NAME P/N QTY	CRIT	FAILURE MODE & CAUSES	FAILURE EFFECT	RATIONALE FOR ACCEPTANCE
ARM BEARING ASSEMBLY, ITEM 103 (1) LEFT, (1) RIGHT --- R/L 9657-08 (2) OR DUAL SEAL ARM BEARING ASSEMBLY, ITEM 103 (1) LEFT (1) RIGHT --- Z 10209-02 (2)	1/1	103FM09: External gas leakage beyond SOP makeup capability. CAUSE: P/N 9657: Contamination, wear or deterioration of the separator/ pressure seal. Defective inner/outer races, helicoils, O-rings or clamping ring. Loose or missing clamping ring screws or ball port plug retainer screw. Cracked outer race. P/N 10209-02: Defective inner/outer races, helicoils, o-rings, static seals, clamping ring, loose or missing screws, ball port plug retaining screw. Defective static seals.	END ITEM: Suit gas leakage to ambient. GFE INTERFACE: Depletion of primary O2 supply and SOP. Rapid depressurization of SSA. MISSION: Loss of EVA. CREW/VEHICLE: Loss of crewman.	A. Design - P/N 9657: Contamination is precluded from entering the arm bearing assembly by dual urethane environmental seals, one on each side of the bearing assembly. These seals fit into mating grooves in the inner and outer races and form a seal to preclude introduction of contamination into the pressure seal and ball raceway areas. The separator/pressure seal is made from polyester polyurethane and is lightly lubricated with Krytox grease to preclude wear. The separator seal acts as a ball separator/spacer and a pressure seal. The seal cross section is "Y" shaped and provides a minimum ungressurized seal squeeze of .004 inch. When pressurized, the top of the "Y" expands to seal firmly against the bearing races to ensure a bearing leak of 4.0 SCCM or less and a torque that will not exceed 10 in-lbs. Incidence of loose clamping ring screws in the arm bearing assembly is precluded in design by adherence to standard engineering torque requirements for screw installation. The ball port keeper is prevented from backing out while the arm is pressurized by the bladder fabric restraint which covers this area of the bearing. The Fluorosilicone screw sealing "O" rings are installed on each clamping ring screw to prevent a pressure leakage path around the screw head and threads to the outside of the arm bearing. The "O" ring is protected from damage by a retaining washer, which prevents the clamping ring screw from crushing the "O" ring during screw installation and torquing. Arm bearing races are made from 7075-T73 aluminum alloy. Bearing balls are 440 stainless steel. Stress analysis of the Arm Bearing shows that inner race stresses are higher than the outer race stresses. The worst bending stress occurs when the inner and outer race axial restraint brackets are rotated 90 degrees to each other resulting in a four point loading of the races. The maximum bending stress occurs at the restraints and is 13,000 psi for the inner race resulting in an ultimate strength safety factor of 5.23. The maximum torsional stress occurs at 45

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	1/1	103FM09:		degrees to the restraints and is 13,657 psi, which is an ultimate shear stress safety factor of 3.26. Maximum bolt shear out stress is 4,522 psi resulting in an ultimate shear safety factor of 978. Design requirements for proper installation of the helicoils are specified in the assembly procedures. Analysis, during the screw thread engagement study, showed that axial restraint/clamping ring screws have a minimum thread shear out yield factor of safety of 1.5. P/N 10209: Arm bearing races and clamping rings are made of 17-4 PH stainless steel. Ball bearings are made of 440C stainless steel. Spacer balls are made of Vespel. The bearing races were determined by analysis to have a minimum ultimate strength of 1440 lbs and a yield strength of 1268 lbs. At 4.4 psid (normal operating pressure) the S/AD limit load is 576 lbs. giving the bearing a safety factor of 2.5 for ultimate and 2.2 for yield. At 5.5 psid (max failure pressure) and 8.8 psid (max BTA operating pressure) the bearing provides safety factors for ultimate of 2.5 and 2.4 respectively. The S/AD minimum safety factor for hardware at 4.4 psid is 2.0 for ultimate and 1.5 for yield. At both 5.5 psid and 8.8 psid the S/AD safety factor for hardware is 1.5 for ultimate. A static seal is provided in the inner threaded race for sealing when mated with a sizing ring or fabric attachment ring. The static seal is made of Lord Kinematics compound US7075. The possibilities of loose clamping ring screws in the arm bearing assembly is precluded in design by adherence to standard engineering torque requirements for screw installation. The Fluorosilicone screw sealing "O" rings are installed on each clamping ring screw to prevent a pressure leakage path around the screw head and threads to the outside of the arm bearing. The "O" ring is protected from damage by a retaining washer, which prevents the clamping ring screw from crushing the "O" ring during screw installation and torquing.

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	1/1	103FM09:		Design requirements for proper installation of the helicoils are specified in the assembly procedures. Analysis, during the screw thread engagement study, showed that axial restraint/clamping ring screws have a minimum thread shear out factor of safety of 1.5. B. Test - Acceptance: P/N 9657: The arm bearing is subjected to testing per ATP 9657 at Airlock with ILC source verification. The assembly is pressurized in the test fixture to 8.0 (+0.2 - 0.0) psig for a 5 minute duration and leakage tested to 4.3 +/- 0.1 psig. The assembly is rotated a minimum of twenty complete turns. The torque while in the test fixture, is verified to be a maximum of 10 in-lbs. P/N 10209: The arm bearing is subjected to testing per ATP 10209 at Airlock with ILC source verification. The primary and secondary seals are proof pressure tested with the bearing in the test fixture. The fixture is pressurized to 8.0 (+ 0.2 - 0.0) psig and held for 5 minutes. Following proof pressure testing, the bearing is pressurized to 4.3 +/- 0.1 psig, testing the primary and secondary separately, and subjected to cycle rotation. Leakage is verified to be less than 4. 0 scc/min. Testing both seals separately, torque is verified to be less than 24 in-lbs. POA: The following tests are conducted at the Arm Assembly level in accordance with ILC Document D111-70028J for P/N 9657 and D111-710112 for P/N 10209: 1. Initial leak test at 4.3 +/- 0.1 psig to verify leakage less than 24 scc/min for P/N 9657 and less than 4.0 scc/min for P/N 10209. 2. Proof pressure test at 8.0 + 0.2 - 0.0 psig to verify no structural damage. 3. Post-proof pressure leak test at 4.3 +/- 0.1 psig to verify leakage less than 24 scc/min for P/N 9657 and less than 4.0 scc/min for P/N 10209. 4. Final leak test at 4.3 +/- 0.1 psig to verify leakage less than 24 scc/min for P/N 9657 and less than 4.0 scc/min for P/N 10209.

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	1/1	103FM09:		5. P/N 9657: Arm bearing (in arm assembly) torque to be less than 30 in-lbs. at 4.3 +/- 0.1 psig which is an indication that the separator/pressure seal is acceptable. P/N 10209: Arm bearing (in arm assembly) torque to be less than 24 in-lbs at 4.3 +/- 0.1 psig which is an indication that the pressure seals are acceptable. Certification: P/N 9657: The arm bearing assembly was successfully tested (manned) during SSA certification to duplicate six year (softgoods) and 15YR (hardgoods) operational life. Ref. Cert Test Report for the SSA, ILC Document 0111-70027 and ILC Engineering Memorandum EM 82-1038. The following usage, reflecting requirements of significance to the arm bearing, was documented during certification: Requirement / S/AO (6yr, 15yr) / Actual (6yr, 15yr) / Equiv Life (6yr, 15yr) Pressure Hours: 461, 1153, 612, 1190, 8.0, 15.5 Pressure Cycles: 432, 1080, 436, 1080, 6.1, 15.1 Elbow Flex/Ext.: 43334, 108382, 65618, 124614, 9.1, 17.3 Arm Rotations: 10142, 25366, 15260, 28980, 9.0, 17.1 The arm assembly was successfully subjected to an ultimate pressure of 10.6 psig during SSA certification testing (Ref. Document 0111-70027). This is two times maximum operating pressure based on 5.3 psi. Recertification to 5.5 psi was by test and analysis (ref. ILC EM 84-1100). The arm bearing flange mounting has successfully passed bench pressure cycling, (Ref. ILC EM 82-0184) and bench shock, vibration and acceleration testing without loss of screw torque (Ref. HSD Test Reports TER 3067, 3068, 3063, and 3076). P/N 10209: The dual seal arm bearing successfully passed SSA certification testing (manned) to duplicate 458 hours operational usage (Ref. ILC Report 0111-711330). The following usage, reflecting requirements of significance to

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	1/1	103FN09:		

the arm bearing, was documented during certification:

Requirement	S/AD	Actual	Equiv. Hrs.
Shoulder Rotation	29348	30000*	468.2
Elbow Cycles	49660	102000	940.7
Don/Doff Cycles	98	400	1869
Pressure Hours	458	916	916

* The "Actuals" reflect the stainless steel arm bearing rotations applicable to this failure mode (Ref. ILC Report 0111-711529).

C. Inspection -
Components and material manufactured to ILC requirements at an Approved Supplier are documented from procurement through shipping by the supplier. ILC incoming receiving inspection verifies that the materials received are as identified in the procurement documents, that no damage has occurred during shipment and that supplier certifications have been received which provides traceability information.

The following MIP's are performed during the arm assembly manufacturing process to assure the failure cause is precluded from the fabricated item:
1. Visually inspect the separator/pressure seal for P/N 9657 and pressure seals for P/N 10209 and environmental seals for gouges, nicks, tears, and mold imperfections.
2. Visually inspect the fluorosilicone screw/clamping ring screw sealing "O" rings for gouges, nicks, tears, or degradation.
3. Verification of the presence of screws during torquing of arm bearing clamping ring screws.
4. Verification of presence of ball keeper retainer screw.
5. Helicoil installation is verified during source inspection at the supplier.

During PDA, the following inspection points are performed at the arm assembly level per ILC Document 0111-70028J for P/N 9657 and 0111-710112 for P/N 10209:
1. Inspection for cleanliness to VC level.
2. Visual inspection for damage, wear or material degradation.
3. Visual inspection for damage following proof-pressure test.

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	1/1	103FM09:		

D. Failure History -
P/N 9657:
No history of this failure mode to date. However the following failures have occurred that were within SOP makeup capability:

1. J-EMU-103-A006 (12/12/86) - Separator seal deformed. Manufacturing defects. ECO 861-007 added leak test and 20x inspection prior to delivery of the seal. No certification impact.

2. B-EMU-103-A010 (2/3/87) - Leakage around restraint brackets. Improper assembly tools. Defined proper tools. No cert impact.

3. B-EMU-103-A005 (12/16/86), B-EMU-103-A006 (12/16/86), B-EMU-103-A009 (2/2/87) - Arm bearing separator seal cracks/leakage. ECO 861-0077 adds improved inspection for seal cracks in V location. No certification impact.

4. B-EMU-103-A024 (7/25/90) - Excessive arm bearing leakage from a 0.5 mm diameter void in the sealing surface of the separator seal. The void was caused by contamination or an air bubble in the seal mold during the seal molding process. A photograph of this seal anomaly has been added to the Air-Lock Seal Acceptance Notebook. The existing visual seal inspection at 20X magnification will include this defect as well as the other criteria contained in the A/L Seal Acceptance Notebook.

5. B-EMU-103-A025 (9/12/90) - Excessive arm bearing leakage due to folded over lip of the Y-lip separator seal. During bearing assembly, the seal lip caught on the edge of the ball groove and inverted as the inner race was assembled into the outer race. Leakage was intermittently masked by out-of-configuration urethane environmental seal which lacked vent holes, causing it to act as a pressure seal. VTN-103-32 inspects all field arm bearing environmental seals for vent holes. ECO 901-0815-1 modifies arm bearing assembly procedures to include steps to pivot inner race from beveled side of separator seal when placing races together. Also, seal is inspected to verify proper seating between races after assembly.

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	1/1	103FM09:		6. B-EMU-103-A026 (9/12/91) - The single seal arm eoye bearing exhibited excessive leakage due to gouged environmental and pressure seals caused by use of a metal tool in the assembly process rather than the specified teflon tool. No Corrective Action taken. P/N 10209: None. E. Ground Turnaround - During ground turnaround, in accordance with FEMU-R-001, the arm assembly/bearing is subjected to a visual inspection (pressurized and unpressurized) for structural integrity material damage or degradation loose/missing screws and rough screw heads. Additionally, the arm/arm bearing is subjected to subjective torque evaluation and SEMU and EMU level structural and leakage tests. The assembly is subjected to pre-flight inspection and EMU structural, leakage, and bearing torque verification. Every two years or 56 hours of manned pressurized time for P/N 9657, every 4 years or 229 hours of manned pressurized time for P/N 10209, the arm bearing assembly is disassembled, cleaned, inspected, lubricated and reassembled. The bearing (at arm level) is then subjected to a quantitative torque test and structural and leakage tests. F. Operational Use - Crew Response - Pre EVA/Post EVA: Trouble shoot problem. If no success use 3rd EMU if available. EMU is no go for EVA. EVA: When CWS data confirms loss of suit pressure integrity coupled with an excessive primary O2 use rate, abort EVA. Training - Standard training covers this failure mode. Operational Considerations - Flight rules define go/no go criteria related to EMU pressure integrity and regulation. EVA checklist procedures verify hardware integrity and systems operational status prior to EVA. Real Time Data System allows ground monitoring of EMU systems.