

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE****NUMBER: 03-1-0414 -X****SUBSYSTEM NAME:** MAIN PROPULSION**REVISION:** 1 07/14/00

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**PART DATA**

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	<b>PART NAME</b>	<b>PART NUMBER</b>
	<b>VENDOR NAME</b>	<b>VENDOR NUMBER</b>
LRU	:LO2 MANIFOLD RELIEF SHUTOFF VALVE UNITED SPACE ALLIANCE - NSLD	MC284-0406-0002 74329000-103

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**EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:**

VALVE, ONE INCH LO2 FEEDLINE RELIEF SHUTOFF, PNEUMATICALLY ACTUATED CLOSED, NORMALLY OPEN.

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:** PV7**QUANTITY OF LIKE ITEMS:** 1**FUNCTION:**

ISOLATES THE LO2 PROPELLANT FEED SYSTEM FROM THE FEED LINE RELIEF SYSTEM. MAINTAINED CLOSED FROM START OF PROPELLANT LOADING UNTIL MECO. VALVE IS MOUNTED ON THE INBOARD FILL & DRAIN VALVE BODY.

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**SUBSYSTEM NAME: MAIN PROPULSION**

**LRU: LO2 MANIFOLD RELIEF SHUTOFF VALVE (PV7)**

**CRITICALITY OF THIS**

**ITEM NAME: LO2 MANIFOLD RELIEF SHUTOFF VALVE (PV7)**

**FAILURE MODE: 1R2**

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**FAILURE MODE:**

FAILS TO REMAIN CLOSED/INTERNAL LEAKAGE DURING PRELAUNCH AND ASCENT.

**MISSION PHASE:**

PL PRE-LAUNCH  
LO LIFT-OFF

**VEHICLE/PAYLOAD/KIT EFFECTIVITY:**

102 COLUMBIA  
103 DISCOVERY  
104 ATLANTIS  
105 ENDEAVOUR

**CAUSE:**

ACTUATOR LEAKAGE, PIECE PART STRUCTURAL FAILURE

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

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**REDUNDANCY SCREEN**

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

**PASS/FAIL RATIONALE:**

A)

B)

POSITION SWITCH INDICATION CANNOT BE USED TO PASS THE B SCREEN. PIECE PART STRUCTURAL FAILURE MAY BE UNDETECTABLE BECAUSE POSITION SWITCHES ARE LOCATED IN THE ACTUATOR AND NOT AT THE END OF THE VALVE DRIVE MECHANISM.

C)

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**- FAILURE EFFECTS -**

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**(A) SUBSYSTEM:**

LOSS OF REDUNDANCY TO PREVENT LO2 OVERBOARD LEAKAGE. FEEDLINE RELIEF VALVE (RV5) WILL PREVENT OVERBOARD LEAKAGE OF LO2 (RELIEF VALVE CRACK PRESSURE IS ABOVE NOMINAL SYSTEM OPERATING PRESSURE).

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PRIOR TO T-9 MINUTES HELIUM LEAKAGE FROM ACTUATOR INTO THE AFT COMPARTMENT MAY BE DETECTED BY HGDS RESULTING IN VIOLATION OF LCC REQUIREMENT. PRIOR TO T-31 SECONDS VALVE FAILING TO REMAIN CLOSED DUE TO ACTUATOR LEAKAGE WILL BE DETECTED BY GLS RESULTING IN VIOLATION OF LCC REQUIREMENT.

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

SAME AS A.

**(C) MISSION:**

ON GROUND, VIOLATION OF THE HGDS AND/OR VALVE POSITION LCC REQUIREMENT WILL RESULT IN LAUNCH SCRUB.

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

NO EFFECT.

**(E) FUNCTIONAL CRITICALITY EFFECTS:**

CASE 1:

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

- 1) SHUTOFF VALVE (PV7) FAILS TO REMAIN CLOSED/LEAKS.
- 2) RELIEF VALVE (RV5) FAILS TO REMAIN CLOSED.

LO2 WILL DUMP OVERBOARD RESULTING IN PROPELLANT LEAKAGE ONTO THE PAD SURFACE. FIRE/EXPLOSION HAZARD EXTERIOR TO THE VEHICLE AND ON THE PAD. FIRE AND/OR LEAKAGE MAY BE DETECTABLE USING TV CAMERAS AND FIRE DETECTOR SENSORS. POSSIBLE LOSS OF CREW/VEHICLE.

CASE 2:

1R/2 2 SUCCESS PATHS. TIME FRAME - ASCENT (PRE MECO).

- 1) SHUTOFF VALVE (PV7) FAILS TO REMAIN CLOSED/LEAKS.
- 2) RELIEF VALVE (RV5) FAILS TO REMAIN CLOSED.

LO2 WILL DUMP OVERBOARD (6200 POUNDS MAXIMUM) RESULTING IN LOSS OF PROPELLANT AND PREMATURE ENGINE SHUTDOWN. FIRE/EXPLOSION HAZARD EXTERIOR TO THE VEHICLE. POSSIBLE VIOLATION OF ET MINIMUM STRUCTURAL REQUIREMENTS DUE TO REDUCED ULLAGE PRESSURE. POSSIBLE LOSS OF CREW/VEHICLE.

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**-DISPOSITION RATIONALE-**

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**(A) DESIGN:**

THE VALVE IS A NORMALLY OPEN, FLAPPER-TYPE SHUTOFF VALVE, WITH A PNEUMATIC ACTUATOR. IT IS SPRING LOADED TO THE OPEN POSITION BY A BELLOWS WITHIN THE

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ACTUATOR. IN THE ACTUATOR-VENTED CONDITION THE BELLOWS SPRING FORCE IS TRANSMITTED TO THE VALVE FLAPPER VIA A BELLOWS GUIDE (SHAFT) AND MECHANICAL LINKAGE TO ROTATE THE FLAPPER AWAY FROM THE VALVE SEAT AND OUT OF THE FLOW STREAM. WHEN ACTUATION PRESSURE IS APPLIED TO THE ACTUATOR THE BELLOWS IS COMPRESSED, CAUSING THE BELLOWS GUIDE AND MECHANICAL LINKAGE TO ROTATE THE FLAPPER TO THE VALVE CLOSED POSITION. VALVE INLET PRESSURE ASSISTS IN HOLDING THE FLAPPER TO THE VALVE SEAT.

FAILURE TO REMAIN IN THE CLOSED POSITION OR INTERNAL LEAKAGE ACROSS THE VALVE SEAT INDICATES THAT ADEQUATE CLOSING FORCE HAS BEEN REMOVED FROM THE FLAPPER. THIS COULD BE CAUSED BY ACTUATOR LEAKAGE OR STRUCTURAL FAILURE OF ANY OF THE FOLLOWING: FLAPPER ARM, FLAPPER LINK, EITHER OF THE TWO LINK PINS, ARM PIN, CLEVIS CYLINDER, BELLOWS GUIDE OR THE BELLOWS. STRESS ANALYSES OF THESE COMPONENTS INDICATE THE VALVE HAS A POSITIVE MARGIN OF SAFETY FOR ALL CONDITIONS OF VALVE OPERATIONS.

THE FLAPPER ASSEMBLY CONSISTS OF THE MAIN SEAL (KEL-F) WHICH IS CONTAINED IN A FLAPPER GUIDE (A286 CRES) AND RETAINED BY A FLAPPER RETAINER (ALSO A286 CRES). THESE COMPONENTS ARE SECURED TO THE FLAPPER ARM THROUGH A BELLEVILLE SPRING (HEAT TREATED ELGILOY).

THE FLAPPER VALVE IS OPERATED BY THE BELLOWS THROUGH A PINNED LINKAGE CONSISTING OF A FLAPPER ARM, A LINK, AND A BELLOWS GUIDE WELDED TO THE BELLOWS. THE FLAPPER ARM IS MADE FROM COPPER-BERYLLIUM #172 AND HEAT TREATED TO CONDITION HT. THE FLAPPER LINK IS OF 2219-T87 AL AND IS .278 INCHES THICK. THE PINS ARE A286 CRES AND HAVE A 0.2475 INCH DIAMETER. THE BELLOWS GUIDE IS MACHINED FROM 304L CRES, WHICH IS SUBSEQUENTLY ANNEALED. THE BELLOWS IS FORMED FROM TWO PLYS OF 0.01 INCH INCONEL 718 AND IS HEAT TREATED AFTER FORMING. IT IS DESIGNED FOR 10,000 CYCLES; 5 TIMES GREATER THAN THE VALVE SPECIFICATION REQUIREMENT. THE BELLOWS ASSEMBLY ACCEPTANCE TESTING INCLUDES PROOF PRESSURE, LEAKAGE, AND CYCLING.

ACTUATOR LEAKAGE IS CONTROLLED BY TWO SEALS; A FACE SEAL (RACO TYPE WITH A 301 CRES SPRING JACKETED WITH FEP TEFLON) BETWEEN THE BELLOWS RETAINER AND THE ACTUATOR HOUSING (AT THE ACTUATOR/VALVE INTERFACE), AND A SHAFT SEAL (ELGILOY WIRE COIL SPRING JACKETED WITH FEP TEFLON) WHERE THE BELLOWS GUIDE PASSES THROUGH THE ACTUATOR HOUSING INTO THE VENTED POSITION SWITCH COMPARTMENT.

**(B) TEST:**

ATP

AMBIENT PROOF

VALVE BODY - 413 PSIG WITH VALVE BOTH OPEN AND CLOSED

ACTUATOR - 1275 PSIG

VALVE RESPONSE TIMES

AMBIENT - VALVE PRESSURIZED TO 5 PSIG; ACTUATOR PRESSURIZED TO 780 AND 400 PSIG (OPEN AND CLOSED).

CRYO (-300 DEG F) -

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OPENING: VALVE PRESSURIZED TO 180 AND 20 PSIG; ACTUATOR 780 PSIG  
CLOSING: VALVE PRESSURIZED TO 0 AND 220 PSIG; ACTUATOR 780 AND 400 PSIG

EXTERNAL LEAKAGE

AMBIENT AND CRYO (-300 DEG F) - VALVE BODY @ 50 AND 200 PSIG GHE, VALVE OPEN; ACTUATOR @ 780 PSIG GHE

INTERNAL LEAKAGE - AMBIENT AND CRYO (-300 DEG F)  
INLET TO OUTLET @ 50 AND 200 PSIG GHE, VALVE CLOSED

POSITION INDICATION - VERIFICATION OF OPERATION (AMBIENT ONLY)

ELECTRICAL TESTS

ELECTRICAL BONDING; DIELECTRIC; INSULATION RESISTANCE

CERTIFICATION (TWO UNITS CERTIFIED)

VALVE RESPONSE TIMES

AMBIENT - VALVE PRESSURIZED TO 5 PSIG; ACTUATOR PRESSURIZED TO 780 AND 400 PSIG (OPEN AND CLOSED).

CRYO (-300 DEG F)

OPENING: VALVE PRESSURIZED TO 180 AND 20 PSIG; ACTUATOR 780 PSIG

CLOSING: VALVE PRESSURIZED TO 0 AND 220 PSIG; ACTUATOR 780 AND 400 PSIG

CRYO (-400 DEG F)

OPENING: VALVE PRESSURIZED TO 30 PSIG; ACTUATOR 780 PSIG

CLOSING: VALVE PRESSURIZED TO 0 AND 60 PSIG; ACTUATOR 780 AND 400 PSIG

EXTERNAL LEAKAGE

AMBIENT - VALVE BODY @ 50 AND 200 PSIG GHE, VALVE OPEN; ACTUATOR @ 780 PSIG GHE

CRYO (-300 DEG F) - VALVE BODY @ 50 AND 200 PSIG GHE, VALVE OPEN; ACTUATOR @ 780 PSIG GHE

CRYO (-400 DEG F) - VALVE BODY @ 50 PSIG GHE, VALVE OPEN; ACTUATOR @ 780 PSIG GHE

INTERNAL LEAKAGE

AMBIENT AND CRYO (-300 DEG F) - INLET TO OUTLET @ 50 AND 200 PSIG GHE, VALVE CLOSED

CRYO (-400 DEG F) - INLET TO OUTLET @ 50 PSIG GHE, VALVE CLOSED

LIFE TEST

CRYO (-400 DEG F) - 250 CYCLES AT 200 PSIG AND 250 CYCLES AT 50 PSIG FOLLOWED BY A CRYO (-400 DEG F) LEAKAGE TEST

AMBIENT - 1500 CYCLES @ 5 PSIG. AFTER EACH 500 CYCLES PERFORM AMBIENT LEAK TESTS.

VIBRATION

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TRANSIENT - (5 - 35 HZ) IN EACH OF THREE AXES, WITH VALVE CLOSED  
RANDOM - (13.3 HOURS IN EACH OF THREE AXES WHILE PRESSURIZED TO 200 PSIG, AT -300 DEG F, AND WITH THE VALVE CLOSED. FOLLOWING EACH AXIS TEST, PERFORM CRYO (-300 DEG F) VALVE RESPONSE TIMES TEST, AND CRYO (- 300 DEG F) LEAKAGE TESTS (EXCEPT ACTUATOR).

DESIGN SHOCK (18 SHOCKS OF 15G EACH) - THREE IN EACH DIRECTION OF THREE AXES). UPON COMPLETION PERFORM AMBIENT VALVE RESPONSE TIMES TEST, AND AMBIENT LEAKAGE TESTS.

THERMAL CYCLE TEST - +70 DEG F TO -400 DEG F TO +70 DEG F TO +275 DEG F TO +150 DEG F TO +70 DEG F PERFORMED THREE TIMES FOLLOWED BY AMBIENT VALVE RESPONSE TIMES TEST, AMBIENT LEAKAGE TESTS, AND ELECTRICAL INSULATION TEST.

ELECTRICAL BONDING (ONE UNIT ONLY)

BURST TEST (ONE UNIT ONLY) - 550 PSIG VALVE BODY, 3400 PSIG ACTUATOR

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. BODY HOUSING FORGING IS ULTRASONICALLY INSPECTED.

CONTAMINATION CONTROL

CONTAMINATION CONTROL PROCESS AND CORROSION PROTECTION PROVISIONS ARE VERIFIED. CLEANLINESS TO LEVEL 400A IS VERIFIED BY INSPECTION.

ASSEMBLY/INSTALLATION

ALL PARTS ARE PROTECTED FROM DAMAGE AND CONTAMINATION. LOG OF CLEAN ROOM AND TOOL CALIBRATION IS VERIFIED BY INSPECTION. DRAWING TORQUE AND SURFACE FINISH REQUIREMENTS ARE VERIFIED. COMPONENTS ARE VISUALLY AND DIMENSIONALLY INSPECTED DURING FABRICATION. SEALS ARE VISUALLY EXAMINED FOR DAMAGE AND CLEANLINESS PRIOR TO INSTALLATION. MANDATORY INSPECTION POINTS ARE INCLUDED IN THE ASSEMBLY PROCEDURE.

CRITICAL PROCESSES

HEAT TREATMENT, PARTS PASSIVATION, AND ANODIZING ARE VERIFIED. DRY FILM LUBRICANT APPLICATION IS VERIFIED BY INSPECTION.

NONDESTRUCTIVE EVALUATION

ULTRASONIC INSPECTION OF BODY HOUSING IS VERIFIED. WELDS ARE DYE PENETRANT INSPECTED.

TESTING

ATP VERIFIED BY INSPECTION.

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**HANDLING/PACKAGING**

HANDLING AND PACKAGING FOR SHIPMENT ARE VERIFIED BY INSPECTION.

**(D) FAILURE HISTORY:**

DURING ATP, INTERNAL LEAKAGE OF 180 SCIM WAS DETECTED (MAX ALLOWABLE IS 75 SCIM). A SMALL NICK ON THE FLAPPER SEAL WAS FOUND; CONSEQUENTLY, A REQUIREMENT WAS ADDED TO THE ASSEMBLY PROCEDURE TO INSPECT SEALS UNDER 10X MAGNIFICATION PRIOR TO ASSEMBLY. THE VALVE WAS REWORKED AND SUCCESSFULLY PASSED ATP (REF CAR A4931).

DURING ATP CRYOGENIC LEAKAGE TESTING, WITH 200 PSIG HELIUM AT THE VALVE INLET, THE LEAKAGE AT THE OUTLET WAS 2400 SCIM (MAX ALLOWABLE IS 75 SCIM). A DING WAS FOUND IN THE SEAT. ANODIZED SURFACES IN THE DING INDICATE THAT THE DAMAGE OCCURRED DURING MANUFACTURING PRIOR TO ASSEMBLY. VALVE SEAT WAS LAPPED AND THE VALVE SUCCESSFULLY PASSED ATP (REF CAR AC3552).

DURING QUALIFICATION CRYOGENIC LIFE CYCLE TESTING, POPPET SEAL LEAKAGE WAS MEASURED AT 106 SCIM (MAX ALLOWABLE IS 75 SCIM). QUAL TESTING WAS ALLOWED TO PROCEED. SUBSEQUENT LEAK CHECKS WERE WELL WITHIN SPECIFICATION. IT WAS BELIEVED THAT THE VALVE HAD NOT BEEN COMPLETELY TEMPERATURE STABILIZED OR THERE WAS CONTAMINATION ON THE SEALING SURFACE WHICH LATER FLUSHED AWAY. NO CORRECTIVE ACTION WAS TAKEN AS THE ANOMALY WAS CONSIDERED A RANDOM OCCURRENCE (REF CAR A5548).

MINOR LEAKAGE AT KSC WAS THE RESULT OF A DAMAGED SEAT IN THE VALVE HOUSING. DAMAGE PROBABLY CAUSED BY TRANSIENT CONTAMINATION (NOT FOUND DURING FAILURE ANALYSIS). BODY AND BELLOWS ASSEMBLY REPLACED. AFTER REFURBISHMENT WITH NEW SEALS, VALVE PASSED ATP (REFERENCE CAR AC8974).

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

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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	: HUGO MARTINEZ	: /S/ HUGO MARTINEZ