FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE
NUMBER: 03-1-0208 -X

SUBSYSTEM NAME:

REVISION: 2 07/26/00

PART DATA

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

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: 03-1-0208-01

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

FAILURE MODE:
FAILS TO OPEN/REMAIN OPEN.

MISSION PHASE: LO LIFT-OFF

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

CAUSE:
FAILURE TO OPEN: PIECE PART STRUCTURAL FAILURE, BINDING, ELECTRICAL SOLENOID FAILURE.

FAILURE TO REMAIN OPEN: PIECE PART STRUCTURAL FAILURE, ELECTRICAL SOLENOID FAILURE.

CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO

REDUNDANCY SCREEN
A) PASS
B) N/A
C) PASS

PASS/FAIL RATIONALE:
A)

B)
CROSSOVER VALVE OPENING IS STANDBY REDUNDANT TO REPLENISHING A PNEUMATIC SYSTEM LEAK.

C)

- FAILURE EFFECTS -

(A) SUBSYSTEM:
LOW PRESSURE HELIUM FROM ENGINE 2 CANNOT BE TRANSFERRED TO PNEUMATIC VALVE ACTUATION SYSTEM; HOWEVER, THE PNEUMATIC SYSTEM WILL PROVIDE PRESSURE TO CLOSE MPS VALVES FOR MECO AND ET SEPARATION. ADDITIONALLY, HIGH PRESSURE HELIUM FROM ALL 3 ENGINE HELIUM SUPPLIES IS TRANSFERRED TO

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- NON-CIL **FAILURE MODE NUMBER: 03-1-0208-01**

PNEUMATIC VALVE ACTUATION SYSTEM WHEN THE ENGINE 1 AND 3 INTERCONNECT "OUT" VALVES ARE OPENED AT MECO+20 SECONDS.

(B) INTERFACING SUBSYSTEM(S):
SAME AS A.

(C) MISSION:
NO EFFECT FOR FIRST FAILURE.

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

(E) FUNCTIONAL CRITICALITY EFFECTS:
CASE 1:
1R/3 3 SUCCESS PATHS. TIME FRAME - ENGINE OPERATION.

1) HELIUM LEAK DOWNSTREAM OF CV9 (ASSUMES LEAK RATE LARGE ENOUGH TO DEPLETE PNEUMATIC HELIUM SUPPLY BUT LESS THAN REQUIRED TO OVERPRESSURIZE THE AFT COMPARTMENT).
2) EITHER PNEUMATIC HELIUM ISOLATION VALVE FAILS TO CLOSE WHEN COMMANDED BY CREW LEAK ISOLATION PROCEDURE OR PNEUMATIC REGULATOR FAILS TO OPEN WHEN ISOLATION VALVES ARE RE-OPENED AT MECO-30 SECONDS. RESULTS IN LOSS OF ABILITY TO USE PNEUMATIC HELIUM SUPPLY TO REPLENISH LEAK.
3) HELIUM CROSSOVER VALVE (LV10) FAILS TO OPEN/REMAIN OPEN (WHEN CREW MANUALLY OPENS LV10 IN RESPONSE TO FIRST FAILURE PRIOR TO MECO).

LOSS OF PNEUMATIC ACTUATION HELIUM RESULTS IN LO2 PREVALVE FAILING TO CLOSE AND INABILITY TO MAINTAIN INJECTED HELIUM AND LO2 PRESSURE TO THE HIGH PRESSURE OXYGEN TURBOPUMP TO PREVENT PUMP OVERSPEED AND CAVITATION AT MECO. RESULTS IN UNCONTAINED ENGINE DAMAGE, AFT COMPARTMENT OVERPRESSURIZATION, AND FIRE/EXPLOSION HAZARD. POSSIBLE LOSS OF CREW/VEHICLE.

CASE 2:
1R/3 3 SUCCESS PATHS. TIME FRAME - POST MECO.

1) HELIUM CROSSOVER VALVE (LV10) FAILS TO OPEN/REMAIN OPEN.
2) PNEUMATIC REGULATOR FAILS CLOSED.
3) EITHER MANIFOLD RELIEF SYSTEM FAILS TO RELIEVE.

LOSS OF HELIUM FROM BOTH TANK GROUPS CAUSES THE HELIUM ACCUMULATORS (AU5,6) TO SUPPLY THE HELIUM FOR MECO AND ET SEPARATION MPS VALVE ACTUATIONS. THIS USES ALL OF THE HELIUM REMAINING IN THE ACCUMULATORS, AND MPS PROPELLANT DUMPS CANNOT BE PERFORMED. EITHER RELIEF SYSTEM FAILING TO RELIEVE WILL RESULT IN RUPTURE OF THE ASSOCIATED FEEDLINE MANIFOLD, AFT COMPARTMENT OVERPRESSURIZATION, AND FIRE/EXPLOSION HAZARD. POSSIBLE LOSS OF ADJACENT CRITICAL FUNCTIONS DUE TO CRYO EXPOSURE.

POSSIBLE LOSS OF CREW/VEHICLE.

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- NON-CIL **FAILURE MODE NUMBER: 03-1-0208-01**

DESIGN CRITICALITY (PRIOR TO DOWNGRADE, DESCRIBED IN (F)): 1R2

(F) RATIONALE FOR CRITICALITY DOWNGRADE:
700 PSIA IS THE LEVEL WHICH SETS OFF THE CAUTION AND WARNING SYSTEM. FLIGHT RULE A5.1.4-1C WILL HAVE THE CREW OPEN THE ENGINE 2/PNEUMATIC CROSSOVER VALVE AT MECO-30 SECONDS TO MAINTAIN SUFFICIENT HELIUM SUPPLY PRESSURE TO CLOSE LO2 PREVALVES AND PROVIDE HELIUM FOR RE-ENTRY PURGE.

-DISPOSITION RATIONALE-

(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 MC284-0403-0013 VALVE ASSEMBLY AND ARE CAPABLE OF 5,000 PRESSURE CYCLES (LIMITED 35 MISSION CERTIFICATION). THE –0023 VALVE 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.

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- NON-CIL **FAILURE MODE NUMBER: 03-1-0208-01**

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

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

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- NON-CIL **FAILURE MODE NUMBER: 03-1-0208-01**

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)

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

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- NON-CIL **FAILURE MODE NUMBER: 03-1-0208-01**

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

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.

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- NON-CIL **FAILURE MODE NUMBER: 03-1-0208-01**

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

(D) FAILURE HISTORY:
THE CURRENT CONFIGURATION USES WELDING INSTEAD OF SOLDERING FOR THE ELECTRICAL CONNECTOR-TO-COIL ASSEMBLY JOINT. IN ALL VEHICLES, SOLDERED SOLENOID VALVES HAVE BEEN REPLACED WITH WELDED VALVES. SOLDERED CONNECTOR JOINTS ON EARLIER CONFIGURATIONS HAVE FAILED DUE TO POOR SOLDERING TECHNIQUES OR BEING STEPPED ON AFTER BEING INSTALLED IN THE VEHICLE (REFERENCE CARS A5449, 01F030, AB1208).

DURING QUAL ENDURANCE CYCLE TESTING, THE VALVE DID NOT ACTUATE AT AN INLET PRESSURE OF 825 PSIG. VALVE ALSO EXHIBITED INTERNAL LEAKAGE (REFERENCE CAR AB0869). THIS FAILURE WAS ATTRIBUTED TO LOSS OF FORCE BALANCE DUE TO A CRACKED BELLOWS. THIS FATIGUE TYPE FAILURE WAS CAUSED BY EXCESSIVE VIBRATION TIME ACCUMULATED ON THE BELLOWS. CORRECTIVE ACTION (MCR 4352) AUTHORIZED THE CHANGE TO MOUNT THE VALVES ON VIBRATION ISOLATERS AND REDUCE THE VIBRATION LEVELS.

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.

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