

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE****NUMBER: 03-1-0310 -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	:LO2 INBOARD 8" FILL/DRAIN VALVE (PV10) UNITED SPACE ALLIANCE - NSLD	MC284-0397-0030 74328000-157

**EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:**

FILL INBOARD LO2 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:** PV10**QUANTITY OF LIKE ITEMS:** 1**FUNCTION:**

PROVIDES A MEANS OF LOADING AND DRAINING THE ET THROUGH THE PROPELLANT FEED SYSTEM. THE VALVE, ALONG WITH THE OUTBOARD FILL AND DRAIN VALVE (PV9), PROVIDES A REDUNDANT MEANS OF CONTAINING PROPELLANT IN THE FEED SYSTEM. THE VALVE IS MOUNTED ON THE FEED LINE MANIFOLD TO ISOLATE THE FILL LINE FROM THE FEED SYSTEM. THE VALVE IS CLOSED AFTER LOADING IN ORDER TO DRAIN THE FILL LINE (PRIOR TO CLOSING THE OUTBOARD FILL & DRAIN VALVE). BOTH THE INBOARD AND OUTBOARD VALVES REMAIN CLOSED DURING ENGINE OPERATION AND ARE OPENED FOR MPS VACUUM INERT TO VENT LO2 RESIDUALS. BOTH VALVES ARE OPEN FOR LO2 DUMP IN RTLs AND TAL ABORTS. THE INBOARD VALVE REMAINS OPEN AFTER DUMP/INERT, THROUGH REENTRY AND LANDING. THE VALVE INCORPORATES AN ANTI-SLAM MECHANISM TO PREVENT SLAMMING DAMAGE DURING IMPROPER VALVE OPEN/CLOSE OPERATIONS. THE VALVE INCORPORATES A RELIEF VALVE, RELIEVING FROM THE FILL LINE INTO THE MANIFOLD; AND A PORT FOR INSTALLATION OF LO2 RELIEF SHUTOFF ISOLATION VALVE (PV7).

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**NUMBER: 03-1-0310-01**

**REVISION#: 1 08/14/00**

**SUBSYSTEM NAME: MAIN PROPULSION**

**LRU: LO2 INBOARD 8" FILL AND DRAIN VALVE (PV10)**

**CRITICALITY OF THIS**

**ITEM NAME: LO2 INBOARD 8" FILL AND DRAIN VALVE (PV10)**

**FAILURE MODE: 1R2**

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**FAILURE MODE:**

FAILS TO OPEN.

**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, BINDING, CONTAMINATION

**CRITICALITY 1/1 DURING INTACT ABORT ONLY? YES**

RTLS RETURN TO LAUNCH SITE

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**REDUNDANCY SCREEN**

A) PASS

B) PASS

C) PASS

**PASS/FAIL RATIONALE:**

A)

B)

C)

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**- FAILURE EFFECTS -**

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**(A) SUBSYSTEM:**

NO EFFECT FOR FIRST FAILURE ON NOMINAL MISSIONS. LO2 DUMP IS ACCOMPLISHED THROUGH THE LO2 PREVALVES AND MOV'S. LO2 VACUUM INERT CANNOT BE ACCOMPLISHED, BUT LEAKAGE THROUGH THE SSME INTERMEDIATE SEALS IS SUFFICIENT TO VENT LO2 MANIFOLD.

CRITICALITY 1/1 FOR RTLS ABORTS.

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FAILURE OF THE OPENING SOLENOID RESULTS IN FAILURE TO APPLY OPENING PRESSURE TO LO2 INBOARD VALVE. FAILURE OF INBOARD FILL AND DRAIN VALVE TO OPEN RESULTS IN FAILURE TO ADEQUATELY DUMP LO2. MAY CAUSE VIOLATION OF MAXIMUM DOWNWEIGHT FOR HEAVY MANIFESTED PAYLOADS.

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

SAME AS A.

**(C) MISSION:**

SAME AS A.

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

SAME AS A.

**(E) FUNCTIONAL CRITICALITY EFFECTS:**

CASE 1:

1R/2 2 SUCCESS PATHS. TIME FRAME – LOADING/DETANK

- 1) INBOARD FILL AND DRAIN VALVE (PV10) FAILS TO OPEN.
- 2) LO2 OVERBOARD BLEED (PV19) FAILS TO OPEN/REMAIN OPEN.

GEYSERING MAY RESULT IN FEEDLINE RUPTURE, EXTERNAL LEAKAGE OF LO2, AND POSSIBLE AFT COMPARTMENT OVERPRESSURIZATION. FIRE/EXPLOSIVE HAZARD BOTH INTERIOR AND EXTERIOR TO THE VEHICLE. POSSIBLE LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CRYO EXPOSURE. POSSIBLE LOSS OF VEHICLE.

CASE 2:

1R/3 3 SUCCESS PATHS. TIME FRAME - POST PAD ABORT DETANK.

- 1) INBOARD FILL AND DRAIN VALVE (PV10) FAILS TO OPEN.
- 2) 1 OF 3 PREVALVES (PV1,2,3) FAIL TO CLOSE.
- 3) LO2 OVERBOARD BLEED (PV19) FAILS TO OPEN/REMAIN OPEN.

TO PREVENT GEYSERING, PREVALVE CLOSURE IS REQUIRED TO LIMIT HEAT SOAKBACK FROM THE MAIN ENGINES INTO THE FEED SYSTEM. FOR PREVALVE FAILURE TO CLOSE, HELIUM INJECTION IS NOT SUFFICIENT TO PREVENT GEYSERING AND OVERBOARD BLEED OR LO2 DRAIN MUST BE INITIATED WITHIN OMRSD REQUIREMENTS.

GEYSERING MAY RESULT IN FEEDLINE RUPTURE, EXTERNAL LEAKAGE OF LO2, AND POSSIBLE AFT COMPARTMENT OVERPRESSURIZATION. FIRE/EXPLOSIVE HAZARD BOTH INTERIOR AND EXTERIOR TO THE VEHICLE. POSSIBLE LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CRYO EXPOSURE. POSSIBLE LOSS OF VEHICLE.

CASE 3:

1R/3 3 SUCCESS PATHS. TIME FRAME - RTLS (POST DUMP).

- 1) FAILURE RESULTING IN RTLS ABORT.
- 2) INBOARD FILL AND DRAIN VALVE (PV10) FAILS TO OPEN.
- 3) LO2 MANIFOLD RELIEF SYSTEM FAILS TO RELIEVE.

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE  
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RESULTS IN RUPTURE OF THE 17-INCH FEEDLINE DUE TO EXPANDING LO2 RESIDUALS AFTER LO2 DUMP. POSSIBLE AFT COMPARTMENT OVERPRESSURIZATION AND FIRE/EXPLOSIVE HAZARD. POSSIBLE LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CRYO EXPOSURE. POSSIBLE LOSS OF CREW/VEHICLE.

FOR TAL ABORTS, THE MAIN OXIDIZER VALVE (MOV) IS OPEN FOR A SUFFICIENT DURATION TO VENT RESIDUAL LO2.

**CASE 4:**

1R/3 5 SUCCESS PATHS. TIME FRAME - LO2 DUMP/VACUUM INERT

- 1) DUMP SWITCH FAILS IN "OFF" POSITION. PREVENTING OPENING OF ALL THREE LO2 PREVALVES (PV1, 2, 3) FOR LO2 DUMP.
- 2,3) BOTH LO2 POGO VALVES (PV20 & 21) FAIL TO REMAIN OPEN
- 4) INBOARD FILL AND DRAIN VALVE (PV10) FAILS TO OPEN. WHEN COMMANDED BY CREW.
- 5) LO2 MANIFOLD RELIEF VALVE (RV5) FAILS TO RELIEVE.

RESULTS IN RUPTURE OF THE 17-INCH FEEDLINE DUE TO EXPANDING LO2 RESIDUALS AFTER LO2 DUMP. POSSIBLE AFT COMPARTMENT OVERPRESSURIZATION AND FIRE/EXPLOSIVE HAZARD. POSSIBLE LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CRYO EXPOSURE. POSSIBLE LOSS OF CREW/VEHICLE.

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**-DISPOSITION RATIONALE-**

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**(A) DESIGN:**

THIS FAILURE MODE CAN OCCUR WITH AN ACTUATOR SHAFT RUPTURE, STRIPPING/SHEARING OF THE ACTUATOR SHAFT SPLINE OR FAILURE OF THE VALVE SHAFT/DRIVER KEY. THE VALVE MAIN SHAFT IS MADE OF INCONEL 718, ,A THE ACTUATOR MAIN PINION SHAFT OF BERYLLIUM-COPPER ALLOY 172 AND THE KEY OF A286 CRES. BASED UPON AN ANALYSIS PERFORMED BY THE VALVE MANUFACTURER, A POSITIVE MARGIN OF SAFETY EXISTS FOR THE ACTUATOR POWER TRAIN, FROM THE POSITION INDICATION CAM TO AND INCLUDING THE ACTUATOR VALVE INTERFACE SPLINE, FOR ALL RANGES OF ACTUATOR PRESSURES. THE WEAK LINK IN THE VALVE/ACTUATOR MECHANISM IS THE VALVE SHAFT/DRIVER KEY. THE ACTUATOR PROVIDES ENOUGH FORCE AT FULL ACTUATION PRESSURE TO APPLY A SHEARING LOAD TO THE KEY. A SEIZURE OF THE VALVE MAIN BLADE OR DRIVER MECHANISM WILL RESULT IN THE ACTUATOR LOAD BEING APPLIED TO SHEAR THE KEY AND CAN RESULT IN ACTUATOR FREE TRAVEL.

DURING THE CERTIFICATION TESTING THIS VALVE WAS CYCLED OPEN/CLOSED A TOTAL OF 5653 TIMES UNDER BOTH CRYOGENIC AND AMBIENT TEMPERATURE CONDITIONS AND AT BOTH NORMAL AND ACCELERATED (SLAM) CYCLE TIMES; THIS REPRESENTS OVER 100 MISSIONS.

**(B) TEST:**

ATP

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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 & 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 PROOF WITH VALVE OPEN (358 PSIG) AND CLOSED (275 PSID) APPLIED AT INBOARD SIDE

CRYO PROOF WITH VALVE OPEN (358 PSIG) AND CLOSED (358 PSID) APPLIED AT INBOARD SIDE

AMBIENT AND CRYO EXTERNAL LEAKAGE OF VALVE BODY (270 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

AMBIENT AND CRYO VALVE SHAFT SEAL (PRIMARY AND SECONDARY) LEAKAGE WITH 270 PSID ACROSS THE SEAL

AMBIENT AND CRYO VALVE INTERNAL LEAKAGE (INLET-TO-OUTLET WITH 15 PSID, OUTLET-TO-INLET WITH 270 PSID)

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

POST TEST EXAMINATION

CERTIFICATION

STRUCTURAL LOAD AT CRYO TEMPS (-300 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), RELIEF VALVE CRACK AND

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RESEAT, AND EXTERNAL LEAKAGE (BODY AND ACTUATOR) TESTS. REPEAT WITH THE VALVE IN COMPRESSION.

VALVE LIFE CYCLING:

2400 CYCLES AT AMBIENT TEMPERATURE 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 220 PSIG WITH GO2

2400 CRYO TEMPERATURE (-300 DEG F) CYCLES WITH 220 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 220 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 (-300 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 LEAKAGE (OUTLET-TO-INLET AND INLET-TO-OUTLET), CRACK AND RESEAT, AND EXTERNAL LEAKAGE (BODY AND ACTUATOR)

TRANSIENT SINUSOIDAL VIBRATION -  
270 PSIG AND -250 DEG F IN EACH AXIS

RANDOM VIBRATION TESTS -

13.3 HOURS IN EACH OF THREE AXES WITH VALVE CLOSED AND AT -250 DEG F MAXIMUM. HALF OF THE TIME THE VALVE INTERNAL PRESSURE IS 270 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:

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AMBIENT - VALVE RESPONSE, INTERNAL AND EXTERNAL LEAKAGES  
CRYO - VALVE RESPONSE, INTERNAL AND EXTERNAL LEAKAGES  
ELECTRICAL CHARACTERISTICS; POSITION INDICATION

BURST: 413 PSIG VALVE OPEN 413 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 800A. 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

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:**

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:**

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**FLIGHT:**

NO CREW ACTION CAN BE TAKEN TO OPEN INBOARD FILL/DRAIN VALVE. FOR FAILURE TO OPEN FOR LO2 DUMP/VACUUM INERT THE CREW CAN BE DIRECTED TO OPEN PREVALVES BY SWITCH THROW IF THEY FAIL TO OPEN DUE TO DUMP SWITCH FAILURE (CASE 4).

GROUND: THE LO2 17" FEED DISCONNECT (PD1) CAN BE CLOSED IN ORDER TO ISOLATE THE ORBITER FROM THE ET TO DELAY/PREVENT GEYSERING PER APPLICABLE OMRSD.

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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
SUBSYSTEM MGR.	: TIM REITH	:/S/ TIM REITH
MOD	: BILL LANE	:/S/ BILL LANE
USA SAM	: MIKE SNYDER	:/S/ MIKE SNYDER
USA ORBITER ELEMENT	: SUZANNE LITTLE	:/S/ SUZANNE LITTLE
NASA SR&QA	: BILL PRINCE	:/S/ BILL PRINCE