

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE

NUMBER: 03-1-0270 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 1 06/22/00

PART DATA

	PART NAME	PART NUMBER
	VENDOR NAME	VENDOR NUMBER
LRU	:LH2 OUTBOARD FILL AND DRAIN VALVE OPENING SOLENOID	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. LH2 OUTBOARD FILL AND DRAIN VALVE 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: LV32

QUANTITY OF LIKE ITEMS: 1

FUNCTION:

CONTROLS PNEUMATIC PRESSURE TO OPEN THE OUTBOARD LH2 FILL VALVE. THE VALVE MUST DEACTUATE TO ALLOW FILL VALVE ACTUATOR TO VENT WHEN FILL VALVE IS CLOSED. CLOSING SOLENOID (LV33) (REFERENCE FMEA/CIL 03-1-0271) MUST DEACTUATE TO ALLOW VALVE TO OPEN.

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REVISION#: 2 08/03/00

SUBSYSTEM NAME: MAIN PROPULSION

LRU: LH2 O/B F/D OPEN SOLENOID VALVE (LV32)

CRITICALITY OF THIS

ITEM NAME: LH2 O/B F/D OPEN SOLENOID VALVE (LV32)

FAILURE MODE: 1R3

FAILURE MODE:

FAILS TO ACTUATE (FILL AND DRAIN VALVE FAILS TO OPEN, REFERENCE FMEA/CIL 03-1-0302-05) WHEN OUTBOARD LH2 FILL VALVE IS COMMANDED OPEN FOR DUMP, DETANKING.

MISSION PHASE: PL PRE-LAUNCH
LO LIFT-OFF

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

CAUSE:

ELECTRICAL SOLENOID FAILURE, BINDING, INLET FILTER CLOGGED, PIECE PART STRUCTURAL FAILURE

CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO

REDUNDANCY SCREEN A) PASS
B) PASS
C) PASS

PASS/FAIL RATIONALE:

A)

B)

PASSES B SCREEN BECAUSE VALVE POSITION SWITCHES WILL INDICATE A FAILURE OF THE FILL AND DRAIN VALVE TO OPEN.

C)

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

RESULTS IN INABILITY TO DETANK. DURING THIS TIME THE HIGH POINT BLEED VALVE (PV22) AND THE ET VENT VALVE WILL PROVIDE RELIEF CAPABILITY. ALSO RESULTS IN LOSS OF CAPABILITY TO DUMP/INERT THROUGH THE FILL AND DRAIN SYSTEM. LH2 PRESSURE RELIEF (POST MECO) IS THROUGH THE MANIFOLD RELIEF SYSTEM.

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(B) INTERFACING SUBSYSTEM(S):

SAME AS A.

(C) MISSION:

NO EFFECT IN FLIGHT. LAUNCH SCRUB FOR FAILURE PRIOR TO TANKING.

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

NO EFFECT ON NOMINAL, TAL, AOA, AND ATO MISSIONS. FOR RTLS ABORTS, THIS FAILURE WOULD RESULT IN APPROXIMATELY 40 POUNDS OF RESIDUAL LH2 ON BOARD AT LANDING. THE FEEDLINE RELIEF SYSTEM DOES NOT HAVE THE CAPACITY TO COMPLETELY DISSIPATE RESIDUAL LH2 PRIOR TO TOUCHDOWN. HAZARD DURING POST LANDING OPS DUE TO EXTENDED LH2 BURNOFF TIME THROUGH THE FLAME ARRESTOR (FL1) (RESULTS IN HIGH HEAT FLUX AT THE VERTICAL STABILIZER).

(E) FUNCTIONAL CRITICALITY EFFECTS:

CASE 1:

1R/3 3 SUCCESS PATHS. TIME FRAME - LH2 DUMP.

- 1) OUTBOARD FILL & DRAIN SOLENOID VALVE (LV32) FAILS TO ACTUATE.
- 2) EITHER RTLS DUMP VALVE (PV17, 18) FAILS TO OPEN. RTLS DUMP VALVES ARE OPENED FOLLOWING MECO FOR 110 SECONDS, BUT CAN BE OPENED BY THE CREW IF MANIFOLD PRESSURE APPROACHES RELIEF PRESSURES. EFFECTIVE FOR OI-29 AND SUBS THE RTLS DUMP VALVES WILL BE USED FOR LH2 VACUUM INERTING.
- 3) MANIFOLD RELIEF SYSTEM FAILS TO RELIEVE.

LH2 REMAINING IN MANIFOLD CANNOT BE RELIEVED. RESULTS IN OVERPRESSURIZATION AND RUPTURE OF THE FEEDLINE MANIFOLD. RTLS DUMP VALVES ARE OPENED FOLLOWING MECO, BUT NOT LONG ENOUGH TO DUMP THE MAJORITY OF THE REMAINING LH2. AFT COMPARTMENT OVERPRESSURIZATION AND FIRE/EXPLOSION HAZARD. POSSIBLE LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CYRO EXPOSURE. POSSIBLE LOSS OF CREW/VEHICLE.

CASE 2:

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

- 1) OUTBOARD FILL & DRAIN SOLENOID VALVE (LV32) FAILS TO ACTUATE.
- 2) ET LH2 RELIEF VALVE FAILS TO RELIEVE.
- 3) HIGH POINT BLEED VALVE (PV22) FAILS TO OPEN/REMAIN OPEN.

LH2 REMAINING IN MANIFOLD CANNOT BE RELIEVED. RESULTS IN OVERPRESSURIZATION AND RUPTURE OF THE FEEDLINE MANIFOLD. AFT COMPARTMENT OVERPRESSURIZATION AND FIRE/EXPLOSION HAZARD. POSSIBLE LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CYRO EXPOSURE. RTLS DUMP VALVES (PV17,18) AND LH2 MANIFOLD RELIEF ISOLATION VALVE (PV8) CAN BE OPENED BY GROUND ACTION, BUT THIS WOULD DUMP LH2 ONTO THE PAD SURFACE. POSSIBLE LOSS OF CREW/VEHICLE.

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-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 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.

TO FAIL TO ACTUATE MEANS THE FORCE TO MOVE THE BALL TO THE VENT SEAT IS NOT DELIVERED TO THE BALL. THE VALVE PARTS INVOLVED ARE THE SOLENOID, THE SOLENOID PLUNGER, THE SOLENOID STOP, TWO PUSHRODS AND A SPRING. THE PUSHRODS ARE ALIGNED IN SERIES, SEPARATED BY THE SPRING FOR CHATTER PREVENTION. THE PUSHRODS ARE MADE OF CRES AND CARRY ONLY AXIAL LOADS. IF THE RODS WERE TO FAIL STRUCTURALLY, THEY WOULD CONTINUE TO PERFORM THEIR FUNCTION BECAUSE THEY ARE TOTALLY CONTAINED IN THE STOP (THE ROD OD IS 0.125 INCH AND THE STOP ID IS 0.126 INCH). THE ROD, IN CONTACT WITH THE BALL, IS GUIDED BY THE SOLENOID STOP FOR OVER 28% OF ITS LENGTH.

BECAUSE OF THE CLOSE TOLERANCES IN THE SOLENOID ASSEMBLY, BINDING DUE TO CONTAMINATION IS A DESIGN CONCERN. TO PRECLUDE BURRS, THE SOLENOID BORE IS HONED. TO PREVENT BINDING, THE PLUNGER IS COATED WITH A DRY-FILM LUBRICANT. THE STOP IS MADE OF A MUCH HARDER MATERIAL THAN EITHER OF THE PUSHRODS TO PREVENT GALLING, AND THE PUSHROD SPRING NOT ONLY CONTROLS CHATTER, BUT REDUCES THE POTENTIAL FOR FRETTING.

CLOGGING OF THE 20 MICRON NOMINAL, 40 MICRON ABSOLUTE, RATED INLET FILTER IS PROTECTED AGAINST BY THE USE OF MULTI-FILTERED HELIUM IN THE ORBITER PNEUMATICS SYSTEM. THE HELIUM IS FILTERED BY THE GROUND SYSTEM BEFORE PRESSURIZING THE VEHICLE PNEUMATICS BOTTLE. IT IS AGAIN FILTERED (25 MICRONS, ABSOLUTE) BEFORE IT ENTERS THE VALVE ACTUATION SYSTEM. ALSO, TO INCREASE THE INLET FILTER'S EFFECTIVE SURFACE AREA THE FILTER IS OF A PLEATED DESIGN.

THE SOLENOID STRUCTURE IS CONSTRUCTED OF CRES AND IS BE WELDED. THE COIL IS VACUUM IMPREGNATED (POTTED). THE UNIT IS PRESSURE AND LEAK TESTED AT MAJOR ASSEMBLY POINTS.

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.

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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 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 UNITS -

PORT AND FITTING TORQUE

SALT FOG EXPOSURE FOLLOWED BY ELECTRICAL AND LEAKAGE CHECKS

AMBIENT VIBRATION TESTS: TOTAL 13.1 HOURS BOTH AXIS 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

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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.

HANDLING/PACKAGING

PACKAGING FOR SHIPMENT VERIFIED BY INSPECTION.

(D) FAILURE HISTORY:

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A NUMBER OF ELECTRICAL CONNECTORS WERE BROKEN AT NSTL DUE TO EXCESSIVE PHYSICAL FORCE APPLIED TO THE CONNECTOR BY TECHNICIANS WORKING IN THE CONFINED AREA (CAR'S AB1813, AB1613, AND AB1208). CORRECTIVE ACTION RESULTED IN THE INSTALLATION OF PROTECTIVE COVERS TO PREVENT CONNECTOR DAMAGE IN HIGH TRAFFIC AREA. ALSO, CONNECTORS WERE WELDED TO THE VALVE BODY IN LIEU OF SOLDERING.

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.

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.

AN ELECTRICAL SHORT DUE TO INCORRECT ALIGNMENT OF SOLDER CUPS (PINS "A" AND "C") WAS DETECTED AT THE PALMDALE FACILITY (CAR AC2687). THE CORRECTIVE ACTION TAKEN WAS THE ADDITION OF HEAT SHRINK TUBING TO ISOLATE THE SOLDER CUPS AND THE ADDITION OF AN INSPECTION POINT AFTER POTTING.

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.

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.

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: FOR POST MECO DUMP OPERATIONS, THE CREW WILL OPEN THE LH2 RTLS DUMP VALVES (PV17,18) WHEN THE LH2 MANIFOLD PRESSURE EXCEEDS CAUTION AND WARNING LIMITS.

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GROUND: GROUND OPERATIONS SAFING PROCEDURES CONTAIN SAFING SEQUENCE OF EVENTS FOR MAJOR LEAKS IN THE HYDROGEN 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
MOD	: WILLIAM LANE	: /S/ WILLIAM LANE
USA SAM	: MICHAEL SNYDER	: /S/ MICHAEL SNYDER
USA ORBITER ELEMENT	: SUZANNE LITTLE	: /S/ SUZANNE LITTLE
NASA SR&QA	: ERICH BASS	: /S/ ERICH BASS