| NAME P/N QTY | CRIT | FAILURE MODE & CAUSES | FAILURE EFFECT | RATIONALE FOR ACCEPTANCE |
|---|---|---|---|---|
| | | 106FM08 | | |
| 4000 BLADDER ASSEMBLY FLOCKED, ITEM 106, (1) LEFT (1) RIGHT<br>---<br>0106-88971-11/12<br>0106-811648-01/02<br>(2)<br><br>OR PHASE VI BLADDER ASSEMBLY ITEM 106 (1) LEFT (1) RIGHT<br>---<br>0106-812537-01/02<br>(2) | 1/1 | External gas leakage beyond SOP makeup capability.<br><br>4000: Defective Material: Puncture or hole in bladder, flange delamination.<br><br>Phase VI: Defective material; puncture or hole in bladder, damaged wrist liner. | END ITEM: Suit gas leakage to ambient.<br><br>GFE INTERFACE: Depletion of primary O2 supply and SOP. Rapid depressurizatio n of the SSA beyond SOP makeup capability.<br><br>MISSION: Abort EVA.<br><br>CREW/VEHICLE: Loss of crewman.<br><br>TIME TO EFFECT /ACTIONS: Seconds.<br><br>TIME AVAILABLE: N/A<br><br>TIME REQUIRED: N/A<br><br>REDUNDANCY SCREENS:<br>A-N/A<br>B-N/A<br>C-N/A | A. Design -<br>4000:<br>The glove bladder is a 5-dip formed assembly with a nominal hand film thickness of .015 inch. It is formed from polyether polyurethane solution which exhibits a minimum tensile strength of 3800 psi and a minimum tear strength of 200 psi. It has excellent abrasion resistance and is unaffected by hydrolysis. (The 4000 bladder is reinforced during the dipping process by the addition of nylon tricot patches to each finger/thumb crotch and by the addition of 3 solution dips to the flange area). The bladder interior is lined with cotton flock attached with a moisture cure polyether polyurethane adhesive. (On the 4000, a reinforced vacuum formed flange is attached to the bladder with a dielectric heat seal). Protection from abrasion is provided by turning all glove restraint seams outward and by terminating all stitching on the restraint exterior. Interior abrasion is reduced by the presence of flock.<br><br>Phase VI:<br>The glove bladder is a dip formed assembly with a nominal hand film thickness of .015 inches and a nominal finger thickness of .012 inches. The flange portion of the glove is integral to the bladder and is reinforced with urethane coated nylon on the finer side of the flange. The reinforcement is provided to preclude screw hole damage during assembly/disassembly. The bladder is formed from polyether polyurethane solution which exhibits a minimum tensile strength of 3800 psi and a minimum tear strength of 200 psi. It has excellent abrasion resistance and is unaffected by hydrolysis. The bladder interior is lined with cotton flock attached with an acrylic moisture adhesive.<br><br>Protection from abrasion is provided by turning glove hand seams outward and by terminating all stitching on the restraint exterior. Interior abrasion is reduced by the presence of flock. Additionally, in the wrist area of the bladder, a teflon liner is provided. The liner extends from the flange to the top gimbal ring. The liner minimizes relative motion against the bladder, thereby providing protection against abrasion.<br><br>B. Test -<br>Component Acceptance Testing:<br>4000/Phase VI:<br>As required by the table of operations governing the stages of fabrication and assembly of the glove, the following tests are conducted:<br><br>1. Physical properties (modulus, ultimate tensile, ultimate elongation and tear strength) for each bladder, pre- and post-flocking, are verified by test of samples fabricated in parallel with the item.<br><br>2. Each bladder, pre- and post-flocked, is bubble leak tested at 10 +/- 1 inch H20 to verify zero bubbles.<br><br>(4000 only):<br>3. Each flocked bladder assembly is bubble leak tested at the flange heat seal at 0.70 psi to verify zero bubbles.<br><br>(4000 only):<br>4. Heat seal samples are tensile tested in the shear and peel mode to verify flange/bladder heat seal acceptability for all assemblies fabricated under a |

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| | | 106FM08 | | common machine set-up. Samples for test are taken in parallel with the fabrication of the first such assembly.<br><br>5. Each glove assembly is leakage/structural/leakage tested during final assembly.<br><br>PDA:<br>(4000/Phase VI):<br>The following tests are conducted at the Glove Assembly level in accordance with ILC Document 0111-70028 (4000 glove) or 011-710112 (Phase VI glove):<br><br>1. Initial leak test at 4.3 +/- 0.1 psig to verify leakage less than 8.0 scc/min.<br>2. Proof pressure test at 8.0 (+ 0.2 - 0.0) psig to verify no structural damage.<br>3. Post-proof pressure leak test at 4.3 +/- 0.1 psig to verify leakage less than 8.0 scc/min.<br>4. Final leak test at 4.3 +/- 0.1 psig to verify leakage less than 8.0 scc/min.<br><br>Certification -<br>4000:<br>The Glove Assembly was successfully tested (manned) during SSA certification to duplicate operational life (Ref. ILC Document 0111-79241).<br><br>The following usage, reflecting requirements of significance to the Bladder Assembly (0106-88971) was documented during certification:<br><br>Requirements (4000) S/AD Actual<br>Glove Joint Cycles<br>Flex/Ext (Fingers) 42412 56726<br>Wrist Joint Cycles<br>Add/Abd 21206 29484<br>Flex/Ext 21206 29484<br>Rotations 21206 29484<br>Pressurized Hours 461 615<br>Pressurized Cycles 432 576<br>Don/Doff 144 192<br><br>The Glove Bladder Assembly (0106-88971) was successfully subjected to an ultimate pressure of 13.2 psig during SSA certification testing (Ref. Document 0111-79241). This is 1.5 times the BTA maximum operating pressure of 8.8 psig. Recertification to 5.5 psi was by test and analysis (Ref. ILC EM 84-1108).<br><br>The following usage, reflecting requirements of significance to the Bladder Assembly (0106-811648), was documented during certification:<br><br>Requirement S/AD Actuals<br>Glove Joint Cycles<br>Flex/Ext 42,412 43,500<br>Wrist Joint Cycles<br>Add/Abd 21,206 22,620 |

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| | | |
|---|---|---|
| Flex/Ext | 21,206 | 22,620 |
| Rotations | 21,206 | 22,620 |
| Pressurized Hours | 461 | 461 |
| Pressurized Cycles | 432 | 437 |
| Don/Doff | 144 | 145 |

The Glove Bladder Assembly (0106-811648) was successfully subjected to an ultimate pressure of 13.2 psig during testing (Ref Document 0111-711671). This is 1.5 times the maximum BTA operating pressure of 8.8 psig.

Phase VI:
The glove restraint assembly was successfully tested (manned) during certification testing to duplicate operational usage (Ref. Certification Test Report for the Phase VI Glove, ILC Doc. 0111-712701). The following usage, reflecting requirements of significance to the glove restraint assembly, was documented during certification testing. The S/AD applies 229 hours in certification while the actual indicates 176 hours toward the Phase VI glove restraint in the Hamilton Sundstrand Limited Life Items list (EMU1-19-001).

| Requirements | S/AD | Actual |
|---|---|---|
| Glove Joint Cycles | | |
| Flex/Ext (fingers) | 45142 | 34834 |
| Wrist Joint Cycles | | |
| Add/Abd | 17104 | 13176 |
| Flex/Ext | 12646 | 9496 |
| Rotations | 20112 | 15421 |
| Pressurized Hours | 229 | 176 |
| Pressurized Cycle @ 4.3 psig | 97 | 99 |
| 5.3 psig | 37 | 63 |
| 6.6 psig | 16 | 18 |
| Don/Doff Cycles | 49 | 49 |

The glove assembly was successfully subjected to an ultimate pressure of 13.2 psig during Certification Testing (Ref. ILC doc 0111-712701). This is 1.5 times the maximum BTA operating pressure based on 8.8 psig.

C. Inspection -
4000/Phase VI:
Component 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 appropriate data have been received which provide traceability information.

The following MIP's are performed during the glove assembly manufacturing process to assure that the failure causes are precluded from the fabricated item:

1. Verification of visual inspection of bladders or convolutes for absence of nicks, tears and holes.
2. An internally illuminated inspection of the bladders while pressurized at 10 +/- 1 inches H20.

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3. Verification of flange seam acceptability test results.

During PDA, the following inspection points are performed at the glove assembly level in accordance with ILC Document 0111-70028 for the 4000 Series gloves and 0111-710112 for the Phase VI gloves:
1. Visual inspection for material degradation.
2. Visual inspection for structural damage after proof-pressure tests.

D. Failure History -
No history of this failure mode to date. However, failures have occurred that were within SOP make-up capability:

4000:
1. I-EMU-106-C014 (10/30/84). Repair patch leaked. Changed repair procedure. Added finger thickness requirement. No certification impact.

2. I-EMU-106-C015 (08/13/85). Bladder leakage caused by abrasion at wrist. Low physical bladders eliminated from use. No certification impact.

3. I-EMU-106-C016 (02/20/86). Tear in bladder caused by abrasion by LPVD. LPVD contacting surfaces have hard sharp radius corners that caused hole in bladder. ECO's 891-0031-1 through -10 remove LPVD from flight configuration and incorporates arm vent ducts terminating above the elbow.

4. J-EMU-106--009 (9-27-85) bladder leakage at flange. Revised heat seal process. No certification impact.

5. B-EMU-106-A018 (8/9/88). Glove leakage due to defects in wrist disconnect pressure seal caused by improperly cleaned mold during manufacturing process. Manufacturing procedures revised.

6. B-EMU-106-A020 (10/13/89). Excessive leakage of left glove bladder due to a pinch in glove bladder external material caused by an unidentified tool during processing and handling. FEMU-R-001 and Maintenance Manual currently provide the proper warnings and cautions when handling or working on the gloves. No corrective action was taken.

7. I-EMU-106--006 (10/13/89). Excessive leakage of left glove assembly due to microscopic cut in glove bladder material caused by an unidentified foreign object which was dragged inside the bladder. FEMU-R-001 and Maintenance Manual currently provide warnings and cautions when handling or working on gloves. In addition, crew members are prohibited from wearing sharp jewelry or having long fingernails when wearing gloves. No corrective action taken.

8. B-EMU-106-A021 (3/22/90). Excessive leakage of left glove due to two cuts in the wrist disconnect bearing pressure seal. Tool used to seat seal during seal installation cut seal resulting in leakage path. ECO 901-0343 revises Maintenance Manual to include a picture of areas not to be contacted during installation of pressure seal.

9. J-EMU-106-F001 (4/18/91) - During post flight inspection of crewman Apt's right 4000 Series Glove (S/N 4063) after STS-37, it was noted that the end of the palm bar had penetrated both the pressure restraint fabric and pressure

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| | | 106FM08 | | bladder. ECO 911-0240 revised 4000 Series Palm Bar Restraint adjustment strap to include two additional stitch rows, one at each end of the bar to preclude palm bar slippage. In addition, the shape of all palm bars will be verified during preflight glove fitchecks and pressurized inspections.<br><br>10. B-EMU-106-A025 (1/6/92), B-EMU-106-A026 (2/13/92) - Delamination of inner and outer disconnect flange-to-bladder heat seal bonds found during 42-hour glove inspection, . Edge delaminations were caused by the lower bond joint strength which occurs at this location because of thinner cross section thickness of material being heat sealed. Bladder inspection criteria revised to allow 1/8 inch maximum delamination on outside heat seal and 1/4 inch maximum on inside heat seal.<br><br>11. B-EMU-106-A027 (2/27/92) - Glove bladder had two small holes at inside of ring finger near first knuckle position caused by scissors used to cut double sided tape used to affix bladder to restraint. ECO 921-0244 revises Maint. Manual and ILC Glove Assembly Procedures to remove all rings and jewelry prior to performing glove work and to use rounded scissors.<br><br>12. B-EMU-106-A037 (08/23/93), B-EMU-106-A038 (09/08/93), B-EMU-106-A039 (10/02/93), B-EMU-106-A040 (03/10/94) - Inspection revealed areas of debonded glove bladder flange overtape due to tack bonds between the castle-shaped extended areas of bladder flange cloth. Castles are formed by cutting out material between them to facilitate forming a round flange with a flat pattern. Cut-out material forms a wedge shaped area that has the potential not to bond correctly during the heat seal hit. Testing shows that the area of overtape directly over the adjacent bladder flange castles provides sufficient bond strength to preclude bladder delamination. No corrective action taken.<br><br>13. B-EMU-106-A044 (5/18/99) -<br>1/2" reinforcement tape debonded on bottom edge inside bladder. Localized debonding is considered minor. Pre-flight visual inspections and leakage tests per FEMU-R-001 exist to identify such anomalies. No corrective action required.<br><br>Phase VI:<br>I-EMU-106-C020 (01/08/99) - Hole in flange area of right glove bladder caused leak test failure. Act: 160 scc/m, Spec: 8.0 scc/m maximum. 3/16 inch long slit-like hole is on a crease approximately 1/8 inch above disconnect on back side. Hole caused by abrasive contact with LCVG tubes and donning loop. Teflon cuff added to LCVG sleeve and a Gore-Tex donning loop replaces stiffer, more abrasive Nylon webbing loop. These two design changes, with the mini vent duct system, reduce bladder abrasion. Ref. CCBD H6924.<br><br>I-EMU-106--008 (5/17/99) -<br>Glove bladder leakage caused by small hole (in abraded area) in bladder. Abrasion and subsequent hole and leakage caused by contact and relative motion between bladder and interfacing components. Per PPDO 99-2.2.3C-110 and CCBD H6954R1, design modified to incorporate double layer Teflon liner in the wrist area of the bladder, add flocking to disconnect, and modify wrist restraint flange attachment.<br><br>I-EMU-106-C021 (1/19/99) -<br>Glove bladder leakage caused by small hole in bladder. Hole located at high |

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| | | 106FM08 | | spot of a wrinkle in the bladder that was secured in position by anchor tape. Comfort glove cuff stitching contacted high spot of wrinkle repetitively, and, combined with relative motion, caused the hole. At subsequent Design Verification Test (DVT) on another glove, anchor tape came loose and re-positioned itself in the same place (approximately 1/2" away from the correct location) capturing a wrinkle and receiving minor abrasion. Procedures modified to change application sequence of anchor tabs to improve bond integrity. Per PPDO 99-2.2.3C-110 and CCBD H6954R1, design modified to incorporate double layer Teflon liner in wrist area of Bladder, add flocking to the disconnect, and modify the wrist restraint flange attachment.<br><br>I-EMU-106-A007 (9/21/99)- Glove unable to hold pressure during final leakage test of glove bladder S/N 028R. Inadequate procedures at ILC Dover to control process of integrating TMG to glove restraint/bladder assembly. ECO 981-0518 revises Enhanced Maint. Manual and ILC's work instructions procedures for glove TMG installation for Phase VI and 4000 series gloves.<br><br>I-EMU-106-C023 (10/7/99) - Right glove leaked at 85 scc/m during daily leak test. Spec: 8.0 scc/m. Root cause is design limitation that prevents bladder from achieving the 25 EVA life requirement. Phase VI glove bladder to be life limited to 176 hours of MPT.<br><br>I-EMU-106-A005 (8/12/99) - Right glove leaked at 400 scc/m (spec: < 8.0 scc/m) during leak test in support of RDR B-EMU-106-A049. Based on appearance of hole, failure believed to be induced. PIR #C0075 issued to request implementation of a FOD awareness program for all personnel.<br><br>B-EMU-106-A054 (3/30/00) - A crease approx. 5/8" long found in bladder material (backhand side) along heat-sealed seam during STS-101 glove bladder assemblies inspection. Failure tracked by B-EMU-106-A053.<br><br>I-EMU-106--009 (9/21/99) - Left glove bladder S/N 052 leaked at 14 sccm (spec: 8 sccm max) during manufacturing leak check. Root cause was inadequate prove-out of tooling/process before use. ECO 992-0217-56 revises tools and processes to ensure Teflon liner installation procedure is adequate.<br><br>B-EMU-106-A053 (3/8/00) - Crease approximately .5 inches long found during inspection of pressure bladder. Bladder material extruded during initial hits by heat seal machine, folded over and was subsequently sealed down. Folded over material lifted from surface of extrusion giving false impression of a surface indentation. Explained closed for all missions. All 4000 series gloves made prior to 1997 to be screened per YTN. Not necessary for gloves made after 5/97, when ILC incorporated this inspection.<br><br>J-EMU-106-T001 (4/7/00) - Hole in bladder (palm side) found during NBL pre-use inspection. Accelerated bladder abrasion caused by relative motion and load experienced during NBL testing. Conditions do not occur in flight or chamber operations. Design acceptable for flight (up to 176 MPT).<br><br>J-EMU-106-T002 (7/20/00) - Hole found in convolute during 40-hour inspection of class IIIW glove. Tracked by J-EMU-106-T001.<br><br>I-EMU-106--011 (2/23/01) During inspection, a crease was noted in bladder near |

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| | | 106FM08 | | flange on thumb side. Portion of bladder thumb convolute captured under restraint flange due to improper assembly. Work instructions and maintenance manual updated.<br><br>J-EMU-106--020 (2/15/01) Following SESL run, all finger heater elements on left glove found bonded to restraint fingernail reinforcements. Overheating of glove bladder due to excessive power at fingertip heaters. In-line Cable Voltage Regulator (ILCVR) implemented to reduce max voltage to heaters.<br><br>E. Ground Turnaround -<br>4000/Phase VI:<br>Tested per FEMU-R-001, Pre-Flight leakage test. Every 56 hours of manned pressurized time (for the 4000 Series glove) the bladder assembly is removed from the restraint (to the fingertips) and visually inspected for structural integrity, material damage or degradation.<br><br>F. Operational Use -<br>4000/Phase VI:<br>1. Crew Response<br>Pre/Post EVA: If during airlock operations, repress airlock. Consider use of backup gloves.<br>EVA : When CWS data confirms SOP activation, abort EVA.<br>2. Special Training<br>Standard training covers this failure mode.<br>3. Operational Considerations -<br>Flight rule A15.1.2-2 of "Space Shuttle Operational Flight Rules", NSTS-12820 defines go/no go criteria related to EMU pressure integrity. Generic EVA Checklist, JSC-48023, procedures Section 3 (EMU Checkout) and 4 (EVA prep) verify hardware integrity and systems operational status prior to EVA. Real Time Data System allows ground monitoring of EMU systems. |

EXTRAVEHICULAR MOBILITY UNIT

SYSTEMS SAFETY REVIEW PANEL REVIEW

FOR THE

I-106 GLOVE ASSEMBLY

CRITICAL ITEM LIST (CIL)

EMU CONTRACT NO. NAS 9-97150

Prepared by: _____
HS - Project Engineering

_____
HS - Reliability

_____
HS - Engineering Manager

Approved by: _____
NASA – SSA/SSM

_____
NASA – EMU/SSM

_____
NASA – S&MA

_____
NASA – MOD

_____
NASA – Crew

_____
NASA – Program Manager