

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE**

NUMBER: 03-1-0302 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 2 08/02/00

**PART DATA**

	<b>PART NAME</b>	<b>PART NUMBER</b>
	<b>VENDOR NAME</b>	<b>VENDOR NUMBER</b>
LRU	: LH2 OUTBOARD 8" FILL/DRAIN VALVE UNITED SPACE ALLIANCE - NSLD	MC284-0397-0031 74328000-159

**EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:**

LH2 OUTBOARD FILL VALVE, 8 INCH. PNEUMATICALLY OPERATED, INCLUDES A RELIEF VALVE.

VALVE WAS ORIGINALLY DESIGNED AND MANUFACTURED BY FAIRCHILD CONTROLS BUT IS NOW MANUFACTURED BY UNITED SPACE ALLIANCE-NSLD AS AN ALTERNATE PRODUCTION AGENCY.

REFERENCE DESIGNATORS: PV11

QUANTITY OF LIKE ITEMS: 1

**FUNCTION:**

PROVIDES A MEANS OF LOADING AND DRAINING THE ET THROUGH THE PROPELLANT FEED SYSTEM. THE OUTBOARD VALVE PREVENTS OVERBOARD LOSS OF PROPELLANT DUE TO LEAKAGE FROM THE LH2 INBOARD FILL & DRAIN VALVE (PV12) AND/OR THE LH2 TOPPING VALVE (PV13). THE VALVE IS MOUNTED ON THE FILL AND DRAIN DISCONNECT AND REMAINS OPEN FROM START OF LOADING OPERATIONS TO COMPLETION OF TSM DRAIN (APPROXIMATELY T - 48 SEC). BOTH THE INBOARD AND OUTBOARD VALVES REMAIN CLOSED DURING ENGINE OPERATION. POST MECO, THE VALVES ARE OPENED BY SOFTWARE COMMAND TO DUMP LH2. THE OUTBOARD VALVE IS SUBSEQUENTLY OPENED BY SOFTWARE TO VENT LH2 RESIDUALS DURING THE FIRST VACUUM INERT. THE OUTBOARD VALVE IS ADDITIONALLY OPENED MANUALLY DURING THE SECOND VACUUM INERT. (EFFECTIVE FOR OI-29 AND SUBS, THE FILL/DRAIN VALVES WILL NO LONGER BE USED FOR VACUUM INERTS. VACUUM INERT WILL BE ACCOMPLISHED VIA THE RTLS DUMP VALVES, PV17 & PV18). THE OUTBOARD VALVE IS CLOSED PRIOR TO ENTRY FOR MANIFOLD REPRESSURIZATION. INCORPORATES AN ANTI-SLAM MECHANISM TO PREVENT SLAMMING DAMAGE DURING IMPROPER VALVE OPEN/CLOSE OPERATIONS. THE VALVE ALSO INCORPORATES A RELIEF VALVE, RELIEVING INTO THE FILL LINE.

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**CRITICALITY OF THIS**

**ITEM NAME: LH2 OUTBOARD 8" FILL/DRAIN VALVE (PV11)**

**FAILURE MODE: 1R2**

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**FAILURE MODE:**

RUPTURE/LEAKAGE OF THE ACTUATOR DURING ASCENT AND DUMP/INERT.

**MISSION PHASE: LO LIFT-OFF**

<b>VEHICLE/PAYLOAD/KIT EFFECTIVITY:</b>	102	COLUMBIA
	103	DISCOVERY
	104	ATLANTIS
	105	ENDEAVOUR

**CAUSE:**

FATIGUE, MATERIAL DEFECT, DAMAGE/DEFECTIVE ACTUATOR SEALS

**CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO**

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**REDUNDANCY SCREEN**

- A) PASS
- B) PASS
- C) PASS

**PASS/FAIL RATIONALE:**

A)

B)

PASSES B SCREEN BECAUSE LEAKAGE IS DETECTABLE BY MONITORING HELIUM SUPPLY PRESSURE MEASUREMENTS.

C)

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**- FAILURE EFFECTS -**

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**(A) SUBSYSTEM:**

COULD RESULT IN THE INABILITY TO OPEN OR CLOSE FILL & DRAIN VALVE. ACTUATOR IS LOCATED ON HELIUM PNEUMATIC LEG UPSTREAM OF CHECK VALVE CV9 (NON ACCUMULATOR LEG). RESULTS IN DEPLETION OF VALVE ACTUATION SUPPLY PRESSURE. HELIUM STORED DOWNSTREAM OF CV9 IS SUFFICIENT TO CLOSE LO2 PREVALVES AT MECO. LEAKAGE MAY BE DETECTABLE ON GROUND USING HAZARDOUS GAS DETECTION SYSTEM (HGDS). ALSO WILL RESULT IN LOSS OF THE AFT COMPARTMENT PURGE. LOSS

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OF AFT COMPARTMENT PURGE IS NOT CRITICAL FOR A NOMINAL LH2 DUMP DURING RTLS/TAL.

**(B) INTERFACING SUBSYSTEM(S):**

SAME AS A.

**(C) MISSION:**

ON GROUND, POSSIBLE VIOLATION OF HGDS LCC WILL RESULT IN LAUNCH SCRUB. LOSS OF GHE SUPPLY HAS NO EFFECT FOR NOMINAL, AOA OR ATO MISSIONS (RESULTS IN POSSIBLE PROPELLANT SYSTEM CONTAMINATION DURING ENTRY).

**(D) CREW, VEHICLE, AND ELEMENT(S):**

SAME AS A.

**(E) FUNCTIONAL CRITICALITY EFFECTS:**

1R/2, 2 SUCCESS PATHS. TIME FRAME - ASCENT.

- 1) FILL AND DRAIN VALVE ACTUATOR RUPTURES.
- 2) CHECK VALVE (CV9) FAILS TO REMAIN CLOSED.

RESULTS IN INABILITY TO CLOSE LO2 PREVALVES AT MECO. THIS RESULTS IN FAILURE TO MAINTAIN INJECTED GHE AND LO2 PRESSURE AT THE SSME PUMP, RESULTING IN POSSIBLE PUMP OVERSPEED AND EXPLOSION. POSSIBLE AFT COMPARTMENT OVERPRESSURIZATION AND FIRE/EXPLOSION HAZARD. ENGINE PURGE HELIUM RESIDUALS ARE TRANSFERRED TO VALVE ACTUATION SUPPLY AT MECO BY SOFTWARE COMMAND, WHICH MAY ACTUATE LO2 PREVALVES CLOSED. POSSIBLE LOSS OF CREW/VEHICLE.

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**-DISPOSITION RATIONALE-**

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**(A) DESIGN:**

FACTORS OF SAFETY ARE 1.5 PROOF AND 2.0 BURST. THE ACTUATOR IS DESIGNED FOR 5000 CYCLES AND WAS TESTED DURING CERTIFICATION TO MORE THAN THAT NUMBER. SUBSEQUENT TO THE LIFE CYCLING THE ACTUATOR WAS BURST TESTED AT 1700 PSIG (MAXIMUM OPERATING PRESSURE IS 850 PSIG) WITHOUT EVIDENCE OF DAMAGE, DEFORMATION OR LEAKAGE.

STRUCTURAL ANALYSIS, PERFORMED BY THE VALVE SUPPLIER, INDICATES POSITIVE MARGINS OF SAFETY FOR ALL CONDITIONS OF ACTUATOR OPERATION, AND FRACTURE ANALYSES SHOW THAT ALL CRITICAL PARTS ARE SATISFACTORY FOR FOUR TIMES THE ORBITER LIFE OF 100 MISSIONS.

POTENTIAL ACTUATOR LEAK PATHS:

- JOINT AT EACH OF THE ANTI-SLAM VALVES

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- AT THE HOUSING/END CAP INTERFACE
- AT THE ACTUATOR SHAFT SEALS
- AT THE ACTUATOR SHAFT SEAL RETAINER COVER
- AT THE CYLINDER/HOUSING INTERFACE

STATIC LEAK PATHS ARE SEALED USING TEFLON JACKETED METALLIC RACO TYPE SEALS. THE METALLIC "V" SPRING IS MADE OF 301 CRES. THE SHAFT SEALS ARE A SPRING LOADED, FLANGED TYPE DESIGN. THE SEAL MATERIAL IS RULON, THE SPRING IS 300 SERIES CRES.

**(B) TEST:**

ATP

ANTI-SLAM VALVES (BEFORE ASSEMBLY INTO THE ACTUATOR) - EXAMINATION OF PRODUCT; AMBIENT PROOF (1275 PSIG); AMBIENT AND CRYO FLOW; AMBIENT AND CRYO CRACKING PRESSURE; POST TEST EXAMINATION.

ACTUATOR (BEFORE ASSEMBLY ONTO THE FILL AND DRAIN VALVE) - EXAMINATION OF PRODUCT; POSITION INDICATION; AMBIENT PROOF (1275); ELECTRICAL CHARACTERISTICS; AMBIENT EXTERNAL LEAKAGE.

RELIEF VALVE ASSEMBLY (BEFORE INSTALLATION INTO THE FILL AND DRAIN VALVE) - EXAMINATION OF THE PRODUCT; AMBIENT PROOF (340 PSIG); AMBIENT AND CRYO CRACK/RESEAT (15-50 PSID) AND INTERNAL LEAKAGE; POST TEST EXAMINATION.

FILL AND DRAIN VALVE ASSEMBLY -

EXAMINATION OF PRODUCT

ELECTRICAL BONDING

AMBIENT AND CRYO PROOF WITH VALVE OPEN AND CLOSED - 143 PSIG

AMBIENT AND CRYO EXTERNAL LEAKAGE OF VALVE BODY (110 PSIG)

CRYO EXTERNAL LEAKAGE OF ACTUATOR (740 PSIG)

AMBIENT AND CRYO RESPONSE TIME (NORMAL AT 400 AND 740 PSIG ACTUATOR PRESSURE, AND SLAM AT 740 PSIG)

AMBIENT AND CRYO ACTUATOR LEAKAGE FROM PORT TO PORT

AMBIENT AND CRYO VALVE SHAFT SEAL (PRIMARY AND SECONDARY) LEAKAGE WITH 110 PSID ACROSS THE SEAL

AMBIENT AND CRYO VALVE INTERNAL LEAKAGE (INLET-TO-OUTLET WITH 15 PSID, OUTLET-TO-INLET WITH 110 PSID)

AMBIENT AND CRYO RELIEF VALVE CRACK AND RESEAT (15 TO 50 PSID)

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POST TEST EXAMINATION

CERTIFICATION

STRUCTURAL LOAD AT CRYO TEMPS (-400 DEG F) (AXIAL, SHEAR, TORSION, BENDING) WITH THE VALVE IN TENSION, PERFORM VALVE RESPONSE TIME (NOMINAL AND SLAM) ACTUATOR INTERNAL LEAKAGE, PRIMARY AND SECONDARY SHAFT SEAL LEAKAGE, INTERNAL LEAKAGE (OUTLET-TO-INLET AND INLET-TO-OUTLET), CRACK AND RESEAT, AND, EXTERNAL LEAKAGE (BODY AND ACTUATOR) TESTS. REPEAT WITH THE VALVE IN COMPRESSION.

VALVE LIFE CYCLING:

2400 AMBIENT TEMPERATURE CYCLES WITH 5 PSIG INTERNAL PRESSURE (525 NORMAL CYCLES AND 1875 SLAM CYCLES)

100 AMBIENT CYCLES (50 NORMAL AND 50 SLAM CYCLES) WITH VALVE INLET VENTED TO ATMOSPHERE AND VALVE OUTLET CONNECTED TO A 4 CUBIC FOOT VOLUME PRESSURIZED TO 110 PSIG WITH GN2

2400 CRYO TEMPERATURE (-400 DEG F) CYCLES WITH 50 - 60 PSIG INTERNAL PRESSURE (1775 NORMAL CYCLES AND 625 SLAM CYCLES)

100 NORMAL CRYO CYCLES WITH THE VALVE INLET VENTED TO ATMOSPHERE AND THE OUTLET PRESSURIZED TO 110 PSIG.

FOR THE FOREGOING LIFE TEST, PRIOR TO AND EVERY 100 CYCLES THEREAFTER, ACTUATOR INTERNAL LEAKAGE, PRIMARY AND SECONDARY SHAFT SEAL LEAKAGE, AND VALVE INTERNAL LEAKAGE (OUTLET-TO-INLET) TESTS WERE PERFORMED.

RELIEF VALVE LIFE CYCLING:

2500 CYCLES AT CRYO (-400 DEG F) TEMP, 2500 CYCLES AT AMBIENT.

FOLLOWING EACH 500 CYCLES PERFORM FILL AND DRAIN VALVE INTERNAL LEAKAGE (OUTLET-TO-INLET AND INLET-TO-OUTLET), AND CRACK/RESEAT TESTS.

POST CYCLE EXAMINATION.

VIBRATION:

PRE-VIBRATION TESTS - VALVE RESPONSE TIME (NORMAL AND SLAM), ACTUATOR INTERNAL LEAKAGE, PRIMARY AND SECONDARY SHAFT SEAL LEAKAGE, INTERNAL LEAKAGE (OUTLET-TO-INLET AND INLET-TO-OUTLET), CRACK AND RESEAT, AND EXTERNAL LEAKAGE (BODY AND ACTUATOR).

TRANSIENT SINUSOIDAL VIBRATION -  
(AT 110 PSIG AND -250 DEG F) IN EACH AXIS

RANDOM VIBRATION TESTS -

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13.3 HRS IN EACH OF THREE AXES WITH VALVE CLOSED AND AT -250 DEG F MAXIMUM. HALF OF THE TIME THE VALVE INTERNAL PRESSURE IS 110 PSIG; THE OTHER HALF AT 5 PSIG. ONCE EACH HOUR, CLOSING PRESSURE IS REMOVED FROM THE ACTUATOR. ALSO BOTH CLOSING AND OPENING PRESSURES ARE APPLIED CONCURRENTLY TO THE ACTUATOR. IN BOTH CASES THE VALVE REMAINS CLOSED.

DESIGN SHOCK: 18 SHOCKS OF 15G EACH - THREE IN EACH DIRECTION ALONG EACH OF THREE AXES, ALL WITH VALVE OPEN AND ACTUATOR VENTED

DESIGN SHOCK POST TEST:

AMBIENT - VALVE RESPONSE, INTERNAL AND EXTERNAL LEAKAGES. CRYO - VALVE RESPONSE, INTERNAL AND EXTERNAL LEAKAGES. ELECTRICAL CHARACTERISTICS; POSITION INDICATION.

BURST: 165 PSIG VALVE OPEN 165 PSIG ON OUTLET OF CLOSED VALVE, 1700 PSIG ACTUATOR

GROUND TURNAROUND TEST

ANY TURNAROUND CHECKOUT IS ACCOMPLISHED IN ACCORDANCE WITH OMRSD.

**(C) INSPECTION:**

RECEIVING INSPECTION

RAW MATERIALS ARE VERIFIED BY INSPECTION FOR MATERIAL AND PROCESS CERTIFICATION. BODY HOUSING FORGING IS ULTRASONICALLY AND PENETRANT INSPECTED.

CONTAMINATION CONTROL

PARTS ARE VERIFIED CLEAN TO LEVEL 400. THE ACTUATOR IS CLEANED TO 400A.

ASSEMBLY/INSTALLATION

ALL PARTS ARE PROTECTED FROM DAMAGE AND CONTAMINATION. LOG OF CLEAN ROOM AND TOOL CALIBRATION ARE VERIFIED BY INSPECTION. ALL SURFACES REQUIRING CORROSION PROTECTION ARE VERIFIED. VISUAL (3X TO 7X) AND DIMENSIONAL INSPECTION OF VALVE BODY AND COMPONENTS ARE VERIFIED DURING ASSEMBLY. THREADED FASTENER TORQUES ARE VERIFIED BY INSPECTION. MANDATORY INSPECTION POINTS ARE INCLUDED IN THE ASSEMBLY PROCEDURE.

CRITICAL PROCESSES

HEAT TREATMENT AND DRY FILM LUBE APPLICATION ARE VERIFIED BY INSPECTION.

NON DESTRUCTIVE EVALUATION

VALVE BODY, PRIOR TO FINAL MACHINING, IS SUBJECTED TO DYE PENETRANT INSPECTION. REQUIREMENTS FOR DETAIL PARTS PENETRANT INSPECTION ARE BASED UPON CONFIGURATION, MATERIAL, AND MANUFACTURING PROCESSES.

TESTING

ACCEPTANCE TEST VERIFIED BY INSPECTION.

HANDLING/PACKAGING

PACKAGING FOR SHIPMENT VERIFIED BY INSPECTION.

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**(D) FAILURE HISTORY:**

MINOR LEAKS HAVE OCCURRED AT KSC, MPTA, AND SUPPLIER FROM THE ACTUATOR CYLINDER BODY FLANGE AND COVER PLATE AREA (CAR AB8134, AB3674, AC7678, AC7920, AC7738, AD0528). CORRECTIVE ACTION INVOLVED SEAL REPLACEMENT, SEALING SURFACE POLISHING, AND CAUTIONING OF PERSONNEL.

FATIGUE CRACKS IN ACTUATOR END CAPS (CAR AD1230) AND LOOSE END CAP BOLTS (CAR AC7678) WERE DETECTED DURING INCIPIENT FAILURE INVESTIGATION. THE PROBLEM WAS CORRECTED BY A REDESIGN OF THE END CAPS. ALSO, THE ATTACHMENT BOLTS WERE CHANGED FROM NAS1101E4-12 TO RD111-4008-0404 WHICH INCREASED THE BOLTS HEAD SIZE. A REQUIREMENT TO RETORQUE THE ATTACHMENT BOLTS 4 HOURS AFTER APPLICATION OF INITIAL TORQUE WAS INSTITUTED.

FIELD INSPECTION OF ALL ACTUATOR BOLTS (SAR J-1648) DISCLOSED A NUMBER OF BOLTS WITH LOW TORQUE VALUE. ALL ACTUATOR BOLTS WERE CHECKED, RETORQUED, AND VERIFIED BY A PROCEDURE DURING SWITCH MODIFICATION.

CURRENT DATA ON TEST FAILURE, FLIGHT FAILURE, UNEXPLAINED ANOMALIES, AND OTHER FAILURES EXPERIENCED DURING GROUND PROCESSING ACTIVITY CAN BE FOUND IN THE PRACA DATABASE.

**(E) OPERATIONAL USE:**

HELIUM BOTTLE PRESSURE IS ON DEDICATED DISPLAY IN COCKPIT. CREW ACTION CAN CLOSE PNEUMATIC ISOLATION VALVES (LV7,8) DURING ASCENT. PRIOR TO MECO, THE ISOLATION VALVES CAN BE REOPENED AND/OR THE LEFT ENGINE LOW PRESSURE GHE CROSSOVER VALVE (LV10) CAN BE OPENED.

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**- APPROVALS -**

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S&R ENGINEERING	: W.P. MUSTY	: /S/ W. P. MUSTY
S&R ENGINEERING ITM	: P. A. STENGER-NGUYEN	: /S/ P. A. STENGER-NGUYEN
DESIGN ENGINEERING	: STUART KOBATA	: /S/ STUART KOBATA
MPS SUBSYSTEM MGR.	: TIM REITH	: /S/ TIM REITH
MOD	: WILLIAM LANE	: /S/ WILLIAM LANE
USA SAM	: MICHAEL SNYDER	: /S/ MICHAEL SNYDER
USA ORBITER ELEMENT	: SUZANNE LITTLE	: /S/ SUZANNE LITTLE
NASA SR&QA	: ERICH BASS	: /S/ ERICH BASS