

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE****NUMBER: 03-1-0401 -X****SUBSYSTEM NAME:** MAIN PROPULSION**REVISION:** 1 07/12/00**PART DATA**

<b>PART NAME</b>	<b>PART NUMBER</b>
<b>VENDOR NAME</b>	<b>VENDOR NUMBER</b>
LRU : LO2 PREVALVE	MC284-0396-0007,-0009
UNITED SPACE ALLIANCE - NSLD	73325000-115,-119

**EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:**

VALVE, PRE, LO2 12 INCH PNEUMATICALLY OPERATED, INCORPORATES REVERSE FLOW RELIEF VALVE

VALVE WAS ORIGINALLY DESIGNED AND MANUFACTURED BY FAIRCHILD CONTROLS BUT IS NOW MANUFACTURED BY UNITED SPACE ALLIANCE-NSLD AS AN ALTERNATE PRODUCTION AGENCY.

**REFERENCE DESIGNATORS:** PV1  
PV2  
PV3

**QUANTITY OF LIKE ITEMS:** 3

**FUNCTION:**

VALVE OPEN DURING CHILLDOWN AND LOADING. REQUIRED TO REMAIN OPEN DURING ENGINE OPERATION. REVERSE FLOW RELIEF VALVE AND A VISOR LIFTOFF MECHANISM PROVIDE MEANS OF RELIEVING BOILOFF PRESSURE WITHIN FEEDLINE WITH PREVALVE IN CLOSED POSITION. ELECTRICAL CIRCUITRY LOCKOUT PREVENTS PREVALVE CLOSURE UNTIL THRUST CHAMBER PRESSURE DECAYS TO 30% LEVEL DURING A NORMAL MISSION. CLOSING OF THE PREVALVE BECOMES CRITICAL DURING MAIN ENGINE CUTOFF (MECO). DURING THIS ZERO G CONDITION, HELIUM IS INJECTED INTO SYSTEM VIA SSME POGO ACCUMULATOR TO MAINTAIN REQUIRED LO2 PRESSURE AT THE SSME HPOTP TO PREVENT OVERSPEED. USED AS AN ISOLATION VALVE FOR THE PROPELLANT FEED SYSTEM FOR A SHUTDOWN/FAILED SSME. THE VALVE IS REOPENED FOR PROPELLANT DUMP AND CLOSED FOR REENTRY. DURING MECO, THE 30% MINIMUM CHAMBER PRESSURE REQUIREMENT IS REMOVED FROM THE ENGINE OPERATION PARAMETERS. VALVE INCORPORATES AN ANTI-SLAM MECHANISM TO PREVENT VALVE SLAMMING DAMAGE DURING IMPROPER VALVE OPEN/CLOSE OPERATIONS.

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**SUBSYSTEM NAME: MAIN PROPULSION**

**LRU: LO2 PREVALVE (PV1, PV2, PV3)**

**ITEM NAME: LO2 PREVALVE (PV1, PV2, PV3)**

**CRITICALITY OF THIS**

**FAILURE MODE: 1/1**

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**FAILURE MODE:**

FAILS TO CLOSE/FAILS TO REMAIN CLOSED/INTERNAL LEAKAGE WITHIN REQUIRED TIMING AT SSME SHUTDOWN, ZERO G CONDITION.

**MISSION PHASE:** PL PRE-LAUNCH  
LO LIFT-OFF

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

**CAUSE:**

FAILS TO CLOSE - PIECE PART STRUCTURAL FAILURE, BINDING, CONTAMINATION, ACTUATOR LEAKAGE, ANTI SLAM VALVE LEAKAGE, ACTUATOR FILTER CLOGGING.

FAILS TO REMAIN CLOSED - PIECE PART STRUCTURAL FAILURE.

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

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

**PASS/FAIL RATIONALE:**

A)

B)

C)

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**- FAILURE EFFECTS -**

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**(A) SUBSYSTEM:**

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FAILS TO MAINTAIN INJECTED HELIUM AND LO2 PRESSURE TO THE HPOTP TO PREVENT PUMP OVERSPEED AND CAVITATION AT MECO. RESULTS IN UNCONTAINED ENGINE DAMAGE, AFT COMPARTMENT OVERPRESSURE, AND FIRE/EXPLOSIVE HAZARD.

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

**(C) MISSION:**  
POSSIBLE LOSS OF CREW/VEHICLE.

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

**(E) FUNCTIONAL CRITICALITY EFFECTS:**

1R/2 2 SUCCESS PATHS. TIME FRAME - PAD ABORT, ASCENT.

- 1) PREMATURE ENGINE SHUTDOWN WITH UNCONTAINED ENGINE DAMAGE (ASSUMES ENGINE IS DAMAGED ONLY TO THE EXTENT THAT ISOLATION OF THE DAMAGE WILL SAVE THE SYSTEM).
- 2) LO2 PREVALVE FOR THE AFFECTED SSME FAILS TO CLOSE/REMAIN CLOSED.

LO2 PREVALVE FAILS TO ISOLATE A SHUTDOWN ENGINE WHICH HAS UNCONTAINED ENGINE DAMAGE. FOR FAILS TO REMAIN CLOSED, POSSIBLE WATER HAMMER CAUSING FEEDLINE RUPTURE. POSSIBLE AFT COMPARTMENT OVERPRESSURIZATION AND FIRE/EXPLOSIVE HAZARD DUE TO LO2 LEAKAGE. POSSIBLE LOSS OF CREW/VEHICLE.

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**-DISPOSITION RATIONALE-**

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**(A) DESIGN:**

DESIGNED FOR FACTORS OF SAFETY OF 1.3 PROOF AND 1.5 BURST FOR THE VALVE BODY, 1.5 PROOF AND 2.0 BURST FOR THE ACTUATOR. STRUCTURAL FAILURE IS AVOIDED BY MANUFACTURING THE POWERTRAIN OF A286 CRES, 21-6-9 CRES OR COPPER-BERYLLIUM COMPONENTS. BINDING IS GUARDED AGAINST BY THE USE OF ROLLER BEARINGS THROUGHOUT.

THE ACTUATOR DRIVES THE VALVE VIA A LINEAR RACK AND PINION GEAR (BOTH OF COPPER-BERYLLIUM), AND THE RACK IS POWERED BY HELIUM-DRIVEN DUAL PISTONS. LEAKAGE ACROSS THE PISTONS IS PRECLUDED BY TWO SEALS OF THE TEFLON JACKETED, METALLIC RACO TYPE (THE METALLIC "V" SPRING IS OF 301 CRES). THIS TYPE OF SEAL IS ALSO USED TO PREVENT EXTERNAL LEAKAGE AT ALL ACTUATOR JOINTS.

VALVE WILL CLOSE WITH A MINIMUM OF 400 PSIA ACTUATION PRESSURE. NORMAL SUPPLY PRESSURE IS 750 PSIA. THE ANTI-SLAM VALVES USE A286 CRES POPPETS SPRING LOADED TO KEL-F SEATS. WITH THE ANTI-SLAM PORT VENTED, ACTUATION

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PRESSURE ASSISTS THE SPRING IN SEALING THE POPPET TO THE SEAT. BINDING IS CONSIDERED UNLIKELY BECAUSE ALL SLIDING SURFACES ARE COATED WITH A DRY FILM LUBRICANT WHICH HAS HAD EXTENSIVE UTILIZATION WITHOUT PROBLEMS.

LEAKAGE ACROSS SEAT IS UNLIKELY EXCEPT FOR CONTAMINATION. THE VALVE IS DESIGNED SO THAT UPSTREAM PRESSURE TENDS TO FORCE THE VISOR (POPPET) INTO THE VISOR SEAL, THEREBY CREATING AN EFFECTIVE SEAL.

THE VALVE IS DESIGNED FOR 5000 LIFE CYCLES AND WAS TESTED THROUGH 5260 CYCLES (OVER 100 MISSIONS) UNDER BOTH CRYOGENIC AND AMBIENT TEMPERATURE CONDITIONS AND AT BOTH NORMAL AND ACCELERATED (SLAM) CYCLE TIMES. THE VALVE, DURING THIS LIFE CYCLE TESTING, NEVER FAILED TO CLOSE OR REMAIN CLOSED. FILTERS ARE PROVIDED ON ALL PNEUMATIC PORTS TO PREVENT ACTUATOR CONTAMINATION.

**(B) TEST:**

ATP

ACTUATOR -

AMBIENT PROOF (1275 PSIG)

CRYO PROOF OF ACTUATOR FLANGE AND SHAFT SEALS (358 PSID)

POSITION INDICATION

ELECTRICAL CHARACTERISTICS

AMBIENT AND CRYO RESPONSE TIME (NORMAL AND SLAM) AT 400 AND 740 PSIG  
ACTUATION PRESSURE

AMBIENT AND CRYO LEAKAGE (FROM PORT TO PORT)

AMBIENT AND CRYO SHAFT SEAL LEAKAGE (PRIMARY AND SECONDARY) WITH 220 PSID  
ACROSS SEAL

AMBIENT AND CRYO EXTERNAL LEAKAGE.

RELIEF VALVE ASSEMBLY -

AMBIENT PROOF (299 PSIG)

AMBIENT AND CRYO CRACK AND RESEAT (15-50 PSID)

PREVALVE ASSEMBLY -

POSITION INDICATION

ELECTRICAL CHARACTERISTICS

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VALVE HOUSING AND VISOR AMBIENT PROOF (299 PSIG)

VALVE HOUSING AND VISOR CRYO PROOF (358 PSID)

ACTUATOR AMBIENT PROOF (1275 PSIG)

AMBIENT AND CRYO EXTERNAL LEAKAGE (WITH VALVE BODY AT 220 PSIG AND ACTUATOR AT 740 PSIG)

AMBIENT AND CRYO RESPONSE TIME AT 400 AND 740 PSIG ACTUATION PRESSURE

AMBIENT AND CRYO ACTUATOR LEAKAGE FROM PORT TO PORT

AMBIENT AND CRYO VALVE SHAFT SEAL (PRIMARY AND SECONDARY) LEAKAGE WITH 220 PSID ACROSS THE SEAL

AMBIENT AND CRYO VISOR LEAKAGE (INLET-TO-OUTLET WITH 200 PSID, OUTLET-TO-INLET WITH 5 PSID AMBIENT AND 15 PSID CRYO)

AMBIENT RELIEF VALVE CRACK (6.7 TO 50 PSID) AND RESEAT (5 TO 50 PSID) WITH ACTUATOR CLOSE PRESSURE ON

CRYO RELIEF VALVE CRACK AND RESEAT (15 TO 50 PSID) WITH ACTUATOR CLOSE PRESSURE ON

AMBIENT VISOR LIFT-OFF (15 PSID MAX) WITH ACTUATOR VENTED

CERTIFICATION

STRUCTURAL LOAD AT CRYO TEMPS (-300 DEG F) (AXIAL, SHEAR, TORSION, BENDING)

LIFE CYCLING (3050 AMBIENT CYCLES, 2050 CRYO CYCLES. ACTUATOR RECEIVED ADDITIONAL 300 AMBIENT AND 200 CRYO SLAM CYCLES); RELIEF VALVE LIFE (500 CYCLES AMBIENT, 500 CYCLES CRYO); ANTI-SLAM VALVE LIFE (2700 CYCLES AMBIENT, 1800 CYCLES CRYO)

THREE THERMAL CYCLES (70 DEG F TO -300 DEG F TO +200 DEG F TO 70 DEG F)

TRANSIENT SINUSOIDAL VIBRATION (AT 200 PSIG AND -250 DEG F); RANDOM VIBRATION (13.3 HRS IN EACH OF THREE AXES WITH VALVE OPEN AND AT 200 PSIG/LESS THAN -250 DEG F. OPEN PRESSURE WAS REMOVED DURING A PORTION OF THE TEST; SUBSEQUENTLY REPEATED TO CERTIFY THE ANTI-SLAM ACTUATOR)

DESIGN SHOCK (18 SHOCKS OF 15G EACH - THREE IN EACH DIRECTION OF THREE AXES, ALL WITH VALVE OPEN AND ACTUATOR VENTED; REPEATED TO CERTIFY THE ANTI-SLAM ACTUATOR)

AMBIENT AND CRYO FUNCTIONAL, INTERNAL AND EXTERNAL LEAKAGE PERFORMANCE

BURST (413 PSIG VALVE BODY, 1700 PSIG ACTUATOR)-

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SPECIAL ANTI SLAM LEAKAGE TEST

BOTH OPEN AND CLOSE ANTI SLAM VALVES TESTED

VALVE FAILED TO CLOSE IN REQUIRED TIME WHEN:  
ANTI SLAM POPPET OPEN 0.0085 INCHES  
EQUIVALENT TO A PARTICLE SIZE OF 216 MICRONS  
RESULTED IN 61 SCFM GHE LEAK (10,472 SCIMS)

THIS REPRESENTS 86% OF MAXIMUM FLOW CAPABILITY OF SYSTEM

OMRSD  
ANY TURNAROUND CHECKOUT IS ACCOMPLISHED IN ACCORDANCE WITH OMRSD.

**(C) INSPECTION:**

RECEIVING INSPECTION  
RAW MATERIALS ARE VERIFIED BY INSPECTION FOR MATERIAL AND PROCESS  
CERTIFICATION.

CONTAMINATION CONTROL  
VALVE IS CLEANED TO LEVEL 800A AND THE ACTUATOR IS CLEANED TO 400A.

ASSEMBLY/INSTALLATION  
ALL PARTS ARE PROTECTED FROM DAMAGE AND CONTAMINATION. LOG OF CLEAN ROOM  
AND TOOL CALIBRATION ARE VERIFIED BY INSPECTION. MICROSCOPIC EXAMINATION OF  
ALL DETAIL PARTS ARE MADE PRIOR TO ASSEMBLY. TORQUE REQUIREMENTS VERIFIED  
BY INSPECTION. MANDATORY INSPECTION POINTS ARE INCLUDED IN THE ASSEMBLY  
PROCEDURES.

CRITICAL PROCESSES  
CRITICAL DIMENSIONS AND SURFACE FINISHES EXAMINED FROM 3X TO 7X MAGNIFICATION  
FOR MATERIAL DEFECTS.

NONDESTRUCTIVE EVALUATION  
FLOW LINER WELD VISUALLY EXAMINED. THE VALVE BODY, PRIOR TO FINAL MACHINING,  
IS SUBJECTED TO DYE PENETRANT INSPECTION. REQUIREMENTS FOR DETAIL PARTS  
PENETRANT INSPECTION ARE BASED UPON CONFIGURATION, MATERIAL, AND  
MANUFACTURING PROCESSES.

TESTING  
ACCEPTANCE TEST VERIFIED BY INSPECTION.

HANDLING/PACKAGING  
PACKAGING FOR CLEANLINESS VERIFIED BY INSPECTION.

**(D) FAILURE HISTORY:**

HAVE EXPERIENCED VALVE DAMAGE INTERNALLY IN OLDER CONFIGURATION OF THE  
VALVE (CRACK IN FLOW LINER, CAR A9981, AND MAIN SEAL FRACTURE, CAR AB6078) FROM

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INCORRECT OPERATION OF THE VALVE (VALVE ACTUATION WITHOUT SNUBBING PRESSURE IN ACTUATOR CAUSES SLAMMING OF THE VALVE). AN ANTI-SLAM MECHANISM HAS BEEN INSTALLED TO PREVENT VALVE DAMAGE DUE TO SLAMMING.

THE ANTISLAM CONFIGURATION EXPERIENCED AN INTERNAL LEAKAGE AFTER VALVE CLOSURE AND DURING A CHECK OUT AT KSC DUE TO A CRACKED MAIN SEAL. THE VALVE WAS REPLACED (CAR AC6572). THE FRACTURE WAS ASSUMED TO BE CAUSED BY CONTAMINATION WHICH LODGED BETWEEN THE SEAT AND VISOR. FIVE CYROGENIC TEST CYCLES WERE CONDUCTED WITHOUT FURTHER SEAL DEGRADATION. SCREEN INSPECTIONS AND SYSTEM PRESSURE DECAY CHECKS DETECTED THESE FAILURES. NO FURTHER CORRECTIVE ACTION WAS REQUIRED. ONE MINOR LH2 VALVE INTERNAL SEAT LEAKAGE WAS WAIVERED (MV0070A-102-316, CAR AC6670). DURING LH2 MANIFOLD PRESSURIZATION EXCESSIVE LEAKAGE HAS BEEN DETECTED THROUGH RELIEF VALVES DUE TO CONTAMINANT. THE RELIEF VALVE ASSEMBLIES HAVE BEEN REPLACED. NO FURTHER CORRECTIVE ACTION WAS REQUIRED (REF CAR AC6355).

VALVE FAILED TO CLOSE (OV-102 AT KSC) DUE TO A BROKEN FACILITY TEMPERATURE PROBE BEING LODGED BETWEEN VALVE SEAT/VISOR/SCREEN. KSC REDESIGNED FACILITY PROBE. A DEBRIS PLATE HAS BEEN ADDED ON INLET SIDE OF THE 8-INCH DISCONNECT TO PREVENT RECURRENCE (CAR AD0676).

ACTUATOR FLANGE LEAKAGE HAS OCCURRED FROM THE ACTUATOR/CYLINDER AND THE ACTUATOR TRIANGULAR END FLANGE INTERFACE SURFACES DURING ATP AND AT PALMDALE. THESE WERE DUE TO IMPERFECT SEALING SURFACES. CORRECTIVE ACTION INCLUDED CHANGING THE SEALING SURFACE FINISH FROM ANODIZED TO CHEM FILM AND IMPROVING THE INSPECTION METHOD (CAR AC5181 AND AC2139).

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.

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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	: STUART KOBATA	: /S/ STUART KOBATA
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