FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE
NUMBER: 03-1-0226 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 2 08/28/00

PART DATA

	PART NAME / **VENDOR NAME**	**PART NUMBER** / **VENDOR NUMBER**
LRU	: LO2 PREVALVE CLOSE 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, 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:
LV13
LV15
LV17
LV80
LV81
LV82

QUANTITY OF LIKE ITEMS: 6
TWO PER PREVALVE

FUNCTION:
CONTROLS PNEUMATIC PRESSURE TO CLOSE THE LOX PREVALVE. TWO SOLENOIDS ARE PROVIDED IN PARALLEL (REDUNDANT) TO ASSURE CLOSING ACTUATION PRESSURE TO THE LO2 PREVALVE AT MECO UNDER ZERO G CONDITION. ONLY ONE OF THE SERIES OPENING SOLENOIDS (LV12,14,16,83,84,85) (REFERENCE FMEA/CIL 03-1-0225) MUST DEACTUATE TO ALLOW THE OPEN SIDE OF THE ACTUATOR TO VENT FOR PREVALVE CLOSURE. BOTH CLOSING SOLENOIDS MUST DEACTUATE TO ALLOW ACTUATOR TO VENT FOR PREVALVE OPENING.

FAILURE MODES EFFECTS ANALYSIS FMEA -- CIL FAILURE MODE

NUMBER: 03-1-0226-05

REVISION#: 2 07/13/00

SUBSYSTEM NAME: MAIN PROPULSION
LRU: LO2 PV CLOSE SOLENOID (LV13,15,17,80,81,82) **CRITICALITY OF THIS**
ITEM NAME: LO2 PV CLOSE SOLENOID (LV13,15,17,80,81,82) **FAILURE MODE:** 1R3

FAILURE MODE:
PREMATURE DEACTUATION (PREVALVE FAILS TO REMAIN CLOSED, REFERENCE FMEA/CIL 03-1-0401-04) CAUSING ACTUATOR CLOSING SIDE TO VENT AT SSME SHUTDOWN.

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, ELECTRICAL SOLENOID FAILURE

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.

C)

- FAILURE EFFECTS -

(A) SUBSYSTEM:
FAILURE IN EITHER SOLENOID WILL NOT AFFECT ACTUATOR CLOSING PRESSURE. THE REMAINING PARALLEL SOLENOID WILL PROVIDE PRESSURE TO THE ACTUATOR. RESULTS IN LOSS OF REDUNDANCY ONLY. PREVALVE IS BISTABLE AND WILL REMAIN IN ITS LAST COMMANDED POSITION. FOR FLIGHT CUTOFF, CLOSING PRESSURE IS APPLIED 1.158

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SECONDS AFTER ENGINE CUTOFF AND MAINTAINED UNTIL 2 SECONDS AFTER LH2 PREVALVE CLOSURE IS INITIATED.

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

(C) MISSION:
NO EFFECT.

(D) CREW, VEHICLE, AND ELEMENT(S):
NO EFFECT.

(E) FUNCTIONAL CRITICALITY EFFECTS:
CASE 1:
1R/3 4 SUCCESS PATHS. TIME FRAME - MECO.
1,2) PREMATURE DEACTUATION OF BOTH PREVALVE CLOSING SOLENOIDS.
3,4) PREMATURE ACTUATION OF BOTH PREVALVE OPENING SOLENOIDS.

RESULTS IN FAILURE OF A PREVALVE TO REMAIN CLOSED AT ENGINE SHUTDOWN, IN TURN CAUSING FAILURE TO MAINTAIN INJECTED HELIUM AND LO2 PRESSURE TO THE HPOTP TO PREVENT PUMP OVERSPEED AND CAVITATION AT MECO. POSSIBLE UNCONTAINED ENGINE DAMAGE DURING SHUTDOWN. POSSIBLE AFT COMPARTMENT OVERPRESS AND FIRE/EXPLOSIVE HAZARD DUE TO LO2 LEAKAGE RESULTING IN LOSS OF CREW/VEHICLE.

CASE 2:
1R/3 5 SUCCESS PATHS. TIME FRAME - PAD ABORT.
1) PREMATURE ENGINE SHUTDOWN WITH UNCONTAINED ENGINE DAMAGE ASSUMES ENGINE IS DAMAGED ONLY TO THE EXTENT THAT ISOLATION OF THE DAMAGE WILL SAFE THE SYSTEM).
2,3) PREMATURE DEACTUATION OF BOTH PREVALVE CLOSING SOLENOIDS (ON A SINGLE ENGINE).
4,5) PREMATURE ACTUATION OF BOTH PREVALVE OPENING SOLENOIDS (ON THE SAME ENGINE).

LO2 PREVALVE FAILS TO ISOLATE A SHUTDOWN ENGINE WHICH HAS UNCONTAINED ENGINE DAMAGE. POSSIBLE WATER HAMMER EFFECT RESULTING IN FEEDLINE RUPTURE. POSSIBLE AFT COMPARTMENT OVERPRESS AND FIRE/EXPLOSIVE HAZARD DUE TO LO2 LEAKAGE. 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 DEACTUATION MEANS THE FORCE HOLDING THE VALVE BALL TO THE VENT SEAT HAS BEEN REMOVED. MECHANICALLY, THE ONLY VALVE PARTS INVOLVED ARE THE SOLENOID PLUNGER, THE SOLENOID STOP, AND TWO PUSHRODS. THE PLUNGER AND STOP ARE MASSIVE BY COMPARISON TO THE PUSHRODS, AND ARE BOTH OF 430 CRES. THE PUSHRODS ARE ALIGNED IN SERIES WITHIN THE STOP. 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.

THE ONLY OTHER APPARENT WAY TO ACHIEVE PREMATURE DEACTUATION WOULD BE BY STRUCTURAL DAMAGE SUCH THAT A LEAK WOULD BE CREATED OF SUFFICIENT CAPACITY TO VENT THE VALVE ACTUATION PORT THROUGH THE VENT PORT. WITH THE POSSIBLE EXCEPTION OF BALL DISINTEGRATION, NO INTERNAL STRUCTURAL FAILURE WILL CAUSE PREMATURE DEACTUATION BECAUSE THE FAILURE POINT IS DOWNSTREAM OF THE ACTUATION PORT. IF A VALVE COMPONENT SHOULD FAIL STRUCTURALLY, IT WOULD NOT DISINTEGRATE AND DISAPPEAR. THE FAILURE WOULD CREATE A FLOW PATH FROM THE HIGH PRESSURE SIDE OF THE VALVE TO THE VENT AND SOMEWHERE IN THAT PATH THE FLOW WILL CHOKE. UPSTREAM OF THAT CHOKE POINT (INCLUDING THE ACTUATION PORT), THE PRESSURE WILL REMAIN ABOVE 400 PSIA. THIS RATIONALE ALSO APPLIES TO SEAT AND SEAL DAMAGE. THE BALL IS MADE FROM 430 CRES.

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

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

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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).

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 UNIT 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 FORGING 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 PROCESSES
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.

NON DESTRUCTIVE 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:
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 AB1813, AB1613, 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. AN ELECTRICAL SHORT BETWEEN PINS "A" AND "C" WAS DETECTED (ZERO OHM RESISTANCE)

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AT PALMDALE FACILITY (CAR AC2687). THE CORRECTIVE ACTION TAKEN WAS TO IMPROVE THE MANUFACTURING PROCESS, I.E., THE ADDITION OF HEAT SHRINK TUBING TO ISOLATE THE SOLDER CUP AND THE ADDITION OF AN INSPECTION POINT AFTER POTTING.

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/ AVE 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	: WILLIAM PRINCE	:/S/ WILLIAM PRINCE