

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE

NUMBER: 03-1-0225 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 2 08/28/00

PART DATA

PART NAME	PART NUMBER
VENDOR NAME	VENDOR NUMBER
LRU : LO2 PREVALVE OPEN SOLENOID UNITED SPACE ALLIANCE - NSLD	MC284-0404-0041,-0051 13110-6, 13110-7

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:

VALVE SOLENOID, NORMALLY CLOSED, 3 WAY 3/8 INCH. LO2 PREVALVE CONTROL. OPENING

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: LV12
LV14
LV16
LV83
LV84
LV85

QUANTITY OF LIKE ITEMS: 6
TWO PER PREVALVE

FUNCTION:

CONTROLS PNEUMATIC PRESSURE TO OPEN THE LOX PREVALVE. BOTH SERIES SOLENOID VALVES MUST ENERGIZE IN ORDER TO PROVIDE PRESSURE TO THE OPENING SIDE OF THE PREVALVE ACTUATOR. ONE OF TWO CLOSING SOLENOIDS ENERGIZED WILL PROVIDE CLOSING PNEUMATICS. BOTH PARALLEL CLOSING SOLENOIDS (LV13, 15, 17, 80, 81, 82) (REFERENCE FMEA/CIL 03-1-0226) MUST DEACTUATE TO ALLOW THE PREVALVE TO OPEN. ONE OF THE TWO OPENING VALVES MUST DEACTUATE TO ALLOW PREVALVE ACTUATOR TO VENT WHEN PREVALVE IS TO BE CLOSED.

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REVISION#: 2 07/12/00

SUBSYSTEM NAME: MAIN PROPULSION

LRU: LO2 PV OPEN SOLENOID (LV12,14,16,83,84,85)

CRITICALITY OF THIS

ITEM NAME: LO2 PV OPEN SOLENOID (LV12,14,16,83,84,85)

FAILURE MODE: 1R2

FAILURE MODE:

FAILS TO DEACTUATE (PREVALVE FAILS TO CLOSE, REFERENCE FMEA/CIL 03-1-0401-04).

FAILS TO PROVIDE VENT TO CLOSE PREVALVE AT MECO.

MISSION PHASE:

PL PRE-LAUNCH

LO LIFT-OFF

VEHICLE/PAYLOAD/KIT EFFECTIVITY:

102 COLUMBIA

103 DISCOVERY

104 ATLANTIS

105 ENDEAVOUR

CAUSE:

PIECE PART STRUCTURAL FAILURE, BINDING, VENT CHECK VALVE FAILS TO OPEN,

ACTUATION PORT FILTER CLOGGED.

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 VALVES DO NOT HAVE POSITION INDICATORS AND ARE INSTALLED SUCH THAT ONLY ONE OF TWO VALVES (LV12, 14, 16) MUST DEACTUATE TO VENT ACTUATOR OPEN PORT. LV83, 84, 85 ARE CONSIDERED STANDBY REDUNDANT TO LV12, 14, 16.

C)

- FAILURE EFFECTS -

(A) SUBSYSTEM:

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NO EFFECT FOR FIRST FAILURE. ONLY FAILURE OF BOTH SOLENOIDS TO DEACTUATE WILL PREVENT THE PREVALVE FROM CLOSING. SINGLE SOLENOID FAILURE HAS NO EFFECT ON VALVE CLOSURE (ACTUATOR WILL VENT).

(B) INTERFACING SUBSYSTEM(S):

SAME AS A.

(C) MISSION:

POSSIBLE LOSS OF CREW/VEHICLE FOR FAILURE OF BOTH SOLENOIDS.

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

SAME AS C.

(E) FUNCTIONAL CRITICALITY EFFECTS:

CASE 1:

1R/2 2 SUCCESS PATHS. TIME FRAME - ASCENT

1, 2) BOTH OPENING SOLENOIDS FAIL TO DEACTUATE AT MECO

PREVALVE FAILING TO CLOSE WILL RESULT IN INABILITY TO MAINTAIN INJECTED HELIUM AND LO2 PRESSURE TO THE HPOTP TO PREVENT PUMP OVERSPEED AND CAVITATION AT MECO. RESULTS IN OXIDIZER RICH SHUTDOWN AND UNCONTAINED ENGINE DAMAGE. POSSIBLE AFT COMPARTMENT OVERPRESS AND FIRE/EXPLOSIVE HAZARD.

CASE 2:

1R/3 3 SUCCESS PATHS. TIME FRAME - PAD ABORT, ASCENT.

1) PREMATURE ENGINE SHUTDOWN WITH UNCONTAINED ENGINE DAMAGE (ASSUMES ENGINE IS DAMAGED ONLY TO THE EXTENT THAT ISOLATION OF THE DAMAGE WILL SAVE THE SYSTEM).

2, 3) BOTH PREVALVE OPENING SOLENOIDS (FOR THE AFFECTED SSME) FAIL TO DEACTUATE.

LO2 PREVALVE FAILS TO ISOLATE A SHUTDOWN ENGINE WHICH HAS UNCONTAINED ENGINE DAMAGE. POSSIBLE AFT COMPARTMENT OVERPRESS AND FIRE/EXPLOSIVE HAZARD DUE TO LO2 LEAKAGE. POSSIBLE LOSS OF CREW/VEHICLE.

-DISPOSITION RATIONALE-

(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 (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

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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.

FOR THE VALVE TO FAIL TO DEACTUATE MEANS THE FORCE TO RETURN THE BALL TO THE INLET SEAT IS NOT PRESENT, THE FORCE HOLDING IT ON THE VENT SEAT IS NOT REMOVED, OR FLOW OUT THE VENT PORT IS PREVENTED. WHEN THE SOLENOID IS DEENERGIZED, THE FORCE TO RETURN THE BALL TO THE INLET SEAT 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 VALVE INLET PRESSURE, THE LOAD BALANCING FEATURE IS ELIMINATED. INLET FLOW AGAINST THE BALL WOULD CONTINUE TO HOLD IT AGAINST THE VENT SEAT (AFTER DEENERGIZING THE SOLENOID) CAUSING THE VALVE TO FAIL TO DEACTUATE THE BELLOWS ARE MADE OF NICKEL-COBALT-COPPER AND ARE ASSEMBLED INTO A SUB-ASSEMBLY. THIS SUB-ASSEMBLY IS PROOF PRESSURE TESTED AT 1550 PSIG PRIOR TO VALVE FINAL ASSEMBLY. IF THE SPRING BREAKS THE PRESSURIZED BELLOWS WOULD EXERT SUFFICIENT FORCE TO RETURN THE BALL TO THE INLET SEAT; HOWEVER, M 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 LB/INCH AND EXERTS A FORCE OF 7.54 LB. IN ITS INSTALLED CONDITION.

FAILURE TO REMOVE THE FORCE HOLDING THE BALL ON THE VENT SEAT, WHEN THE SOLENOID IS DEENERGIZED, COULD BE CAUSED BY BINDING IN THE SOLENOID. FORCE TO DRIVE THE BALL TO THE VENT SEAT IS DELIVERED FROM THE SOLENOID BY A PLUNGER AND TWO PUSHRODS (ALIGNED IN SERIES WITHIN, AND GUIDED BY, THE SOLENOID STOP). THE AREAS OF POTENTIAL BINDING ARE BETWEEN THE PUSHRODS AND THE SOLENOID STOP. TO PRECLUDE BURRS THE SOLENOID BORE IS HONED, AND TO PREVENT BINDING, THE PLUNGER IS COATED WITH A DRY-FILM LUBRICANT. THE SOLENOID STOP IS MADE OF A MUCH HARDER MATERIAL (430 CRES) THAN EITHER OF THE PUSHRODS (17-4PH AND 304 CRES) TO PREVENT GALLING.

THE VENT CHECK VALVE, WHICH SCREWS INTO THE SOLENOID VALVE VENT PORT, IS OF SIMPLE DESIGN, CONTAINING ONLY 5 PARTS. CRACK AND RESEAT PRESSURES ARE 0.5 PSID AND THE UNIT IS DESIGNED FOR 10,000 CYCLES. HIGH INLET PRESSURE (710 PSIA NOMINAL) ACTING ON A LARGE POPPET (0.603 INCH DIAMETER) PRODUCES A FORCE IN EXCESS OF 400 POUNDS TO ASSURE CHECK VALVE OPENING. THE CHECK VALVE BODY AND POPPET ARE OF 2024-T6 ALUMINUM, AND TO PREVENT GALLING OR BINDING, HAVE BEEN HARD ANODIZED. TO PRECLUDE COCKING, THE POPPET STEM IS CLOSELY GUIDED OVER 50% OF ITS LENGTH BY THE BODY BORE (STEM, 0.1349 INCH DIAMETER; BORE, 0.141 INCH DIAMETER).

CLOGGING OF THE 20 MICRON NOMINAL, 40 MICRON ABSOLUTE, RATED ACTUATION PORT FILTER WOULD PREVENT THE SOLENOID FROM VENTING THE ACTUATOR, CREATING THE EFFECT OF FAILURE TO DEACTUATE. THE FILTER IS PLEATED IN ORDER TO INCREASE SURFACE AREA.

THE -0031 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

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DAMAGE OCCURRED DURING ATP, VALVES ALREADY IN THE FLEET (-0021 CONFIGURATION) WERE X-RAY TESTED AND ONLY VALVES WHICH HAD SQUIRMED BELLOWS WERE UPGRADED TO THE -0031 CONFIGURATION.

THE -0041 AND -0051 CONFIGURATION SOLENOID VALVES ARE IDENTICAL TO THE -0021 AND -0031 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 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 UNIT ENERGIZED AND ONE DEENERGIZED - FOLLOWED BY ELECTRICAL CHARACTERISTICS AND LEAKAGE CHECKS.

HANDLING SHOCK TEST

ENERGIZED AND DEENERGIZED FLOW TESTS

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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.

(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.

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HANDLING/PACKAGING
PACKAGING FOR SHIPMENT VERIFIED BY INSPECTION.

(D) FAILURE HISTORY:

THE SOLENOID VALVE EXPERIENCED ERRATIC BUT ACCEPTABLE PERFORMANCE AT KSC DUE TO EXCESSIVE SLIDING FRICTION CAUSED BY BURRS, AND SHARP EDGES ON THE ARMATURE (CAR AC1181). THE CONTROLLED PNEUMATIC VALVE OPERATION WAS ACCEPTABLE. THE CORRECTIVE ACTION RESULTED IN THE REDESIGN OF THE VALVE TO ELIMINATE THE BURRS AND SHARP EDGES. INSPECTION WAS IMPROVED AND AN OMRSD REQUIREMENT FOR CURRENT SIGNATURE TRACE WAS IMPOSED.

AFTER THE ACTUATION SIGNAL WAS REMOVED, TWO VALVES AT NSTL VENTED CONTINUOUSLY (CAR A7662) DUE TO BINDING OF THE PLUNGER CAUSED BY BURRS AND GALLING. DETAIL PARTS WERE INCORRECTLY FABRICATED/ASSEMBLED. THESE VALVE DEFECTS WERE REPAIRED.

DURING QUALIFICATION TESTING AT THE SUPPLIER (CAR AC3193), AND SUBSEQUENTLY AT KSC (CAR AC8975 AND AD0352), THE VALVES FAILED TO CYCLE (ACTUATE OR DEACTUATE) WHICH OCCASIONALLY PREVENTED PROPER OPERATION OF THE CONTROLLED PNEUMATIC VALVE. FAILURE INVESTIGATION DISCLOSED FRETTING ON THE PLUNGER AND IN THE BORE AREA. THIS GENERATED SMALL PARTICLES LEADING TO BINDING OF THE VALVES. THE FRETTING WAS THE RESULT OF A LACK OF REQUIRED LUBRICANT. THE CORRECTIVE ACTION WAS THE APPLICATION OF MICROSEAL (DRY FILM LUBRICANT) ON ALL NEW PARTS AND THE REPLACEMENT OF PLUNGERS WITH MICROSEAL WHEN VALVES WERE RETURNED TO THE SUPPLIER FOR REWORK.

FOUR SOLENOID VALVES FAILED TO ACTUATE PROPERLY DURING ATP. TWO FAILED TO ACTUATE DUE TO BINDING (CARS AC0737, ACO894) AND THE OTHER TWO FAILED DUE TO INCORRECT STROKE OF THE PLUNGER (CARS ACO739, AC1469). DETAIL PARTS WERE INCORRECTLY FABRICATED/ASSEMBLED. THESE VALVE DEFECTS WERE REPAIRED AND ARE ATP SCREENABLE.

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:

FLIGHT: NO CREW ACTION CAN BE TAKEN.

GROUND: GROUND OPERATIONS SAFING PROCEDURES CONTAIN SAFING SEQUENCE OF EVENTS FOR MAJOR LEAKS IN THE OXYGEN SYSTEM.

- 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	: JEFFREY L. MUSLER	:/S/ JEFFREY L. MUSLER
USA SAM	: MICHAEL SNYDER	:/S/ MICHAEL SNYDER
USA ORBITER ELEMENT	: SUZANNE LITTLE	:/S/ SUZANNE LITTLE
NASA SR&QA	: WILLIAM PRINCE	:/S/ WILLIAM PRINCE