

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE

NUMBER: 03-1-0601 -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, LO2 MANIFOLD REPRESSURIZATION, NORMALLY CLOSED (0.5 INCH DIA).

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: LV40
LV41

QUANTITY OF LIKE ITEMS: 2

FUNCTION:

TWO VALVES IN SERIES ISOLATE PNEUMATIC SYSTEM HELIUM PRESSURE (750 PSIA) FROM THE 20 PSIG REGULATOR (PR5). THE TWO VALVES ARE OPENED TO PROVIDE A FLOW PATH TO THE REGULATOR FOR PRESSURIZING THE LO2 MANIFOLD AS AN AID IN DUMPING PROPELLANTS AND IN REPRESSURIZING THE LO2/GO2 SYSTEMS FOR ENTRY.

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SUBSYSTEM NAME: MAIN PROPULSION

LRU: VALVE, SOLENOID, NC 2W

ITEM NAME: LO2 MANIFOLD REPRESS SOL VLV (LV40, 41)

CRITICALITY OF THIS

FAILURE MODE: 1R3

FAILURE MODE:

FAILS TO REMAIN CLOSED, INTERNAL LEAKAGE.

MISSION PHASE:

| | |
|----|------------|
| PL | PRE-LAUNCH |
| LO | LIFT-OFF |
| DO | DE-ORBIT |

VEHICLE/PAYLOAD/KIT EFFECTIVITY:

| | |
|-----|-----------|
| 102 | COLUMBIA |
| 103 | DISCOVERY |
| 104 | ATLANTIS |
| 105 | ENDEAVOUR |

CAUSE:

PIECE PART STRUCTURAL FAILURE

CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO

REDUNDANCY SCREEN

- A) PASS
- B) N/A
- C) FAIL

PASS/FAIL RATIONALE:

A)

B)

ISOLATION VALVES ARE STANDBY REDUNDANT TO LO2 REPRESSURIZATION REG FAILED OPEN.

C)

FAILS C SCREEN SINCE COMMON CONTAMINATION CAN CAUSE FAILURE OF SOLENOID VALVES AND REPRESS REG.

- FAILURE EFFECTS -

(A) SUBSYSTEM:

NO EFFECT. THE SERIES REDUNDANT VALVES WILL PREVENT LEAKAGE OF GHE INTO THE MANIFOLD.

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(B) INTERFACING SUBSYSTEM(S):

SAME AS A.

(C) MISSION:

NO EFFECT.

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

SAME AS C.

(E) FUNCTIONAL CRITICALITY EFFECTS:

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

1,2) LV40 AND LV41 BOTH FAIL TO REMAIN CLOSED.

3) LO2 REPRESS REGULATOR (PR5) FAILS WIDE OPEN (MAXIMUM FLOW).

RESULTS IN HELIUM ENTERING THE FEEDLINE MANIFOLD. THIS MAY CAUSE MULTIPLE UNCONTAINED ENGINE FAILURES DUE TO HELIUM BUBBLE INGESTION AND TURBOPUMP CAVITATION. POSSIBLE LOSS OF CREW/VEHICLE.

-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 110 LB/INCH OVER A STROKE OF 0.060 INCH, OR 6.6 LB FORCE). THE WEAK LINK IN THIS

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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)

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/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
DRY FILM LUBRICATION

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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:

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:

PNEUMATIC ACTUATION HELIUM BOTTLE PRESSURE IS ON A DEDICATED DISPLAY IN COCKPIT. CREW ACTION IS TO FOLLOW NORMAL LEAK ISOLATION PROCEDURE. PRIOR TO MECO, ISOLATION VALVES (LV7, LV8) WILL BE REOPENED AND THE LEFT ENGINE HELIUM CROSSOVER VALVE (LV10) WILL BE OPENED.

PNEUMATIC TANK, REGULATOR, AND ACCUMULATOR PRESSURE ARE ON S/M ALERT FDA SYSTEM AND THE BFS SYSTEM SUMMARY DISPLAY. THIS ALLOWS THE FLIGHT CREW TO RESPOND TO A PNEUMATIC HELIUM SYSTEM LEAK INDEPENDENT OF GROUND CONTROL.

- 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 | : MICHAEL SNYDER | :/S/ MICHAEL SNYDER |
| USA ORBITER ELEMENT | : SUZANNE LITTLE | :/S/ SUZANNE LITTLE |

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NASA SR&QA

: BILL PRINCE

:/S/ BILL PRINCE