

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

NUMBER: 03-1-0229 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 2 11/06/00

**PART DATA**

	<b>PART NAME</b>	<b>PART NUMBER</b>
	<b>VENDOR NAME</b>	<b>VENDOR NUMBER</b>
LRU	: VALVE SOLENOID, NC 3W, TYPE 2 UNITED SPACE ALLIANCE - NSLD	MC284-0404-0032, -0042 13111-5

**EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:**

VALVE, SOLENOID, NORMALLY CLOSED, 3-WAY, 1/4 INCH. LH2 RECIRCULATION BYPASS VALVE CONTROL. OPENING (LV36).

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: 1

**FUNCTION:**

CONTROLS PNEUMATIC PRESSURE TO OPEN THE NORMALLY CLOSED LH2 RECIRCULATION BYPASS VALVES (PV14,15,16). ENERGIZING THE SOLENOID ALLOWS HELIUM PRESSURE TO OPEN THE 3 RECIRCULATION BYPASS VALVES. DEENERGIZING THE SOLENOID VALVE PROVIDES A VENT FOR THE HELIUM FROM THE RECIRCULATION VALVE ACTUATORS. RECIRCULATION VALVES ARE CLOSED AT T-10 SECONDS.

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FAILS TO DEACTUATE (BYPASS VALVE FAILS TO CLOSE, REFERENCE FMEA/CIL 03-1-0403-02). FAILS TO PROVIDE VENT TO CLOSE RECIRCULATION VALVES. FOR ENGINE OPERATION.

**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, ACTUATION PORT FILTER CLOGGED, VENT CHECK VALVE FAILS TO OPEN

**CRITICALITY 1/1 DURING INTACT ABORT ONLY? YES**

AOA	ABORT ONCE AROUND
ATO	ABORT TO ORBIT
PAD	PAD ABORT
RTLS	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 BYPASS VALVES (PV14-16) CLOSE POSITION SWITCH WILL NOT INDICATE ON. SOLENOID VALVE DOES NOT HAVE POSITION INDICATORS.

C)

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**- FAILURE EFFECTS -**

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**(A) SUBSYSTEM:**

SOLENOID FAILING TO DEACTUATE HAS NO EFFECT DURING NORMAL ENGINE OPERATION. LOSS OF CAPABILITY TO ISOLATE THE ET PROPELLANT SUPPLY FROM AN SSME. NO LCC EXISTS TO VERIFY VALVE IS CLOSED PRIOR TO LIFTOFF - GLS DOES NOT VERIFY FUNCTION AND POSITION SWITCHES ARE NOT GPC MEASUREMENTS (PRECLUDING ORBITER SOFTWARE MONITORING).

FOR ABORTS, RECIRCULATION VALVE FAILS TO ISOLATE A SHUTDOWN ENGINE WITH UNCONTAINED DAMAGE (ASSUMES ENGINE IS DAMAGED ONLY TO THE EXTENT THAT ISOLATION OF THE DAMAGE WILL SAFE THE SYSTEM) CAUSING POSSIBLE AFT COMPT OVERPRESS, FIRE/EXPLOSION HAZARD, AND POSSIBLE LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CRYO EXPOSURE. FOR PAD ABORTS, A PARTIALLY OPEN MAIN FUEL VALVE RESULTS IN HAZARDOUS OVERBOARD LEAKAGE OF H2.

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

SAME AS A.

**(C) MISSION:**

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

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

SAME AS C.

**(E) FUNCTIONAL CRITICALITY EFFECTS:**

1R/2 2 SUCCESS PATHS. TIME FRAME: PAD ABORT/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) RECIRCULATION VALVE OPENING SOLENOID (LV36) FAILS TO DEACTUATE (RECIRCULATION BYPASS VALVE FAILS TO CLOSE).

FAILURE TO ISOLATE A SHUTDOWN ENGINE WHICH HAS UNCONTAINED ENGINE DAMAGE. POSSIBLE AFT COMPARTMENT OVERPRESSURIZATION AND FIRE/EXPLOSION HAZARD. POSSIBLE LOSS OF ADJACENT CRITICAL FUNCTIONS DUE TO CRYO EXPOSURE. POSSIBLE LOSS OF CREW/VEHICLE.

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**-DISPOSITION RATIONALE-**

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**(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.

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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.

FOR THE VALVE TO FAIL TO DEACTUATE MEANS THE FORCE TO RETURN THE BALL TO THE INLET SEAT IS NOT PRESENT, THE FORCE HOLDING IT ON THE VENT SEAT IS NOT REMOVED, OR FLOW OUT THE VENT PORT IS PREVENTED. WHEN THE SOLENOID IS DEENERGIZED, THE FORCE TO RETURN THE BALL TO THE INLET SEAT IS PROVIDED BY THE BELLOWS ASSEMBLY AND SPRING THROUGH THE VALVE POPPET. IF THE BELLOWS FAILS, OR LEAKS TO THE POINT OF REDUCING THE BELLOWS INTERNAL PRESSURE TO LESS THAN THE VALVE INLET PRESSURE, THE LOAD BALANCING FEATURE IS ELIMINATED. INLET FLOW AGAINST THE BALL WOULD CONTINUE TO HOLD IT AGAINST THE VENT SEAT (AFTER DEENERGIZING THE SOLENOID) CAUSING THE VALVE TO FAIL TO DEACTUATE. THE BELLOWS ARE MADE OF NICKEL-COBALT-COPPER AND ARE ASSEMBLED INTO A SUB-ASSEMBLY. THIS SUB-ASSEMBLY IS PROOF PRESSURE TESTED AT 1550 PSIG PRIOR TO VALVE FINAL ASSEMBLY. IF THE SPRING BREAKS THE PRESSURIZED BELLOWS WOULD EXERT SUFFICIENT FORCE TO RETURN THE BALL TO THE INLET SEAT; HOWEVER, SEAT LEAKAGE MAY RESULT. THE SPRING IS MADE FROM 17-7PH CRES (ELGILOY) WIRE AND IS HEAT TREATED FOLLOWING FORMING. IT HAS A SPRING RATE OF 13.5 LBF/INCH AND EXERTS A FORCE OF 7.54 LBF IN ITS INSTALLED CONDITION.

FAILURE TO REMOVE THE FORCE HOLDING THE BALL ON THE VENT SEAT, WHEN THE SOLENOID IS DEENERGIZED, COULD BE CAUSED BY BINDING IN THE SOLENOID. FORCE TO DRIVE THE BALL TO THE VENT SEAT IS DELIVERED FROM THE SOLENOID BY A PLUNGER AND BY TWO PUSHRODS (ALIGNED IN SERIES WITHIN, AND GUIDED BY, THE SOLENOID STOP). THE AREAS OF POTENTIAL BINDING ARE BETWEEN THE PLUNGER AND SOLENOID OR BETWEEN THE PUSHRODS AND THE SOLENOID STOP. TO PRECLUDE BURRS THE SOLENOID BORE IS HONED, AND TO PREVENT BINDING, THE PLUNGER IS COATED WITH A DRY-FILM LUBRICANT. THE SOLENOID STOP IS MADE OF A MUCH HARDER MATERIAL (430 CRES) THAN EITHER OF THE PUSHRODS (17-4PH AND 304 CRES) TO PREVENT GALLING.

THE VENT CHECK VALVE, WHICH SCREWS INTO THE SOLENOID VALVE VENT PORT, IS OF SIMPLE DESIGN, CONTAINING ONLY 5 PARTS. CRACK AND RESEAT PRESSURES ARE 0.5 PSID AND THE UNIT IS DESIGNED FOR 10,000 CYCLES. HIGH INLET PRESSURE (710 PSIA NOMINAL) ACTING ON A LARGE POPPET (0.603 INCH DIAMETER) PRODUCES A FORCE IN EXCESS OF 400 POUNDS TO ASSURE CHECK VALVE OPENING. THE CHECK VALVE BODY AND POPPET ARE OF 2024-T6 ALUMINUM, AND TO PREVENT GALLING OR BINDING, HAVE BEEN HARD ANODIZED. TO PRECLUDE COCKING, THE POPPET STEM IS CLOSELY GUIDED OVER 50% OF ITS LENGTH BY THE BODY BORE (STEM, 0.139 INCH DIAMETER; BORE, 0.141 INCH DIAMETER).

CLOGGING OF THE 20 MICRON NOMINAL, 40 MICRON ABSOLUTE RATED, ACTUATION PORT FILTER WOULD PREVENT THE SOLENOID FROM VENTING THE ACTUATOR, CREATING THE EFFECT OF FAILURE TO DEACTUATE. THE FILTER IS PLEATED IN ORDER TO INCREASE SURFACE AREA.

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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); 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

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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 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.

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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:**

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.

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.

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.

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.

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.

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

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