NAME P/N QTY	CRIT	FAILURE MODE & CAUSES	FAILURE EFFECT	RATIONALE FOR ACCEPTANCE
		490FM04		
BATTERY, ITEM 490 ---------- SV767789-12 (1) OR BATTERY, ITEM 490 ---------- SV819600-01 (1)	2/1RA	External leakage, battery electrolyte. Failure, relief valve adapter seal, poor bond joint.	END ITEM: Electrolyte water sublimation to space. GFE INTERFACE: Loss of one battery cell. Loss of battery voltage output. MISSION: Terminate EVA. Loss of use of one EMU. CREW/VEHICLE: None for single failure. Possible loss of crewman with loss of SOP. TIME TO EFFECT /ACTIONS: Seconds. If EVA, and battery fails, turn off the battery by switching to the SCU power and open the purge valve to activate the SOP. Terminate EVA. TIME AVAILABLE: Minutes. TIME REQUIRED: Seconds. REDUNDANCY SCREENS: A-FAIL	A. Design - P/N SV767789-12 Housing 0-ring design dimensions and rigidness of assembly provide squeeze under all load conditions. The 0-ring material is ethylene propylene rubber. During normal operation, the fluid temperature and pressure are not extreme (potassium hydroxide or hydrogen at 40 psid and 35 deg. F to 120 deg. F). Rabbet-Type bonded joint used on cell caps, rest of the cell is one-piece molded construction. The cell covers and monoblocks are cleaned with I.P.A. and bonded with EC-3569 cement per Yardney procedure WIP-258. Absorbent Nomex pads (wicks) are installed alongside each relief valve and over the relief valves which will absorb leaking electrolyte. P/N SV819600-00 The Enhanced Battery consists of 11 cells of polysulfone bonded together with EA 9360. The cells are two pieces: a five-sided polysulfone box and a glass-filled polysulfone top ultrasonically welded together. AMS 5643 or AMS 5604 steel reinforcing plates are bonded onto each end. The cells are installed in a battery case made of 6061 aluminum, and potted on five sides and the buss bar surface. The battery is designed for a maximum operating pressure of 40 psig, a proof pressure of 60 psig, and a burst pressure of 80 psig. The minimum structural factor of safety of the battery is the bending stress at the hinge plate webbing from the external airlock launch loads. It is a yield strength factor of safety of 1.5. The cell top to box weld joint has a 3.76 yield strength factor of safety against bending stress at 60 psid proof pressure. B. Test - Component Acceptance Test - The relief valve assembly is leakage tested per AT-E-490RV for P/N SV767789-12 and per AT-E-490RV-1 for P/N SV819600-00. The valve is fixtured so that any leakage will enter a vent tube, which has its end under water. The valve is pressurized with nitrogen at 9 - 16.5 PSIG for P/N SV767789-12 and at 29.5 +/- 0.5 psig for P/N SV819600-00. The end of the vent tube is observed. Leakage is defined as any bubbles escaping from the vent tube within a five-minute period. The battery is leakage tested per AT-EMU-490 for P/N SV767789-12 and per AT-EMU-490-1 for P/N SV819600-00. All the cells are pressurized with 40.0 +/- 1.0 psig of nitrogen. A leak detecting solution is used to check for leaks around the vent ports of the battery. The individual cells are leakage and proof pressure tested per SVHS 7820. The cells are completely submerged in water and pressurized, by nitrogen through the activating plug, to 60 psid. There shall be no bubbles in five-minutes and no permanent deformation. Certification Test - P/N SV767789-12 The item completed the 15 year structural vibration and shock certification requirement during 10/83. P/N SV819600-00 The item completed structural vibration and shock requirement by test during 9/98. The item has completed all certification requirements. C. Inspection -

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			B-PASS C-PASS	The o-seals that seal the relief valves to the battery are inspected for dimensional requirements and surface defects per 1.5% AQL sampling. (1.5 AQL reduces to a lot sample size of 12 pieces for 12 to 90 pieces with no defects allowed and a lot sample size of 18 pieces for lot sizes of 91 to 280 pieces with no defects. In actual practice there are always defects, so the o-seals are 100% inspected). P/N SV767789-12 The vendor (Yardney Corporation) does a visual verification that each cell cover is properly cleaned with IPA per Yardney procedure WIP-258 and sealed all around the case lip and that there is a continuous run of EC-3569 cement with no excess buildups or voids. P/N SV819600-00 The vendor (BST) does a visual verification that each cell cover is welded to the cell body per their internal ultrasonic welding procedure, and has a sealant is applied along the entire weld joint. D. Failure History - P/N SV767789-12 H-EMU-490-A002 (10-10-83) External leakage caused by scratch on sealing surface between the cell and relief valve. No corrective action taken, considered isolated case, caught during acceptance. J-EMU-490-004 (1-22-85) External leakage caused by loads imparted to battery by test fixture. Fixtures were reworked and in-house test procedures revised to include "Leak-Tek" to detect any external leaks around the vent ports on the top side of the battery. During the test the battery is pressurized to 49-51 psig and is visually examined for bubbles in the "Leak Tek" solution. Bubbles indicates leakage. After this revision, the order of testing is: weight, proof pressure, external leakage, internal leakage, continuity and insulation resistance. B-EMU-490-A001 (7-16-88) External leakage from the first cell at the connector end of the battery prior to activation. No failure analysis per NASA direction. No Corrective action. B-EMU-490-A007 (3/23/90) Pressure Relief Valve broken during installation of side wicking due to excessive force applied to the relief valve during wick installation between the relief valve channel and the relief valves. EC 163402-430 and CCBD G6180 allow technicians to cut the wick, so as to aide in the placement of wicks around relief valves that tend to be near the relief valve channel wall. This action will remove the need to apply force to wick and relief valves. B-EMU-490-A004 (12/29/89) and B-EMU-490-A008 (3/12/90) - Unactivated battery S/N 1131 exhibited external leakage at the bond joint between cell cover and monoblock case caused by inadequate bond joint (EC2216) strength. A stronger bond material/procedure, EC 3569, has been implemented by EC 163402-592. In addition, battery pressure cycles for proof/pressure at the vendor, PDA at Hamilton Standard and formation procedures, as well as maximum pressure limits have all been lowered to reduce the potential for damage to the bond joint between cell cover and monoblock cases. Also, EC 163402-430 incorporates an improved wicking/tape configuration to improve electrolyte containment.

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B-EMU-490-A010 (5/21/91), B-EMU-490-A011 (5/22/91) - Two Relief Valves each on both battery S/N 1170 and battery S/N 1172 decomposed when exposed to electrolyte (kOH) due to the use of incorrect housing material (Lexan instead of Noryl). Screening tests for the proper material, Noryl, have been added to the manufacturing process at the vendor.

H-EMU-490-A004 (9/9/92) - Battery S/N 1214 exhibited external leakage while pressurized to 40.0 PSIG. Investigation revealed a crack in the cell cover initiating at the relief valve threads and continuing laterally across the cover. Per customer concurrence, no corrective action was taken.

B-EMU-490-A013 (4/12/93), B-EMU-490-A014 (6/14/93), B-EMU-490-A015 (6/28/93), B-EMU-490-A016 (6/28/93), B-EMU-490-A019 (7/2/93) and B-EMU-490-A020 (7/15/93) - External battery leakage in battery S/Ns 1200, 1205, 1228, 1229, 1202 and 1203, respectively, caused by inadequate bonds between the battery case and cover due to silicone contamination of the monoblock case. Yardney op sheets have been updated to include an improved cleaning procedure which adds an IPA flush, IPA wipe and a final IPA flush within 1 hour of bonding. Analysis of these procedures shows all evidence of silicone has been removed.

H-EMU-490-A005 (8/6/93) - During Acceptance Proof Pressure testing at Yardney, six monoblocks bonded with EC2216 Epoxy exhibited leakage (spec: No bubbles in 5 minutes under water at 60 psig; Actual: leakage noted by excessive bubbles along the outside, long cell wall). Leakage was due to an improper test fixture set-up which failed to support the case-to-cover bond area adequately during proof pressure testing. Yardney Proof Test Procedure, TM-1033 has been revised to provide proper test fixture support during proof.

H-EMU-490-A006 (9/9/93) - Battery S/N 1265 leaked during 40 psig External Leakage Test due to cracks in cell covers. Cracks were caused by thermal stresses during cure of the potting that seals the terminals in the covers. Cure temperature for cover potting has been reduced from 200 to 175 degrees to preclude excessive thermal stresses.

B-EMU-490-A026 (07/15/97) - During post formation charge leakage test using Battery Backfill Adapters (BBA), bubbles were noticed in the fill port area. Most probable cause was contamination between sealing surfaces. Field procedures will add a step to verify seal area cleanliness prior to BBA installation.

P/N SV819600-00
H-EMU-490-C028 (7/31/98) -
External electrolyte leak in battery cell during cert testing. Leakage was caused by cracks in the cell cases. Cell cases are annealed with a cover in place, however, covers are removed after annealing and the same cover is not necessarily used during final assembly. Slight variations in the fit of a different cover (after annealing) will reintroduce stresses into the case. Assembly process has been revised to ensure that cell cases and covers are processed as a matched set from the annealing process on. Also, EC 182135-259 changes the cell case design to remove the molded in spacers to eliminate a stress riser. The external edge radius of the case has been decreased to provide for better load sharing in the cells. All cell assembly and test

NAME P/N QTY	CRIT	FAILURE MODE & CAUSES	FAILURE EFFECT	RATIONALE FOR ACCEPTANCE
		490FM04		fixturing redesigned. B-EMU-490-F001 (7/13/01) Increased capacity battery (ICB) leaked KOH on orbit and contaminated various EMU components and softgoods. Investigation found that this battery was stored inverted on the Pad and leaked before launch when battery relief valves opened on high internal pressure. USA formation ICB batteries showed higher internal pressure generation than BST's resulting in higher amount of free KOH. Standpipe was not designed to withstand higher than normal excess amount of KOH. Redesign of ICB cells to provide higher KOH retention capability and USA ICB formation procedures were updated to align HS/ BST procedure. B-EMU-490-F002 (3/16/02) EMU increased capacity battery (ICB) exhibited KOH leakage in the vent hole during post flight processing. This condition was caused by battery inversion in 1 or more G for extensive period of time (approx 5 days) when the battery relief valve was cracked open as internal pressure was high enough. The investigation for RC and CA was tracked by similar failure B-EMU-490-F001. E. Ground Turnaround - None. Testing would be invasive. Wicking material and tape covering the relief valve area prevents inspection of the joint between flights. F. Operational Use - Crew Response - PreEVA/PostEVA: Swap out EMU battery. EVA: When loss of battery power detected, terminate EVA to standby on SCU. Training - Standard EMU training covers this failure mode. Operational Considerations - Flight rule A15.1.2-2 of "Space Shuttle Operational Flight Rules", NSTS-12820 defines go/no go criteria related to EMU battery. 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-490 BATTERY

CRITICAL ITEM LIST (CIL)

EMU CONTRACT NO. NAS 9-97150

Prepared by: _____
HS - Project Engineering

_____
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_____
HS - Engineering Manager

Approved by: _____ 5/24/02
NASA ~~SFA~~/SSM
ES5

_____ 5/21/02
NASA ~~EMU~~/SSM

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NASA ~~S & MA~~

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NASA ~~Crew~~

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NASA ~~Program~~ Manager