FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE
NUMBER: 03-1-0223 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 1 08/02/00

PART DATA

	PART NAME / **VENDOR NAME**	**PART NUMBER** / **VENDOR NUMBER**
LRU	:LO2 INBOARD FILL/DRAIN VALVE OPENING SOLENOID VALVE (LV30)	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, OPENING (LV30).

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: LV30

QUANTITY OF LIKE ITEMS: 1

FUNCTION:
CONTROLS PNEUMATIC PRESSURE TO OPEN THE INBOARD LO2 FILL AND DRAIN VALVE. THE SOLENOID MUST DEACTUATE TO ALLOW FILL VALVE ACTUATOR TO VENT WHEN FILL VALVE IS CLOSED. CLOSING SOLENOID (LV31) (REFERENCE FMEA/CIL 03-1-0224) MUST DEACTUATE TO ALLOW VALVE TO OPEN.

FAILURE MODES EFFECTS ANALYSIS FMEA -- CIL FAILURE MODE

NUMBER: 03-1-0223-01

REVISION#: 1 08/14/00

SUBSYSTEM NAME: MAIN PROPULSION
LRU: LO2 I/B F/D OPEN SOLENOID VALVE (LV30) **CRITICALITY OF THIS**
ITEM NAME: LO2 I/B F/D OPEN SOLENOID VALVE (LV30) **FAILURE MODE:** 1R2

FAILURE MODE:
FAILS TO ACTUATE (INBOARD FILL AND DRAIN VALVE FAILS TO OPEN, REFERENCE FMEA/CIL 03-1-0310-01).

MISSION PHASE: LO LIFT-OFF

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

CAUSE:
PIECE PART STRUCTURAL FAILURE, CONTAMINATION

CRITICALITY 1/1 DURING INTACT ABORT ONLY? YES
RTLS RETURN TO LAUNCH SITE

REDUNDANCY SCREEN
A) PASS
B) PASS
C) PASS

PASS/FAIL RATIONALE:
A)

B)

C)

- FAILURE EFFECTS -

(A) SUBSYSTEM:
NO EFFECT FOR FIRST FAILURE ON NOMINAL MISSIONS. LO2 DUMP IS ACCOMPLISHED THROUGH THE LO2 PREVALVES AND MOV'S. LO2 VACUUM INERT CANNOT BE ACCOMPLISHED, BUT LEAKAGE THROUGH THE SSME INTERMEDIATE SEALS IS SUFFICIENT TO VENT LO2 MANIFOLD.

CRITICALITY 1/1 FOR RTLS ABORTS.

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FAILURE OF THE OPENING SOLENOID RESULTS IN FAILURE TO APPLY OPENING PRESSURE TO LO2 INBOARD VALVE. FAILURE OF INBOARD FILL AND DRAIN VALVE TO OPEN RESULTS IN FAILURE TO ADEQUATELY DUMP LO2. MAY CAUSE VIOLATION OF MAXIMUM DOWNWEIGHT FOR HEAVY MANIFESTED PAYLOADS.

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

(C) MISSION:
SAME AS A.

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

(E) FUNCTIONAL CRITICALITY EFFECTS:
CASE 1:
1R/2 2 SUCCESS PATHS. TIME FRAME – LOADING/DETANK
1) INBOARD FILL AND DRAIN VALVE OPENING SOLENOID (LV30) FAILS TO ACTUATE.
2) LO2 OVERBOARD BLEED (PV19) FAILS TO OPEN/REMAIN OPEN.

GEYSERING MAY RESULT IN FEEDLINE RUPTURE, EXTERNAL LEAKAGE OF LO2, AND POSSIBLE AFT COMPARTMENT OVERPRESSURIZATION. FIRE/EXPLOSIVE HAZARD BOTH INTERIOR AND EXTERIOR TO THE VEHICLE. POSSIBLE LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CRYO EXPOSURE. POSSIBLE LOSS OF VEHICLE.

CASE 2:
1R/3 3 SUCCESS PATHS. TIME FRAME - POST PAD ABORT DETANK.
1) INBOARD FILL AND DRAIN VALVE OPENING SOLENOID (LV30) FAILS TO ACTUATE.
2) 1 OF 3 PREVALVES (PV1,2,3) FAIL TO CLOSE.
3) LO2 OVERBOARD BLEED (PV19) FAILS TO OPEN/REMAIN OPEN.

TO PREVENT GEYSERING, PREVALVE CLOSURE IS REQUIRED TO LIMIT HEAT SOAKBACK FROM THE MAIN ENGINES INTO THE FEED SYSTEM. FOR PREVALVE FAILURE TO CLOSE, HELIUM INJECTION IS NOT SUFFICIENT TO PREVENT GEYSERING AND OVERBOARD BLEED OR LO2 DRAIN MUST BE INITIATED WITHIN OMRSD REQUIREMENTS.

GEYSERING MAY RESULT IN FEEDLINE RUPTURE, EXTERNAL LEAKAGE OF LO2, AND POSSIBLE AFT COMPARTMENT OVERPRESSURIZATION. FIRE/EXPLOSIVE HAZARD BOTH INTERIOR AND EXTERIOR TO THE VEHICLE. POSSIBLE LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CRYO EXPOSURE. POSSIBLE LOSS OF VEHICLE.

CASE 3:
1R/3 3 SUCCESS PATHS. TIME FRAME - RTLS (POST DUMP).
1) FAILURE RESULTING IN RTLS ABORT.
2) INBOARD FILL AND DRAIN VALVE OPENING SOLENOID (LV30) FAILS TO ACTUATE.
3) LO2 MANIFOLD RELIEF SYSTEM FAILS TO RELIEVE.

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RESULTS IN RUPTURE OF THE 17-INCH FEEDLINE DUE TO EXPANDING LO2 RESIDUALS AFTER LO2 DUMP. POSSIBLE AFT COMPARTMENT OVERPRESSURIZATION AND FIRE/EXPLOSIVE HAZARD. POSSIBLE LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CRYO EXPOSURE. POSSIBLE LOSS OF CREW/VEHICLE.

FOR TAL ABORTS, THE MAIN OXIDIZER VALVE (MOV) IS OPEN FOR A SUFFICIENT DURATION TO VENT RESIDUAL LO2.

CASE 4:
1R/3 5 SUCCESS PATHS. TIME FRAME - LO2 DUMP/VACUUM INERT
1) DUMP SWITCH FAILS IN "OFF" POSITION. PREVENTING OPENING OF ALL THREE LO2 PREVALVES (PV1, 2, 3) FOR LO2 DUMP.
2,3) BOTH LO2 POGO VALVES (PV20 & 21) FAIL TO REMAIN OPEN
4) INBOARD FILL AND DRAIN VALVE OPENING SOLENOID VALVE (LV30) FAILS TO ACTUATE WHEN COMMANDED BY CREW TO OPEN LO2 INBOARD FILL/DRAIN VALVE.
5) LO2 MANIFOLD RELIEF VALVE (RV5) FAILS TO RELIEVE.

RESULTS IN RUPTURE OF THE 17-INCH FEEDLINE DUE TO EXPANDING LO2 RESIDUALS AFTER LO2 DUMP. POSSIBLE AFT COMPARTMENT OVERPRESSURIZATION AND FIRE/EXPLOSIVE HAZARD. POSSIBLE LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CRYO EXPOSURE. POSSIBLE LOSS OF CREW/VEHICLE.

-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.

FAILURE TO ACTUATE, FROM THE MECHANICAL VIEW, MEANS FAILURE OF THE VALVE BALL TO TO MOVE FROM THE INLET SEAT TO THE VENT SEAT. 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 MECHANICAL WAY TO FAIL TO ACTUATE WOULD BE BY STRUCTURAL DAMAGE SUCH THAT A LEAK WOULD BE CREATED OF SUFFICIENT CAPACITY TO VENT THE VALVE ACTUATION PRESSURE THROUGH THE VENT PORT RATHER THAN TO 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 (PREMATURE ACTUATION). THIS RATIONALE ALSO APPLIES TO SEAT AND SEAL DAMAGE. THE BALL IS MADE FROM 430 CRES.

FAILURE OF THE SOLENOID TO STROKE DUE TO ELECTRICAL FAILURE CAN BE DUE TO FAILURE OF EITHER THE CONNNECTOR OR COIL. 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

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

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SOLENOID SUBASSEMBLY TESTS
ELECTRICAL CHARACTERISTICS; ENCLOSURE LEAKAGE (ONE ATMOSPHERE)

CERTIFICATION

TWO SPECIMENS -

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

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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:
FLIGHT:
NO CREW ACTION CAN BE TAKEN TO OPEN INBOARD FILL/DRAIN VALVE IF THE SOLENOID FAILS TO ACTUATE.

FOR FAILURE TO OPEN FOR LO2 DUMP/VACUUM INERT THE CREW CAN BE DIRECTED TO OPEN PREVALVES BY SWITCH THROW IF THEY FAIL TO OPEN DUE TO DUMP SWITCH FAILURE (CASE 4).

GROUND: THE LO2 17" FEED DISCONNECT (PD1) CAN BE CLOSED IN ORDER TO ISOLATE THE ORBITER FROM THE ET TO DELAY/PREVENT GEYSERING PER APPLICABLE OMRSD.

- 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	: BILL LANE	:/S/ BILL LANE

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