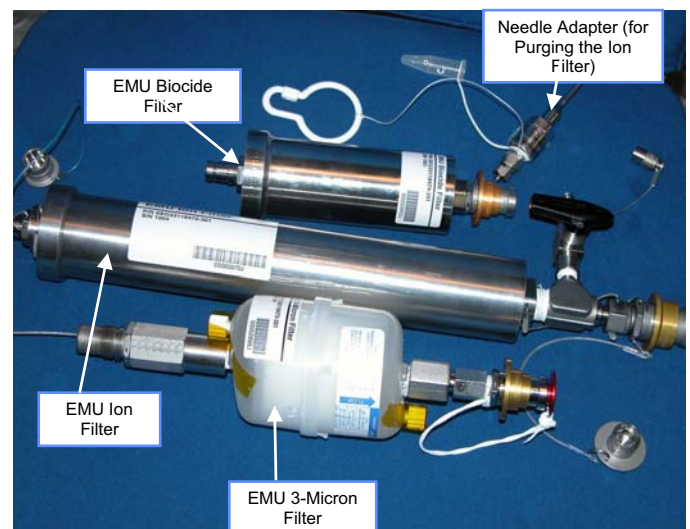


Figure 3
A/L CLR Water Processing Kit Components

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. That use schedule was revised after an evaluation of the initial performance of the A/L CLR hardware with two EMUs that were on-orbit for 14-months. Those findings were the subject of a 2008 ICES Paper. The preliminary and revised use schedules are summarized in Table 1. (5)(6)

Activity	Item	Initial Requirement s	Revised Requirement s
Max stagnation time	EMU	90-days	180-days
Pre-EVA scrub	EMU	≤ 2-weeks	≤ 4-weeks
Post-EVA scrub	EMU	≤ 2-weeks	≤ 2-weeks
Number of uses	Ion bed	4	8
Shelf life after first use	Ion bed	2-years	2-years
Number of uses	3-micron filter	1	4
Shelf life after first use	3-micron filter	N/A	2-years

Table 1
Preliminary and Revised A/L CLR Kit Use Schedule

The initial maximum stagnation time for an EMU on-orbit was set at 90-days before an A/L CLR scrub cycle was initiated. That was revised to 180-days after the evaluation of the first two EMUs that underwent this processing for 14-months. Furthermore, the A/L CLR scrub requirement was initially set at ≤ 2-weeks before a scheduled EVA and that was revised to ≤ 4-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, and that was maintained. (5)(6)

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. A revision to 8 uses was made after the ion exchange resin and charcoal capacities from two 4-use A/L CLR beds was conducted. Shelf life of the ion bed was set at 2-years after the first use and that has been maintained. (5)(6)

The number of uses of the 3-micron filter was initially set at 1, with the item not used thereafter. That was revised to 4 as a result of the initial series of uses. (5)(6)

SAMPLE IDENTIFICATION AND ANALYSIS METHODS

Three-micron Filters

A total of seven expended 3-micron filters were evaluated after 4 uses in the course of this study. The evaluation consisted of pre-use and post-use pressure drop comparisons (in three cases), and disassembly followed by SEM (Scanning Electron Microscope) and EDS (Energy Dispersive Spectrum) evaluation of six of the filter elements. The water contained in seven 3-micron filters (the six that were received by HSWL, and a seventh retained by NASA/JSC – S/N 1021) underwent chemical and microbial analyses as well. The use schedule of the seven 3-micron filters is shown in Table 2 of this report.

Flight Number	Serial Number	Total Number of Uses	Range of Time (initial use in flight to time of analysis)	Comments
STS-117	1013	4	13-mo	12/22/06 – 05/28/07 use Received 01/25/08
STS-117	1018	4	13-mo	12/22/06 – 05/28/07 use Received 01//08
STS-120	1019	4	14-mo	02/17/07 – 06/29/07 use Received 04/08
STS-122	1020	4	11-mo	06/29/07 – 12/01/07 Received 05/08
STS-123	1021	4	13-mo	08/06/07 – 02/20/08 Received 09/12/08
STS-123	1025	4	15-mo	06/29/07 – 02/20/08 Received 09/12/08
STS-123	1027	4	11-mo	10/26/07 – 02/29/08 Received 09/12/08

Table 2
Use Schedule Of The A/L CLR 3-Micron Filters

Ion Bed Ion Exchange Resin

The two A/L CLR ion exchange / charcoal beds used in flight (S/N 1002 & 1007) were disassembled at JSC and the resin & charcoal samples were sent to HSWL to evaluate capacity used and constituents removed from the SEMU coolant water. The use schedules for the two beds are detailed in Table 3. Unused resin and charcoal were received as well to be utilized to acquire baseline data.

The capacity of the ion exchange resin was determined using a derivation of ASTM 3375-95A "Column Capacity of Particulate Mixed Ion Exchange Materials". Each sample was homogenized, packed into a column (25 grams vs. the ASTM recommended 270 grams), and challenged with a 10 meq NaCl solution at a set flow rate. Effluent conductivity was monitored until a measurement of 50.0 uS/cm was observed. Capacity was determined as a function of elution volume.

Date	Episode	Ion Bed S/N 1002 (hrs:mins)	Ion Bed S/N 1007 (hrs:mins)	EMU S/N
09/23/06	Post 12A	-	1:04	3006
09/23/06	Post 12A	-	1:04	3008
12/22/06	Post 12A.1	1:29	-	3006
12/22/06	Post 12A.1	-	1:27	3018
01/23/07	Inc 14 Pre US EVA 6	1:06	-	3018
01/23/07	Post 12A.1 Pre EVA6	-	1:10	3008
02/16/07	Post Inc 14 Stage EVA	-	2:17	3008
02/16/07	Post Inc 14 Stage EVA	2:12	-	3018
05/28/07	Post Inc 15 Pre 13A	-	1:18	3018
05/28/07	Pre 13A	1:20	-	3018
06/29/07	Post 13A	1:04	-	3018
06/29/07	Post 13A	-	1:07	3006
07/16/07	Pre US EVA 9	0:35	-	3008
07/25/07	Post US EVA 9	0:40	-	3006
08/06/07	Post US EVA 9	1:05	-	3006
08/28/07	Post 13A.1	-	1:09	3006
10/16/07	Pre 10A	-	1:30	3018
Totals	-	9:52	12:10	-

Table 3
Use Schedule of the A/L CLR Ion Beds

Ion Bed Activated Carbon

The capacity of the two charcoal samples removed from the S/N 1002 & 1007 A/L CLR ion exchange resin / charcoal beds was determined with a derivation of ASTM 3860-98 "Determination of Adsorptive Capacity of Activated Carbon by Aqueous Phase Isotherm Technique". Samples were homogenized, and then packed in different vials containing 0.5, 0.8, 1.0 and 5.0 grams of each charcoal sample. An aqueous solution of glutaraldehyde was used as the challenge added to each vial. After glutaraldehyde addition, each vial was

capped and mixed for 24-hours to allow equilibrium to be reached. Thereafter, liquid samples were drawn and analyzed for free glutaraldehyde content using gas chromatography / flame ionization detection. Capacity was determined as a function of reduction of glutaraldehyde content, and resultant isotherms were drawn for comparison.

Transport Loop Water Samples

Transport Loop water samples were drawn from each of the subject SEMUs (3006 & 3008) through the HUT W LVTA Supply at USA in Houston. These samples were

refrigerated and sent to HSWL for chemical analysis using Ion Chromatography, Inductively Coupled Plasma Spectroscopy, and other laboratory standard methods. A split-sample of each was retained and forwarded to Wyle Labs Houston for microbiological analysis (microbial counts and predominant colony speciation).

Item-123 Fan/Pump/Separator Rotors and Surface Swabs

The Item-123 Fan/Pump/Separator Rotors from each of the subject SEMUs (3006 and 3008) were disassembled, examined, dimensionally checked and sampled at the USA Flight Crew Equipment Facility in Houston. Examinations were conducted with the unaided eye and microscopically. Sampling included surface swabs for microbial analyses and SEM/EDS for elemental analysis. Sampling also included chemical analysis of small volumes of water using Ion Chromatography, Inductively Coupled Plasma Spectroscopy, and other laboratory standard methods.

The serial number of the Rotor removed from the Item-123 Fan/Pump/Separator (S/N 003) that was removed from SEMU 3006 is S/N NT001.

The serial number of the Rotor removed from the Item-123 Fan/Pump/Separator (S/N 013) that was removed from SEMU 3008 is S/N N3C02.

Item-141 Gas Traps

The Item-141 Gas Traps from each of the subject SEMUs (3006 and 3008) were disassembled at the USA Flight Crew Equipment Facility in Houston and sent to HSWL for examination. Examinations were conducted with the unaided eye, microscopically and with SEM/EDS for elemental analysis.

The serial number of the Item-141 Gas Trap removed from SEMU 3006 is S/N 038.

The serial number of the Item-141 Gas Trap removed from SEMU 3008 is S/N 018.

Item-127 Inlet Filters

The Item-127 Inlet Filters from each of the subject SEMUs (3006 and 3008) were disassembled at the USA Flight Crew Equipment Facility in Houston and sent to HSWL for examination. Examinations were conducted with the unaided eye, microscopically and with SEM/EDS for elemental analysis.

The serial number of the Item-127 Inlet Filter removed from SEMU 3006 is S/N 1008.

The serial number of the Item-127 Inlet Filter removed from SEMU 3008 is S/N 1030.

RESULTS

Three-micron Filters

Three of the six 3-micron filters (S/N 1013, 1018 and 1019) that were evaluated as part of this study underwent flow/ Δ pressure testing prior to their launch at the JSC Building 7 Room 336 CELSE Laboratory. This was conducted per TPS EB0620190 dated 03/23/06 for filter S/N 1013 and 1018 prior to flight. Testing consisted of challenging each filter with a controlled flow of deionized water at a reference pressure, then determining the time it took to flow a set amount of deionized water through the filter. The reference pressure range was 1 – 20 psid.

The same three 3-micron filters (S/N 1013, 1018 and 1019) underwent flow/ Δ pressure testing after use and return at the JSC Building 7 Room 336 CELSE Laboratory. This was conducted per TPS 13082004 dated 01/04/08.

In all three cases, there was no significant increase in the flow/ Δ pressure data. For the most part, a slight reduction (< 0.5 psid) in the Δ pressure data was observed

All filter housings received by HSWL were first disassembled by scoring the polypropylene housing, then the filter element was removed thereafter and spread out.

The influent and effluent sides of each filter were examined under high magnification with a Scanning Electron Microscope (SEM). Observed particulates were sparse in each examined field. Figure 4 shows a representative SEM image (the Filter S/N 1019 influent side)

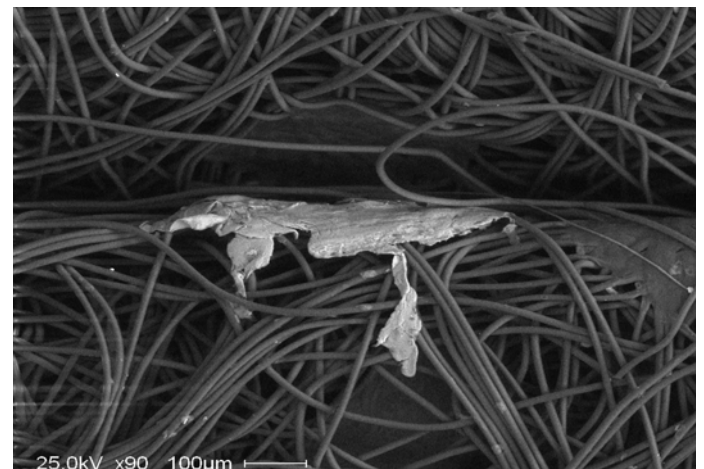


Figure 4
Representative Particle on 3-micron Filter Influent Side (S/N 1019)