

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE****NUMBER: 03-1-0402 -X****SUBSYSTEM NAME:** MAIN PROPULSION**REVISION:** 1 07/10/00**PART DATA**

	<b>PART NAME</b>	<b>PART NUMBER</b>
	<b>VENDOR NAME</b>	<b>VENDOR NUMBER</b>
LRU	:LH2 PREVALVE UNITED SPACE ALLIANCE-NSLD	MC284-0396-0008,-0010 73325000-117,-121

**EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:**

VALVE, PRE, LH2 12 INCH PNEUMATICALLY OPERATED. INCORPORATES REVERSE FLOW RELIEF VALVE.

VALVE WAS ORIGINALLY DESIGNED AND MANUFACTURED BY FAIRCHILD COMPONENTS (NOW ORBITAL SCIENCES CORP.) BUT IS NOW MANUFACTURED BY UNITED SPACE ALLIANCE-NSLD AS AN ALTERNATE PRODUCTION AGENCY.

**REFERENCE DESIGNATORS:** PV4  
PV5  
PV6

**QUANTITY OF LIKE ITEMS:** 3

**FUNCTION:**

VALVE OPEN DURING CHILLDOWN AND INITIAL PHASES OF LOADING. MUST CLOSE FOR RECIRC OPERATION. REQ'D TO REMAIN OPEN FOR ENGINE OPERATION. ELECTRICAL CIRCUITRY LOCKOUT PREVENTS PREVALVE CLOSURE UNTIL THRUST CHAMBER PRESSURE DECAYS TO 30% LEVEL (30% PC LOCKOUT IS REMOVED DURING MECO). USED AS AN ISOLATION VALVE TO PROPELLANT FEED SYSTEM FOR A SHUTDOWN/FAILED SSME. VALVE IS REOPENED FOR DUMPS AND LEFT OPEN FOR RE/ENTRY. VALVE INCORPORATES AN ANTI-SLAM MECHANISM TO PREVENT VALVE SLAMMING DURING IMPROPER OPEN/CLOSE OPERATIONS. VALVE RELIEF SYSTEMS INCLUDE VISOR LIFTOFF AND A BYPASS RELIEF VALVE.

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**SUBSYSTEM NAME: MAIN PROPULSION**

**LRU: LH2 PREVALVE (PV4, PV5, PV6)**

**ITEM NAME: LH2 PREVALVE (PV4, PV5, PV6)**

**CRITICALITY OF THIS**

**FAILURE MODE: 1R2**

**FAILURE MODE:**

FAILS TO OPEN FOR SYSTEM DUMP FOLLOWING SSME SHUTDOWN.

**MISSION PHASE: LO LIFT-OFF**

<b>VEHICLE/PAYLOAD/KIT EFFECTIVITY:</b>	102	COLUMBIA
	103	DISCOVERY
	104	ATLANTIS
	105	ENDEAVOUR

**CAUSE:**

PIECE PART STRUCTURAL FAILURE, BINDING, ANTI SLAM VALVE LEAKAGE, ACTUATOR LEAKAGE, ACTUATOR FILTER CLOGGING.

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

**REDUNDANCY SCREEN**

- A) PASS
- B) PASS
- C) PASS

**PASS/FAIL RATIONALE:**

A)

B)

ENGINE INLET PRESSURE PROVIDES VERIFICATION OF PREVALVE OPENING AT START OF DUMP.

C)

**- FAILURE EFFECTS -**

**(A) SUBSYSTEM:**

FAILURE OCCURRENCE AT LH2 DUMP RESULTS IN TRAPPED LH2/GH2 BETWEEN THE PREVALVE AND THE MAIN FUEL VALVE. PREVALVE RELIEF SYSTEM (BUILT IN RELIEF VALVE AND VISOR RELIEF) WILL RELIEVE REMAINING H2 INTO THE MANIFOLD. LH2 MANIFOLD RELIEF SYSTEM IS OPERATIVE POST MECO TO LANDING.

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

SAME AS A.

**(C) MISSION:**

FAILURE ON GROUND RESULTS IN LCC VIOLATION AND LAUNCH SCRUB. RESIDUAL GH2/LH2 MAY BE PRESENT - NO EFFECT ON MISSION.

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

SAME AS C.

**(E) FUNCTIONAL CRITICALITY EFFECTS:**

1R/2 2 SUCCESS PATHS. TIME FRAME - LH2 DUMP/POST DUMP.

- 1) PREVALVE FAILS TO OPEN (STRUCTURAL FAILURE INHIBITING VISOR LIFTOFF).
- 2) PREVALVE BYPASS RELIEF VALVE FAILS TO RELIEVE.

AT DUMP-STOP THE SSME LH2 BLEED VALVES CLOSE ISOLATING THE 12" FEEDLINES. TRAPPED RESIDUAL LH2 RESULTS IN RUPTURE OF THE 12 INCH FEEDLINE CAUSING AFT COMPARTMENT OVERPRESSURIZATION AND FIRE/EXPLOSIVE HAZARD. POSSIBLE LOSS OF CRITICAL ADJACENT FUNCTIONS DUE TO CRYOGENIC EXPOSURE. 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). SIMILAR TYPE SEALS ARE USED TO PREVENT EXTERNAL LEAKAGE AT ALL ACTUATOR JOINTS.

THE ANTI-SLAM VALVES USE A286 CRES POPPETS SPRING LOADED TO KEL-F SEATS. WITH THE ANTI-SLAM PORT VENTED, ACTUATION 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.

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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 OPEN. FILTERS ARE PROVIDED ON ALL PNEUMATIC PORTS TO PREVENT 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; VALVE HOUSING AND VISOR AMBIENT PROOF (85 PSIG); VALVE HOUSING AND VISOR CRYO PROOF (143 PSID); ACTUATOR AMBIENT PROOF (1275 PSIG); AMBIENT AND CRYO EXTERNAL LEAKAGE (WITH VALVE BODY AT 60 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 60 PSID ACROSS THE SEAL; AMBIENT AND CRYO VISOR LEAKAGE (INLET-TO-OUTLET WITH 50 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 (-400 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 -400 DEG F TO +200 DEG F TO 70 DEG F).

TRANSIENT SINUSOIDAL VIBRATION (AT 50 PSIG AND -250 DEG F); RANDOM VIBRATION (13.3 HRS IN EACH OF THREE AXES WITH VALVE OPEN AND AT 50 PSIG/LESS THAN -250 DEG F. OPEN PRESSURE WAS REMOVED DURING A PORTION OF THE TEST; SUBSEQUENTLY REPEATED TO CERTIFY THE ANTI-SLAM ACTUATOR).

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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 (165 PSIG VALVE BODY, 1700 PSIG ACTUATOR).

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

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 PROCESS CERTIFICATION.

CONTAMINATION CONTROL  
VALVE IS CLEANED TO LEVEL 400 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 PROCEDURES VERIFIED BY INSPECTION.

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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, MAIN SEAL FRACTURE) FROM INCORRECT OPERATION OF 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.

MINOR ACTUATOR FLANGE LEAKAGE OCCURRED FROM THE ACTUATOR/CYLINDER AND THE ACTUATOR TRIANGULAR END FLANGE INTERFACE SURFACE (8 DURING ATP AND 1 AT SUBSYSTEM CHECKOUT). THESE WERE DUE TO THE IMPERFECT SEALING SURFACES. CORRECTIVE ACTION INCLUDED CHANGING THE SEALING SURFACE FINISH FROM ANODIZE TO CHEM FILM AND IMPROVING THE INSPECTION METHODS. (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:**

SECOND VACUUM INERTING OPERATIONS ARE PERFORMED AFTER COMPLETION OF THE SOFTWARE CONTROLLED PROPELLANT DUMP AND FIRST VACUUM INERT. SUBSEQUENT VACUUM INERTINGS WILL BE PERFORMED IF REQUIRED.

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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	: BILL PRINCE	:/S/ BILL PRINCE