

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE

NUMBER: 03-1-0245 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 3 11/07/00

PART DATA

	PART NAME	PART NUMBER
	VENDOR NAME	VENDOR NUMBER
LRU	: VALVE SOLENOID, NC 3W, TYPE 2 UNITED SPACE ALLIANCE - NSLD	MC284-0404-0032,-0042 13111-3

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:

VALVE, SOLENOID, NORMALLY CLOSED, 3-WAY, 1/4 INCH. LH2 RTLS DUMP VALVE CONTROL. OPENING (LV72,73).

VALVE WAS ORIGINALLY DESIGNED AND MANUFACTURED BY WRIGHT COMPONENTS (NOW PERKIN ELMER) BUT IS NOW MANUFACTURED BY UNITED SPACE ALLIANCE-NSLD AS AN ALTERNATE PRODUCTION AGENCY.

REFERENCE DESIGNATORS:

QUANTITY OF LIKE ITEMS: 2

FUNCTION:

THE SOLENOID VALVES CONTROL PNEUMATIC PRESSURE TO OPEN THE LH2 RTLS DUMP VALVES (PV17, PV18). THE SOLENOID VALVES (LV77, LV78) MUST ENERGIZE IN ORDER TO PROVIDE ACTUATION PRESSURE TO OPEN THE SERIES REDUNDANT RTLS DUMP VALVES. THE OPEN SOLENOIDS MUST DEACTUATE TO VENT SO THE DUMP VALVES CAN CLOSE.

TWO SERIES REDUNDANT RTLS DUMP VALVES PROVIDE A PATH TO DUMP LH2 OVERBOARD FROM THE LH2 FEEDLINE MANIFOLD. FOR NOMINAL, ATO AND AOA MISSIONS THE VALVES ARE SOFTWARE COMMANDED OPEN AT MECO+11 SECONDS AND CLOSED AT DUMP STOP. THE VALVES ARE THEN RE-OPENED FOR ENTRY TO PERFORM A FINAL VACUUM INERT PRIOR TO ENTRY. FOR RTLS AND TAL MISSIONS, THE VALVES ARE OPENED NOMINALLY AND THEN REMAIN OPEN UNTIL ENTRY AT VREL=5300 FT/SEC. THE RTLS INBOARD VALVE, PV17, PROVIDES A RELIEF FEATURE FOR LH2 TRAPPED BETWEEN THE INBOARD AND OUTBOARD, PV18, VALVES.

FAILURE MODES EFFECTS ANALYSIS FMEA -- NON-CIL FAILURE MODE**NUMBER: 03-1-0245-01****REVISION#:** 2 11/07/00**SUBSYSTEM NAME:** MAIN PROPULSION**LRU:** LH2 RTLS DUMP VALVE OP SOLENOIDS, PV17, 18**CRITICALITY OF THIS****ITEM NAME:** LH2 RTLS DUMP VALVE OP SOLENOIDS, PV17, 18**FAILURE MODE:** 1R3**FAILURE MODE:**

FAILS TO ACTUATE (RTLS DUMP VALVE FAILS TO OPEN, REFERENCE FMEA/CIL 03-1-0651-03). FAILS TO PRESSURIZE ACTUATOR FOLLOWING MECO.

MISSION PHASE: LO LIFT-OFF

VEHICLE/PAYLOAD/KIT EFFECTIVITY:

102	COLUMBIA
103	DISCOVERY
104	ATLANTIS
105	ENDEAVOUR

CAUSE:

PIECE PART STRUCTURAL FAILURE, ELECTRICAL SOLENOID FAILURE, BINDING, INLET FILTER CLOGGED

CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO

REDUNDANCY SCREEN

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

PASS/FAIL RATIONALE:

A)

B)

PASSES B SCREEN SINCE FAILURE OF EITHER RTLS DUMP VALVE TO OPEN IS DETECTABLE BY MONITORING LH2 MANIFOLD PRESSURE INCREASE. RELIEF VALVE WILL CYCLE SEVERAL TIMES PRIOR TO INITIATION OF NOMINAL PROPELLANT DUMP.

C)

- FAILURE EFFECTS -**(A) SUBSYSTEM:**

FAILURE OF EITHER SOLENOID VALVE TO ACTUATE CAUSES THE CORRESPONDING RTLS DUMP VALVE TO FAIL TO OPEN (FROM MECO + 11 TO MECO + 240 SECONDS). THIS PREVENTS DUMPING LH2 THROUGH THE RTLS LINE WHICH RESULTS IN LOSS OF REDUNDANCY TO RELIEVE LH2. RTLS DUMP VALVE IS REDUNDANT TO THE RELIEF VALVE SINCE RELIEF VALVE CYCLING IS NOT EXPECTED.

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(B) INTERFACING SUBSYSTEM(S):

SAME AS A.

(C) MISSION:

NO EFFECT.

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

SAME AS C.

(E) FUNCTIONAL CRITICALITY EFFECTS:

1R/3 3 SUCCESS PATHS. TIME FRAME - POST MECO, PRE DUMP.

- 1) FAILS TO ACTUATE EITHER RTLS DUMP VALVE OPENING SOLENOID (LV72 OR LV73).
- 2) LH2 MANIFOLD RELIEF SYSTEM FAILS TO RELIEVE.
- 3) LH2 MANIFOLD PRESSURE TRANSDUCER FAILS OR LH2 OUTBOARD FILL/DRAIN VALVE (PV11) FAILS CLOSED. DEFEATS VEHICLE SOFTWARE CHECK OF LH2 MANIFOLD PRESSURE EXCEEDING 60 PSIA AND INITIATION OF LH2 DUMP.

RESULTS IN LACK OF RELIEF CAPABILITY. POSSIBLE RUPTURE OF THE LH2 MANIFOLD CAUSING LH2 LEAKAGE INTO THE AFT COMPARTMENT, OVERPRESSURIZATION, AND FIRE/EXPLOSION HAZARD. POSSIBLE LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CRYOGENIC EXPOSURE. POSSIBLE LOSS OF CREW/VEHICLE.

-DISPOSITION RATIONALE-

(A) DESIGN:

VALVE IS DESIGNED FOR A PRESSURE FACTOR OF SAFETY OF 2.0 PROOF, 4.0 BURST. THE CLOSURE DEVICE IS A 430 CRES BALL ACTING UPON EITHER OF TWO VESPEL SEATS. THE VALVE FEATURES A BALANCED LOAD ON THE BALL BY APPLYING INLET PRESSURE (750 PSIG NOMINAL) DIRECTLY TO THE BALL AT THE INLET SEAT AND INDIRECTLY (VIA A BELLOWS) THROUGH THE VENT SEAT. THE BELLOWS IS ASSISTED BY A SPRING, THE FORCE OF WHICH INSURES THE BALL IS HELD SECURELY AGAINST THE INLET SEAT WHEN THE SOLENOID IS DEENERGIZED. UPON BEING ENERGIZED THE SOLENOID DEVELOPS THE FORCE TO OVERCOME THE SPRING LOAD AND SEATS THE BALL ONTO THE VENT SEAT TO ALLOW HELIUM FLOW. TOTAL POPPET MOVEMENT (STROKE) IS LESS THAN 0.040 INCH.

TO FAIL TO ACTUATE MEANS THE FORCE TO MOVE THE BALL TO THE VENT SEAT IS NOT DELIVERED TO THE BALL. THE VALVE PARTS INVOLVED ARE THE SOLENOID, THE SOLENOID PLUNGER, THE SOLENOID STOP, TWO PUSHRODS AND A SPRING. THE PUSHRODS ARE ALIGNED IN SERIES, SEPARATED BY THE SPRING FOR CHATTER PREVENTION. THE PUSHRODS ARE MADE OF CRES AND CARRY ONLY AXIAL LOADS. IF THE RODS WERE TO FAIL STRUCTURALLY, THEY WOULD CONTINUE TO PERFORM THEIR FUNCTION BECAUSE THEY ARE TOTALLY CONTAINED IN THE STOP (THE ROD O.D. IS 0.125

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INCH AND THE STOP ID IS 0.126 INCH). THE ROD, IN CONTACT WITH THE BALL, IS GUIDED BY THE SOLENOID STOP FOR OVER 28% OF ITS LENGTH.

BECAUSE OF THE CLOSE TOLERANCES IN THE SOLENOID ASSEMBLY, BINDING DUE TO CONTAMINATION IS A DESIGN CONCERN. TO PRECLUDE BURRS, THE SOLENOID BORE IS HONED. TO PREVENT BINDING, THE PLUNGER IS COATED WITH A DRY-FILM LUBRICANT. THE STOP IS MADE OF A MUCH HARDER MATERIAL THAN EITHER OF THE PUSHRODS TO PREVENT GALLING, AND THE PUSHROD SPRING NOT ONLY CONTROLS CHATTER, BUT REDUCES THE POTENTIAL FOR FRETTING.

CLOGGING OF THE 20 MICRON NOMINAL, 40 MICRON ABSOLUTE RATED, INLET FILTER IS PROTECTED AGAINST BY THE USE OF MULTI-FILTERED HELIUM IN THE ORBITER PNEUMATICS SYSTEM. THE HELIUM IS FILTERED BY THE GROUND SYSTEM BEFORE PRESSURIZING THE VEHICLE PNEUMATICS BOTTLE. IT IS AGAIN FILTERED (25 MICRONS, ABSOLUTE) BEFORE IT ENTERS THE VALVE ACTUATION SYSTEM. ALSO, TO INCREASE THE INLET FILTER'S EFFECTIVE SURFACE AREA THE FILTER IS OF A PLEATED DESIGN.

THE SOLENOID STRUCTURE IS CONSTRUCTED OF CRES AND IS EB WELDED. THE COIL IS VACUUM IMPREGNATED (POTTED). THE UNIT IS PRESSURE AND LEAK TESTED AT MAJOR ASSEMBLY POINTS.

THE -0022 CONFIGURATION WAS ADDED DUE TO A BELLOWS ASSEMBLY DESIGN CHANGE (P/N 24340 TO P/N 24340-1) TO ELIMINATE THE "SQUIRMED" CONDITION WHICH SOME OF THE ORIGINAL BELLOWS ASSEMBLIES EXPERIENCED DURING PROOF PRESSURE TESTING AT ATP. THE DESIGN CHANGE WAS MADE TO STRENGTHEN THE BELLOWS. BECAUSE THE DAMAGE OCCURRED DURING ATP, VALVES ALREADY IN THE FLEET (-0012 CONFIGURATION) WERE X-RAY TESTED AND ONLY VALVES WHICH HAD SQUIRMED BELLOWS WERE UPGRADED TO THE -0022 CONFIGURATION.

THE -0032 AND -0042 CONFIGURATION SOLENOID VALVES ARE IDENTICAL TO THE -0012 AND -0022 CONFIGURATION SOLENOID VALVES (RESPECTIVELY) WITH THE EXCEPTIONS OF ADDING THE FILTER (10 MICRON NOMINAL, 25 MICRON ABSOLUTE) IN THE VENT PORT OF THE SOLENOID VALVE AND REDESIGN OF THE VENT PORT CHECK VALVE. THIS FILTER WAS ADDED TO PREVENT CONTAMINATION AND METALLIC PARTICLES GENERATED DURING THE REMOVAL OF THE VENT PORT CHECK VALVE DURING OMRSD LEAKAGE MEASUREMENTS FROM ENTERING THE SOLENOID VALVE.

THE VENT PORT CHECK VALVE (P/N 11107-5) WAS REDESIGNED (P/N 11107-7) TO PREVENT THE POPPET FROM BEING EJECTED DUE TO SHEARING OF THE RETAINING NUT THREAD. A PIN WAS ADDED TO THE CHECK VALVE HOUSING, WHICH RETAINS THE POPPET WITHIN THE CHECK VALVE HOUSING. A NEW ALUMINUM NUT, WHICH PROVIDES A MINIMUM ENGAGEMENT OF THREE THREADS, WAS UTILIZED TO INCREASE RELIABILITY.

(B) TEST:

ATP

AMBIENT TEMPERATURE TESTS
PROOF PRESSURE: 1560 PSIG
EXTERNAL LEAKAGE: 850 PSIG

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INTERNAL LEAKAGE: 740 PSIG, ENERGIZED AND DEENERGIZED ELECTRICAL CHARACTERISTICS AND RESPONSE

REDUCED TEMPERATURE TESTS (-160 DEG F)
ELECTRICAL CHARACTERISTICS AND RESPONSE
INTERNAL LEAKAGE

ELECTRICAL BONDING TESTS

SOLENOID SUBASSEMBLY TESTS
ELECTRICAL CHARACTERISTICS
ENCLOSURE LEAKAGE (ONE ATMOSPHERE)

CERTIFICATION

TWO UNITS -

PORT AND FITTING TORQUE

SALT FOG EXPOSURE FOLLOWED BY ELECTRICAL AND LEAKAGE CHECKS

VIBRATION - AMBIENT
RANDOM VIBRATION TEST: 13.1 HOURS BOTH AXES FOR TWO VIBRATION LEVELS
TRANSIENT VIBRATION SWEEP: RUN WITH ONE SPECIMEN ENERGIZED AND ONE DEENERGIZED, FOLLOWED BY ELECTRICAL CHARACTERISTICS AND LEAKAGE CHECKS

SHOCK
HANDLING

FLOW
ENERGIZED
DEENERGIZED

ELECTRICAL
FIFTY HOUR CONTINUOUS CURRENT TEST AT 130 DEG F

LIFE
AMBIENT TEMPERATURE ENDURANCE (4500 CYCLES FOLLOWED BY ELECTRICAL AND LEAKAGE CHECKS)
130 DEG F ENDURANCE (500 CYCLES FOLLOWED BY ELECTRICAL AND LEAKAGE CHECKS)
OPERATION CYCLES (REPEATED 20 TIMES)
REPEAT OF AMBIENT TEMPERATURE ENDURANCE
-160 DEG F ENDURANCE (500 CYCLES FOLLOWED BY ELECTRICAL AND LEAKAGE CHECKS)

DISASSEMBLY AND INSPECTION

BURST PRESSURE: 3400 PSIG

GROUND TURNAROUND TEST
ANY TURNAROUND CHECKOUT IS ACCOMPLISHED IN ACCORDANCE WITH OMRSD.

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(C) INSPECTION:

RECEIVING INSPECTION

RAW MATERIALS ARE VERIFIED BY INSPECTION FOR MATERIAL AND PROCESSES CERTIFICATION. BODY HOUSING BAR STOCK IS ULTRASONICALLY INSPECTED.

CONTAMINATION CONTROL

CLEANLINESS LEVEL VERIFIED TO 100A. CORROSION PROTECTION IS VERIFIED BY INSPECTION.

ASSEMBLY/INSTALLATION

10X MAGNIFICATION EXAMINATION OF ALL DETAIL PARTS FOR BURRS, DAMAGE AND CORROSION IS MADE PRIOR TO ASSEMBLY. ALL DETAIL PARTS ARE INSPECTED FOR DIMENSIONS. CRITICAL SURFACE FINISHES ARE INSPECTED USING A COMPARATOR AT 10X MAGNIFICATION. OTHER SURFACE FINISHES ARE INSPECTED AND VERIFIED WITH A PROFILOMETER. TORQUES ARE VERIFIED TO BE IN ACCORDANCE WITH DRAWING REQUIREMENTS. MANDATORY INSPECTION POINTS ARE INCLUDED IN THE ASSEMBLY PROCEDURE.

CRITICAL PROCESS

WELDING, HEAT TREATMENT AND PARTS PASSIVATION VERIFIED BY INSPECTION. POTTING OF SOLDER CUPS, ELECTRICAL WIRE STRIPPING, AND SOLDERING OF CONNECTORS ARE VERIFIED BY INSPECTION. CHROME PLATING AND DRY FILM LUBRICATION ARE VERIFIED BY INSPECTION.

NONDESTRUCTIVE EVALUATION

WELDS VISUALLY EXAMINED & VERIFIED BY X-RAY AND DYE PENETRANT INSPECTIONS. THE SOLENOID ASSEMBLY IS SUBJECTED TO LEAKAGE VERIFICATION USING RADIOACTIVE TRACER TECHNIQUES. SOME VALVE BODIES WERE SUBJECTED TO 10X MAGNIFICATION INSPECTION ONLY. OTHER VALVE BODIES WERE SUBJECTED TO EDDY CURRENT INSPECTION, IN ADDITION TO 10X MAGNIFICATION. THE REMAINING VALVE BODIES WERE SUBJECTED TO 10X MAGNIFICATION, ETCH AND DYE PENETRANT INSPECTIONS. REFURBISHED VALVE BODIES WERE SUBJECTED TO 40X MAGNIFICATION INSPECTION. BELLOWS ASSEMBLY IS PROOF PRESSURE TESTED AND LEAK CHECKED.

TESTING

ATP VERIFIED BY INSPECTION.

HANDLING/PACKAGING

HANDLING, PACKAGING, STORAGE AND SHIPPING REQUIREMENTS ARE VERIFIED BY INSPECTION.

(D) FAILURE HISTORY:

DURING QUALIFICATION TESTING AT THE SUPPLIER (CAR AC3193), AND SUBSEQUENTLY AT KSC (CAR AC8975 AND AD0352), THE VALVES FAILED TO CYCLE (ACTUATE OR DEACTUATE) WHICH OCCASIONALLY PREVENTED PROPER OPERATION OF THE CONTROLLED PNEUMATIC VALVE. FAILURE INVESTIGATION DISCLOSED FRETTING ON THE PLUNGER AND IN THE BORE AREA. THIS GENERATED SMALL PARTICLES LEADING TO BINDING OF THE VALVES. THE FRETTING WAS THE RESULT OF A LACK OF REQUIRED LUBRICANT. THE CORRECTIVE ACTION WAS THE APPLICATION OF MICROSEAL (DRY FILM LUBRICANT) ON ALL

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NEW PARTS AND THE REPLACEMENT OF PLUNGERS WITH MICROSEAL WHEN VALVES WERE RETURNED TO THE SUPPLIER FOR REWORK. FOUR SOLENOID VALVES FAILED TO ACTUATE PROPERLY DURING ATP. TWO FAILED TO ACTUATE DUE TO BINDING (CARS AC0737, ACO894) AND THE OTHER TWO FAILED DUE TO INCORRECT STROKE OF THE PLUNGER (CARS ACO739, AC1469). DETAIL PARTS WERE INCORRECTLY FABRICATED/ASSEMBLED. THESE VALVE DEFECTS WERE REPAIRED AND ARE ATP SCREENABLE.

AN ELECTRICAL SHORT DUE TO INCORRECT ALIGNMENT OF SOLDER CUPS (PINS "A" AND "C") WAS DETECTED AT THE PALMDALE FACILITY (CAR AC2687). THE CORRECTIVE ACTION TAKEN WAS THE ADDITION OF HEAT SHRINK TUBING TO ISOLATE THE SOLDER CUPS AND THE ADDITION OF AN INSPECTION POINT AFTER POTTING.

A NUMBER OF ELECTRICAL CONNECTORS WERE BROKEN AT NSTL DUE TO EXCESSIVE PHYSICAL FORCE APPLIED TO THE CONNECTOR BY TECHNICIANS WORKING IN THE CONFINED AREA (CAR'S AB1813, AB1613, AND AB1208). CORRECTIVE ACTION RESULTED IN THE INSTALLATION OF PROTECTIVE COVERS TO PREVENT CONNECTOR DAMAGE IN HIGH TRAFFIC AREA. ALSO, CONNECTORS WERE WELDED TO THE VALVE BODY IN LIEU OF SOLDERING.

AFTER THE ACTUATION SIGNAL WAS REMOVED, TWO VALVES AT NSTL VENTED CONTINUOUSLY (CAR A7662) DUE TO BINDING OF THE PLUNGER CAUSED BY BURRS AND GALLING. DETAIL PARTS WERE INCORRECTLY FABRICATED/ASSEMBLED. THESE VALVE DEFECTS WERE REPAIRED.

THE SOLENOID VALVE EXPERIENCED ERRATIC BUT ACCEPTABLE PERFORMANCE AT KSC DUE TO EXCESSIVE SLIDING FRICTION CAUSED BY BURRS, AND SHARP EDGES ON THE ARMATURE (CAR AC1181). THE CONTROLLED PNEUMATIC VALVE OPERATION WAS ACCEPTABLE. THE CORRECTIVE ACTION RESULTED IN THE REDESIGN OF THE VALVE TO ELIMINATE THE BURRS AND SHARP EDGES. INSPECTION WAS IMPROVED AND AN OMRSD REQUIREMENT FOR CURRENT SIGNATURE TRACE WAS IMPOSED.

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:

NO ADDITIONAL CREW ACTION CAN BE TAKEN.

- 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	: DAVE NEARY	: /S/ DAVE NEARY
MPS SUBSYSTEM MGR.	: TIM REITH	: /S/ TIM REITH
MOD	: JEFF MUSLER	: /S/ JEFF MUSLER
USA SAM	: MIKE SNYDER	: /S/ MIKE SNYDER

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USA ORBITER ELEMENT	: SUZANNE LITTLE	: /S/ SUZANNE LITTLE
NASA SR&QA	: ERICH BASS	: /S/ ERICH BASS