

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

NUMBER: 03-1-0302 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 2 08/02/00

**PART DATA**

	<b>PART NAME</b>	<b>PART NUMBER</b>
	<b>VENDOR NAME</b>	<b>VENDOR NUMBER</b>
LRU	: LH2 OUTBOARD 8" FILL/DRAIN VALVE UNITED SPACE ALLIANCE - NSLD	MC284-0397-0031 74328000-159

**EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:**

LH2 OUTBOARD FILL VALVE, 8 INCH. PNEUMATICALLY OPERATED, INCLUDES A 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: PV11

QUANTITY OF LIKE ITEMS: 1

**FUNCTION:**

PROVIDES A MEANS OF LOADING AND DRAINING THE ET THROUGH THE PROPELLANT FEED SYSTEM. THE OUTBOARD VALVE PREVENTS OVERBOARD LOSS OF PROPELLANT DUE TO LEAKAGE FROM THE LH2 INBOARD FILL & DRAIN VALVE (PV12) AND/OR THE LH2 TOPPING VALVE (PV13). THE VALVE IS MOUNTED ON THE FILL AND DRAIN DISCONNECT AND REMAINS OPEN FROM START OF LOADING OPERATIONS TO COMPLETION OF TSM DRAIN (APPROXIMATELY T - 48 SEC). BOTH THE INBOARD AND OUTBOARD VALVES REMAIN CLOSED DURING ENGINE OPERATION. POST MECO, THE VALVES ARE OPENED BY SOFTWARE COMMAND TO DUMP LH2. THE OUTBOARD VALVE IS SUBSEQUENTLY OPENED BY SOFTWARE TO VENT LH2 RESIDUALS DURING THE FIRST VACUUM INERT. THE OUTBOARD VALVE IS ADDITIONALLY OPENED MANUALLY DURING THE SECOND VACUUM INERT. (EFFECTIVE FOR OI-29 AND SUBS, THE FILL/DRAIN VALVES WILL NO LONGER BE USED FOR VACUUM INERTS. VACUUM INERT WILL BE ACCOMPLISHED VIA THE RTLS DUMP VALVES, PV17 & PV18). THE OUTBOARD VALVE IS CLOSED PRIOR TO ENTRY FOR MANIFOLD REPRESSURIZATION. INCORPORATES AN ANTI-SLAM MECHANISM TO PREVENT SLAMMING DAMAGE DURING IMPROPER VALVE OPEN/CLOSE OPERATIONS. THE VALVE ALSO INCORPORATES A RELIEF VALVE, RELIEVING INTO THE FILL LINE.

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**SUBSYSTEM NAME: MAIN PROPULSION**

**LRU: LH2 OUTBOARD 8" FILL/DRAIN VALVE (PV11)**

**CRITICALITY OF THIS**

**ITEM NAME: LH2 OUTBOARD 8" FILL/DRAIN VALVE (PV11)**

**FAILURE MODE: 1/1**

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**FAILURE MODE:**

FAILS TO REMAIN OPEN DURING PROPELLANT LOADING, DETANKING, AND DUMP

**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

**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:**

RESULTS IN TERMINATION OF PROPELLANT LOADING OR DETANKING WHICH MAY CAUSE A PRESSURE SPIKE AND POSSIBLE RUPTURE OF ORBITER FILL LINE, FEED LINE AND/OR GSE INTERFACE/FACILITY LINES. POSSIBLE AFT COMPARTMENT OVERPRESSURIZATION AND FIRE/EXPLOSION HAZARD. POSSIBLE LOSS OF ADJACENT CRITICAL FUNCTIONS DUE TO CRYO EXPOSURE.

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**(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:**

CASE 1:

1R/3 3 SUCCESS PATHS. TIME FRAME - LH2 DUMP.

- 1) OUTBOARD FILL & DRAIN VALVE (PV11) FAILS TO REMAIN OPEN.
- 2) EITHER RTLS DUMP VALVE (PV17, 18) FAILS TO OPEN. RTLS DUMP VALVES ARE OPENED FOLLOWING MECO FOR 110 SECONDS, BUT CAN BE OPENED BY THE CREW IF MANIFOLD PRESSURE APPROACHES RELIEF PRESSURES. EFFECTIVE FOR OI-29 AND SUBS THE RTLS DUMP VALVES WILL BE USED FOR LH2 VACUUM INERTING.
- 3) MANIFOLD RELIEF SYSTEM FAILS TO RELIEVE.

LH2 REMAINING IN MANIFOLD CANNOT BE RELIEVED. RESULTS IN OVERPRESSURIZATION AND RUPTURE OF THE FEEDLINE MANIFOLD. RTLS DUMP VALVES ARE OPENED FOLLOWING MECO, BUT NOT LONG ENOUGH TO DUMP THE MAJORITY OF THE REMAINING LH2. AFT COMPARTMENT OVERPRESSURIZATION AND FIRE/EXPLOSIVE HAZARD. POSSIBLE LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CRYO EXPOSURE. POSSIBLE LOSS OF CREW/VEHICLE.

CASE 2:

1R/3 3 SUCCESS PATHS. TIME FRAME - DETANK.

- 1) OUTBOARD FILL & DRAIN (PV11) FAILS TO REMAIN OPEN.
- 2) ET LH2 RELIEF VALVE FAILS TO RELIEVE.
- 3) HIGH POINT BLEED VALVE (PV22) FAILS TO OPEN/REMAIN OPEN.

LH2 REMAINING IN MANIFOLD CANNOT BE RELIEVED. RESULTS IN OVERPRESSURIZATION AND RUPTURE OF THE FEEDLINE MANIFOLD. AFT COMPARTMENT OVERPRESSURIZATION AND FIRE/EXPLOSION HAZARD. POSSIBLE LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CRYO EXPOSURE. RTLS DUMP VALVES (PV17,18) AND THE LH2 MANIFOLD RELIEF ISOLATION VALVE (PV8) CAN BE OPENED BY GROUND ACTION, BUT THIS WOULD DUMP LH2 ONTO THE PAD SURFACE. POSSIBLE LOSS OF CREW/VEHICLE.

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**-DISPOSITION RATIONALE-**

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**(A) DESIGN:**

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VALVE IS BI-STABLE - WILL REMAIN IN LAST COMMANDED POSITION. AN INTEGRAL PART OF THE COPPER-BERYLLIUM ACTUATOR SHAFT IS A CAM WITH DETENTS IN THE OPEN AND CLOSED POSITION. THE CAM IS FOLLOWED BY A BELLVILLE - SPRING LOADED DETENT ROLLER. THE SEVEN STACKED BELLVILLES ARE SHIMMED, UPON INSTALLATION, TO PRODUCE A FORCE OF 140 LBS BY THE ROLLER UPON THE CAM, WHEN IN EITHER THE OPEN OR CLOSED POSITION. TO LEAVE EITHER POSITION THE ROLLER MUST PASS OVER A 0.105 INCH HIGH SHOULDER ON THE CAM.

THE POWER TRAIN FROM THE DETENT CAM THROUGH THE BRIDGE AND BLADE CONSISTS OF COMPONENTS MANUFACTURED FROM INCONEL 718, A286 CRES, AND COPPER-BERYLLIUM.

THE VALVE IS DESIGNED FOR 5000 LIFE CYCLES AND WAS CYCLED OPEN/CLOSED 5,256 TIMES (OVER 100 MISSIONS) DURING CERTIFICATION TESTING. CYCLING WAS AT BOTH CRYOGENIC AND AMBIENT TEMPERATURES AND WITH BOTH NORMAL AND ACCELERATED (SLAM) CYCLE TIMES.

**(B) TEST:**  
ATP

ANTI-SLAM VALVES (BEFORE ASSEMBLY INTO THE ACTUATOR) - EXAMINATION OF PRODUCT; AMBIENT PROOF (1275 PSIG); AMBIENT AND CRYO FLOW; AMBIENT AND CRYO CRACKING PRESSURE; POST TEST EXAMINATION.

ACTUATOR (BEFORE ASSEMBLY ONTO THE FILL AND DRAIN VALVE) - EXAMINATION OF PRODUCT; POSITION INDICATION; AMBIENT PROOF (1275); ELECTRICAL CHARACTERISTICS; AMBIENT EXTERNAL LEAKAGE.

RELIEF VALVE ASSEMBLY (BEFORE INSTALLATION INTO THE FILL AND DRAIN VALVE) - EXAMINATION OF THE PRODUCT; AMBIENT PROOF (340 PSIG); AMBIENT AND CRYO CRACK/RESEAT (15-50 PSID) AND INTERNAL LEAKAGE; POST TEST EXAMINATION.

FILL AND DRAIN VALVE ASSEMBLY -

EXAMINATION OF PRODUCT

ELECTRICAL BONDING

AMBIENT AND CRYO PROOF WITH VALVE OPEN AND CLOSED - 143 PSIG

AMBIENT AND CRYO EXTERNAL LEAKAGE OF VALVE BODY (110 PSIG)

CRYO EXTERNAL LEAKAGE OF ACTUATOR (740 PSIG)

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

AMBIENT AND CRYO ACTUATOR LEAKAGE FROM PORT TO PORT

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AMBIENT AND CRYO VALVE SHAFT SEAL (PRIMARY AND SECONDARY) LEAKAGE WITH 110 PSID ACROSS THE SEAL

AMBIENT AND CRYO VALVE INTERNAL LEAKAGE (INLET-TO-OUTLET WITH 15 PSID, OUTLET-TO-INLET WITH 110 PSID)

AMBIENT AND CRYO RELIEF VALVE CRACK AND RESEAT (15 TO 50 PSID)

POST TEST EXAMINATION

CERTIFICATION

STRUCTURAL LOAD AT CRYO TEMPS (-400 DEG F) (AXIAL, SHEAR, TORSION, BENDING) WITH THE VALVE IN TENSION, PERFORM VALVE RESPONSE TIME (NOMINAL AND SLAM) ACTUATOR INTERNAL LEAKAGE, PRIMARY AND SECONDARY SHAFT SEAL LEAKAGE, INTERNAL LEAKAGE (OUTLET-TO-INLET AND INLET-TO-OUTLET), CRACK AND RESEAT, AND, EXTERNAL LEAKAGE (BODY AND ACTUATOR) TESTS. REPEAT WITH THE VALVE IN COMPRESSION.

VALVE LIFE CYCLING:

2400 AMBIENT TEMPERATURE CYCLES WITH 5 PSIG INTERNAL PRESSURE (525 NORMAL CYCLES AND 1875 SLAM CYCLES)

100 AMBIENT CYCLES (50 NORMAL AND 50 SLAM CYCLES) WITH VALVE INLET VENTED TO ATMOSPHERE AND VALVE OUTLET CONNECTED TO A 4 CUBIC FOOT VOLUME PRESSURIZED TO 110 PSIG WITH GN2

2400 CRYO TEMPERATURE (-400 DEG F) CYCLES WITH 50 - 60 PSIG INTERNAL PRESSURE (1775 NORMAL CYCLES AND 625 SLAM CYCLES)

100 NORMAL CRYO CYCLES WITH THE VALVE INLET VENTED TO ATMOSPHERE AND THE OUTLET PRESSURIZED TO 110 PSIG.

FOR THE FOREGOING LIFE TEST, PRIOR TO AND EVERY 100 CYCLES THEREAFTER, ACTUATOR INTERNAL LEAKAGE, PRIMARY AND SECONDARY SHAFT SEAL LEAKAGE, AND VALVE INTERNAL LEAKAGE (OUTLET-TO-INLET) TESTS WERE PERFORMED.

RELIEF VALVE LIFE CYCLING:

2500 CYCLES AT CRYO (-400 DEG F) TEMP, 2500 CYCLES AT AMBIENT.

FOLLOWING EACH 500 CYCLES PERFORM FILL AND DRAIN VALVE INTERNAL LEAKAGE (OUTLET-TO-INLET AND INLET-TO-OUTLET), AND CRACK/RESEAT TESTS. POST CYCLE EXAMINATION.

VIBRATION:

PRE-VIBRATION TESTS - VALVE RESPONSE TIME (NORMAL AND SLAM), ACTUATOR INTERNAL LEAKAGE, PRIMARY AND SECONDARY SHAFT SEAL LEAKAGE, INTERNAL

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LEAKAGE (OUTLET-TO-INLET AND INLET-TO-OUTLET), CRACK AND RESEAT, AND EXTERNAL LEAKAGE (BODY AND ACTUATOR).

TRANSIENT SINUSOIDAL VIBRATION -  
(AT 110 PSIG AND -250 DEG F) IN EACH AXIS

RANDOM VIBRATION TESTS -  
13.3 HRS IN EACH OF THREE AXES WITH VALVE CLOSED AND AT -250 DEG F MAXIMUM. HALF OF THE TIME THE VALVE INTERNAL PRESSURE IS 110 PSIG; THE OTHER HALF AT 5 PSIG. ONCE EACH HOUR, CLOSING PRESSURE IS REMOVED FROM THE ACTUATOR. ALSO BOTH CLOSING AND OPENING PRESSURES ARE APPLIED CONCURRENTLY TO THE ACTUATOR. IN BOTH CASES THE VALVE REMAINS CLOSED.

DESIGN SHOCK: 18 SHOCKS OF 15G EACH - THREE IN EACH DIRECTION ALONG EACH OF THREE AXES, ALL WITH VALVE OPEN AND ACTUATOR VENTED

DESIGN SHOCK POST TEST:  
AMBIENT - VALVE RESPONSE, INTERNAL AND EXTERNAL LEAKAGES. CRYO - VALVE RESPONSE, INTERNAL AND EXTERNAL LEAKAGES. ELECTRICAL CHARACTERISTICS; POSITION INDICATION.

BURST: 165 PSIG VALVE OPEN 165 PSIG ON OUTLET OF CLOSED VALVE, 1700 PSIG ACTUATOR

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. BODY HOUSING FORGING IS ULTRASONICALLY AND PENETRANT INSPECTED.

CONTAMINATION CONTROL  
PARTS ARE VERIFIED CLEAN TO LEVEL 400. 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. ALL SURFACES REQUIRING CORROSION PROTECTION ARE VERIFIED. VISUAL (3X TO 7X) AND DIMENSIONAL INSPECTION OF VALVE BODY AND COMPONENTS ARE VERIFIED DURING ASSEMBLY. THREADED FASTENER TORQUES ARE VERIFIED BY INSPECTION. MANDATORY INSPECTION POINTS ARE INCLUDED IN THE ASSEMBLY PROCEDURE.

CRITICAL PROCESSES  
HEAT TREATMENT AND DRY FILM LUBE APPLICATION ARE VERIFIED BY INSPECTION.

NON DESTRUCTIVE EVALUATION

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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 SHIPMENT VERIFIED BY INSPECTION.

**(D) FAILURE HISTORY:**

THE DEVELOPMENT VALVE EXPERIENCED A NEEDLE BEARING FAILURE DURING VIBRATION TEST (CAR A7673). ANOTHER BEARING FAILED IN THE LO2 OUTBOARD F/D VALVE THAT WAS INSTALLED IN THE MPTA (CAR A9452), RESULTING IN BEARING COMPONENT DEBRIS IN THE MPS. THIS CONDITION WAS CORRECTED BY REDESIGN OF THE BEARING ASSEMBLY. IN ADDITION, FEEDLINE SCREENS WERE ADDED AT BOTH THE LH2 AND LO2 PREVALVE OUTLETS TO PREVENT DEBRIS OVER 1000 MICRONS FROM ENTERING THE ENGINE INLETS.

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: FOR POST MECO DUMP OPERATIONS, THE CREW WILL OPEN THE LH2 RTLS DUMP VALVES (PV17,18) WHEN THE LH2 MANIFOLD PRESSURE EXCEEDS CAUTION AND WARNING LIMITS.

GROUND: GROUND OPERATIONS SAFING PROCEDURES CONTAIN SAFING SEQUENCE OF EVENTS FOR MAJOR LEAKS IN THE HYDROGEN 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	: WILLIAM LANE	: /S/ WILLIAM LANE
USA SAM	: MICHAEL SNYDER	: /S/ MICHAEL SNYDER
USA ORBITER ELEMENT	: SUZANNE LITTLE	: /S/ SUZANNE LITTLE
NASA SR&QA	: ERICH BASS	: /S/ ERICH BASS