

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE**NUMBER: 03-1-0216 -X****SUBSYSTEM NAME:** MAIN PROPULSION**REVISION:** 2 08/08/00**PART DATA**

	PART NAME	PART NUMBER
	VENDOR NAME	VENDOR NUMBER
LRU	:LH2 4" DISCONNECT CLOSING SOLENOID VALVE, TYPE 2 UNITED SPACE ALLIANCE - NSLD	MC284-0404-0032, -0042 13111-5, -6

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:

VALVE, SOLENOID, NORMALLY CLOSED 3-WAY, 1/4 INCH. LH2 RECIRCULATION DISCONNECT CONTROL. CLOSING.

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: LV51**QUANTITY OF LIKE ITEMS:** 1**FUNCTION:**

CONTROLS PNEUMATIC PRESSURE TO CLOSE THE 4" LH2 RECIRCULATION DISCONNECT VALVE (PD3). THE OPEN SOLENOID (LV50) MUST DEACTUATE TO ALLOW THE DISCONNECT ACTUATOR TO VENT SO THE DISCONNECT CAN BE CLOSED. CLOSING SOLENOID (LV51) (REFERENCE FMEA/CIL 03-1-0215) IS NORMALLY DEACTUATED TO ALLOW VALVE TO OPEN, BUT THE DISCONNECT ACTUATOR IS BIASED OPEN (WITH PRESSURE APPLIED, THE OPEN SIDE WILL WIN FORCE FIGHT). THE DISCONNECT IS COMMANDED OPEN PRIOR TO ENGINE CONDITIONING AND COMMANDED CLOSED UPON ENGINE SHUTDOWN.

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FAILS TO ACTUATE (DISCONNECT FAILS TO CLOSE, REFERENCE FMEA/CIL 03-1-0405-06),
WHEN DISCONNECT VALVE IS COMMANDED CLOSED, FOR PREMATURE ENGINE
SHUTDOWN.

MISSION PHASE: PL PRE-LAUNCH
LO LIFT-OFF

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

CAUSE:

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

CRITICALITY 1/1 DURING INTACT ABORT ONLY? YES

AOA ABORT ONCE AROUND
ATO ABORT TO ORBIT
PAD PAD ABORT
RTLTS RETURN TO LAUNCH SITE
TAL TRANS-ATLANTIC LANDING

REDUNDANCY SCREEN A) PASS
B) PASS
C) PASS

PASS/FAIL RATIONALE:

A)

B)

PASSES SCREEN B SINCE THE RECIRCULATION DISCONNECT VALVE (PD3) CLOSE POSITION
SWITCH WILL NOT INDICATE "ON". SOLENOID VALVE DOES NOT HAVE POSITION
INDICATORS.

C)

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- FAILURE EFFECTS -

(A) SUBSYSTEM:

CASE 1: PREMATURE ENGINE SHUTDOWN

RESULTS IN FAILURE OF THE LH2 RECIRCULATION RETURN DISCONNECT VALVE (PD3) TO CLOSE PNEUMATICALLY. FOR ANY PREMATURE ENGINE OUT OCCURRENCE (INCLUDING PAD ABORT), FAILS TO ISOLATE ET PROPELLANT SUPPLY FROM AN ENGINE WITH UNCONTAINED DAMAGE (ASSUMES ENGINE IS DAMAGED ONLY TO THE EXTENT THAT ISOLATION OF THE DAMAGE WILL SAFE THE SYSTEM). LH2 WILL LEAK INTO THE AFT COMPARTMENT. POSSIBLE AFT COMPARTMENT OVERPRESSURIZATION AND FIRE/EXPLOSION HAZARD. POSSIBLE LOSS OF ADJACENT CRITICAL FUNCTIONS DUE TO CRYO EXPOSURE.

CASE 2: ORBITER/ET SEP

NO EFFECT, LH2 RECIRCULATION RETURN DISCONNECT VALVE (PD3) WILL NOT CLOSE PNEUMATICALLY. VALVE WILL AUTOMATICALLY BE CLOSED (MECHANICALLY) DURING UMBILICAL RETRACT. NO CONSTRAINT TO ET SEPARATION SINCE PROPULSIVE FORCES FROM H2 VENTING ARE NEGLIGIBLE.

(B) INTERFACING SUBSYSTEM(S):

SAME AS A.

(C) MISSION:

NO EFFECT FOR NOMINAL MISSIONS. POSSIBLE LOSS OF CREW/VEHICLE FOR ABORTS.

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

SAME AS C.

(E) FUNCTIONAL CRITICALITY EFFECTS:

CASE 1:

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

- 1) ENGINE SHUTDOWN WITH UNCONTAINED DAMAGE (ASSUMES ENGINE IS DAMAGED ONLY TO THE EXTENT THAT ISOLATION OF THE DAMAGE WILL SAFE THE SYSTEM).
- 2) DISCONNECT CLOSING SOLENOID (LV51) FAILS TO ACTUATE.

LH2 WILL LEAK INTO THE AFT COMPARTMENT. POSSIBLE AFT COMPARTMENT OVERPRESSURIZATION AND FIRE/EXPLOSION HAZARD. POSSIBLE LOSS OF ADJACENT CRITICAL FUNCTIONS DUE TO CRYO EXPOSURE. POSSIBLE LOSS OF CREW/VEHICLE.

CASE 2:

3/3. TIME FRAME - ORBITER/ET SEPARATION.

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IF THE DISCONNECT WILL NOT CLOSE IN THE BACKUP MODE, IT WILL NOT CLOSE PNEUMATICALLY. THEREFORE, THE SOLENOID IS NOT CONSIDERED REDUNDANT TO THE MECHANICAL BACKUP (REFERENCE FMEA/CIL 03-1-0405-06).

-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 OD IS 0.125 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 -0032, -0042 CONFIGURATION SOLENOID VALVES ARE IDENTICAL TO THE -0012 CONFIGURATION WITH THE EXCEPTION OF ADDING THE FILTER (10 MICRON NOMINAL, 25

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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 WAS REDESIGNED 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 PROVIDE 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); ELECTRICAL CHARACTERISTICS AND RESPONSE; INTERNAL LEAKAGE (740 PSIG, ENERGIZED AND DEENERGIZED).

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

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

HANDLING SHOCK TEST

ENERGIZED AND DEENERGIZED FLOW TESTS

FIFTY HOUR CONTINUOUS CURRENT TEST AT 130 DEG F

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

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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.

(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.

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(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 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:

FLIGHT:

NO CREW ACTION CAN BE TAKEN.

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GROUND:

GROUND OPERATIONS SAFING PROCEDURES CONTAIN SAFING SEQUENCE OF EVENTS FOR MAJOR LEAKS IN THE HYDROGEN SYSTEM.

- 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	: BILL LANE	:/S/ BILL LANE
USA SAM	: MIKE SNYDER	:/S/ MIKE SNYDER
USA ORBITER ELEMENT	: SUZANNE LITTLE	:/S/ SUZANNE LITTLE
NASA SR&QA	: ERICH BASS	:/S/ ERICH BASS