

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE**

NUMBER: 03-1-0225 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 2 08/28/00

**PART DATA**

	<b>PART NAME</b>	<b>PART NUMBER</b>
	<b>VENDOR NAME</b>	<b>VENDOR NUMBER</b>
LRU	: LO2 PREVALVE OPEN 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. OPENING

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:** LV12  
LV14  
LV16  
LV83  
LV84  
LV85

**QUANTITY OF LIKE ITEMS:** 6  
TWO PER PREVALVE

**FUNCTION:**

CONTROLS PNEUMATIC PRESSURE TO OPEN THE LOX PREVALVE. BOTH SERIES SOLENOID VALVES MUST ENERGIZE IN ORDER TO PROVIDE PRESSURE TO THE OPENING SIDE OF THE PREVALVE ACTUATOR. ONE OF TWO CLOSING SOLENOIDS ENERGIZED WILL PROVIDE CLOSING PNEUMATICS. BOTH PARALLEL CLOSING SOLENOIDS (LV13, 15, 17, 80, 81, 82) (REFERENCE FMEA/CIL 03-1-0226) MUST DEACTUATE TO ALLOW THE PREVALVE TO OPEN. ONE OF THE TWO OPENING VALVES MUST DEACTUATE TO ALLOW PREVALVE ACTUATOR TO VENT WHEN PREVALVE IS TO BE CLOSED.

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**NUMBER: 03-1-0225-04**

**REVISION#:** 2 07/12/00

**SUBSYSTEM NAME:** MAIN PROPULSION

**LRU:** LO2 PV OPEN SOLENOID (LV12,14,16,83,84,85)

**CRITICALITY OF THIS**

**ITEM NAME:** LO2 PV OPEN SOLENOID (LV12,14,16,83,84,85)

**FAILURE MODE:** 1R2

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**FAILURE MODE:**

PREMATURE DEACTUATION (PREVALVE FAILS TO REMAIN OPEN, REFERENCE FMEA/CIL 03-1-0401-03), CAUSING ACTUATOR OPENING SIDE TO VENT 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, ELECTRICAL SOLENOID FAILURE.

**CRITICALITY 1/1 DURING INTACT ABORT ONLY?** NO

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**REDUNDANCY SCREEN** A) PASS  
B) FAIL  
C) PASS

**PASS/FAIL RATIONALE:**

A)

B)

FAILS B SCREEN BECAUSE SOLENOID VALVES DO NOT HAVE POSITION INDICATORS. OPEN SOLENOID PRESSURIZATION AND CLOSE SOLENOID VENT FUNCTIONS ARE BOTH OPERATIONALLY REDUNDANT.

C)

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**- FAILURE EFFECTS -**

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**(A) SUBSYSTEM:**

FAILURE IN EITHER OF THE TWO SERIES SOLENOIDS RESULTS IN VENTING OF ACTUATOR OPENING PRESSURE. THE PREVALVE IS BISTABLE AND WILL REMAIN IN THE LAST

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COMMANDED POSITION. RESULTS IN LOSS OF REDUNDANCY ONLY. OPENING PRESSURE IS NOMINALLY APPLIED DURING ASCENT.

**(B) INTERFACING SUBSYSTEM(S):**

SAME AS A.

**(C) MISSION:**

FAILURE HAS NO EFFECT.

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

SAME AS C.

**(E) FUNCTIONAL CRITICALITY EFFECTS:**

1R/2 2 SUCCESS PATHS. TIME FRAME - DURING ENGINE OPERATION.

- 1) PREMATURE DEACTUATION OF EITHER PREVALVE OPENING SOLENOID.
- 2) PREMATURE ACTUATION OF EITHER PREVALVE CLOSING SOLENOID.

RESULTS IN LOSS OF OXIDIZER FLOW TO ONE ENGINE. ONE ENGINE WOULD SHUTDOWN. POSSIBLE LO2 PUMP CAVITATION AND OVERSPEED, RESULTING IN UNCONTAINED ENGINE DAMAGE.

POSSIBLE FEEDLINE/MANIFOLD RUPTURE DUE TO WATER HAMMER EFFECT. (LINE PRESSURE EXCEEDS 600 PSI). RESULTS IN EARLY LO2 DEPLETION, AFT COMPARTMENT OVERPRESS, AND POSSIBLE LOSS OF CRITICAL COMPONENTS DUE TO CRYO EXPOSURE. POSSIBLE VALVE VISOR FRACTURE AND INGESTION INTO ENGINE (ENGINE INLET SCREENS MAY NOT CONTAIN PARTS OF THIS SIZE). VALVE FAILURE TO REMAIN OPEN DURING LOADING HAS NO EFFECT - RESULTS IN LAUNCH SCRUB. FAILURE DURING NORMAL/ABORT DUMPS ALSO HAS NO EFFECT. POSSIBLE LOSS OF CREW/VEHICLE.

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**-DISPOSITION RATIONALE-**

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**(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.

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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 -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.

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:**

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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 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.

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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:**

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.

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**(E) OPERATIONAL USE:**  
NO CREW ACTION CAN BE TAKEN.

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**- APPROVALS -**

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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	: WILLIAM PRINCE	:/S/ WILLIAM PRINCE