

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

	PART NAME	PART NUMBER
	VENDOR NAME	VENDOR NUMBER
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 CLOSE/INTERNAL LEAKAGE/FAILS TO REMAIN CLOSED AT SSME SHUTDOWN.

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.

TO REMAIN CLOSED - PIECE PART STRUCTURAL FAILURE.

CRITICALITY 1/1 DURING INTACT ABORT ONLY? YES

AOA ABORT ONCE AROUND

ATO ABORT TO ORBIT

PAD PAD ABORT

RTLS RETURN TO LAUNCH SITE

TAL TRANS-ATLANTIC LANDING

REDUNDANCY SCREEN

A) PASS

B) N/A

C) PASS

PASS/FAIL RATIONALE:

A)

B)

PREVALVE CLOSE CAPABILITY IS STANDBY REDUNDANT TO CONTAINED SSME SHUTDOWN

C)

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(A) SUBSYSTEM:

NO EFFECT AT MECO. RESULTS IN LEAKAGE PAST THE PREVALVE, BUT MAIN FUEL VALVE IS ALREADY CLOSED. ALSO NO EFFECT FOLLOWING DUMP/INERT. DOWNSTREAM SYSTEM IS ISOLATED BY CLOSED MAIN FUEL VALVE.

(B) INTERFACING SUBSYSTEM(S):

SAME AS A.

(C) MISSION:

NO EFFECT FOR NOMINAL MISSIONS. FOR ABORTS, PREVALVE FAILS TO ISOLATE A SHUTDOWN ENGINE WITH UNCONTAINED DAMAGE (ASSUMES ENGINE IS DAMAGED ONLY TO THE EXTENT THAT ISOLATION OF THE DAMAGE WILL SAFE THE SYSTEM) CAUSING POSSIBLE AFT COMPARTMENT OVERPRESSURIZATION AND FIRE/EXPLOSION HAZARD AND POSSIBLE LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CRYO EXPOSURE. FOR PAD ABORTS MAIN FUEL VALVE LEAKAGE RESULTS IN HAZARDOUS OVERBOARD LEAKAGE OF LH2. FAILURE TO CLOSE/REMAIN CLOSED AT BEGINNING OF LH2 RECIRCULATION (LOADING) RESULTS IN LAUNCH SCRUB.

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

SAME AS C.

(E) FUNCTIONAL CRITICALITY EFFECTS:

1R/2 2 SUCCESS PATHS. TIME FRAME - ASCENT

- 1) ENGINE SHUTDOWN WITH UNCONTAINED DAMAGE (ASSUMES ENGINE IS DAMAGED ONLY TO THE EXTENT THAT ISOLATION OF THE DAMAGE WILL SAFE THE SYSTEM) - FOR PAD ABORTS A PARTIALLY OPEN MAIN FUEL VALVE.
- 2) PREVALVE FAILS TO CLOSE/REMAIN CLOSED.

PREVALVE WOULD FAIL TO ISOLATE THE AFFECTED ENGINE. POSSIBLE WATER HAMMER EFFECT CAUSING FEEDLINE RUPTURE. RESULTS IN LH2/GH2 LEAKAGE IN AFT FUSELAGE LEADING TO OVERPRESS, FIRE/EXPLOSION HAZARD, AND POSSIBLE LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CRYO EXPOSURE. MAIN FUEL VALVE LEAKAGE AFTER A PAD ABORT RESULTS IN HAZARDOUS OVERBOARD LEAKAGE OF LH2. POSSIBLE LOSS OF CREW/VEHICLE.

-DISPOSITION RATIONALE-

(A) DESIGN:

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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 RACO TYPE SEALS ARE 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 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 THE 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; 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

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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).

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.

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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 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 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 INSPECTION AND SYSTEM PRESSURE DECAY CHECK DETECT 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 WAS DETECTED THROUGH A RELIEF VALVE DUE TO A SMALL METALLIC CONTAMINANT. THE RELIEF VALVE ASSEMBLY WAS 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 PERFORATED PLATE HAS BEEN ADDED ON INLET SIDE OF THE 8-INCH DISCONNECT TO PREVENT RECURRENCE (CAR AD0676).

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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 HYDROGEN 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	: 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