

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE**NUMBER: 03-1-0310 -X****SUBSYSTEM NAME:** MAIN PROPULSION**REVISION:** 2 08/02/00**PART DATA**

	PART NAME	PART NUMBER
	VENDOR NAME	VENDOR NUMBER
LRU	:LO2 INBOARD 8" FILL/DRAIN VALVE (PV10) UNITED SPACE ALLIANCE - NSLD	MC284-0397-0030 74328000-157

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:

FILL INBOARD LO2 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: PV10**QUANTITY OF LIKE ITEMS:** 1**FUNCTION:**

PROVIDES A MEANS OF LOADING AND DRAINING THE ET THROUGH THE PROPELLANT FEED SYSTEM. THE VALVE, ALONG WITH THE OUTBOARD FILL AND DRAIN VALVE (PV9), PROVIDES A REDUNDANT MEANS OF CONTAINING PROPELLANT IN THE FEED SYSTEM. THE VALVE IS MOUNTED ON THE FEED LINE MANIFOLD TO ISOLATE THE FILL LINE FROM THE FEED SYSTEM. THE VALVE IS CLOSED AFTER LOADING IN ORDER TO DRAIN THE FILL LINE (PRIOR TO CLOSING THE OUTBOARD FILL & DRAIN VALVE). BOTH THE INBOARD AND OUTBOARD VALVES REMAIN CLOSED DURING ENGINE OPERATION AND ARE OPENED FOR MPS VACUUM INERT TO VENT LO2 RESIDUALS. BOTH VALVES ARE OPEN FOR LO2 DUMP IN RTLS AND TAL ABORTS. THE INBOARD VALVE REMAINS OPEN AFTER DUMP/INERT, THROUGH REENTRY AND LANDING. THE VALVE INCORPORATES AN ANTI-SLAM MECHANISM TO PREVENT SLAMMING DAMAGE DURING IMPROPER VALVE OPEN/CLOSE OPERATIONS. THE VALVE INCORPORATES A RELIEF VALVE, RELIEVING FROM THE FILL LINE INTO THE MANIFOLD; AND A PORT FOR INSTALLATION OF LO2 RELIEF SHUTOFF ISOLATION VALVE (PV7).

FAILURE MODES EFFECTS ANALYSIS FMEA -- CIL FAILURE MODE

NUMBER: 03-1-0310-11

REVISION#: 2 08/02/00

SUBSYSTEM NAME: MAIN PROPULSION

LRU: LO2 INBOARD 8" FILL AND DRAIN VALVE (PV10)

CRITICALITY OF THIS

ITEM NAME: LO2 INBOARD 8" FILL AND DRAIN VALVE (PV10)

FAILURE MODE: 1/1

FAILURE MODE:

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

MISSION PHASE:

PL PRE-LAUNCH
LO LIFT-OFF

VEHICLE/PAYLOAD/KIT EFFECTIVITY:

102 COLUMBIA
103 DISCOVERY
104 ATLANTIS
105 ENDEAVOUR

CAUSE:

FATIGUE, MATERIAL DEFECT, DAMAGED/DEFECTIVE ACTUATOR SEALS

CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO

REDUNDANCY SCREEN

A) N/A
B) N/A
C) N/A

PASS/FAIL RATIONALE:

A)

B)

C)

- FAILURE EFFECTS -

(A) SUBSYSTEM:

DEPENDING ON LOCATION, FAILURE COULD RESULT IN THE INABILITY TO OPEN OR CLOSE FILL & DRAIN VALVE. ACTUATOR RUPTURE/LEAKAGE ON THE CLOSING SIDE CAN CAUSE VALVE TO SLAM OPEN WHEN COMMANDED OPEN TO INITIATE LO2 DETANKING. IF THE GROUND PORTION OF THE FILL AND DRAIN LINE (TAIL SERVICE MAST) IS DRAINED, SLUG FLOW FROM THE ORBITER WILL IMPACT THE GSE DEBRIS PLATE WHICH SUBSEQUENTLY CAUSES A WATERHAMMER (PRESSURE SPIKE 415 PSIG). THE WATER HAMMER COULD

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
NUMBER: 03-1-0310-11**

CAUSE RUPTURE OF THE ORBITER FILL LINE AND/OR THE GSE INTERFACE/FACILITY LINES. THE SLOWER RESPONSE TIME OF THE NORMAL (NON-SLAM) VALVE OPERATION DOES NOT CAUSE A PRESSURE SPIKE WHICH WOULD LEAD TO LINE RUPTURE.

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. ALSO RESULTS IN LOSS OF AFT COMPARTMENT PURGE. LEAKAGE MAY BE DETECTABLE ON GROUND USING HAZARDOUS GAS DETECTION SYSTEM (HGDS).

(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 (RESULTS IN POSSIBLE PROPELLANT SYSTEM CONTAMINATION DURING REENTRY).

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

SAME AS C.

(E) FUNCTIONAL CRITICALITY EFFECTS:

CASE 1:

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.

CASE 2:

1R/2 2 SUCCESS PATHS, TIME FRAME – RTLS ABORTS

- 1) FIRST FAILURE CAUSES RTLS ABORT
- 2) ACTUATOR FAILURE RESULTING IN INABILITY TO OPEN LO2 INBOARD FILL AND DRAIN VALVE

RESULTS IN FAILURE TO ADEQUATELY DUMP LO2. MAY CAUSE VIOLATION OF MAXIMUM DOWNWEIGHT FOR HEAVY MANIFESTED PAYLOADS.

CASE 3:

1R/2 2 SUCCESS PATHS, TIME FRAME – RTLS/TAL ABORTS

- 1) FIRST FAILURE CAUSES RTLS/TAL ABORT
- 2) ACTUATOR RUPTURE/LEAKAGE.

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
NUMBER: 03-1-0310-11**

RESULTS IN LOSS OF GHE SUPPLY DURING MANIFOLD REPRESSURIZATION CAUSING LOSS OF AFT COMPARTMENT PURGE (RTLS AND TAL ABORT CRITICAL).

-DISPOSITION RATIONALE-

(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
- 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 & DRAIN VALVE)- EXAMINATION OF THE PRODUCT; AMBIENT PROOF (340 PSIG); AMBIENT AND CRYO CRACK/RESEAT (15-50 PSID) AND INTERNAL LEAKAGE; POST TEST EXAMINATION.

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
NUMBER: 03-1-0310-11**

FILL AND DRAIN VALVE ASSEMBLY -

EXAMINATION OF PRODUCT

ELECTRICAL BONDING

AMBIENT PROOF WITH VALVE OPEN (358 PSIG) AND CLOSED (275 PSID) APPLIED AT INBOARD SIDE

CRYO PROOF WITH VALVE OPEN (358 PSIG) AND CLOSED (358 PSID) APPLIED AT INBOARD SIDE

AMBIENT AND CRYO EXTERNAL LEAKAGE OF VALVE BODY (270 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 270 PSID ACROSS THE SEAL

AMBIENT AND CRYO VALVE INTERNAL LEAKAGE (INLET-TO-OUTLET WITH 15 PSID, OUTLET-TO-INLET WITH 270 PSID)

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

POST TEST EXAMINATION

CERTIFICATION

STRUCTURAL LOAD AT CRYO TEMPS (-300 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), RELIEF VALVE CRACK AND RESEAT, AND EXTERNAL LEAKAGE (BODY AND ACTUATOR) TESTS. REPEAT WITH THE VALVE IN COMPRESSION.

VALVE LIFE CYCLING:

2400 CYCLES AT AMBIENT TEMPERATURE 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 220 PSIG WITH GO2

2400 CRYO TEMPERATURE (-300 DEG F) CYCLES WITH 220 PSIG INTERNAL PRESSURE (1775 NORMAL CYCLES AND 625 SLAM CYCLES)

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
NUMBER: 03-1-0310-11**

100 NORMAL CRYO CYCLES WITH THE VALVE INLET VENTED TO ATMOSPHERE AND THE OUTLET PRESSURIZED TO 220 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 (-300 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 -
270 PSIG AND -250 DEG F IN EACH AXIS

RANDOM VIBRATION TESTS -

13.3 HOURS IN EACH OF THREE AXES WITH VALVE CLOSED AND AT -250 DEG F MAXIMUM. HALF OF THE TIME THE VALVE INTERNAL PRESSURE IS 270 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: 413 PSIG VALVE OPEN 413 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

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
NUMBER: 03-1-0310-11**

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 800A. 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.

(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, 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 BOLT HEAD SIZE. A RETORQUE REQUIREMENT OF ATTACHMENT BOLTS AFTER 4 HOURS WAS INSTITUTED.

A FIELD INSPECTION OF ALL ACTUATOR BOLTS (SAR J-1648) DISCLOSED A NUMBER OF BOLTS WITH LOW TORQUE VALUE. ALL ACTUATOR BOLTS WERE CHECKED AND 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.

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE
NUMBER: 03-1-0310-11**

(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.

- APPROVALS -

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	: MIKE SNYDER	: /S/ MIKE SNYDER
USA ORBITER ELEMENT	: SUZANNE LITTLE	: /S/ SUZANNE LITTLE
NASA SR&QA	: BILL PRINCE	: /S/ BILL PRINCE