Development Requirements for the Exploration PLSS (xPLSS) Feedwater Supply Assembly (FSA)

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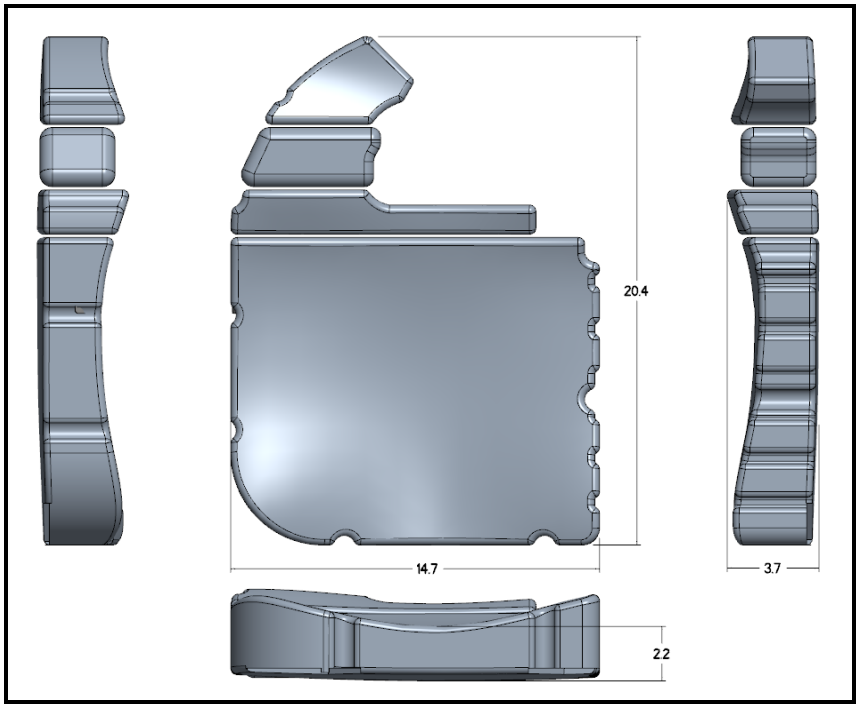
Functional Requirements for the FSA:

1) The Feedwater Supply Assembly (FSA) is a component of the Exploration Portable Life Support System (xPLSS). It stores and provides makeup feedwater for the thermal control loop as it consumed by the evaporative cooling process. The water is an essential component that allows crewmembers to perform Extra-vehicular Activities (EVA) in a various environments continuously for up to 8 hours.
2) The FSA consists of primary and auxiliary units and uses suit pressure to provide pressurization of the primary and auxiliary thermal control loops.
3) The FSA provides low-level detection via a check valve system. This enables an EVA to be ended without use of the reserve system under most operations concepts.
4) Each FSA unit, i.e. primary and auxiliary, are divided into two water sources, primary and reserve. The primary and reserve sources are separated to allow for system redundancy as well as the low-level detection capability.

Primary Performance Requirements for the FSA:

1) The FSA shall meet the following dry mass requirement:
    a. Primary = 1.50 lb
    b. Auxiliary = 1.2 lb
2) The FSA shall have an operation life of at least 696 cycles (NOTE: a cycle is described as a fill/empty/refill)
3) Useful life of FSA shall be 15 years minimum
4) The primary FSA shall provide a minimum of 10 lbs of usable water. (NOTE: usable water is defined as the water available for extraction)
    a. Primary: 8.5 lbs
    b. Reserve: 1.5 lbs
5) The auxiliary FSA shall provide a minimum of 2 lbs of usable water. (NOTE: usable water is defined as the water available for extraction)
    a. Primary: 1 lb
    b. Reserve: 1 lb
6) The FSA shall be capable of operating autonomously in EVA mode for 8 hours minimum.
7) The FSA shall be capable of operating and meeting requirements after 2 years of quiescence.
8) The FSA shall exhibit component level external leakage rates less than 0 cc/hr.
9) The FSA shall contain relief valves between the primary and reserve of each FSA unit, primary & auxiliary, with a crack pressure of 0.25 – 0.55 psid.

10) The FSA shall meet the Outer Mold Line (OML) requirements listed below in inches:



Operating Conditions:

1) The FSA shall be compatible with clean Source water as described in the table below:

Source Water Key Attributes

Property	Requirement
Iodine and Iodine	1 – 4 ppm (parts per million)
Total Silicon	< 500 ppb (part per billion)
Chlorides	< 500 ppb
Particulate	NOTE 1
TOC (Total Organic Carbon)	< 600 ppb
Bacteria	NOTE 1 NOTE 2

NOTE 1: Particulate shall be controlled by an affiliate point-of-use (meaning point of interface with the hardware) filter to an equal or better level than the hardware particulate cleanliness.. When bacterial control is required, the point-of-use filter shall be 0.2-micron maximum particulate rating. The point-of-use filter should be changed out periodically based on number of days in use and/or amount of water passed through it. The frequency of change-out should be established for the water processing system used.

NOTE 2: There is no pass/fail requirement for bacterial levels. This information is for reference only. Reference JSC 66695 Table 7.3-2 - Iodinated Water Quality Requirements for EMU Flight Hardware.

2) The FSA shall be compatible with Contaminated Source water as described in the tables below:

Water Processor Assembly Sourced Contaminants

Property	Requirement or Range
pH	(report)
Conductivity (micro-Siemens/cm)	(report)
TOC (Total Organic Carbon)	(report)
Aluminum (ppm)	< 0.1
Nickel (ppm)	< 0.1
Calcium (ppm)	< 0.1
Ammonium (ppm)	< 0.1
Sulfate(ppm)	< 0.1
Chloride (ppm)	< 0.1
Silicon (ppm)	2.0 – 4.0
Methyl Sulfone	0.09 – 0.11
WPA IRA-67 Extract (Multifiltration Bed resin) (ppm)	0.5 – 2.5
WPA DMSD (dimethylsilanediol) (ppm)	10.0 – 20.0

ISS EMU Transport Water Loop Contaminants

Property	Range
pH	5.5 – 7.5
Conductivity (micro-Siemens/cm)	40 - 60
TOC (Total organic Carbon)	5.0 – 10.0
Aluminum (ppm)	0.2 – 0.6
Nickel (ppm)	1.0 – 2.0
Ammonium (ppm)	2.0 – 4.0
Sulfate (ppm)	2.0 – 4.0
Silicon (ppm)	1.0 – 2.0

Iodide (ppm)	0.5 – 1.5

3) The FSA shall be compatible and operate using silver at concentrations of 0.3 - 1ppm on influent feedwater.
4) The FSA shall be compatible and operate using Iodine at concentrations of 0.5 - 6ppm on influent feedwater.
5) The FSA shall be designed to withstand a Maximum Design Pressure (MDP) of 15 psid and Burst pressure of 37.5 psid.
6) The FSA shall exhibit component level water leakage rates less than 0cc/hr.
7) The FSA shall accept supply pressures up to 15 psid and enable recharge at the following rates:
    a. Primary = 10 min (EVA) or 30 min (IVA
    b. Auxiliary = 5 min (EVA) or 20 min (IVA)
8) The FSA shall operate in all orientations regardless of g-field.
9) The FSA shall operate after stowage and exposure to a pressure environment ranging from 0 to 15.2 psia.
10) The FSA shall operate after exposure to 25 lbs of inadvertent kick loads.

Development Requirements for the Exploration PLSS (xPLSS) Bypass Relief Valve (RV)

Co-Authors: Kristina Todd (Jacobs) and Teresa Shurtz (NASA)

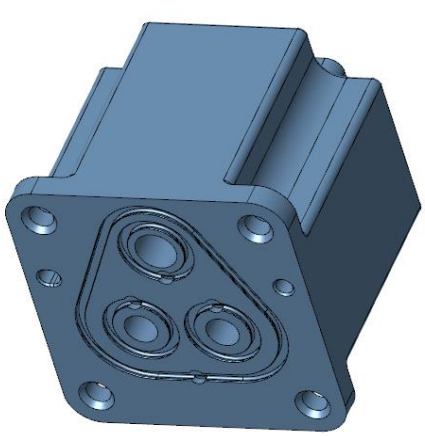
Functional Requirements for the RV:

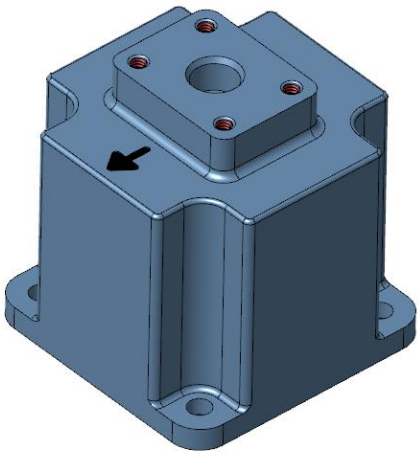
1) The Bypass Relief Valve (RV) is a component of the Exploration Portable Life Support System (xPLSS) and is used to limit the head pressure that can be generated by the positive displacement pump within the Thermal and Auxiliary Thermal Control Loop.
2) In order to limit the pump pressure conveyed to the rest of the loop components, the Bypass RV cracks and flows from the pump outlet to the pump to the pump inlet, short circuiting the pump until the pressure dampens.
3) The RV is used in two locations within the PLSS:
    a. RV-424 Water Pump Bypass Relief Valve
    b. RV-524 Auxiliary Water Pump Bypass Relief Valve
4) Each RV unit (424 & 524) include in a single housing, two redundant relief valves (A & B) meeting the full crack, reseat, flow, and leakage performance requirements listed below.

Primary Performance Requirements for the Bypass RV:

1) The Bypass RV shall meet the following mass requirement:
    a. Primary = 0.40 lb
    b. Auxiliary = 0.40lb
2) The Bypass RV shall operate for a minimum of 864 cycles.
3) The Bypass RV shall have a useful life of 15 years minimum.
4) The Bypass RV shall be capable of operating and meeting requirements after 2 years of quiescence.
5) The Bypass RV shall exhibit component level external leakage rates less than 0 cc/hr.
6) The Bypass RV shall meet the Outer Mold Line (OML) shown. Critical dimensions listed below:

L = 2.16 in	H = 2.2 in
W = 2.16 in	Hole ID = 0.313 in





Development Requirements for the Exploration PLSS (xPLSS) Bypass Relief Valve (RV)

Operating Conditions:

1) The Bypass RV shall be compatible and operate with supplied Source water as described below:

Feedwater Key Attributes

Property	Requirement
Iodine and Iodine	1 – 4 ppm (parts per million)
Total Silicon	< 500 ppb (part per billion)
Chlorides	< 500 ppb
Particulate	NOTE 1
TOC (Total Organic Carbon)	< 600 ppb
Bacteria	NOTE 1 NOTE 2

NOTE 1: Particulate shall be controlled by an affiliate point-of-use (meaning point of interface with the hardware). When bacterial control is required, the point-of-use filter shall be 0.2-micron maximum particulate rating. The point-of-use filter should be changed out periodically based on number of days in use and/or amount of water passed through it. The frequency of change-out should be established for the water processing system used.
NOTE 2: There is no pass/fail requirement for bacterial levels. This information is for reference only. Reference JSC 66695 Table 7.3-2 - Iodinated Water Quality Requirements for EMU Flight Hardware.

2) The Bypass RV shall be compatible and operate with contaminated source water as described in the tables below:

Water Processor Assembly Sourced Contaminants

Property	Requirement or Range
pH	(report)
Conductivity (micro-Siemens/cm)	(report)
TOC (Total Organic Carbon)	(report)
Aluminum (ppm)	< 0.1
Nickel (ppm)	< 0.1
Calcium (ppm)	< 0.1
Ammonium (ppm)	< 0.1
Sulfate(ppm)	< 0.1
Chloride (ppm)	< 0.1

Silicon (ppm)	2.0 – 4.0
Methyl Sulfone	0.09 – 0.11
WPA IRA-67 Extract (Multifiltration Bed resin) (ppm)	0.5 – 2.5
WPA DMSD (dimethylsilanediol) (ppm)	10.0 – 20.0

ISS EMU Transport Water Loop Contaminants

Property	Range
pH	5.5 – 7.5
Conductivity (micro-Siemens/cm)	40 - 60
TOC (Total organic Carbon)	5.0 – 10.0
Aluminum (ppm)	0.2 – 0.6
Nickel (ppm)	1.0 – 2.0
Ammonium (ppm)	2.0 – 4.0
Sulfate (ppm)	2.0 – 4.0
Silicon (ppm)	1.0 – 2.0
Iodide (ppm)	0.5 – 1.5

3) The Bypass RV shall be compatible and operate using silver at concentrations of 0.3 - 1ppm in influent feedwater.
4) The Bypass RV shall be compatible and operate using Iodine at concentrations of 0.5 - 6ppm in influent feedwater.
5) The Bypass RV shall be designed to withstand a Maximum Design Pressure of 20 psid and Burst pressure of 50 psid.
6) Each relief valve within the unit shall crack at a pressure of 14 – 15 psid in all possible orientations.
7) Each relief valve within the unit shall reseat at a pressure of 13 – 15 psid in all possible orientations.
8) Each relief valve within the unit shall flow a minimum of 220 lbm/hr water at 70°F with a differential pressure of 18 psid applied from inlet to outlet.
9) Each relief valve within the unit, under a credible failed open condition, should flow a maximum of 25 lbm/hr water at 50°F with a differential pressure of 10 psid.
10) Each relief valve within the unit shall include an inlet filter sized at 40 micron or smaller.
11) The unit shall exhibit component level external leakage rates less than 0.01 cc/hr.
12) The Bypass RV shall operate in all orientations regardless of g-field.

Development Requirements for the
Exploration PLSS (xPLSS) Bypass Relief Valve (RV)

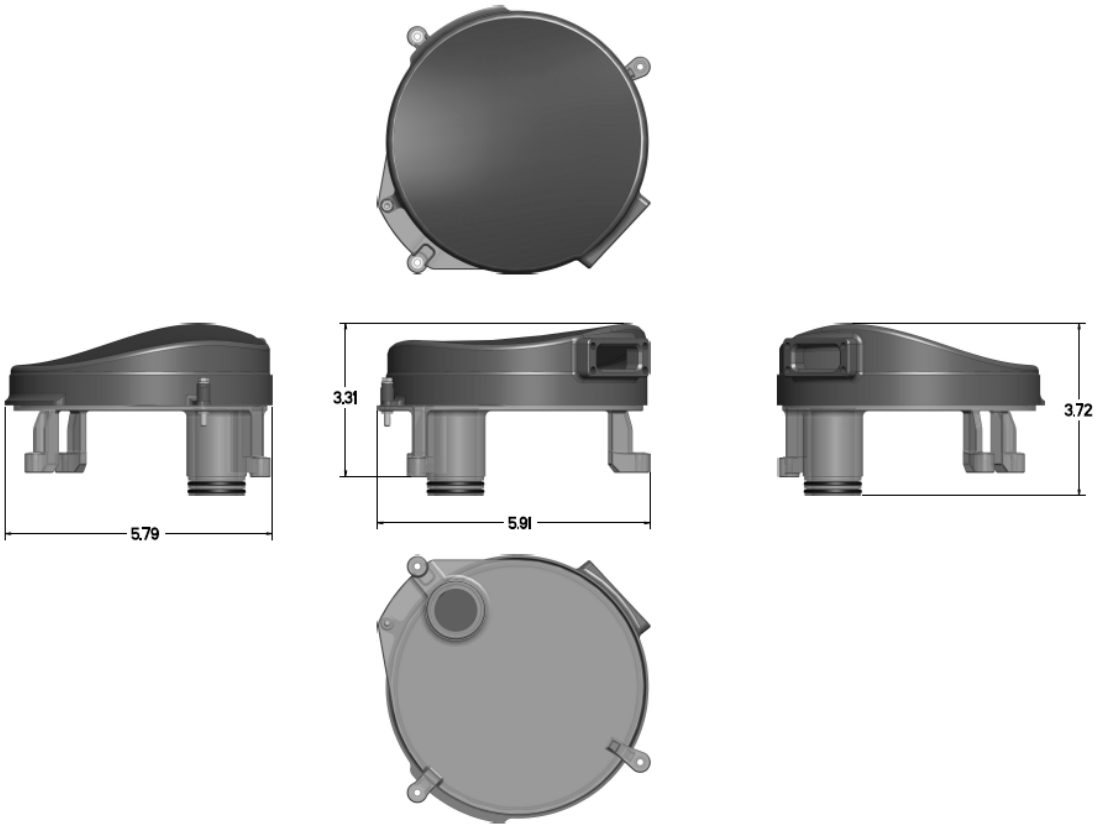
13) The Bypass RV shall operate after stowage and exposure to a pressure environment ranging from 0 to 15.2 psia.
14) The Bypass RV shall operate after exposure to 25 lbs of inadvertent kick loads.

Requirements for the Exploration PLSS (xPLSS) Trace Contaminant Control System (TCC)

Co-Authors: John Hostetler (Jacobs) and Teresa Shurtz (NASA)

Functional Requirements for the TCC:

1) The Trace Contamination Control System (TCC) is a component in the ventilation loop of the Exploration Portable Life Support System (xPLSS) which removes contaminates present in the ventilation system. These contaminants are generated by materials and processes contained within the suit, as well as by the crewmember themselves. Without the TCC, accumulated contaminants such as Ammonia and other Volatile Organic Compounds (VOC) that could pose a threat to the crewmember.
2) The TCC utilizes a packed powder bed to capture Ammonia (the primary contaminant of concern) via chemisorption, necessitating that the TCC be a consumable.



Primary Performance Requirements for the TCC:

1) The TCC shall not have a mass exceeding 4.5lmb when in flight configuration.
2) The TCC shall have an operating life of 150 hours Extra-vehicular Activity (EVA) time without replacing the sorbent.

3) The TCC's consumables shall be replaceable in the Intra-vehicular Activity (IVA) environment without the use of tools.
4) The TCC shall provide particulate filtration of all particles greater than 25 microns.
5) The TCC shall limit trace contaminants in compliance with the 7-day Spacecraft Maximum Allowable Concentrations (SMAC) limits as identified in the following table:

Compound	Formula	Total Source Rate (mg/day)	7-day SMAC Limit (ppm)	7-day SMAC Limit (mg/m^3)
Acetaldehyde	CH_3CHO	0.663	2	4
Acetic Acid	CH_3COOH	0.227	3.01	7.4
Acetone	CH_3COCH_3	0.193	22	52
Acrolein	C_3H_4O	0.006	0.015	0.03
Ammonia	NH_3	80	3	2
1-Butanol	BuOH	0.50	25	80
Carbon Monoxide	CO	18	55	63
Ethanol	C_2H_5OH	4.51	1000	2000
Formaldehyde	CH_2O	0.42	0.1	0.12
Furan	C_4H_4O	0.3	0.025	0.07
Hexamethyl-cyclotrisiloxane	$C_6H_{18}O_3Si_3$	3.96E-03	10	90
Hydrogen	H_2	42.0	4100	340
Methane	CH_4	329	5300	3500
Methanol	CH_3OH	1.02	70	90
Methyl-Ethyl Ketone (MEK)	$CH_3C(O)CH_2CH_3$	0.907(12)	10	30
Methyl mercaptan (Methanethiol)	CH_3SH	---	0.2	0.1
Toluene	C_7H_8	1.35	4	15
Trimethyl Silanol	$C_3H_{10}OSi$	0.2	1	4

6) The TCC shall function properly in an ambient environment with an oxygen concentration up to 26.5% with the balance composed of nitrogen, metabolic products (CO2 and H20), and trace gases.

7) The TCC shall have operating pressures as described in the table below:

Operating Pressure	Oxygen Ventilation Loop [psid]
Nominal Operating Pressure	8.4
Maximum Design Pressure (MDP)	10.6
Structural Pressure (1.1 x MDP)	11.7
Proof Pressure (1.5 x MDP)	15.9
Burst Pressure (2.5 x MDP)	26.5

Operating Conditions for the TCC:

1) The TCC shall be compatible with and operate using:
    a. Gaseous Nitrogen
    b. Gaseous Oxygen
    c. Gaseous Heliox
    d. Gaseous Helium
2) The TCC shall not exceed 0.3 in-H2O of pressure drop with gas flowing at 170 lpm [6 ACFM] at a ventilation loop pressure of 29.7 kPa [4.3 psia] and temperature of 15.6°C [60°F].
3) The TCC shall operate with 250 cc of free water introduced at the inlet under normal EVA.
4) The TCC shall function properly in all orientations, regardless of g-field.
5) The TCC shall operate after being exposed to a pressure environment ranging from 0.0 to 15.2 psia.
6) The TCC shall function during and after an ambient pressure drop of -156 torr/min [-3 psi/min] for up to 4.8 minutes.
7) The TCC shall maintain positive margins after exposure to an ambient environment depressurization rate of < -7.75 psi/min.
8) The TCC shall function during and after an ambient environment pressure increase of 6.9 kPa/sec [1 psi/sec] for 14 seconds.
9) The TCC shall meet all performance requirements when exposed to a temperature of 1.7 °C [35 °F] to 51.7 °C [125°F].
10) The TCC shall operate after exposure to an environment with Relative Humidity (RH) ranging from a -29.2 °F to 65°F dewpoint at 68°F (90% RH).