

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE

NUMBER: 03-1-0291 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 2 07/27/00

PART DATA

	PART NAME	PART NUMBER
	VENDOR NAME	VENDOR NUMBER
LRU	:GHE 3-WAY SOLENOID VALVE, NC TYPE 2 UNITED SPACE ALLIANCE - NSLD	MC284-0404-0032, -0042 13111-5, -6
LRU	:GHE 3-WAY SOLENOID VALVE, NC TYPE 1 UNITED SPACE ALLIANCE - NSLD	MC284-0404-0041, -0051 13110-6, -7

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:

THREE-WAY SOLENOID VALVE, NORMALLY CLOSED. BOTH 1/4 AND 3/8 INCH. FOR ALL VALVE ACTUATION CONTROL UPSTREAM OF HELIUM PNEUMATIC CHECK VALVE, CV9.

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
LV29
LV30
LV31
LV32
LV33
LV34
LV35
LV36
LV39
LV77
LV78

QUANTITY OF LIKE ITEMS: 12
VALVES UPSTREAM OF CHECK VALVE, CV9.

FUNCTION:

EACH SOLENOID CONTROLS PNEUMATIC PRESSURE TO OPEN OR CLOSE ITS CORRESPONDING ACTUATOR/VALVE. THE VALVES OPERATED BY THESE SOLENOIDS ARE:

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LO2 OUTBOARD FILL & DRAIN VALVE (LV28,29),
LO2 INBOARD FILL & DRAIN VALVE (LV30,31),
LH2 OUTBOARD FILL & DRAIN VALVE (LV32,33),
LH2 INBOARD FILL & DRAIN VALVE (LV34,35),
LH2 RECIRCULATION VALVES (LV36),
LH2 TOPPING VALVE (LV39),
LO2 POGO/RECIRCULATION VALVES (LV77,78)

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LRU: GHE 3-WAY SOLENOID VALVE, NC

ITEM NAME: GHE 3-WAY SOL VALVES, REGULATOR LEG

CRITICALITY OF THIS

FAILURE MODE: 1R2

FAILURE MODE:

LEAKAGE, EXTERNAL, THRU VENT PORT.

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, CONTAMINATION, 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 SCREEN B SINCE FAILURE WILL NOT BE READILY DETECTABLE FOR CERTAIN SOLENOID VALVE LEAKAGES, (I.E. CLOSE SOLENOID VALVE LEAKAGE FOR FILL/DRAIN VALVES IN THE CLOSED POSITION DOES NOT PREVENT VALVE FROM OPENING. THEREFORE, THIS FAILURE IS NOT DETECTABLE).

C)

- FAILURE EFFECTS -

(A) SUBSYSTEM:

LEAKAGE MAY PREVENT THE:

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CLOSING AND/OR OPENING OF THE LO2 INBOARD FILL & DRAIN VALVE (REFERENCE FMEA/CIL 03-1-0310),

CLOSING AND/OR OPENING OF THE LO2 OUTBOARD FILL & DRAIN VALVE (REFERENCE FMEA/CIL 03-1-0311),

CLOSING AND/OR OPENING OF THE LH2 INBOARD FILL & DRAIN VALVE (REFERENCE FMEA/CIL 03-1-0301),

CLOSING AND/OR OPENING OF THE LH2 OUTBOARD FILL & DRAIN VALVE (REFERENCE FMEA/CIL 03-1-0302),

OPERATION OF THE LH2 RECIRCULATION VALVE (REFERENCE FMEA/CIL 03-1-0403),

OPENING OF THE LH2 TOPPING VALVE (REFERENCE FMEA/CIL 03-1-0304),

OPERATION OF THE LO2 POGO ACCUMULATOR RECIRCULATION VALVES (REFERENCE FMEA/CIL 03-1-0453).

(B) INTERFACING SUBSYSTEM(S):

SOLENOIDS ARE LOCATED ON HELIUM PNEUMATIC LEG UPSTREAM OF CHECK VALVE CV9 (NON-ACCUMULATOR LEG). RESULTS IN DEPLETION OF THE MPS VALVE ACTUATION HELIUM SUPPLY. AT MECO THE ENGINE NUMBER TWO HELIUM SUPPLY IS SWITCHED INTO THE PNEUMATIC VALVE SYSTEM (VIA LV10) AS A BACKUP, BY SOFTWARE COMMAND, WHICH MAY BE SUFFICIENT FOR VALVE ACTUATION. HELIUM REMAINING DOWNSTREAM OF CV9 (ACCUMULATOR LEG) IS SUFFICIENT TO CLOSE LO2 PREVALVES AT MECO. RESULTS IN LACK OF AFT COMPARTMENT PURGE DURING REENTRY. LEAKAGE MAY BE DETECTABLE ON GROUND USING HAZARDOUS GAS DETECTION SYSTEM (HGDS).

(C) MISSION:

ON GROUND, POSSIBLE VIOLATION OF HGDS LCC WILL RESULT IN LAUNCH SCRUB. LOSS OF HELIUM SUPPLY GAS HAS NO EFFECT (RESULTS IN POSSIBLE SYSTEM CONTAMINATION DURING ENTRY).

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

SAME AS C.

(E) FUNCTIONAL CRITICALITY EFFECTS:

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

- 1) VENT PORT LEAKAGE OF A THREE WAY SOLENOID UPSTREAM OF CHECK VALVE CV9.
- 2) FAILURE OF CV9 TO CHECK/REMAIN CLOSED.

RESULTS IN INABILITY TO CLOSE LO2 PREVALVES AT MECO DUE TO LOSS OF HELIUM SUPPLY (BOTH ACCUMULATOR AND NON ACCUMULATOR LEGS). FAILURE OF THE PREVALVES TO CLOSE CAUSES THE INABILITY TO MAINTAIN INJECTED HELIUM AND LO2 PRESSURE TO THE HPOTP TO PREVENT PUMP OVERSPEED AND CAVITATION AT MECO.

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MAY RESULT IN UNCONTAINED ENGINE DAMAGE, AFT COMPARTMENT OVERPRESS, AND FIRE/EXPLOSIVE HAZARD. AT MECO THE ENGINE NUMBER TWO HELIUM SUPPLY IS SWITCHED INTO THE PNEUMATIC VALVE SYSTEM (VIA LV10) AS A BACKUP, BY SOFTWARE COMMAND, WHICH MAY ACTUATE THE LO2 PREVALVES CLOSED. POSSIBLE LOSS OF CREW/VEHICLE.

-DISPOSITION RATIONALE-

(A) DESIGN:

THE VALVE IS DESIGNED FOR A PRESSURE FACTOR OF SAFETY OF 2.0 PROOF, 4.0 BURST, AND FOR A 10,000 CYCLE LIFE. 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.

RUPTURE/LEAKAGE OF THE BELLOWS WILL CAUSE HELIUM LEAKAGE OUT OF THE VENT PORT VIA THE REFERENCE PASSAGE AT A RATE OF APPROXIMATELY 0.03 POUNDS/SEC (MAXIMUM).

FAILURE OF THE BELLOWS-ASSISTING-SPRING WOULD CREATE THE POTENTIAL FOR A LEAK ACROSS THE INLET SEAT, WITH THE VALVE DEENERGIZED. THE BELLOWS IS DESIGNED TO PROVIDE SUFFICIENT FORCE TO SEAL THE BALL TO THE INLET SEAT; HOWEVER, THE SPRING PROVIDES ADDITIONAL FORCE TO SEAT THE BALL. 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.

INTERNAL LEAKAGE IS CONTROLLED BY THE USE OF SILVER PLATED INCONEL V-SHAPED SEALS. THE OPEN SIDE OF THE "V" SEAL IS EXPOSED TO THE HIGH PRESSURE SIDE OF EACH JOINT SO THAT THE PRESSURE WILL AUGMENT THE SEALING PROPERTIES OF THE SEAL. CONTAMINATION IS CONTROLLED BY THE INSTALLATION OF 20 MICRON NOMINAL, 40 MICRON ABSOLUTE, RATED FILTERS IN BOTH THE INLET AND ACTUATION PORTS. FURTHER, THE HELIUM IN THE ORBITER PNEUMATICS SYSTEM IS MULTI-FILTERED. IT IS FIRST 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.

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 DAMAGE OCCURRED DURING ATP, VALVES ALREADY IN THE FLEET (-0021 CONFIGURATION)

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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 -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 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

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TWO UNITS -

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.

(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

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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:

FIVE CASES OF LEAKAGE OCCURRED AT KSC DURING GROUND CHECKOUT (CARS AC1362, ADO819, AC5880, AC6683, ADO577). THESE FAILURES WERE ATTRIBUTED TO CONTAMINATION WITHIN THE VEHICLE SYSTEM. CLEANLINESS PROCEDURES HAVE BEEN IMPLEMENTED DURING COMPONENT REPLACEMENT.

THREE CASES OF LEAKAGE OCCURRED AT KSC DURING GROUND CHECKOUT (CARS AC8541, AC9720, AC8383) WHICH WERE CAUSED BY CONTAMINATION. SOME OF THESE UNITS HAD DAMAGED POPPET SEATS WHICH MAY HAVE BEEN CAUSED BY METALLIC BURRS THAT WERE FOUND. CLEANLINESS PROCEDURES HAVE BEEN IMPLEMENTED DURING COMPONENT REPLACEMENT. IN ADDITION SUPPLIER CLEANLINESS PROCEDURES HAVE BEEN IMPROVED AND FILTERS HAVE BEEN ADDED TO THE VENT PORTS FOR LO2 PREVALVE SOLENOIDS LV13,15,17.

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.

ATP LEAKAGE WAS CAUSED BY CONTAMINATION AND AN OFF CENTER BALL (REFERENCE CARS AB9393 AND AB9394). A DRAWING CHANGE WAS MADE TO TIGHTEN THE TOLERANCES TO INSURE PROPER ALIGNMENT OF THE BALL/SEAT. FAILURE IS ATP SCREENABLE.

ATP MAIN POPPET LEAKAGE WAS CAUSED BY AN ASSEMBLY PROCEDURE PROBLEM (REFERENCE CAR ADO283). REVISION WAS MADE TO CORRECT PROCEDURE. FAILURE IS ATP SCREENABLE.

ATP LEAKAGE WAS CAUSED BY SOLENOID RETAINING SCREWS BEING IMPROPERLY TORQUED RESULTING IN INSUFFICIENT V-SEAL COMPRESSION (REFERENCE CAR ADO877). INSPECTION OF THE PROPER TORQUE PROCEDURE WAS ADDED TO PRODUCTION WORKSHEETS. FAILURE IS ATP SCREENABLE.

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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:

HELIUM BOTTLE PRESSURE IS ON DISPLAY IN COCKPIT. CREW ACTION CAN CLOSE ISOLATION VALVES DURING ASCENT. PRIOR TO MECO, ISOLATION VALVES (LV7,LV8) CAN BE REOPENED OR THE LEFT ENGINE LOW PRESSURE GHE CROSSOVER VALVE (LV10) CAN BE OPENED.

- 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	: DAVID NEARY	: /S/ DAVID 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
NASA SR&QA	: ERICH BASS	: /S/ ERICH BASS