# Development Specification for the FN-323/324, Oxygen Ventilation Loop Fan Assembly

Engineering Directorate
Crew and Thermal Systems Division

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National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas 77058

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# Development Specification for the FN-323/324, Oxygen Ventilation Loop Fan Assembly

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# 1.0 INTRODUCTION

## 1.1 SCOPE

This specification establishes the requirements for design, performance, safety, and manufacture of the FN-323/324, Oxygen Ventilation Loop Fan Assembly as part of the Advanced EMU (AEMU) Portable Life Support System (PLSS).

## 1.2 CONVENTIONS AND NOTATIONS

### 1.2.1 RATIONALE

A rationale statement is included for each requirement. The purpose of the rationale statement is to indicate why the requirement is needed, the basis for its inclusion in this requirements document, and to provide context and examples to stakeholders. It is important to note that rationale is not binding, and it only provides supporting information. In the event there is an inconsistency between the requirement and the rationale, the requirement is binding and takes precedence. If there is any confusion between the requirement and rationale, seek further guidance from the responsible technical authority.

### 1.2.2 DESIGNATIONS AND PRIORITIZATION

The convention used in this document to indicate requirements, goals, and statements of fact is as follows:

| Designation | Description |
|---|---|
| "Shall" | used to indicate a requirement which must be implemented and its implementation verified |
| "Should" | used to indicate a goal which must be addressed by the design but is not formally verified |
| "Will" | used to indicate a statement of fact and is not verified |

### 1.2.3 BACKGROUND

Fan development for the advanced Portable Life Support System (PLSS) began in 2009 with the development of Fan 1.0. This fan was used in PLSS 2.0 for circulation of the ventilation loop gas. Fan 2.0 was delivered in 2015 and will be used in the PLSS 2.5 Live Loads test series. This fan used the same motor as Fan 1.0, but had a larger volute and impeller in hopes of achieving lower speeds. The next iteration of the advanced PLSS fan is the subject of the requirements contained within this document, and will be used with the PLSS 2.5 -302 configuration.

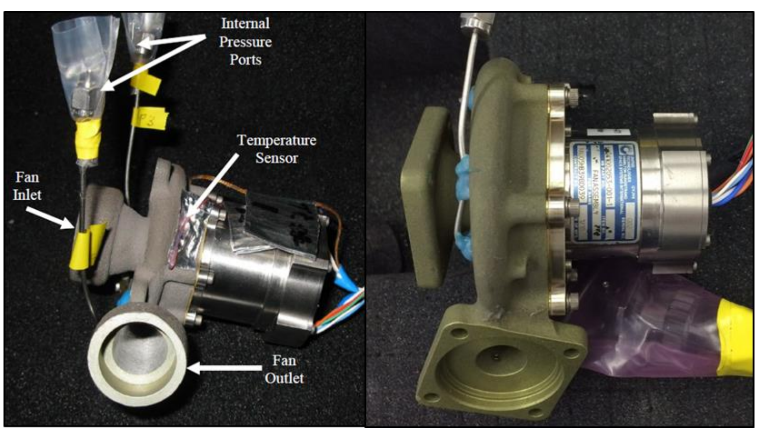



**Figure 1-1: PLSS Development Fans (Fan 1.0 on Left, Fan 2.0 on Right)**

### 1.2.4 NOMENCLATURE

Each requirement contained in this development specification is denoted by a unique identifier (Table 1.2-1) that transcends traditional paragraph numbering to keep requirements traceability more clear and achievable.

| Requirement Nomenclature | PLSS Sub-Assembly or Loop |
|---|---|
| [R.FAN.000.XXX] | Fan Performance Requirements |
| [R.FAN.100.XXX] | Fan Environmental Requirements |
| [R.FAN.200.XXX] | Fan Induced Environmental Requirements |
| [R.FAN.300.XXX] | Fan Safety Requirements |
| [R.FAN.400.XXX] | Fan Design and Construction Requirements |
| [R.FAN.500.XXX] | Fan Interface Control Requirements |

**Table 1-1 – Requirements Nomenclature Key**

### 1.2.5 PLSS COMPONENT IDENTIFIERS

The PLSS utilizes unique identifiers for each of the components as shown in Table 1.2-2.

| Item | | Description |
|---|---|---|
| FN-323 | | Oxygen Ventilation Loop Fan |
| | FN-323A | Fan, Primary |
| | FN-323B | BLDC Motor, Fan |
| | FN-323D | RTD, Stator Temperature |
| FN-324 | | Oxygen Ventilation Loop Fan |
| | FN-324A | Fan, Secondary |
| | FN-324B | BLDC Motor, Fan |
| | FN-324D | RTD, Stator Temperature |

**Table 1-2 – Fan Component Identifiers**

The Fan ORU assembly in the PLSS 2.5 design consists of the following items: FN-323, FN-324, a check valve for each fan, a fan inlet manifold, and a fan outlet manifold. Fan FN-323 is considered the primary fan, and FN-324 is considered a secondary fan. FN-324 will be powered off while FN-323 is operating, acting as a cold spare. They are of the exact same design, and only differ in serial number.

## 1.3 RESPONSIBILITY AND CHANGE AUTHORITY

The responsibility for the development and management of the Fan Development Specification lies with the Space Suit and Crew Survival Systems Branch within the Crew and Thermal Systems Division (CTSD).

# 2.0 DOCUMENTS

The documents listed in this section represent the documents that have been identified either in part or in whole within this document.

## 2.1 APPLICABLE DOCUMENTS

The applicable documents are documents that have been explicitly identified within requirements statements (i.e., “shall” statements) and are invoked as technical requirements, in part or in whole, for implementation. Each requirement statement identifies the applicable subsections of a document unless it has been deemed appropriate to invoke the entire document.

| | |
|---|---|
| ANSI/ESD S20.20-2014 | Protection of Electrical and Electronic Parts, Assemblies, and Equipment |
| IEC 60751 Edition 2.0 | Industrial Platinum Resistance Thermometers and Platinum Temperature Sensors |
| JPR 5322.1 Rev H | Contamination Control Requirements Manual |
| J-STD-011 Rev F | Requirements for Soldered Electrical and Electronic Assemblies |
| MIL-PRF-27210 Rev J | Performance Specification for Oxygen, Aviators Breathing, Liquid and Gas |
| MIL-PRF-27401 Rev G | Performance Specification for Propellant Pressurizing Agent, Nitrogen |
| MIL-PRF-27407 Rev D | Performance Specification Propellant Pressurizing Agent, Helium |
| MIL-STD-1686 Rev C | Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies, and Equipment (Excluding Electrically Initiated Explosive Devices) |

| | |
|---|---|
| MIL-STD-750-1 Rev A W/Change 2 | Environmental Test Methods for Semiconductor Devices |
| MIL-STD-810 Rev G W/Change 1 | Environmental Engineering Considerations and Laboratory Tests |
| NASA-STD-5006 Rev A W/Change 1 (2016-05-03) | General Fusion Welding Requirements for aerospace Materials Used In Flight Hardware |
| NASA-STD-5020 Baseline | Requirements for Threaded Fastening Systems in Spaceflight Hardware |
| NASA-STD-6008 W/Change 1 | NASA Fastener Procurement, Receiving Inspection, and Storage Practices for Spaceflight Hardware |
| NASA-STD-6012 Baseline | Corrosion Protection for Space Flight Hardware |
| NASA-STD-6016 Baseline | Standard Materials and Processes Requirements for Spacecraft |
| NASA-STD-8739.4 Rev A | Crimping, Interconnecting Cables, Harnesses, and Wiring |
| NASA-STD-8739.6 Rev A | Implementation Requirements for NASA Workmanship Standards |
| SLN13122232 Rev N/C | Fan Interface Control Drawing |
| SSP 30233 Rev H | Space Station Requirements for Materials and Processes |
| SSP 30312 Rev H | Electrical, Electronic, and Electromechanical and Mechanical Parts Management and Implementation Plan for Space Station Program |
| SSP 30423 Rev L | Space Station Approved Electrical, Electronic, and Electromechanical Parts List |
| SSP 30425 Rev AC | Space Station Program Natural Environment Definition for Design |
| SSP 30558 Rev D | Fracture Control Requirements for Space Station |

**Table 2-1 - Applicable Documents**

## 2.2 REFERENCE DOCUMENTS

Documents that are identified but are not invoked within requirements statements are listed below.

| | |
|---|---|
| ANSI S12.2 | American National Standard Criteria for Evaluating Room Noise |
| CTSD-ADV-780 | Development Specification for the Advanced EMU (AEMU) Portable Life Support System (PLSS) |
| CTSD-ADV-959 | Schematics and Behavioral Description for the Advanced EMU (AEMU) Portable Life Support Subsystem (PLSS) |
| JPR 1710.13 Rev F | Design, Inspection, and Certification of Pressure Vessels and Pressurized Systems |
| NASA-STD-6002 Rev B | Applying Data Matrix Identification Symbols on Aerospace Parts |
| SSP 30240 Rev H | Space Station Grounding Requirements |
| SSP 30559 Rev D | ISS Structural Design and Verification Requirements |
| SSP 41172 Rev AC | Qualification and Acceptance Environmental Test Requirements |
| SSP 50835 Rev D | ISS Pressurized Volume Hardware Common Interface Requirements Document |

**Table 2-2 – Reference Documents**

## 2.3 INTERFACE CONTROL DOCUMENTS (ICD)

The following documents define the interfaces between the fan component and the rest of the PLSS system.

| | |
|---|---|
| SLN13122232 Rev NC | Fan Interface Control Drawing |

**Table 2-3 – Interface Control Documents**

# 3.0 OXYGEN VENTILATION LOOP FAN ASSEMBLY

This section contains the technical design and performance requirements.

## 3.1 FUNCTIONAL OVERVIEW

The function of the Oxygen Ventilation Loop Fan Assembly is to provide breathing gas circulation within the spacesuit assembly (SSA) under a range of load conditions and SSA configurations.

## 3.2 PERFORMANCE REQUIREMENTS

### 3.2.1 LIFE

#### 3.2.1.1 [R.FAN.000.001] OPERATIONAL LIFE

The Fan shall have operating life as specified in Table 3-1:

| Component | Function | Minimum Duration (hrs) | On/Off Cycles |
|---|---|---|---|
| FN-323/FN-324, Fan | Circulate ventilation loop gas | 4000[(1)] | 11600[(2)] |

**Table 3-1 – Operational Duration and Cycles**

*Rationale: The goal is to make the hardware and its associated certification "robust-enough" such that detailed tracking of operating cycles and the resultant operational over-head is not required.*

*(1) This is based on 100 EVAs at 8 hours per EVA and 2 hours pre/post-EVA functional time for pre-breathe and other activities with a scatter factor of 4, per CTSD-ADV-780.*

*(2) This is based on 2 cycles per 100 EVAs with monthly In-Flight Maintenance (IFM) cycles over a 6 year operational period with another 1250 cycles to cover Pre-Installation Acceptance (PIA), ground testing, and preflight checks. This is then multiplied by 2 (2 flight tours), all multiplied by a scatter factor of 4. A single cycle is defined as going from OFF to ON and back to OFF.*

#### 3.2.1.2 [R.FAN.000.002] USEFUL LIFE

The Fan shall have a useful life of 15 years minimum without refurbishment assuming that the usage rate does not exceed operational life (R.FAN.000.001).

*Rationale: Rationale: The usage life is the total chronological time that an assembly, component, or detail part may be used. It is the total of shelf life and operational life. Useful life begins at the item's birth date which can be initial acceptance, date of manufacture, date of cure, etc. The component may sit on the shelf in controlled storage for 15 years until it expires, it may be placed into service for 15 years (but within the operational life) until it expires, or some combination with the total tracked time of 15 years and total operating hours as defined in the operational life.*

#### 3.2.1.3 [R.FAN.000.003] SHELF LIFE

The Fan shall have a shelf-life of 15 years minimum.

*Rationale: This allows for program logistics flexibility without recertification.*

#### 3.2.1.4 [R.FAN.000.004] LAUNCH/LANDING CYCLES

The Fan shall tolerate and operate after 9 launch and landing cycles minimum.

*Rationale: The intent is to dictate that the Fan will be designed for multiple launches and landings in support of its as yet undetermined missions. The details of what each launch/landing cycle entails depends on the vehicle chosen but is encompassed by the requirements provided in the environments section.*

### 3.2.2 OPERATING FLUIDS

#### 3.2.2.1 [R.FAN.000.005] GASEOUS NITROGEN

The fan shall be compatible with and operate using gaseous nitrogen per MIL-PRF-27401, Performance Specification for Propellant Pressurizing Agent, Nitrogen, Type I, Grade B as a test fluid.

*Rationale: Gaseous nitrogen provides a safe and effective method for performing development tests prior to oxygen compatibility testing and approval. It will be the gas used for a variety of fan and PLSS level tests.*

#### 3.2.2.2 [R.FAN.000.006] GASEOUS OXYGEN

The fan shall be compatible with and operate using gaseous oxygen per MIL-PRF-27210, Performance Specification for Oxygen, Aviators Breathing, Liquid and Gas, Type I as the working fluid.

*Rationale: The primary function of the fan is to circulate the oxygen in the ventilation loop of the gas. In order to fulfill this function, all wetted components must be oxygen compatible and cleaned for oxygen use as stated in R.FAN.010.*

#### 3.2.2.3 [R.FAN.000.007] GASEOUS HELIOX

The fan shall be compatible with and operate using a mixture of 0.5% +/- .02% helium per MIL-PRF-27407C with Amendment 1, Grade A with balance gaseous oxygen per MIL-PRF-27210, Type I as the working fluid.

*Rationale: Gaseous heliox provides increased resolution for preflight leakage checks but is not anticipated as working fluid during mission events. Heliox has been used for this purpose during the Shuttle/ISS EMU Program per SE-S-0073, Table 6.3-38.*

#### 3.2.2.4 [R.FAN.000.008] GASEOUS HELIUM AND NITROGEN

The fan shall be compatible with and operate using a mixture of 0.5% $\pm$ .02% helium per MIL-PRF-27407C with Amendment 1, Grade A with balance gaseous nitrogen per MIL-PRF-27401F, Performance Specification for Propellant Pressurizing Agent, Nitrogen, Type I, Grade B as a test fluid.

*Rationale: Gaseous helium provides increased resolution for preflight acceptance leakage checks but is not anticipated as working fluid during mission events. This is relevant to the Primary, Secondary, and Ventilation loops.*

#### 3.2.2.5 [R.FAN.000.009] ATMOSPHERIC AIR

The fan shall be compatible with and operate using atmospheric air described as follows:

***Composition***

| | |
|---|---|
| Gaseous Oxygen | 20 +/- 5% |
| Gaseous Nitrogen | 80 +/- 5% (balance) |

***Humidity***

25% RH at 80F dry bulb to 85% RH at 65F dry bulb

*Rationale: In some situations, the gas used to repress the airlock and hence the working fluid for the NPRV will be ambient air which may or may not be air conditioned or managed beyond that described. This also provides the capability to use ambient air for ground testing of the fan.*

### 3.2.3 [R.FAN.000.010] OPERATING PRESSURES

The fan shall have operating pressures as described in Table 3-2.

| **Operating Pressure** | ***Oxygen Ventilation Loop kPa (diff) [psid]** |
|---|---|
| Maximum Design Pressure (MDP)(1) | 73.1 [10.6] |
| Structural Pressure (1.1 x MDP)(2) | 80.4 [11.7] |
| Proof Pressure (1.5 x MDP) | 110.0 [15.9] |
| Minimum Allowable Burst Pressure (2.5 x MDP)(3) | 183 [26.5] |
| Minimum Allowable Collapse Pressure(4) | 104.8 [15.2] |

**Table 3-2 – Operating Pressures Table**

*Rationale:*

*(1) The MDP for the Oxygen Ventilation Loop is based on the pressure at full-open flow for RV-348, one of the AEMU positive pressure relief valves, with .5 psid margin at 10.6 psid.*

*(2) Structural pressure testing for the Pressure Garment System (PGS) as attached to the Oxygen Ventilation Loop is 1.5 x Nominal Operating Pressure (NOP) defined as 8.8*1.5 = 13.2 psid. This will be done separately and does not apply to the fan. When assembled to the PLSS, the structural pressure will be as defined in this table.*

*(3) This satisfies Table 3.3.1-1 (Minimum Factors of Safety for Structure), Sub paragraph 3.d (Actuating cylinders, valves, filters,..) in SSP 30559, ISS Structural Design and Verification Requirements.*

*(4) The collapse pressure is pressure at which a negatively or externally loaded pressure vessel will collapse on itself. This is mainly useful for ensuring that helium leakage testing can be performed where the fan is at vacuum internally, but surrounded by ambient pressure externally. 15.2 is the maximum expected pressure of a cabin environment.*

**For the first four rows of this table, the greater pressure is on the inside of the fan. Only the collapse pressure has the greater pressure outside of the fan.*

### 3.2.4 [R.FAN.000.011] EXTERNAL LEAKAGE

The Fan shall limit external leakage as indicated in Table 3-3 when at an internal pressure of 8.4 psia over vacuum ambient and a gas temperature of 60F.

| **GOX (kg/sec)** | **GOX (lb/hr)** | **GOX (lab equivalent) (lb/hr)(1)** | **GN2 (lab equivalent) (lb/hr)(1)** |
|---|---|---|---|
| 7.54E-13 | 5.98E-09 | 1.33E-08 | 1.24E-08 |

**Table 3-3 – External Leakage**

*Rationale: The entire PLSS Oxygen Ventilation Loop leakage allocation is 2.22E-09 kg/sec (1.77E-05 lb/hr) of GOX; component leakage rate is based on the analytical estimates from assumed construction, as specified in CTSD-ADV-780, Development Specification for the AEMU Portable Life Support System (PLSS).*

*(1) The "lab equivalent" numbers are based on sea level ambient pressure conditions and an internal differential pressure of 8.4 psid while at 70F.*

### 3.2.5 [R.FAN.000.012] CLEANLINESS

The fan shall have cleanliness levels per JPR 5322.1 as dictated per Table 3-4.

| Cleanliness Level | Internal Surfaces(1) | External Surfaces |
|---|---|---|
| Initial Build(2) | 150A | VC |
| Maintained | 150 | GC |

**Table 3-4 – Cleanliness Table**

*Rationale:*

*(1) The ventilation loop is originally cleaned to an "A" rating of less than 1 mg/ft$^2$ of NVR. This can be verified using precision cleaning solvent evaporation and gravimetric analysis, but cannot be verified during operation at the system level with the presence of a human and other components in the ventilation loop and the fact that the assembled and lubricated system will not be conducive to the solvent flush needed to verify the NVR level.*

*(2) The initial build refers to the cleaning level of parts before assembly. The fan should be delivered to the customer with the inlet and outlet ports sealed to maintain cleanliness. The assembly should also be double-bagged to help maintain cleanliness.*

### 3.2.6 [R.FAN.000.013] VENTILATION FLOW OPERATING POINTS

The fan shall provide flow and head-rise per Table 3-5 maximizing the total efficiency(1) at Operating Point 1, then addressing the remainder in the order of precedence listed.

| Operating Point | Volumetric Flowrate Lpm [acfm] | Fan Inlet Pressure kPa [psia] | Fan Inlet Gas Temperature °C [°F](2) | Minimum Pressure Rise Pa [in-H2O] | Maximum Power Draw (W) | Voltage |
|---|---|---|---|---|---|---|
| 1 | 178.5 [6.3] | 29.7 [4.3] | 26.7 [80.0] | 1440 [5.8] | 12.1 | 22 |
| 2 | 178.5 [6.3] | 56.5 [8.2] | 26.7 [80.0] | 3340 [13.4] | 12.1(5) | 22 |
| 3 | 136.5 [4.7] | 29.7 [4.3] | 26.7 [80.0] | 1330 [5.3] | 9.0(5) | 22 |
| 4 | 136.5 [4.7] | 163 [23.6](3) | 26.7 [80.0] | 7470 [30] | 52 | 22 |
| 5 | 178.5 [4.7] | 104.1 [15.1](4) | 26.7 [80.0] | 5076 [20.4] | 21 | 22 |

**Table 3-5– Ventilation Flow Operating Points**

*Rationale: These operating points ensure that the ventilation loop can maintain flow requirements with the attached SSA and are listed in order of priority with respect to fan operating point optimization. It is anticipated that the suit will be operated most frequently at operating point 1; operating points 2 and 3 are permitted to have less relative efficiency. The required head rise was computed using PLSS 2.0 as a basic design with scaling of the associated pressure drops based on the type; reference ESCG-4470-12-TEAN-DOC-0098.*

*(1) Total efficiency is defined as total power added to the air over power input to the fan motor.*

*(2) The suit gas temperature is increased over previous values used due to the relocation of the fan within the PLSS ventilation loop. It is now located at the outlet of the SSA which is anticipated to be in the 70-80F range under most thermal environments and metabolic rate ranges (Reference JSC-16646, Shuttle EMU Thermal Vacuum Test Report, 1982).*

*(3) The suit pressure is composed of a maximum DCS treatment pressure setting of 8.4 psig over an increased cabin pressure of 15.2 psia.*

*(4) The suit pressure during IVA operations would nominally be 0.4psid above a cabin pressure of 14.7psia resulting in 15.1 psia.*

*(5) Estimated number, not a hard requirement*

### 3.2.7 [R.FAN.000.014] INLET TEMPERATURE

The fan shall operate given a gas inlet temperature of 1.67°C [35°F] to 51.7°C [125°F].

*Rationale: The typical temperature range is around 60°F to 100°F, however there are test conditions and off nominal conditions outside of this range that the fan may encounter. Temperatures in the EMU have achieved over 104°F during pre-breathe in order to help condition the MET-OX $CO_2$ removing canister. While this would not be a necessary protocol for an RCA based $CO_2$ removal capability, higher temperatures are expected in the suit from crew comfort as well.*

### 3.2.8 [R.FAN.000.015] FREE WATER TOLERANCE

The fan shall operate while passing a minimum of 251 cc [8 fl oz] injected at the inlet at a rate of 60 cc/min.

*Rationale: The PLSS design does not intend to have free water present in the ventilation loop as a nominal condition but with an inlet from the SSA, there are multiple failure modes that could provide free water ingestion (i.e. drink bag rupture). This requirement is intended to make the design tolerable of free water passage in hopes of having a more robust system overall. Initial water sequestration capability has been analyzed per JETS-JE33-13-TAED-DOC-0005.*

### 3.2.9 MOTOR

#### 3.2.9.1 [R.FAN.000.016] OPERATING VOLTAGE RANGE

The fan shall be capable of operating with an input rail voltage of 22 to 34 VDC.

*Rationale: It is understood the attached controller will accept an input supply of 22-34VDC from the PLSS.*

#### 3.2.9.2 [R.FAN.000.017] MOTOR TYPE

The fan shall include a 3-phase Wye connected, 4-pole BLDC motor.

*Rationale: The motor connections are needed to maintain an interface to the CON-350, Oxygen Ventilation Loop Controller within the PLSS.*

#### 3.2.9.3 [R.FAN.000.018] MOTOR SPEED

The fan shall perform at all operating points without exceeding 50,000 RPM.

*Rationale: The Oxygen Ventilation Loop Controller (CON-350) will be designed to control up to this speed. A variety of speeds are desired for flexibility in lab testing, and so that the ventilation flow rate can be adjusted if necessary when the fan is installed in the PLSS.*

### 3.2.10 SENSORS

#### 3.2.10.1 [R.FAN.000.019] STATOR TEMPERATURE SENSOR

The fan shall include a single stator temperature sensor that is a 1kΩ RTD with both leads brought out to the common electrical connector.

*Rationale: This enables the monitoring of motor health to ensure that waste heat is being properly dissipated prior to degradation of the insulation resistance for windings. This is referred to as FN-323D in the PLSS 2.5 schematic.*

#### 3.2.10.2 [R.FAN.000.020] STATOR TEMPERATURE SENSOR EXCITATION

The fan stator temperature sensor shall operate fully with an excitation of 1mA or less.

*Rationale: This excitation will be provided by the Oxygen Ventilation Loop Controller (CON-350), and thus the RTD needs to work with this excitation. A lower excitation current will provide a more accurate RTD by reducing the self-heating error.*

#### 3.2.10.3 [R.FAN.000.021] STATOR TEMPERATURE ACCURACY AND RANGE

The temperature sensor that monitors the fan stator temperature shall meet tolerance class A, B, or C as defined in paragraph 5.1.3 of IEC 60751 Edition 2.0.

*Rationale: This ensures that the fan motor temperature can be gathered within a reasonable accuracy. This will also ensure that the full range of expected motor temperatures will be read.*

#### 3.2.10.4 [R.FAN.000.022] HALL EFFECT DEVICE (HED)

The fan shall include a HED for each motor phase which generates Transistor---Transistor Logic (TTL) level outputs for each phase of the motor.

*Rationale: The HEDs are required to commutate the BLDC motor without using more elaborate algorithms that infer the armature position.*

#### 3.2.10.5 [R.FAN.000.023] HALL EFFECT EXCITATION

The fan HEDs shall be excited by 5 VDC.

*Rationale: This excitation will be provided by the Oxygen Ventilation Loop Controller (CON-350), but the HEDs should be designed to use this excitation.*

### 3.2.11 [R.FAN.000.024] MASS

The fan shall have a mass that is less than 0.68 kg [1.5 lbs] in flight configuration.

*Rationale: This is based on the mass allocation from CTSD-ADV-780, Development Specification for the AEMU Portable Life Support System (PLSS). This mass does not include the check valves or fan manifolds, and only includes the fan assembly itself.*

## 3.3 ENVIRONMENTS

### 3.3.1 PRESSURE

#### 3.3.1.1 [R.FAN.100.001] AMBIENT PRESSURE - OPERATIONAL

The fan shall operate in an external pressure environment ranging from at least 0.0 to 105 kPa [0.0 to 15.2 psia].

*Rationale: The selected pressure spans from hard vacuum experienced in space away from support vehicles to ambient pressure at sea level locations such as those at NASA Johnson Space Center (JSC). This also includes the slightly higher pressure that the ISS is permitted to operate at ~15.2 psia.*

#### 3.3.1.2 [R.FAN.100.002] AMBIENT PRESSURE - NON-OPERATIONAL

The fan shall operate after exposure to an external pressure environment ranging from 0.0 to 130 kPa [0.0 to 18.9 psia].

*Rationale: This addresses the range of pressure regimes across the potential launch vehicles with Progress being the driving case on the upper end and vacuum being common to some cargo vehicles.*

#### 3.3.1.3 [R.FAN.100.003] AMBIENT PRESSURE RATE DECREASING -- OPERATIONAL

The fan shall operate during and after an ambient environment pressure drop of -156 torr/min [-3 psi/min] for up to 4.8 minutes.

*Rationale: This is an approximate depress rate for the U.S. Airlock. The range of depress rates possible for a suit port connection to a Lunar Electric Rover or other similarly equipped vehicle has not been considered.*

#### 3.3.1.4 [R.FAN.100.004] AMBIENT PRESSURE RATE DECREASING -- NON-OPERATIONAL

The Fan, while installed in a stowed PLSS, shall operate after exposure to an external environment pressure drop of at least -6000 torr/min [-116 psi/min] for approximately 7 seconds.

*Rationale: The driving requirement is derived from the depress curve of the Progress launch vehicle.*

#### 3.3.1.5 [R.FAN.100.005] AMBIENT PRESSURE RATE INCREASING -- OPERATIONAL

The Fan shall function at operating points 1, 2 and, 3 listed in [R.FAN.011] during and after an ambient environment pressure increase of 6.9 kPa/sec [1 psi/sec] for 15 seconds.

*Rationale: This is analogous to repressing a vacuum chamber from hard vacuum (10-6 torr) to sea level (14.7 psia) in a 15 second period. This would be the case if we had an emergency repress event following an EVA.*

### 3.3.2 TEMPERATURE

#### 3.3.2.1 [R.FAN.100.006] ENVIRONMENTAL TEMPERATURE PROFILE

The fan shall operate during exposure to an ambient external temperature of 1.67°C [35°F] to 51.7°C [125°F].

*Rationale: This is intended to provide a thermal bounding range for the fan inside the PLSS volume given external heat fluxes, internal heat sources, thermal mass, duty cycle, etc. Reference JETS-JE33-16-TAED-DOC-0021-PLSS 2.5 Thermal Hydraulic Performance Analysis for expected fan temperatures in various environments.*

### 3.3.3 [R.FAN.100.007] EXTERNAL HUMIDITY

The fan shall operate in an environment with Relative Humidity (RH) cycling between 30 ± 10% and 80 ± 10% for ten 24 hr cycles per MIL-STD-810G, Method 507.5, Induced Cycle B3.

*Rationale: This specification is identical to what was used for the Shuttle EMU. While there are few if any instances where this will actually be required as an operational environment during micro-gravity, Lunar, or Mars EVAs, relative humidity in the lab or in chamber tests, especially upon man-lock repress does provide a measure of this sort of exposure. This test will be a conservative screen for potential materials or hermeticity issues. A cycle is defined as a variation in temperature from 25 ± 5 °C [77 ± 9 °F] and 30 ± 10% RH to 65 ± 5 °C [149 ± 9 °F] and 80 ± 10% RH and back over a 24hr period.*

### 3.3.4 G-FIELD ORIENTATION

The fan shall meet all requirements in any orientation for the following G-fields.

| Orientations | G-field (g) | Location |
|---|---|---|
| All | 0 | Low Earth Orbit, Space |
| All | 0.17 | Lunar Surface |
| All | 0.38 | Mars Surface |
| All | 1 | Earth Surface |

*Rationale: The PLSS may be operated in a variety of G-fields, and thus the fan needs to fully operate in any of these fields and in any orientation.*

### 3.3.5 DYNAMIC LOADS

The PLSS axes for dynamic load conditions are provided in Figure 3-1 below. These are simply for reference, and the same axes are shown on FN-323 and FN-343 in Figure 3-2. The positive X-axis extends from the bottom of the launch vehicle through the nose of the vehicle and would be considered the vertical direction on the launch pad.

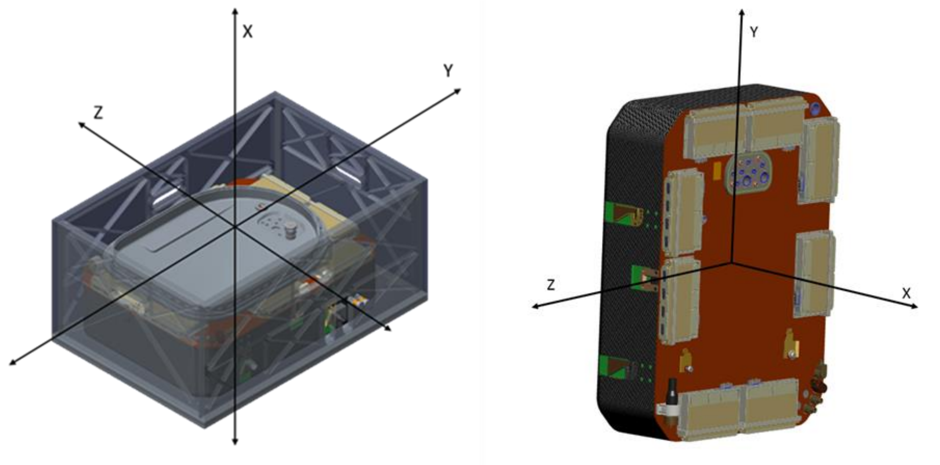



**Figure 3-1 – PLSS Axes for Dynamic Load Conditions**

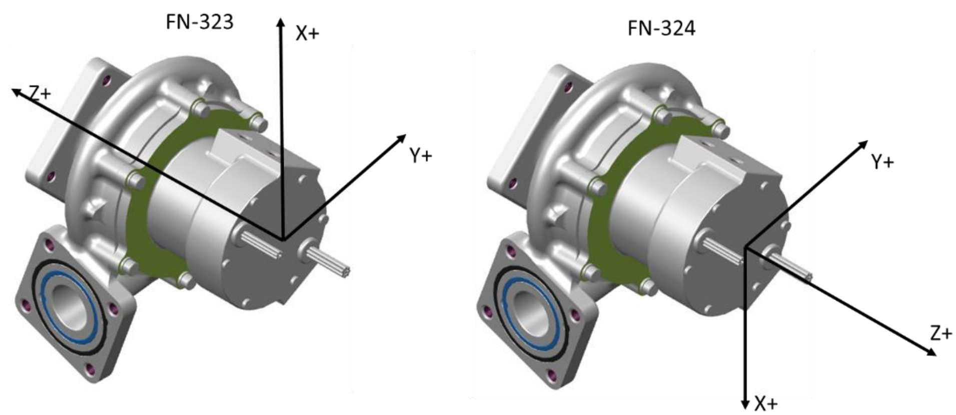



**Figure 3-2 – Fan 323/324 Axes for Dynamic Load Conditions**

While it is intended for there to be no physical difference in the design of FN-323 and FN-324, the axes point in different directions because the current PLSS packaging has them mounted opposite each other, with one fan flipped.

#### 3.3.5.1 [R.FAN.100.008] ACCELERATION -- LAUNCH VEHICLES

The fan shall meet requirements after exposure to the accelerations defined in Table 3-6.

| | Nx (g) | Ny (g) | Nz (g) | Rx (rad/sec$^2$) | Ry (rad/sec$^2$) | Rz (rad/sec$^2$) |
|---|---|---|---|---|---|---|
| Launch | +/- 7.0 | +/- 4.0 | +/- 4.0 | +/-13.5 (1) | +/-8.5 (1) | +/-11.5 (1) |

**Table 3-6– Design Load Factors for Launch Vehicles**

*Rationale: The values listed envelope the ground transportation loads and the following launch vehicles: Progress, HTV, Atlas V, and Delta IV.*

*(1) While the PLSS will not be launched on ATV or Soyuz, it is ideal to keep those options open for a fan ORU, and thus the fans need to tolerate the vehicles' rotational accelerations.*

*(2) The reference frame for the enveloped load factors is as follows:*

*a. X: The longitudinal axis of the vehicle. Positive X-axis extends from the base or bottom of the spacecraft to the nose of the spacecraft.*

*b. Y: Y axis is perpendicular to the x axis.*

*c. Z: Z axis is perpendicular to the x and y axes and completes the right handed coordinate system.*

#### 3.3.5.2 [R.FAN.100.009] ACCELERATION -- SURVIVABLE

The fan shall meet requirements after exposure to the accelerations defined in Table 3-7. The values listed envelope the ground transportation loads and the following launch vehicles: Progress, HTV, Dragon, ATV, Atlas V, and Delta IV.

| | Nx (g) | Ny (g) | Nz (g) | Rx (rad/sec2) | Ry (rad/sec2) | Rz (rad/sec2) |
|---|---|---|---|---|---|---|
| Launch | +9.0/-7.0 | +/- 4.0 | +/- 4.0 | +/- 13.5 | +/- 8.5 | +/- 11.5 |
| Landing | +/-10.0 | +/-6.6 | +/-6.6 | --- | --- | --- |

**Table 3-7 – Design Load Factors for Launch Vehicles - Goal**

*Rationale: Values obtained from SSP-50835 Rev D. section 3.1.1.2.1.1.1-1, inclusive of PIRN 0022b*

### 3.3.5.3 [R.FAN.100.010] RANDOM VIBRATION -- OPERATING

The fan shall operate during and after exposure to the vibration profile shown in Table 3-8 for a minimum of 30 minutes in each axis.

| FREQUENCY (Hz) | LEVEL |
|---|---|
| 10 – 40 | 0.0549 $g^2$/Hz |
| 40 – 500 | -5.49 dB/oct |
| 500 | 0.0006 $g^2$/Hz |
| **COMPOSITE** | **2.00 grms** |

**Table 3-8 – Fan Random Vibration Profile – Operating**

*Rationale: The fan needs to tolerate transport across terrestrial surfaces as part of a roving vehicle demonstration followed by eventual flight usage on a roving vehicle in the lunar and Martian environments. The selection of time per axis is currently arbitrary given that the final vehicle configurations and operations concepts are not known. The vibration profile is more aggressive than the original MIL-STD-810G, Method 514.6, Category 4, Common Carrier US Truck vibration reference. This particular profile was the limit profile (2 grms) in which the Primary Oxygen Regulator 2.0 design successfully operated in all axes without issue. It was also tested up to 3.3 grms with some regulation anomalies.*

### 3.3.5.4 [R.FAN.100.011] RANDOM VIBRATION -- NON-OPERATING

The fan shall operate during and after exposure to the vibration profile shown in Table 3-9 for a minimum of 30 minutes in each axis.

| FREQUENCY (Hz) | LEVEL |
|---|---|
| 20 – 153 | 0.057 $g^2$/Hz |
| 153 – 190 | +7.67 dB/oct |
| 190 – 250 | 0.099 $g^2$/Hz |
| 250 – 750 | -1.61 dB/oct |
| 750 | 0.055 $g^2$/Hz |
| 750 – 2000 | -3.43 dB/oct |
| 2000 | 0.018 $g^2$/Hz |
| **COMPOSITE** | **9.47 grms** |
| **Duration** | **60 sec for 1 launch** |

**Table 3-9 - AEMU Random Vibration Profile (Reference SSP-50835, Table 3.1.1.2.1.2.1-1)**

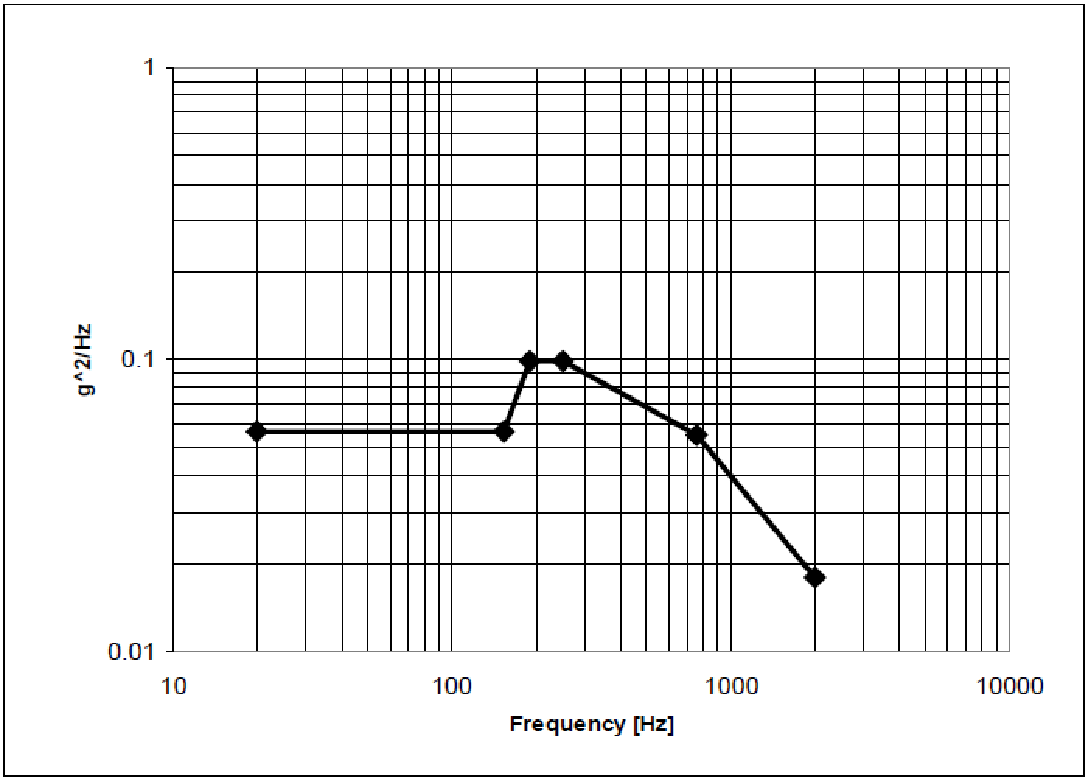



**Figure 3-3 - AEMU Random Vibration Profile (Reference SSP-50835, Figure 3.1.1.2.1.2.1-1)**

*Rational:*

*(1) The flight package for the PLSS or Fan ORU has not yet been defined but is assumed to be a "soft-stow" approach similar to the EMU Launch Enclosure used for the ISS EMU. This excitation would exist at the package interface.*

*(2) This environment envelopes the maximum unattenuated flight launch shock and random vibration environments for Progress in orbital flight. This environment does not envelope the maximum flight shock environment for the Progress launch escape system shock loads nor does it envelope the maximum flight launch shock environment for Dragon shock loads.*

*(3) Criteria are the same for all directions (X, Y, Z).*

*(4) Qualification and Acceptance test margins are described in SSP 41172.*

*(5) A separate shock test is not required when the end item is tested to the equivalent damage potential random vibration environment defined in this table.*

*(6) Equivalent shock environments were determined using the methodology from TR-2004(8583)-1, Test Requirements for Launch, Upper Stage, and Space Vehicles, Paragraph 10.2.6, Threshold Response Spectrum for Shock Significance.*

*(7) Dragon is excluded because the shock levels are too high to perform an equivalent random vibration damage potential test.*

### 3.3.6 [R.FAN.100.012] DC MAGNETIC FIELD

The fan shall operate at all design points during and after exposure to a DC Magnetic Field of 250 Gauss as measured from 1-inch off the surface of the fan motor.

*Rationale: This is considered a baseline capability that the suit must have to provide development freedom to vehicle systems. It is also characteristic of historical Shuttle/ISS EMU performance.*

### 3.3.7 [R.FAN.100.013] SALT FOG

The fan, as packaged for flight, shall operate at all design points after exposure to a salt fog environment as defined by MIL-STD-810G, Method 509.5 with a NaCl concentration of 1% by weight for a period of 30 days.

*Rationale: The PLSS and components must be capable of being shipped and handled in coastal regions such as the Kennedy Space Center (KSC) without compromising the mission.*

### 3.3.8 [R.FAN.100.014] FUNGUS

The fan, as packaged for flight, shall operate at all design points after exposure to fungus as defined in MIL-STD-810G, Method 508.6.

*Rationale: The PLSS and components must be capable of being handled in coastal regions such as the Kennedy Space Center (KSC) and Johnson Space Center (JSC) without compromising the mission. The test itself requires a 28 day dwell in specified elevated temperature and humidity conditions after doping with specified fungi. Execution of this test on flight hardware would be ludicrous as there is no intention to expose the hardware to this environment which will either be an air conditioned lab, vacuum chamber, or exploration environment such as LEO, lunar, mars, etc all of which would not promote fungus growth.*

### 3.3.9 [R. FAN.100.015] OZONE

The fan, as packaged for flight, shall meet all performance requirements after exposure to environmental ozone at concentrations of 3 to 6 parts per 100 million at sea level to a maximum of 100 parts per 100 million during air transportation at an altitude of 35,000 feet for up to 30 days total exposure duration.

*Rationale: This provides flexibility with transportation of the fan and PLSS.*

### 3.3.10 [R.FAN.100.016] IONIZING RADIATION

The fan shall meet requirements while operating in an ionizing radiation environment as defined in SSP 30512 by meeting the LET and TID requirements listed in Table 3-10.

**Table 3-10: Ionizing Radiation Dosage**

| Component | Non-Destructive SEE/SEFI(2) Rates | Destructive SEE(3) (MeV-cm²/mg) | Total Dose Rad (Si)(1) |
|---|---|---|---|
| Fan | $\leq 10^{-2}$/2000hrs | $\geq 36$ | 10000 |

*Rationale: The radiation environment is provided in two phases: one that addresses a more benign environment in Low Earth Orbit (LEO) that may allow for the use of CMOS or enhanced CMOS parts without the use of Rad-Hard by Design (RHD) parts and one that addresses a much more stringent environment required for deep space exploration which will likely result in extensive use of RHD components. The RHD components drive cost, schedule, SWAP, as well as parts obsolescence issues given the relatively small specialized market. Hence, it is efficient to design for the planned LEO usage with expectations of additional test or upgrades for operations beyond LEO using components that are available at that time.*

(1) *Assumptions for Total Ionizing Dose calculation*
  a. *EVA duration = 8hrs*
  b. *Total life-time EVAs = 250*
  c. *EVA on-orbit duration = 2000 hrs*
  d. *IVA on-orbit duration = 10 years-2000hrs = 85600 hrs*
  e. *Safety Factor = 2x*

(2) *Non-destructive Single Event Effects (SEE) or Single Event Functional Interrupt (SEFI) can include the following:*
  a. *Single Event Upset (SEU)*
  b. *Single Event Transient (SET)*

  *The component must tolerate SEE without propagation to functions.*

(3) *Destructive Single Event Effects (SEE) can include the following:*
  c. *Single Event Latch-up (SEL)*
  d. *Single Event Burn-out (SEB)*

e. *Single Event Gate Rutpure (SEGR)*

### 3.3.11 [R.FAN.100.017] Atomic Oxygen

The fan shall operate at all design points with an exposure of 4.4 x $10^{19}$ atomic oxygen particles/cm2-day over the duration of the operational life.

*Rationale: Since the PLSS does not have a prolonged exposure under nominal operations with airlock-based LEO missions, the short-term daily ram fluence value for ISS is applied.*

### 3.3.12 [R.FAN.100.018] Atmospheric Composition

The fan shall meet requirements while operating in an ambient environment with an oxygen concentration up to 26.5% with the balance composed of nitrogen, metabolic products (CO2 and H2O), and trace gases.

*Rationale: The 26.5% value is derived from the upper bound published in JSC-63309, Recommendations for Exploration Spacecraft Internal Atmospheres and exceeds the maximum value permitted in SSP 50835 of 24.1%.*

## 3.4 INDUCED ENVIRONMENTAL CONTRIBUTIONS

### 3.4.1 Noise

#### 3.4.1.1 [R.FAN.200.001] Fan Noise

The fan shall limit noise output into the oxygen ventilation loop as described in Table 3.4.1.1-1 as measured through the outlet port.

| Case | Operating Conditions | Typical Duration for Airlock Operations | Frequency Band (Hz) | SPL (dB) |
|---|---|---|---|---|
| IVA | Pressure = 15.1 psia<br>Ambient Temperature = 80F | 2 hours | A-weighted | 75 |
| EVA | Pressure = 4.3 psia<br>Ambient Temperature = 80F | 8 hours | NC-55 | --- |
| [redacted] | | | 16 | 89 |
| | | | 31.5 | 82 |
| | | | 63 | 74 |
| | | | 125 | 67 |
| | | | 250 | 62 |
| | | | 500 | 58 |
| | | | 1000 | 56 |
| | | | 2000 | 54 |
| | | | 4000 | 53 |
| | | | 8000 | 52 |

**Table 3-11– Fan Internal Noise Output**

*Rationale: This assumes that the PLSS as-packaged will attenuate the output noise from the fan in the vent loop by ~15 dB centered around 1kHz. This is a tall order to accomplish while minimizing the pressure drop impacts and may not be possible within the functional constraints, which is why the fan component must push to improve upon these requirements.*

#### 3.4.1.2 [R.FAN.200.002] External Noise

The fan shall limit noise generation as described in Table 3-12 as measured 0.6 m [2 ft] from the fan housing.

| Case | Operating Conditions | Typical Duration for Airlock Operations | Frequency Band (Hz) | SPL (dB) |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| IVA | Pressure = 14.7 psia<br>Ambient Temperature = 80F | 2 hours | NC-60 | --- |
| [redacted] | | | 16 | 90 |
| | | | 31.5 | 85 |
| | | | 63 | 77 |
| | | | 125 | 71 |
| | | | 250 | 66 |
| | | | 500 | 63 |
| | | | 1000 | 60 |
| | | | 2000 | 59 |
| | | | 4000 | 58 |
| | | | 8000 | 57 |

**Table 3-12 – Fan Generated Noise**

*Rationale: This is based on the continuous and intermittent noise requirements from the ISS Pressurized Volume Common IRD (SSP 50835, Para 3.12.3.3) which requires compliance to ANSI S12.2, NC-40 with temporary excursions; in this case, the IVA operational condition is a temporary excursion that is permitted to reach 60 dB over the typical 2 hour period of IVA ops. This assumes minimal attenuation by the PLSS package.*

## 3.5 SAFETY

### 3.5.1 [R.FAN.300.001] CATASTROPHIC HAZARDS

The fan shall be designed in accordance with SSP 50021, Safety Requirements Document and follow safety analysis methodology in SSP 30309, Safety Analysis and Risk Assessment Requirements Document to control catastrophic hazards such that no combination of two failures, two operator errors, or one of each can result in a disabling or fatal personnel injury, loss of the ISS, or other vehicles. Exceptions from the failure tolerance requirements may be granted for those areas where Design for Minimum Risk has been approved via the hazard analysis review process in accordance with SSP 30309, Safety Analysis and Risk Assessment Requirements Document.

*Rationale: Adopted from CTSD-ADV-780, AEMU PLSS Specification Document*

### 3.5.2 [R.FAN.300.002] CRITICAL SEAL REDUNDANCY

The fan shall incorporate redundant seals between the pressurized PLSS ventilation loop volume and vacuum ambient.

*Rationale: This provides an added layer of protection for sealing the vent loop. This requirement is levied on the entire fan assembly, not just the inlet and outlet ports. Thus the motor and drive shaft should be redundantly sealed as well as any other paths from the vent loop to vacuum.*

### 3.5.3 [R.FAN.300.003] LEAKAGE BEYOND SECONDARY OXYGEN MAKE-UP

The fan shall be designed such that no single credible failure may result in a leakage rate from the oxygen ventilation loop exceeding .767 kg/hr [1.69pph].

*Rationale: The intent of this requirement is to prohibit a design that allows a single failure to outrun the gas supply capability of the secondary oxygen regulator supply. This leak rate corresponds to an abort time of 1 hour.*

## 3.6 DESIGN AND CONSTRUCTION

### 3.6.1 [R.FAN.400.001] MATERIALS AND PROCESSES

The fan shall comply with SSP 30233, Space Station Requirements for Materials and Processes with exception of the following:

Para 4.6.5 => Printed Wiring Boards
Para 4.6.5.1 Rigid PWB => Rigid Printed Wiring Boards shall be designed to IPC-2222
Para 4.6.5.2 Flexible PWB => Flex Printed Wiring Boards shall be designed to IPC-2223

*Rationale: A review of this document indicates that it is in basic agreement with NASA-STD-6016 with the addition of soldering, crimping, and board standards which are exceptions as listed above to enable the use of the latest IPC standards. The IPC standards are stated as being capable of being followed in lieu of the NASA standards per NASA-STD-8739.6.*

### 3.6.2 [R.FAN.400.002] PART IDENTIFICATION

The fan shall be marked with name, part number, dash number, and serial number in letters at least .080in high where size and shape permit.

*Rationale: This satisfies the requirements of NASA-STD-6002 and MIL-STD-130 which are intended to provide proper marking and identification of hardware. Because there is no physical difference between FN-323 and FN-324, and all fans in the PLSS will be interchangeable, the only difference between part markings of the fans should be serial number (i.e. FN-323 might be S/N:1001 and FN-324 might be S/N:1002, but they would have the same part and dash number).*

### 3.6.3 [R.FAN.400.003] LIKE-COMPONENT INTERCHANGEABILITY

The fan shall be interchangeable with other fans of the same part and dash number, but different serial numbers.

*Rationale: The definition as provided in JSC EA-WI-027 is as follows:*
*Two or more parts are interchangeable when they possess such physical and functional characteristics as to be equivalent in performance and durability, and are capable of being exchanged one for another without alteration of the items themselves or adjoining items. Functional and physical characteristics, which would constitute interchangeability, are:*

- *Parts must have the same design envelope and have no limitations imposed on use.*
- *Parts must utilize the same attachments, mountings or mating surfaces. Attachments, connectors, wiring, ground support equipment, and tubing must be the same to the extent that no re-work is required on installation.*
- *Parts must meet all baselined design requirements for performance and durability. Performance or durability design requirements include the same safety, strength, electrical, mechanical, reliability, maintainability, tolerance, and weight and center of gravity requirements.*
- *Parts must have the same adjustments, testing, operations, and maintenance requirements and design to the extent that the same test procedures, specifications, and operating procedures have been and/or may be utilized.*

### 3.6.4 [R.FAN.400.004] COMMON FASTENERS

The fan shall use socket head cap screws as fasteners for all external components and parts.

*Rationale: While it is not expected that maintenance of the fan itself would be performed in orbit, it is still desired that service of the fan be easily done with common tools. This will also maximize contingency repair capability on in orbit. This is also intended to preclude the use of offset cruciform fasteners which can be difficult to remove.*

### 3.6.5 [R.FAN.400.005] OXYGEN COMPATIBILITY ASSESSMENT

The fan shall comply with NASA-STD-6016, Paragraph 4.2.1.4.

*Rationale: This requires an OCA, materials assessments, and tests. The OCA will be performed by WSTF, however the vendor providing the fan will need to supply annotated cross-sections of the fan design showing materials used. Critical dimensions will also need to be provided (e.g. tip clearance) so that the OCA can be completed.*

### 3.6.6 [R.FAN.400.006] MECHANICAL STRUCTURAL MARGIN

The fan shall possess a minimum factor of safety of 1.1 to yield and 1.5 to ultimate for all structural loads not driven by the pressurized volume requirements.

*Rationale: This complies with the structural requirements conveyed in SSP 30559, ISS Structural Design and Verification Requirements, Table 3.3.1-1, paragraph A (Minimum Factors of Safety for Metallic Flight Structures).*

### 3.6.7 [R.FAN.400.007] Combined Structural Margin

The fan shall possess a minimum factor of safety of 1.1 to yield and 1.5 to ultimate for combined pressure and structural/mechanical loads.

*Rationale: This complies with the combined pressure and mechanical loading requirements conveyed in SSP 30559, Structural Design and Verification Requirements, Tabel 3.3.1-1, sub paragraph C5 (Minimum Factors of Safety for Pressure-on-orbit).*

### 3.6.8 [R.FAN.400.008] Toxic Off-Gassing

The fan shall meet the requirements of NASA-STD-6016, paragraph 4.2.1.2.

*Rationale: This examines both the need for low quantities of off-gassed products when operating in closed loop mode and low quantities of off-gassed products when stored in a vehicle cabin with continuous exposure to the crew volume.*

### 3.6.9 [R.FAN.400.009] Vacuum Stability

The fan surfaces that will be exposed to the vacuum environment shall be rated as vacuum compatible per Para 4.2.3.6 of NASA-STD-6016.

*Rationale: Components or surfaces that are nominally exposed to vacuum should not lose a significant amount of mass if they are to retain their function over time. Mission specific requirements such as a Hubble Servicing mission will further restrict allowable volatile condensable materials.*

### 3.6.10 [R.FAN.400.010] Welding

The fan shall comply with NASA-STD-5006A, General Fusion Welding Requirements for aerospace Materials Used In Flight Hardware for all welding.

*Rationale: Welding is not an expected manufacturing technique for the fan design currently envisioned. However, if welding is necessary, it needs to comply with the NASA standard above.*

### 3.6.11 [R.FAN.400.011] Fragment Containment

The fan shall contain all fragments in the case of breakage of any frangible materials contained in the assembly.

*Rationale: The intent of this requirement is to design the fan such that a blade failure of the fan would not result in puncturing of the volute in the event the fan blade failed or shed material. This also applies to items inside the motor housing.*

### 3.6.12 [R.FAN.400.012] General Workmanship

The fan shall adhere to NASA-STD-8739.6, Implementation Requirements for NASA Workmanship Standards.

*Rationale: This is standard practice for NASA spaceflight hardware.*

### 3.6.13 [R.FAN.400.013] Crimping, Interconnecting Cables, Harnesses, and Wiring

The fan cables/harness shall comply with NASA-STD-8739.4, Crimping, Interconnecting Cables, Harnesses, and Wiring.

*Rationale: This is standard practice for NASA spaceflight hardware.*

### 3.6.14 [R.FAN.400.14] SOLDERED ELECTRICAL AND ELECTRONIC ASSEMBLIES

The fan soldered electrical and electronic components shall adhere to IPC J-STD-001ES, Space Applications Electronic Hardware Addendum to J-STD-011E, Requirements for Soldered Electrical and Electronic Assemblies with exception of Chapter 10.

*Rationale: Adopted from CTSD-ADV-780, AEMU PLSS Specification Document*

### 3.6.15 [R.FAN.400.15] ELECTROSTATIC DISCHARGE DESIGN

The Fan shall meet Class 3A or better across the case or any external pin when tested in an unpowered state per MIL-STD-750-1A, Method 1020.5. If the component does not achieve the "insensitive" classification, it shall be labeled per MIL-STD-1686C in a clearly visible location.

*Rationale: This assumes the Human Body Model (HBM) and is necessary given charges that may be accumulated during ground processing and handling. It is assumed that the system being maintained is unpowered and the crew will be wearing a ground strap when doing the work, but since they will not be able to verify the ground connection, this protection is necessary. Class 3A or better meets the ISS requirements stating that no damage will occur below 4000V.*

### 3.6.16 [R.FAN.400.16] ELECTROSTATIC DISCHARGE PROTECTION

The fan shall comply with ANSI/ESD S20.20-2014, Protection of Electrical and Electronic Parts, Assemblies, and Equipment.

*Rationale: Adopted from CTSD-ADV-780, AEMU PLSS Specification Document*

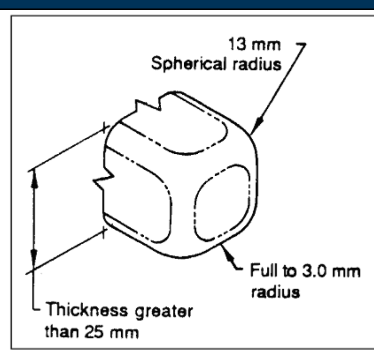
### 3.6.17 [R.FAN.400.17] CORROSION CONTROL

The fan shall utilize materials and surface treatments that comply with NASA-STD-6012, Corrosion Protection for Space Flight Hardware.

*Rationale: Protecting the fan from corrosion will be critical to ensuring it can meet life and performance requirements.*

### 3.6.18 [R.FAN.400.18] SHARP EDGE LIMITS

The fan shall comply with the Corners and Edges limits established in Table 3-13 for all external surfaces.

| Material Thickness, t | Minimum Corner | Minimum Edge Radius | Figure |
|---|---|---|---|
| t > 1 in<br>(t > 25 mm) | 0.5 in<br>(13 mm (spherical)) | 0.125 in<br>(3.0 mm). |  |

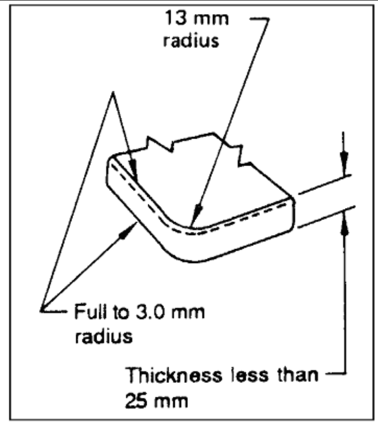
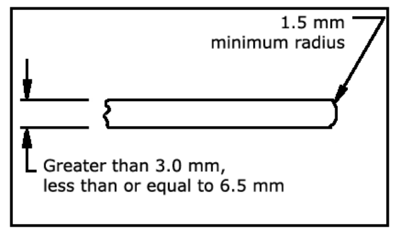
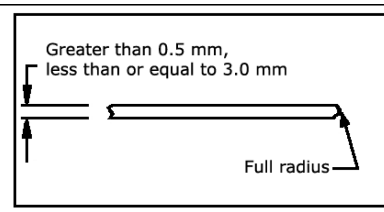
| Material Thickness, t | Minimum Corner | Minimum Edge Radius | Figure |
|---|---|---|---|
| 0.25 in. < t ≤ 1 in. (6.5 mm < t ≤ 25 mm) | 0.5 in. (13 mm) | 0.125 in. (3.0 mm) |  |
| 0.125 in. < t ≤ 0.25 in. (3.0 mm < t ≤ 6.5 mm) | 0.25 in. (6.5 mm) | 0.06 in. (1.5 mm) |  |
| 0.02 in. < t ≤ 0.125 in. (0.5 mm < t < 3.0 mm) | 0.25 in. (6.5 mm) | Full radius |  |

**Table 3-13 – Corners and Edges**

*Rationale: The Human Systems Integration Requirements (HSIR), Section 3.3.2 Mechanical Hazards requires this for Crew interfaces. Although the fan is located within the PLSS, it is part of an ORU, and on-orbit replacement of a single fan is a real possibility. Preventing sharp edges will also be beneficial for initial assembly and ground maintenance.*

### 3.6.19 [R.FAN.400.019] Fastener Design

The fan shall implement fastener design in accordance with NASA-STD-5020, Requirements for Threaded Fastening Systems in Spaceflight Hardware.

*Rationale: Implementing fasteners that meet the requirements of NASA-STD-5020 will help increase the safety and reliability of the fan design.*

### 3.6.20 [R.FAN.400.020] Fastener Integrity

The fan shall implement fastener integrity verification in accordance with NASA-STD-6008, NASA Fastener Procurement, Receiving Inspection, and Storage Practices for Spaceflight Hardware.

*Rationale: This ensures quality fasteners are used in the design.*

### 3.6.21 [R.FAN.400.021] Grounding

The fan shall electrically isolate the motor windings from the chassis.

*Rationale: Electrically parallel components can provide conductive paths between flight elements, systems, subsystems, and equipment. The parallel conductive paths may provide the opportunity for ground loops and spurious common impedance sources for noise coupling. Noise represents a varying, uncontrolled, and detrimental contribution to the performance of electrical, electronic, and electromechanical equipment. Grounding is designed to preclude the environmental effects that can cause potential differences. Isolating the windings from the chassis will help prevent shock hazards. This will satisfy the grounding requirements in SSP 30240, Space Station Grounding Requirements.*

#### 3.6.22 [R.FAN.400.022] Electronic, Electrical, and Electromechanical (EEE) Parts

The fan shall implement a design using EEE parts from the NASA Parts Selection List (NPSL) or SSP 30423, Space Station Approved Electrical, Electronic, and Electromechanical Parts List or obtain approval to use a non-EEE part via an Irregular Parts Approval Request (IPAR).

*Rationale: This will help ensure that parts used in the design have proven supply chains.*

#### 3.6.23 [R.FAN.400.023] Parts Derating

The fan shall be designed with electrical and thermal derating as defined in SSP 30312, Electrical, Electronic, and Electromechanical and Mechanical Parts Management and Implementation Plan for Space Station Program.

*Rationale: The AEMU Project has not yet defined a EEE parts plan but it is expected that using already approved hardware will be more cost effective where added capability, reduced SWAP, or other advantages do not necessitate selection of unapproved parts that carry risk and cost burden.*

#### 3.6.24 [R.FAN.400.024] Destructive physical analysis (DPA)

The fan, for flight production, shall screen all non-approved or Grade 2 EEE parts per MIL-STD-1580.

*Rationale: This is intended to enable increased reliability of the components used in the fan by physical screening of parts that do not have proven supply chains.*

#### 3.6.25 [R.FAN.400.025] Fracture Control

The fan, shall comply with SSP 30558, Fracture Control Requirements for Space Station.

*Rationale: Given that the fan is primarily metallic, and is part of a pressure system, it needs to be evaluated under SSP 30558. Per paragraph 4.4.2.1 of SSP 30558, the fan will be considered a fracture critical pressure system component because loss of pressurization would result in a catastrophic hazard. Proof testing the fan per the factor of safety requirements in SSP 30559, section 3.3, will eliminate the requirement to perform a safe-life analysis.*

### 3.7 INTERFACE CONTROL

#### 3.7.1 [R.FAN.500.001] Interface Control Document

The fan shall interface with the PLSS assembly per the Fan Interface Control Drawing, SLN13102232.

*Rationale: This drawing defines the mechanical and electrical interfaces of the fan with the PLSS assembly. As currently envisioned, the fan inlet attaches to the inlet manifold, and the fan outlet attaches to a check valve. Electrical wires terminate in a Glenair Mighty-Mouse 805 series connector.*

## 4.0 FAN 3.0 VERIFICATION MATRIX

The manner in which each requirement shall be verified is outlined below.
Verification methods include:
I = Inspection
A = Analysis
T = Test
D = Demonstration

For the Fan 3.0 iteration of the design, some of the requirements will be verified by NASA after delivery of the fan, and some will be verified by the vendor before delivery of the fan to NASA. The "Responsible for Verification" Columns show who will verify which requirement for the current fan design/procurement. If a given requirement is blank, this indicates that the vendor should design the fan strongly considering the requirement, but no verification method or data is required at this time.

| FAN Requirement | Title | Method | | | | Responsible for Verification | | Reference | Notes |
|---|---|---|---|---|---|---|---|---|---|
| | | I | A | T | D | Vendor | NASA | | |
| | | | | | | | | | |
| [R.FAN.000.001] | Operational Life | | | | | | | | |
| [R.FAN.000.002] | Useful Life | | | | | | | | |
| [R.FAN.000.003] | Shelf Life | | | | | | | | |
| [R.FAN.000.004] | Launch / Landing Cycles | | | | | | | | |
| [R.FAN.000.005] | Gaseous Nitrogen | | | | X | | X | | |
| [R.FAN.000.006] | Gaseous Oxygen | | | | | | | | |
| [R.FAN.000.007] | Gaseous Heliox | | | | | | | | |
| [R.FAN.000.008] | Gaseous Helium and Nitrogen | | | | | | | | |
| [R.FAN.000.009] | Atmospheric Air | | | | X | X | | | |
| [R.FAN.000.010] | Operating Pressures | | | | X | X | | | |
| [R.FAN.000.011] | External Leakage | | | X | | X | | | |
| [R.FAN.000.012] | Cleanliness | X | | | | X | | | |
| [R.FAN.000.013] | Ventilation Flow | | | | X | X | | | |
| [R.FAN.000.014] | Inlet Temperature | | | | | | | | |
| [R.FAN.000.015] | Free Water Tolerance | | | | X | X | | | Demonstration should account for various fan orientations. |
| [R.FAN.000.016] | Operating Voltage Range | | | | X | X | | | |
| [R.FAN.000.017] | Motor Type | X | | | | X | | | |
| [R.FAN.000.018] | Motor Speed | | | | X | X | | | |
| [R.FAN.000.019] | Stator Temperature Sensor | X | | | | X | | | |
| [R.FAN.000.020] | Stator Temperature Sensor Excitation | | | | X | X | | | |

| FAN Requirement | Title | Method | | | | Responsible for Verification | | Reference | Notes |
|---|---|---|---|---|---|---|---|---|---|
| | | I | A | T | D | Vendor | NASA | | |
| [R.FAN.000.021] | Stator Temperature Accuracy and Range | | | | X | X | | | |
| [R.FAN.000.022] | Hall Effect Device (HED) | X | | | | X | | | |
| [R.FAN.000.023] | Hall Effect Excitation | | | | X | X | | | |
| [R.FAN.000.024] | Mass | | | X | | X | | | |
| [R.FAN.100.001] | Ambient Pressure – Operational | | | | | | | | |
| [R.FAN.100.002] | Ambient Pressure – Non-Operational | | | | | | | | |
| [R.FAN.100.003] | Ambient Pressure Rate Decreasing – Operational | | | | | | | | |
| [R.FAN.100.004] | Ambient Pressure Rate Decreasing – Non-Operational | | | | | | | | |
| [R.FAN.100.005] | Ambient Pressure Rate Increasing – Operational | | | | | | | | |
| [R.FAN.100.006] | Environmental Temperature Profile | | | | | | | | |
| [R.FAN.100.007] | External Humidity | | | | | | | | |
| [R.FAN.100.008] | Acceleration – Launch Vehicles | | | | | | | | |
| [R.FAN.100.009] | Acceleration – Survivable | | | | | | | | |
| [R.FAN.100.010] | Random Vibration – Operating | | | | | | | | |
| [R.FAN.100.011] | Random Vibration – Non-Operating | | | | | | | | |
| [R.FAN.100.012] | DC Magnetic Field | | | | | | | | |
| [R.FAN.100.013] | Salt Fog | | | | | | | | |
| [R.FAN.100.014] | Fungus | | | | | | | | |
| [R.FAN.100.015] | Ozone | | | | | | | | |
| [R.FAN.100.016] | Ionizing Radiation | | | | | | | | |
| [R.FAN.100.017] | Atomic Oxygen | | | | | | | | |
| [R.FAN.100.018] | Atmospheric Composition | | | | | | | | |
| [R.FAN.200.001] | Fan Noise | | | X | | X | | | It is understood that this may be a difficult requirement to achieve with the fan. However, testing against this |

| FAN Requirement | Title | Method | | | | Responsible for Verification | | Reference | Notes |
|---|---|---|---|---|---|---|---|---|---|
| | | I | A | T | D | Vendor | NASA | | |
| | | | | | | | | | requirement will help quantify the fan noise generation for use in the future. |
| [R.FAN.200.002] | External Noise | | | X | | X | | | |
| [R.FAN.300.001] | Catastrophic Hazards | | X | | | X | | | |
| [R.FAN.300.002] | Critical Seal Redundancy | X | | | | X | | | |
| [R.FAN.300.003] | Leakage beyond secondary oxygen make-up | | X | | | X | | | |
| [R.FAN.400.001] | Materials and Processes | X | | | | X | | | |
| [R.FAN.400.002] | Part Identification | X | | | | X | | | |
| [R.FAN.400.003] | Like-Component Interchangeability | X | | | | X | | | |
| [R.FAN.400.004] | Common Fasteners | X | | | | X | | | |
| [R.FAN.400.005] | Oxygen Compatibility Assessment | | X | | | X | | | OCA to be performed at WSTF, Analysis involves providing annotated cross-sections and any other data necessary to complete the OCA. |
| [R.FAN.400.006] | Mechanical Structural Margin | | X | | | X | | | |
| [R.FAN.400.007] | Combined Structural Margin | | X | | | X | | | |
| [R.FAN.400.008] | Toxic Off-Gassing | | | | | | | | |
| [R.FAN.400.009] | Vacuum Stability | | X | | | X | | | |
| [R.FAN.400.010] | Welding | X | | | | X | | | |
| [R.FAN.400.011] | Fragment Containment | | X | | | X | | | |
| [R.FAN.400.012] | General Workmanship | X | | | | X | | | |
| [R.FAN.400.013] | Crimping, Interconnecting Cables, Harnesses, and Wiring | X | | | | X | | | |
| [R.FAN.400.014] | Soldered Electrical and Electronic Assemblies | X | | | | X | | | |
| [R.FAN.400.015] | Electrostatic Discharge Design | X | | | | X | | | |
| [R.FAN.400.016] | Electrostatic Discharge Protection | X | | | | X | | | |
| [R.FAN.400.017] | Corrosion Control | X | | | | X | | | |
| [R.FAN.400.018] | Sharp Edge Limits | X | | | | X | | | |
| [R.FAN.400.019] | Fastener Design | X | | | | X | | | |
| [R.FAN.400.020] | Fastener Integrity | X | | | | X | | | |
| [R.FAN.400.021] | Grounding | X | | | | X | | | |

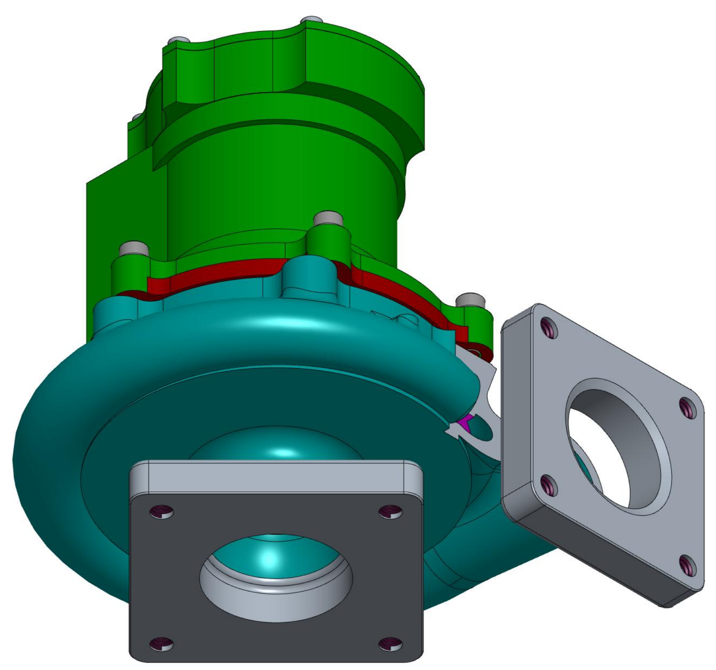
| FAN Requirement | Title | Method | | | | Responsible for Verification | | Reference | Notes |
|---|---|---|---|---|---|---|---|---|---|
| | | I | A | T | D | Vendor | NASA | | |
| [R.FAN.400.022] | Electronic, Electrical, and Electromechanical (EEE) Parts | | | | | | | | |
| [R.FAN.400.023] | Parts De-rating | | | | | | | | |
| [R.FAN.400.024] | Destructive Physical Analysis | | | | | | | | |
| [R.FAN.400.025] | Fracture Control | | | | | | | | |
| [R.FAN.500.001] | Interface Control Document | X | | | | X | | | |

**Table 4-1 – Verification Matrix**

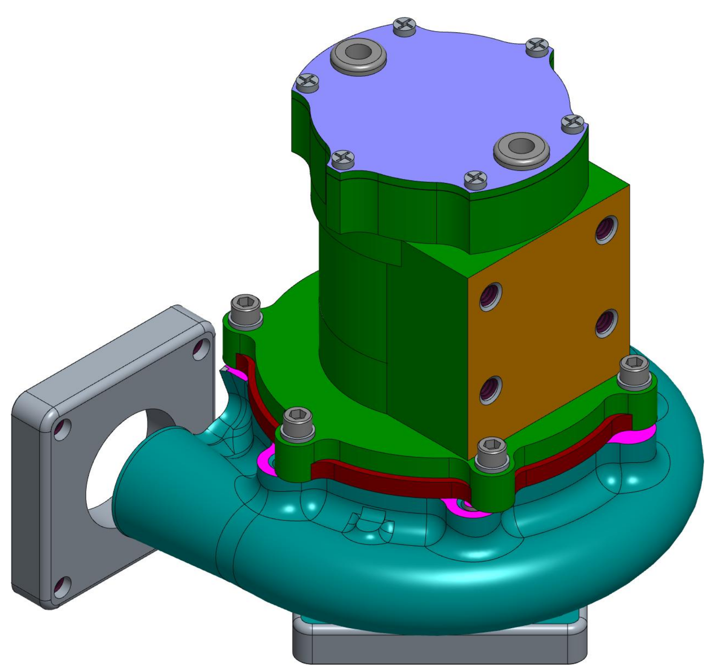
## APPENDIX A - ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| CASEO | Cabin Air Separator for EVA Oxygen |
| CTSD | Crew and Thermal Systems Division |
| Cx | Constellation |
| CxP | Constellation Program |
| DAQ | Data-Acquisition |
| DCS | Decompression Sickness |
| DPA | Destructive Physical Analysis |
| EEE | Electronic, Electrical, and Electromechanical |
| EMU | Extravehicular Mobility Unit |
| EV | Extra-Vehicular |
| EVA | Extravehicular Activity |
| FMEA | Failure Mode and Effects Analysis |
| GOX | Gaseous Oxygen |
| GSE | Ground Support Equipment |
| HED | Hall Effect Device |
| HSIR | Human Systems Integration Requirements |
| ICD | Interface Control Document |
| IFM | In-Flight Maintenance |
| IPAR | Irregular Parts Approval Request |
| IRD | Interface Requirements Document |
| IV | Intra-Vehicular |
| IVA | Intra-Vehicular Activity |
| JPR | JSC Procedural Requirement |
| JSC | Johnson Space Center |
| MDP | Maximum Design Pressure |
| NASA | National Aeronautics and Space Administration |
| NOP | Nominal Operating Pressure |
| NPSL | NASA Parts Selection List |
| NVR | Non-Volatile Residue |
| OML | Outer Mold Line |
| ORU | On-orbit Replacement Unit |
| PGS | Pressure Garment System |
| PIA | Pre-Installation Acceptance |
| PLSS | Primary Life Support System or Portable Life Support System |
| PWM | Pulse Width Modulation |
| RH | Relative Humidity |
| SPL | Sound Pressure Level |
| SSA | Space Suit Assembly |
| SVM | Space Vector Modulation |
| TTL | Transistor-Transistor Logic |
| T&V | Test and Verification |
| TBD | To Be Defined |
| WSTF | White Sands Test Facility |

| REV | ZONE | DESCRIPTION OF CHANGE |
|---|---|---|



REFERENCE VIEW 1



REFERENCE VIEW 2

| PIN | DEFINITION |
|---|---|
| 1 | HED POWER |
| 2 | HED POWER RTN |
| 3 | HED A OUTPUT |
| 4 | HED B OUTPUT |
| 5 | HED C OUTPUT |
| 6 | PHASE A |
| 7 | PHASE B |
| 8 | PHASE C |
| 9 | TEMP SENSOR + |
| 10 | TEMP SENSOR RTN |

FAN CONNECTOR: 805-003-02M9-10PA *WILL BE UPDATED AT FUTURE DATE

8. APPLY SUPER KOROPON EPOXY PRIMER BASE PER NASA/JSC PRC-4004 BEFORE INSTALLING HELICAL COIL INSERTS.

7. INSTALL HELICAL COIL INSERTS PER NASA/JSC PRC-9008 WITH SUPER KOROPON EPOXY PRIMER BASE.

6. FAN MOTOR HARNESS SHOULD HAVE A LENGTH BETWEEN X AND X INCHES.******WILL BE UPDATED

5. FAN MOTOR HOUSING SHOULD BE MADE FROM ALUMINUM TO MINIMIZE WEIGHT AND MAXIMIZE THERMAL CONDUCTIVITY IF POSSIBLE.

4. ITEM PERFORMANCE REQUIREMENTS ARE DEFINED IN CTSD-ADV-1082

3. CLEANLINESS REQUIREMENTS PER JPR 5322.1
   EXTERNAL SURFACES: LEVEL GC
   WETTED SURFACES: LEVEL 150A

2. FABRICATION TOLERANCES AND PRACTICES PER SKZ36103755.

1. INTERPRET PER JPR 8500.4.

NOTES: UNLESS OTHERWISE SPECIFIED

FLAG NOTES

| QTY | CAGE CODE | PART NUMBER | DESCRIPTION | MATERIAL | SPECIFICATION | FRAC CRIT | TRACE CODE | REF DES | ITEM | FLAG NOTES |
|---|---|---|---|---|---|---|---|---|---|---|
| AR | 83574 | 515-700 | SUPER KOROPON EPOXY PRIMER BASE | | | N | TE | | 2 | |
| 12 | 80205 | MS21209C0615L | INSERT, LKG, HELICAL COIL, .138-32 UNC X .207 LG | | | N | TL | | 1 | |
| | 21356 | 301 | PLSS FAN 323/324 | VARIOUS | | N | TS | | | |

UNLESS NOTED OTHERWISE DIM ARE IN INCHES, TOL ARE:
.0 $\pm$ .1 .000 $\pm$ .005
.00 $\pm$ .02 ANGULAR $\pm$ .5°

SURFACE FINISH IN MICROINCHES RMS UNLESS NOTED OTHERWISE ✓

NEXT ASSY

DWG FILENAME SLN13102232.DRW

DRAWING TYPE DEVELOPMENTAL

| SIGNATURES | | DATE |
|---|---|---|
| DR | R. RALSTON | 06/09/17 |
| ENG | R. RALSTON | 06/09/17 |
| CH | J. CASTILLO | 06/09/17 |
| APP | | |
| QE | | |
| MATL | | |
| STRESS | | |
| AUTH | | |

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

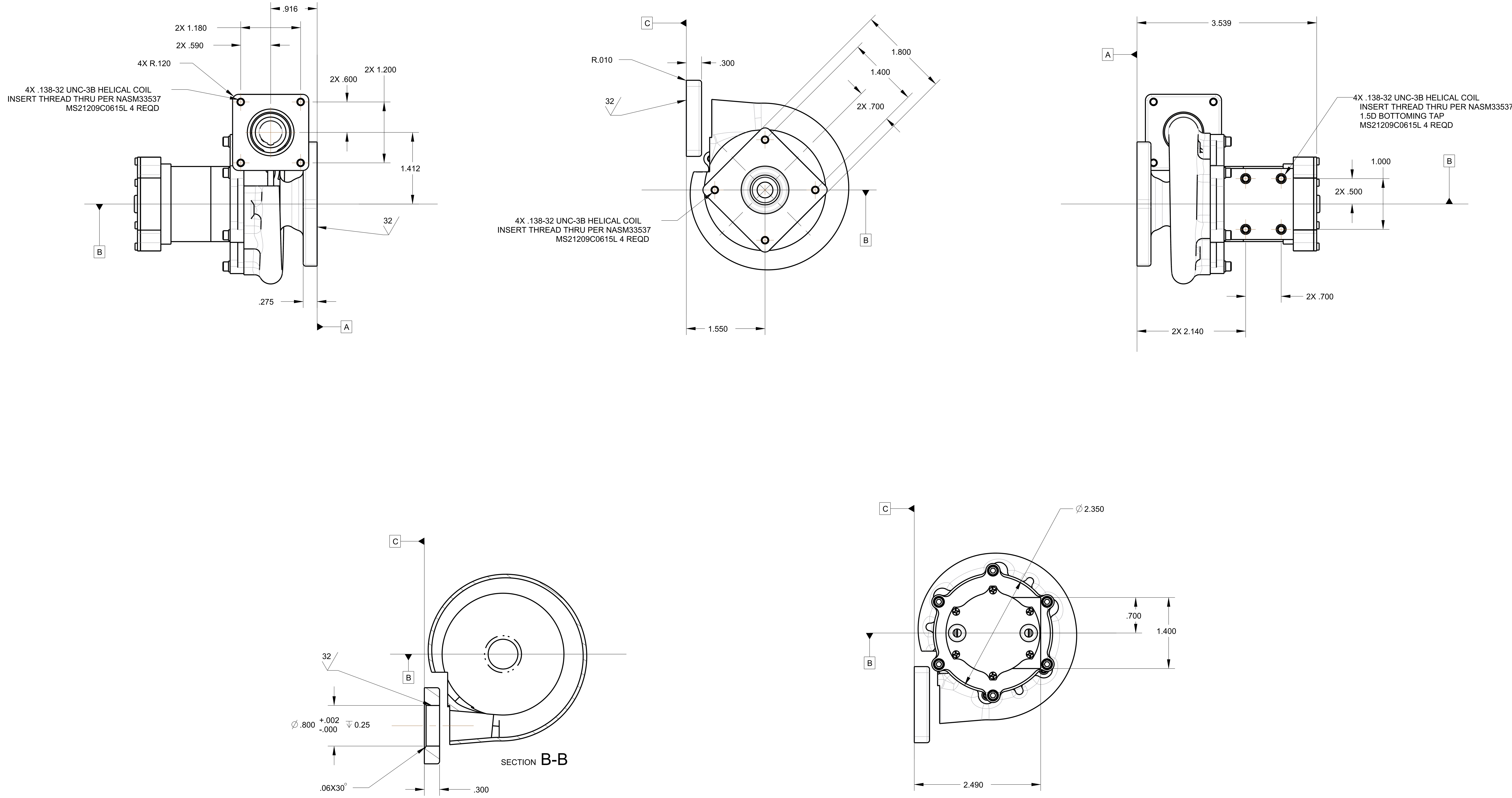
LYNDON B. JOHNSON SPACE CENTER HOUSTON, TEXAS

PLSS FAN 323/324

PROJECT AES ADVANCED EMU

SIZE D CAGE CODE 21356 DWG NO SLN13102232 REV

SCALE 1/1 ORG EC5 FMT P02MAY04 SHEET 1 OF 2




| SIZE | CAGE CODE | DWG NO | REV |
|---|---|---|---|
| D | 21356 | SLN13102232 | |
| SCALE 1/1 | ORG EC-5 | FMT P02MAY04 | SHEET 2 OF 2 |