FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE
NUMBER: 03-1-0228 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 2 08/22/00

PART DATA

	PART NAME **VENDOR NAME**	**PART NUMBER** **VENDOR NUMBER**
LRU	:LH2 PREVALVE CLOSING 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. LH2 PREVALVE CONTROL, CLOSING

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: LV19, 21, 23

QUANTITY OF LIKE ITEMS: 3

FUNCTION:
CONTROLS PNEUMATIC PRESSURE TO CLOSE THE LH2 PREVALVE. VALVE MUST DEACTUATE TO ALLOW PREVALVE ACTUATOR TO VENT WHEN PREVALVE IS OPENED. OPENING SOLENOID (LV18,20,22) (REFERENCE FMEA/CIL 03-1-0227) MUST DEACTUATE TO ALLOW VALVE TO CLOSE.

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SUBSYSTEM NAME: MAIN PROPULSION
LRU: LH2 PREVALVE CLOSING SOLENOID (LV19, 21, 23) **CRITICALITY OF THIS**
ITEM NAME: LH2 PREVALVE CLOSING SOLENOID (LV19, 21, 23) **FAILURE MODE:** 1R2

FAILURE MODE:
PREMATURE ACTUATION (PREVALVE FAILS TO REMAIN OPEN, REFERENCE FMEA/CIL 03-1-0402-03) CAUSING ACTUATOR CLOSING SIDE TO PRESSURIZE DURING ENGINE OPERATION.

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, 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 VALVE DOES NOT HAVE POSITION INDICATORS. CLOSE SOLENOID IS OPERATIONALLY REDUNDANT TO OPEN SOLENOID.

C)

- FAILURE EFFECTS -

(A) SUBSYSTEM:
NO EFFECT FOR FIRST FAILURE. RESULTS IN APPLICATION OF ACTUATOR CLOSING PRESSURE. VALVE IS BISTABLE AND WILL REMAIN IN ITS LAST COMMANDED POSITION WITH BOTH OPENING AND CLOSING PRESSURE APPLIED. OPENING PRESSURE IS NOMINALLY APPLIED DURING ASCENT. RESULTS IN LOSS OF REDUNDANCY ONLY.

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(B) INTERFACING SUBSYSTEM(S):
SAME AS A.

(C) MISSION:
FAILURE HAS NO EFFECT. VALVE FAILURE DURING CHILLDOWN AND INITIAL PHASES OF LOADING HAS NO EFFECT, POSSIBLE LAUNCH SCRUB.

(D) CREW, VEHICLE, AND ELEMENT(S):
SAME AS C.

(E) FUNCTIONAL CRITICALITY EFFECTS:
CASE 1:
1R/2 2 SUCCESS PATHS. TIME FRAME - ENGINE OPERATION.
1) PREMATURE ACTUATION OF PREVALVE CLOSING SOLENOID (LV19,21,23)
2) PREMATURE DEACTUATION OF CORRESPONDING PREVALVE OPENING SOLENOID (LV18,20,22).

RESULTS IN STOPPED FUEL FLOW TO ONE SSME RESULTING IN AN LO2 RICH ENGINE SHUTDOWN, PUMP CAVITATION & OVERSPEED. RESULTS IN UNCONTAINED ENGINE DAMAGE. POSSIBLE LINE RUPTURE DUE TO WATER HAMMER EFFECT (LINE PRESSURE EXCEEDS 150 PSI). POSSIBLE AFT COMPARTMENT OVERPRESS AND FIRE/EXPLOSIVE HAZARD. POSSIBLE VALVE VISOR FRACTURE AND INGESTION INTO ENGINE (ENGINE INLET SCREENS MAY NOT CONTAIN PARTS OF THIS SIZE). POSSIBLE LOSS OF CREW/VEHICLE.

CASE 2:
1R/3 4 SUCCESS PATHS. TIME FRAME - LH2 DUMP.
1) PREMATURE ACTUATION OF PREVALVE CLOSING SOLENOID (LV19,21,23).
2) PREMATURE DEACTUATION OF CORRESPONDING PREVALVE OPENING SOLENOID (LV18,20,22).
3) PREVALVE BYPASS RELIEF VALVE FAILS TO RELIEVE.
4) PREVALVE VISOR LIFTOFF FAILS TO RELIEVE.

RESULTS IN RUPTURE OF THE 12 INCH FEEDLINE CAUSING AFT COMPARTMENT OVERPRESS AND FIRE/EXPLOSIVE HAZARD. POSSIBLE LOSS OF CRITICAL ADJACENT FUNCTIONS DUE TO CRYO EXPOSURE. POSSIBLE LOSS OF CREW/VEHICLE.

-DISPOSITION RATIONALE-

(A) DESIGN:

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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.

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 -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) 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.

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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 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)

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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:
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 CAN BE TAKEN.

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- 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	: 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	: BILL PRINCE	:/S/ BILL PRINCE