

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE

NUMBER: 03-1-0606 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 1 07/26/00

PART DATA

	PART NAME	PART NUMBER
	VENDOR NAME	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, LH2 MANIFOLD REPRESSURIZATION, NORMALLY CLOSED (0.5 INCH).

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: LV42
LV43

QUANTITY OF LIKE ITEMS: 2

FUNCTION:

TWO VALVES IN SERIES ISOLATE PNEUMATIC SYSTEM HELIUM PRESSURE (750 PSIA) FROM THE 20 PSIG REGULATOR (PR6). THE TWO VALVES ARE OPENED TO PROVIDE A FLOW PATH TO THE REGULATOR FOR PRESSURIZING THE LH2 MANIFOLD AND IN REPRESSURIZING THE LH2/GH2 SYSTEMS FOR ENTRY.

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SUBSYSTEM NAME: MAIN PROPULSION

LRU: VALVE, SOLENOID, NC 2W

ITEM NAME: LH2 MANIFOLD REPRESS SOL VLV (LV42, 43)

CRITICALITY OF THIS

FAILURE MODE: 3/3

FAILURE MODE:

FAILS TO OPEN/REMAIN OPEN

MISSION PHASE: LS LANDING/SAFING

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? YES

RTLS	RETURN TO LAUNCH SITE
TAL	TRANS-ATLANTIC LANDING

REDUNDANCY SCREEN

A) N/A
B) N/A
C) N/A

PASS/FAIL RATIONALE:

A)

B)

C)

- FAILURE EFFECTS -

(A) SUBSYSTEM:

LH2 MANIFOLD REPRESSURIZATION SYSTEM FUNCTION CONSIDERED NON MANDATORY FOR NOMINAL, AOA, AND ATO MISSIONS. NOMINAL POST DUMP RESIDUALS

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(APPROXIMATELY THREE LBM) ARE SUFFICIENT TO CAUSE PROPELLANT SYSTEM RUPTURE IN CASE OF RELIEF SYSTEM FAILURE, REGARDLESS OF REPRESS SYSTEM OPERATION.

DURING RTLS AND TAL ABORT ENTRIES, FAILURE RESULTS IN LOSS OF THE LH2 MANIFOLD REPRESS (MANDATORY TO PRECLUDE FLAMMABLE CONCENTRATIONS IN THE LH2 PROPELLANT SYSTEM) CAUSING POSSIBLE FIRE/EXPLOSION HAZARD IN THE LH2 PROPELLANT SYSTEM.

(B) INTERFACING SUBSYSTEM(S):

SAME AS A.

(C) MISSION:

POSSIBLE LOSS OF CREW/VEHICLE DURING RTLS AND TAL ABORTS.

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

SAME AS C.

(E) FUNCTIONAL CRITICALITY EFFECTS:

NONE.

-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.

VALVE FAILURE TO OPEN/REMAIN OPEN WOULD REQUIRE STRUCTURAL FAILURE OF THE PLUNGER ASSEMBLY, OR SOLENOID ASSEMBLY FAILURE. BINDING OF THE PLUNGER TO THE SOLENOID CORE ASSEMBLY CAN CAUSE VALVE FAILURE TO OPEN. TO PREVENT BINDING, BOTH THE PLUNGER AND THE SOLENOID CORE ASSEMBLY (THROUGH WHICH IT SLIDES) ARE MADE FROM 430 AND 304L CRES AND MANUFACTURED TO CLOSE TOLERANCES (THE CORE ASSEMBLY INTERNAL DIAMETER IS 0.674/0.675, AND THE PLUNGER OUTER DIAMETER IS 0.67325/0.67220). THE PLUNGER IS TREATED WITH A DRY LUBRICANT AND HAS A FAVORABLE LENGTH TO DIAMETER RATIO (L/D).

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

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110 LB/INCH OVER A STROKE OF 0.060 INCH, OR 6.6 LB FORCE). THE WEAK LINK IN THIS POWER TRAIN WOULD BE THE PIN (0.093 OUTER DIAMETER), IF IT WERE NOT FOR THE NEAR NEGLIGIBLE LOAD.

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

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 USNE 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

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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

VIBRATION (2 UNITS)

TRANSIENT: 5 TO 35 HZ

RANDOM:

ONE UNITS TESTED ENERGIZED AND FLOWING 100 SCIM, SECOND UNIT
TESTED DE ENERGIZED

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)

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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/DE ENERGIZED
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

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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.

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

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MOD	: JEFF MUSLER	:/S/ JEFF MUSLER
USA SAM	: MICHAEL SNYDER	:/S/ MICHAEL SNYDER
USA ORBITER ELEMENT	: SUZANNE LITTLE	:/S/ SUZANNE LITTLE
NASA SR&QA	: BILL PRINCE	:/S/ BILL PRINCE