FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE
NUMBER: 03-1-0224 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 2 08/02/00

PART DATA

	PART NAME / **VENDOR NAME**	**PART NUMBER** / **VENDOR NUMBER**
LRU	:LO2 INBOARD FILL/DRAIN VALVE CLOSING SOLENOID VALVE (LV31)	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. LO2 INBOARD FILL AND DRAIN VALVE CONTROL, CLOSING (LV31).

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: LV31

QUANTITY OF LIKE ITEMS: 1

FUNCTION:
CONTROLS PNEUMATIC PRESSURE TO CLOSE THE INBOARD LO2 FILL VALVE. THE VALVE MUST DEACTUATE TO ALLOW FILL VALVE ACTUATOR TO VENT WHEN FILL VALVE IS OPENED. OPENING SOLENOID (LV30) (REFERENCE FMEA/CIL 03-1-0223) MUST DEACTUATE FOR VALVE TO CLOSE.

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SUBSYSTEM NAME: MAIN PROPULSION
LRU: LO2 I/B F/D CLOSING SOLENOID VALVE (LV31) **CRITICALITY OF THIS**
ITEM NAME: LO2 I/B F/D CLOSING SOLENOID VALVE (LV31) **FAILURE MODE:** 1/1

FAILURE MODE:
PREMATURE DEACTUATION (INBOARD LO2 FILL AND DRAIN VALVE SLAMS OPEN) CAUSING ACTUATOR CLOSING PRESSURE TO VENT. FOR DETANKING AND ASCENT (REFERENCE FMEA/CIL 03-1-0310-04).

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, SEAT/SEAL LEAKAGE

CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO

REDUNDANCY SCREEN
A) N/A
B) N/A
C) N/A

PASS/FAIL RATIONALE:
A)

B)

C)

- FAILURE EFFECTS -

(A) SUBSYSTEM:
FAILURE RESULTS IN LOSS OF ACTUATOR CLOSING PRESSURE. CLOSING PRESSURE IS NOMINALLY APPLIED WHEN THE INBOARD FILL & DRAIN VALVE IS CLOSED AT TERMINATION OF REPLENISH (LOADING). FAILURE CAUSES INBOARD FILL AND DRAIN VALVE TO SLAM OPEN WHEN COMMANDED OPEN TO INITIATE LO2 DETANKING. IF THE GROUND PORTION

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OF THE FILL AND DRAIN LINE (TAIL SERVICE MAST) IS DRAINED, SLUG FLOW FROM THE ORBITER WILL IMPACT THE GSE DEBRIS PLATE WHICH SUBSEQUENTLY CAUSES A WATERHAMMER (PRESSURE SPIKE 415 PSIG). THE WATER HAMMER COULD CAUSE RUPTURE OF THE ORBITER FILL LINE AND/OR THE GSE INTERFACE/FACILITY LINES. FILL AND DRAIN VALVE ANTI-SLAM CAPABILITY WILL PREVENT VALVE DAMAGE BUT MAY NOT PROTECT THE FILL & DRAIN SYSTEM FROM A PRESSURE SPIKE. THE SLOWER RESPONSE TIME OF THE NORMAL (NON-SLAM) VALVE OPERATION DOES NOT CAUSE A PRESSURE SPIKE WHICH WOULD LEAD TO LINE RUPTURE.

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

(C) MISSION:
POSSIBLE LOSS OF VEHICLE IF FAILURE OCCURS DURING DETANKING. OTHERWISE, NO EFFECT.

(D) CREW, VEHICLE, AND ELEMENT(S):
POSSIBLE LOSS OF VEHICLE IF FAILURE OCCURS DURING DETANKING. OTHERWISE, NO EFFECT.

(E) FUNCTIONAL CRITICALITY EFFECTS:
CASE 1:
1R/2 2 SUCCESS PATHS. TIME FRAME - ASCENT.
1) PREMATURE DEACTUATION OF THE INBOARD FILL & DRAIN CLOSING SOLENOID VALVE (LV31).
2) PREMATURE ACTUATION OF THE INBOARD FILL & DRAIN OPENING SOLENOID VALVE (LV30).

RESULTS IN ASCENT WITH FILL LINE FULL OR PARTIALLY FULL OF LO2. POTENTIAL WATER HAMMER EFFECT OF APPROXIMATELY 700 PSI (AT 1-G). FAILURE RESULTS IN POSSIBLE RUPTURE OF THE LO2 FILL LINE, AFT COMPARTMENT OVERPRESS AND FIRE/EXPLOSIVE HAZARD. POSSIBLE LOSS OF CRITICAL ADJACENT FUNCTIONS DUE TO CRYO EXPOSURE. DISPLACED GAS MAY ENTER ENGINE CAUSING UNCONTAINED ENGINE DAMAGE AND POSSIBLE SHUTDOWN OF ONE OR MORE SSME(S). POSSIBLE LOSS OF CREW/VEHICLE.

CASE 2:
1R/3 3 SUCCESS PATHS. TIME FRAME - ASCENT.
1) PREMATURE DEACTUATION OF THE INBOARD FILL & DRAIN CLOSING SOLENOID VALVE (LV31).
2) PREMATURE ACTUATION OF THE INBOARD FILL & DRAIN OPENING SOLENOID VALVE (LV30).
3) OUTBOARD FILL & DRAIN (PV9) FAILS TO CLOSE/REMAIN CLOSED.

RESULTS IN THE OVERBOARD LEAKAGE OF LO2. FIRE HAZARD AT THE VEHICLE EXTERIOR. LOSS OF USABLE PROPELLANT WILL LEAD TO A PREMATURE ENGINE CUTOFF. POSSIBLE VIOLATION OF ET MINIMUM STRUCTURAL REQUIREMENTS DUE TO REDUCED ULLAGE PRESSURE. 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.

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 OF CRES AND IS EB WELDED. THE COIL IS VACUUM IMPREGNATED (POTTED). THE UNIT IS PRESSURE AND LEAK TESTED AT THE 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.

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 (SOLENOID VALVE)

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).

ATP (LO2 FILL AND DRAIN VALVE)

ALL VALVES DELIVERED TO DATE EXHIBIT SLAM OPEN RESPONSE TIMES SLOW ENOUGH SUCH THAT THE PRESSURE SPIKE RESULTING FROM WATER HAMMER IS LESS THAN VALVE AND SYSTEM PROOF PRESSURE LEVELS. ACCEPTANCE TEST AND OMRSD MINIMUM ALLOWABLE SLAM OPEN RESPONSE TIME REQUIREMENTS ARE FAST ENOUGH TO CAUSE WATER HAMMER PRESSURES IN EXCESS OF VALVE AND SYSTEM PROOF/BURST PRESSURE LEVELS.

CERTIFICATION (SOLENOID VALVE)

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)

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

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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'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.

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.

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
MOD	: WILLIAM LANE	:/S/ WILLIAM LANE
USA SAM	: MIKE SNYDER	:/S/ MIKE SNYDER
USA ORBITER ELEMENT	: SUZANNE LITTLE	:/S/ SUZANNE LITTLE
NASA SR&QA	: BILL PRINCE	:/S/ BILL PRINCE