

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

**NUMBER: 03-1-0208 -X**

**SUBSYSTEM NAME:**

**REVISION: 2 07/26/00**

**PART DATA**

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<b>PART NAME</b>	<b>PART NUMBER</b>
<b>VENDOR NAME</b>	<b>VENDOR NUMBER</b>
LRU : LOW PRESSURE 2-WAY SOLENOID VALVE, NC	MC284-0403-0013/-0023
UNITED SPACE ALLIANCE - NSLD	12201-2/-3

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**EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:**

VALVE, 2-WAY, DIRECT ACTING SOLENOID, ENGINE 2 HELIUM CROSSOVER VALVE (LV10), NORMALLY CLOSED (0.5" DIAMETER).

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: LV10**

**QUANTITY OF LIKE ITEMS: 1**

**FUNCTION:**

ISOLATES THE HE SUPPLY DEDICATED TO ENGINE 2 FROM THE PNEUMATIC VALVE ACTUATION HELIUM SUPPLY. CROSSOVER VALVE IS NORMALLY OPENED AT MECO TO COMBINE RESIDUAL HELIUM FROM THE ENGINE 2 SUPPLY WITH THE PNEUMATIC VALVE ACTUATION HELIUM SUPPLY FOR MECO VALVE ACTUATION AND MPS PROPELLANT DUMP. IT IS ALSO OPEN DURING ENTRY (AT MAJOR MODE 303) TO SUPPORT AFT COMPARTMENT PURGE AND MPS SYSTEM REPRESSURIZATION.

**FAILURE MODES EFFECTS ANALYSIS FMEA -- NON-CIL FAILURE MODE**

**NUMBER: 03-1-0208-02**

**REVISION#: 2 07/26/00**

**SUBSYSTEM NAME:** MAIN PROPULSION

**LRU:** VALVE, SOLENOID, NC 2W

**CRITICALITY OF THIS**

**ITEM NAME:** ENGINE 2/PNEUMATIC CROSSOVER VALVE (LV10)

**FAILURE MODE:** 1R3

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**FAILURE MODE:**

FAILS TO REMAIN CLOSED, INTERNAL LEAKAGE.

**MISSION PHASE:** LO LIFT-OFF

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

**CAUSE:**

PIECE PART STRUCTURAL FAILURE.

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

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<b>REDUNDANCY SCREEN</b>	A) PASS
	B) N/A
	C) PASS

**PASS/FAIL RATIONALE:**

A)

B)

CROSSOVER VALVE REMAINING CLOSED IS STANDBY REDUNDANT TO A PNEUMATIC SYSTEM LEAK.

C)

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**- FAILURE EFFECTS -**

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**(A) SUBSYSTEM:**

LOSS OF ISOLATION BETWEEN ENGINE NO. 2 AND PNEUMATIC HELIUM SYSTEMS.

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

SAME AS A.

**(C) MISSION:**

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NO EFFECT FOR FIRST FAILURE.

**(D) CREW, VEHICLE, AND ELEMENT(S):**  
SAME AS C.

**(E) FUNCTIONAL CRITICALITY EFFECTS:**

1R/3 3 SUCCESS PATHS. TIME FRAME: ENGINE OPERATION.

- 1) LV10 CROSSOVER VALVE FAILS TO REMAIN CLOSED.
- 2) HELIUM LINE LEAKAGE BETWEEN CV9 AND CV8 (ASSUMES LEAK RATE LARGE ENOUGH TO DEplete COMBINED PNEUMATIC AND ENGINE NO. 2 HELIUM SUPPLY BUT LESS THAN REQUIRED TO OVERPRESSURIZE AFT COMPARTMENT) CAUSING RESPECTIVE ENGINE REDLINE SHUTDOWN. REMAINING ENGINES ARE LIMIT SHUTDOWN INHIBITED BY VEHICLE SOFTWARE.
- 3) ANOTHER SSME EXCEEDS REDLINE BEFORE CREW CAN RE-ENABLE SSME REDLINE LIMITS.

RESULTS IN UNCONTAINED ENGINE DAMAGE DUE TO REDLINE EXCEEDANCE WHILE LIMIT SHUTDOWN IS INHIBITED. POSSIBLE LOSS OF CREW/VEHICLE.

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**-DISPOSITION RATIONALE-**

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**(A) DESIGN:**

THE SOLENOID VALVE IS A NORMALLY CLOSED, DIRECT-ACTING VALVE. WHEN DEENERGIZED, THE VALVE POPPET IS HELD AGAINST THE VALVE SEAT BY A SPRING AND A BELLOWS, EITHER OF WHICH CAN MAINTAIN THE CLOSED POSITION. THE BELLOWS ASSEMBLY INTYERIOR IS EXPOSED TO OUTLET PRESSURE BY VENT HOLES THROUGH THE POPPET, PROVIDING A FORCE BALANCE WHICH ALLOWS THE SOLENOID, WHEN ENERGIZED, TO DEVELOP SUFFICIENT FORCE TO OPEN THE VALVE.

STRUCTURAL FAILURE OF THE BELLOWS (NOT BELLOWS LEAKAGE, BUT MAJOR STRUCTURAL LOSS) IN COMBINATION WITH EITHER THE LOSS OF THE POPPET-TO-PLUNGER PIN OR THE SPRING WOULD CAUSE VALVE FAILURE TO REMAIN CLOSED.

STRUCTURAL FAILURE OF THE PLUNGER, THE POPPET, THE BELLOWS ASSEMBLY, OR THE POPPET-TO-PLUNGER PIN CAN CAUSE VALVE FAILURE TO OPEN/REMAIN OPEN. THE 430 CRES PLUNGER, 304 CRES RETAINER AND POPPET, AND 17-4 PH HEAT TREATED CRES PIN TRANSFER ONLY THE LOAD OVERCOMING THE BELLOWS RESISTANCE (SPRING RATE OF 110 LB/INCH OVER A STROKE OF 0.060 INCH, OR 6.6 LB FORCE).

THE BELLOWS (P/N 24408-1 AND 24408-2) ARE MADE OF TWO NICKEL-COBALT-COPPER PLIES USING AN ELECTRO DEPOSITING PROCESS AND ARE ASSEMBLED INTO A SUB-ASSEMBLY. THIS SUB-ASSEMBLY IS PROOF PRESSURE TESTED AT 1550 PSIG AND LEAK CHECKED AT 850 PSID PRIOR TO VALVE FINAL ASSEMBLY. BELLOWS P/N 24408-1 ARE INSTALLED IN THE MC284-0403-0012 VALVE ASSEMBLY AND ARE CAPABLE OF 5,000 PRESSURE CYCLES (LIMITED 35 MISSION CERTIFICATION). THE -0022 VALVE

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CONFIGURATION USES A BELLOWS P/N 24408-2 WHICH IS CAPABLE OF 20,000 PRESSURE CYCLES (100 MISSION CERTIFICATION).

WHEN THE VALVE IS IN THE CLOSED (DE ENERGIZED) POSITION, THE ONLY LOADS EXPERIENCED BY THE POPPET-TO-PLUNGER PIN ARE THOSE EXERTED BY THE SPRING (13.5 LB IN THE INSTALLED CONFIGURATION). THE PIN IS MADE OF 17-7 PH CRES, IS HEAT TREATED, AND HAS A 0.093 INCH DIAMETER.

THE SPRING IS FORMED FROM 0.035 INCH DIAMETER ELGILOY SPRING WIRE AND IS HEAT TREATED FOLLOWING FORMING. IT HAS A SPRING RATE OF 40 LB/INCH.

THE SOLENOID COIL IS HOUSED IN AN EB WELDED AND LEAK-TESTED CRES ASSEMBLY. THE COIL UTILIZES HIGH TEMPERATURE WIRE WOUND ON A CORE. AN ELECTRICAL CONNECTOR IS WELDED ON THE HOUSING. HIGH TEMPERATURE WIRES BETWEEN THE CONNECTOR AND THE COIL ARE SILVER SOLDERED AT THEIR CONNECTIONS. THE COMPLETE ASSEMBLY IS IMPREGNATED WITH EPOXY UNDER VACUUM CONDITIONS. THIS TYPE OF SOLENOID CONSTRUCTION HAS BEEN SUCCESSFULLY USE ON MANY PROGRAMS AND HAS BEEN SUBJECTED TO OVER 10,000 LIFE AND THERMAL QUALIFICATION CYCLES.

**(B) TEST:**  
ATP

EXAMINATION OF PRODUCT

AMBIENT TEMPERATURE TESTS:

PROOF PRESSURE (1550 PSIG)  
EXTERNAL LEAKAGE (850 PSIG)  
INTERNAL LEAKAGE  
(INLET-TO-OUTLET AT 825 PSID AND OUTLET-TO-INLET AT 150 PSID)  
ELECTRICAL CHARACTERISTICS  
(PULL-IN/DROPOUT VOLTAGE, CURRENT SIGNATURE AT 850 PSIG)  
VALVE RESPONSE TIMES (850 PSIG)  
REVERSE PRESSURE VALVE RESPONSE TIMES (150 PSIG)

REDUCED TEMPERATURE TESTS (-160 DEG F)

INTERNAL LEAKAGE  
(INLET-TO-OUTLET AT 825 PSID AND OUTLET-TO-INLET AT 150 PSID)  
ELECTRICAL CHARACTERISTICS (PULL-IN/DROPOUT VOLTAGE AT 850 PSIG)  
VALVE RESPONSE TIMES (850 PSIG)  
REVERSE PRESSURE VALVE RESPONSE TIMES (150 PSIG)

ELECTRICAL TESTS  
ELECTRICAL BONDING  
DIELECTRIC WITHSTANDING VOLTAGE  
INSULATION RESISTANCE

CERTIFICATION

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PORT AND FITTING TORQUE (2 UNITS)  
(TWICE NORMAL INSTALLATION TORQUE)

SALT FOG TEST (1 UNIT)  
PER MIL-STD-810

SHOCK  
PER MIL-STD-810  
BENCH HANDLING  
DESIGN

VIBRATION (2 UNITS)

TRANSIENT: 5 TO 35 HZ

RANDOM:  
ONE UNIT TESTED ENERGIZED AND FLOWING 100 SCIM, SECOND UNIT TESTED  
DEENERGIZED  
INLET PRESSURE: 750 PSIG AMBIENT HELIUM  
13.3 HOURS FOR EACH OF 2 AXES

PANEL MOUNTED (2 UNITS)  
INLET PRESSURE: 750 PSIG AMBIENT HELIUM  
13.3 HOURS FOR EACH OF 3 AXES

ELECTRICAL CHARACTERISTICS, VALVE RESPONSE, AND INTERNAL LEAKAGE AFTER EACH  
AXIS

FLOW TEST

DIFFERENTIAL PRESSURE TEST (1 UNIT)  
INLET PRESSURE: 525 PSIG AMBIENT HELIUM  
FLOW RATES: 0.15 TO 0.25 LBS/SEC  
PRESSURE DROP NOT TO EXCEED 125 PSID

HIGH FLOW CLOSURE TEST (1 UNIT)  
3 CYCLES:  
INLET PRESSURE: 850 PSIG AMBIENT HELIUM  
FLOW RATE: 0.3 LB/SEC  
CYCLE VALVE CLOSED AND VERIFY BY LEAKAGE TEST

CONTINUOUS CURRENT TEST (2 UNITS)

50 HOURS WITH SOLENOID ENERGIZED  
TEMPERATURE: +130 DEG F SURROUNDING ENVIRONMENT  
INSULATION RESISTANCE TEST (+130 DEG F MAINTAINED)  
INSULATION RESISTANCE TEST (AMBIENT TEMPERATURE)

THERMAL VACUUM AND ENDURANCE TEST (2 UNITS)

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9000 CYCLES: 850 PSIG, AMBIENT HELIUM  
500 CYCLES: 850 PSIG, +130 DEG F HELIUM  
500 CYCLES: 850 PSIG, -160 DEG F HELIUM

**OPERATIONAL CYCLE TEST**

3 CYCLES PERFORMED DURING EXPOSURE TO FOLLOWING CONDITIONS:  
VALVE ENERGIZED/DEENERGIZED  
INLET PRESSURE: 750 TO 200 PSIG  
TEMPERATURE: +130 TO +250 DEG F HELIUM  
SURROUNDING TEMPERATURE: AMBIENT TO +275 DEG F  
SURROUNDING ENVIRONMENT: AMBIENT TO VACUUM

ELECTRICAL CHARACTERISTICS AND INTERNAL LEAKAGE AFTER EACH SET OF CYCLES AT APPROPRIATE TEMPERATURE CONDITIONS

BURST TEST (1 UNIT)  
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 IS VERIFIED TO 100A. CORROSION PROTECTION IS VERIFIED BY INSPECTION.

**ASSEMBLY/INSTALLATION**

ALL DETAIL PARTS AND ASSEMBLIES ARE EXAMINED FOR BURRS, DAMAGE AND CORROSION (AT 10X MAGNIFICATION) AND INSPECTED FOR CORRECT DIMENSIONS PRIOR TO ASSEMBLY. 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. BELLOWS ASSEMBLY IS PROOF PRESSURE TESTED AND LEAK CHECKED. MANDATORY INSPECTION POINTS ARE INCLUDED IN THE ASSEMBLY PROCEDURE.

**CRITICAL PROCESS**

THE FOLLOWING ARE VERIFIED BY INSPECTION:

WELDING  
HEAT TREATMENT  
PARTS PASSIVATION  
POTTING OF SOLDER CUPS  
ELECTRICAL WIRE STRIPPING  
DRY FILM LUBRICATION  
CHROME PLATING

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**NONDESTRUCTIVE EVALUATION**

ALL WELDS ARE VISUALLY EXAMINED AND VERIFIED BY X-RAY OR 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. REFURBISHED VALVE BODIES ARE SUBJECTED TO 40X MAGNIFICATION INSPECTION.

**TESTING**

ATP VERIFIED BY INSPECTION.

**HANDLING/PACKAGING**

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

**(D) FAILURE HISTORY:**

DURING QUALIFICATION TESTING, (VIBRATION ALONG THE SOLENOID PLUNGER AXIS), INTERNAL LEAKAGE WAS GREATER THAN 200 SCCM (REFERENCE CAR A6053). MAXIMUM ALLOWED IS 20 SCCM. THE PLUNGER POPPET WAS FOUND TO BE MOVING OFF THE SEAT AT CERTAIN FREQUENCIES. MCR 4352 AUTHORIZED THE USE OF VIBRATION ISOLATORS TO REDUCE VIBRATION LEVELS FOR THE SOLENOID VALVE.

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 CREW ACTION CAN BE TAKEN.

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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