

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

NUMBER: 03-1-0221 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 2 08/02/00

**PART DATA**

|     | <b>PART NAME</b>  | <b>PART NUMBER</b>     |
|-----|---|------------------------|
|     | <b>VENDOR NAME</b>  | <b>VENDOR NUMBER</b>   |
| LRU | :LO2 OUTBOARD FILL/DRAIN VALVE OPENING<br>SOLENOID VALVE (LV28) | MC284-0404-0032, -0042 |
|     | UNITED SPACE ALLIANCE - NSLD                                    | 13111-5, -6            |

**EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:**

VALVE, SOLENOID, NORMALLY CLOSED 3 WAY 1/4 INCH. LO2 OUTBOARD FILL/DRAIN VALVE CONTROL, OPENING (LV28).

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: LV28

QUANTITY OF LIKE ITEMS: 1

**FUNCTION:**

CONTROLS PNEUMATIC PRESSURE TO OPEN THE OUTBOARD LOX FILL AND DRAIN VALVE. THE SOLENOID MUST DEACTUATE TO ALLOW FILL AND DRAIN VALVE ACTUATOR TO VENT WHEN FILL VALVE IS CLOSED. CLOSING SOLENOID (LV29) (REFERENCE FMEA/CIL 0222) MUST DEACTUATE TO ALLOW VALVE TO OPEN.

**FAILURE MODES EFFECTS ANALYSIS FMEA -- CIL FAILURE MODE****NUMBER: 03-1-0221-05****REVISION#:** 2 08/02/00**SUBSYSTEM NAME:** MAIN PROPULSION**LRU:** LO2 O/B F/D OPENING SOLENOID VALVE (LV28)**CRITICALITY OF THIS****ITEM NAME:** LO2 O/B F/D OPENING SOLENOID VALVE (LV28)**FAILURE MODE:** 1R3**FAILURE MODE:**

PREMATURE ACTUATION (OUTBOARD FILL AND DRAIN VALVE FAILS TO REMAIN CLOSED, REFERENCE FMEA/CIL 03-1-0311-04) CAUSING ACTUATOR OPENING SIDE TO PRESSURIZE. DURING ENGINE OPERATION AND ENTRY.

**MISSION PHASE:** LO LIFT-OFF

**VEHICLE/PAYLOAD/KIT EFFECTIVITY:**

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

**CAUSE:**

PIECE PART STRUCTURAL FAILURE, SEAL/SEAT DAMAGE

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

- A) PASS
- B) FAIL
- C) PASS

**PASS/FAIL RATIONALE:**

A)

B)

FAILS B SCREEN BECAUSE SOLENOID DOES NOT HAVE POSITION INDICATORS. OPEN SOLENOID IS OPERATIONALLY REDUNDANT TO CLOSE SOLENOID.

C)

**- FAILURE EFFECTS -****(A) SUBSYSTEM:**

FAILURE OF THE OPENING SOLENOID RESULTS IN APPLICATION OF ACTUATOR OPENING PRESSURE. FILL AND DRAIN VALVE IS BISTABLE AND WILL REMAIN IN LAST COMMANDED POSITION WITH BOTH OPENING AND CLOSING PRESSURE APPLIED. RESULTS IN LOSS OF REDUNDANCY ONLY.

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

SAME AS A.

**(C) MISSION:**

NO EFFECT. VALVE WILL REMAIN CLOSED.

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

SAME AS C.

**(E) FUNCTIONAL CRITICALITY EFFECTS:**

CASE 1:

1R/3 3 SUCCESS PATHS. TIME FRAME - ASCENT.

- 1) PREMATURE ACTUATION OF OUTBOARD FILL AND DRAIN VALVE OPENING SOLENOID (LV28).
- 2) PREMATURE DEACTUATION OF OUTBOARD FILL AND DRAIN VALVE CLOSING SOLENOID (LV29).
- 3) INBOARD FILL & DRAIN VALVE (PV10) FAILS TO REMAIN CLOSED.

RESULTS IN THE OVERBOARD LEAKAGE OF LO2. FIRE HAZARD AT THE VEHICLE EXTERIOR. LOSS OF USABLE PROPELLANT WILL LEAD TO A PREMATURE ENGINE CUTOFF. POSSIBLE VIOLATION OF ET MINIMUM STRUCTURAL REQUIREMENTS DUE TO REDUCED ULLAGE PRESSURE. POSSIBLE LOSS OF CREW/VEHICLE.

CASE 2:

1R/3 3 SUCCESS PATHS. TIME FRAME - RTLS AND TAL.

- 1) FAILURE RESULTING IN RTLS OR TAL ABORT.
- 2) PREMATURE ACTUATION OF OUTBOARD FILL AND DRAIN VALVE OPENING SOLENOID (LV28).
- 3) PREMATURE DEACTUATION OF OUTBOARD FILL AND DRAIN VALVE CLOSING SOLENOID (LV29).

LOSS OF GHE SUPPLY DURING MANIFOLD REPRESS CAUSING LACK OF AFT COMPARTMENT PURGE. FIRE/EXPLOSION HAZARD EXTERIOR TO THE VEHICLE (THE INBOARD FILL & DRAIN VALVE IS NOMINALLY OPEN DURING ENTRY). 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. THE VALVE FEATURES A BALANCED LOAD ON THE BALL BY APPLYING INLET PRESSURE

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(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.

PREMATURE ACTUATION, FROM THE MECHANICAL VIEW, MEANS APPLICATION OF A DIFFERENTIAL FORCE TO THE VALVE BALL TO CAUSE IT TO MOVE FROM THE INLET SEAT TO THE VENT SEAT. ON THE SOLENOID SIDE OF THE BALL, NO MECHANICAL FAILURES WOULD CAUSE PREMATURE ACTUATION. ON THE OTHER HAND, IF THE CLOSING FORCE OF THE BELLOWS/SPRING WERE REMOVED, INLET PRESSURE AND FLOW ACTING ON THE BALL WOULD DRIVE IT TO THE VENT SEAT, CAUSING PREMATURE ACTUATION.

THE FORCE TO HOLD THE BALL TO THE INLET SEAT, WHEN THE SOLENOID IS DEENERGIZED, 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 AND THE BALL WOULD MOVE TO THE VENT SEAT. THE BELLOWS IS MADE OF NICKEL-COBALT-COPPER AND IS PROOF PRESSURE TESTED AT 1550 PSIG PRIOR TO ASSEMBLY INTO THE VALVE. 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 POUNDS/INCH AND EXERTS A FORCE OF 7.54 POUNDS IN ITS INSTALLED CONDITION.

PREMATURE ACTUATION DUE TO SEAT/SEAL DAMAGE IS VERY UNLIKELY. THIS PRESUMES FLOW PAST THE SEATED BALL AT A RATE SUFFICIENT TO PRESSURIZE THE ACTUATION PORT TO A PRESSURE OF 400 PSIA MINIMUM, WHILE THE VENT PORT IS OPEN. THE BALL IS OF 430 CRES AND THE SEAT IS OF VESPEL.

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

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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 SPECIMENS -

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

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.

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**(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

ALL PARTS ARE PROTECTED FROM DAMAGE AND CONTAMINATION. MICROSCOPIC EXAMINATION OF ALL DETAIL PARTS IS MADE PRIOR TO ASSEMBLY. ALL SURFACES REQUIRING CORROSION PROTECTION ARE VERIFIED. MANDATORY INSPECTION POINTS ARE INCLUDED IN THE ASSEMBLY PROCEDURE. MECHANICAL SURFACE FINISH AT 125 RMS IS INSPECTED AND VERIFIED WITH A PROFILOMETER. SURFACE FINISHES SMOOTHER THAN 125 RMS ARE INSPECTED USING A COMPARATOR AT 10X MAGNIFICATION. ALL CRITICAL DIMENSIONS ARE VERIFIED BY INSPECTION.

CRITICAL PROCESS

HEAT TREATMENT AND PARTS PASSIVATION VERIFIED BY INSPECTION. POTTING OF SOLDER CUPS, ELECTRICAL WIRE STRIPPING, AND SOLDERING OF CONNECTORS ARE VERIFIED BY INSPECTION. DRY FILM LUBRICATION APPLIED TO THE PLUNGER IS VERIFIED BY INSPECTION.

NONDESTRUCTIVE EVALUATION

WELDS VISUALLY EXAMINED & VERIFIED BY X-RAY, DYE PENETRANT, AND EDDY CURRENT. THE SOLENOID ASSEMBLY IS SUBJECTED TO LEAKAGE VERIFICATION USING RADIOACTIVE TRACER TECHNIQUES. THE VALVE BODY, PRIOR TO FINAL MACHINING, IS SUBJECTED TO ETCH AND DYE PENETRANT INSPECTION. BELLOWS ASSEMBLY IS PROOF PRESSURE TESTED AND LEAK CHECKED.

TESTING

ATP VERIFIED BY INSPECTION.

HANDLING/PACKAGING

PACKAGING FOR SHIPMENT VERIFIED BY INSPECTION.

**(D) FAILURE HISTORY:**

LEAKAGE RESULTING FROM SEAL/SEAT DAMAGE (OR CONTAMINATION) HAS OCCURRED BUT HAS NOT BEEN OF SUFFICIENT MAGNITUDE TO CAUSE PREMATURE ACTUATION (REFERENCE FMEA/CIL 0291-1, SOLENOID EXTERNAL LEAKAGE THROUGH VENT PORT).

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 REQUIRED (FIRST FAILURE).

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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  | : DAVID NEARY          | :/S/ DAVID NEARY          |
| MPS SUBSYSTEM MGR.  | : TIMOTHY REITH        | :/S/ TIMOTHY REITH        |
| MOD                 | : WILLIAM LANE         | :/S/ WILLIAM LANE         |
| USA SAM             | : MICHAEL SNYDER       | :/S/ MICHAEL SNYDER       |
| USA ORBITER ELEMENT | : SUZANNE LITTLE       | :/S/ SUZANNE LITTLE       |
| NASA SR&QA          | : BILL PRINCE          | :/S/ BILL PRINCE          |