

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE****NUMBER: 03-1-0651 -X****SUBSYSTEM NAME:** MAIN PROPULSION**REVISION:** 2 11/07/00**PART DATA**


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	<b>PART NAME</b>	<b>PART NUMBER</b>
	<b>VENDOR NAME</b>	<b>VENDOR NUMBER</b>
LRU	: LH2 INBOARD RTLS DUMP VALVE, TYPE 3 (PV17) VACCO INDUSTRIES	MC284-0395-0053 1440-511
LRU	: LH2 OUTBOARD RTLS DUMP VALVE, TYPE 4 (PV18) VACCO INDUSTRIES	MC284-0395-0054 1441-511

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**EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:**

VALVE, 1.5 INCH, RTLS DUMP, LH2 FEEDLINE MANIFOLD, NORMALLY CLOSED, PNEUMATICALLY ACTUATED OPEN.

VALVE WAS ORIGINALLY DESIGNED AND MANUFACTURED BY VACCO INDUSTRIES (EATON). THE UNITED SPACE ALLIANCE-NSLD IS A CERTIFIED REPAIR DEPOT BUT HAS NOT YET BEEN CERTIFIED AS AN ALTERNATE PRODUCTION AGENCY.

**REFERENCE DESIGNATORS:** PV17  
PV18

**QUANTITY OF LIKE ITEMS:** 2

**FUNCTION:**

TWO SERIES REDUNDANT VALVES PROVIDE A PATH TO DUMP LH2 OVERBOARD FROM THE LH2 FEEDLINE MANIFOLD. FOR NOMINAL, ATO AND AOA MISSIONS THE VALVES ARE SOFTWARE COMMANDED OPEN AT MECO+11 SECONDS AND CLOSED AT DUMP STOP. THE VALVES ARE THEN RE-OPENED FOR ENTRY TO PERFORM A FINAL VACUUM INERT PRIOR TO ENTRY. FOR RTLS AND TAL MISSIONS, THE VALVES ARE OPENED NOMINALLY AND THEN REMAIN OPEN UNTIL ENTRY AT VREL=5300 FT/SEC. THE RTLS INBOARD VALVE, PV17, PROVIDES A RELIEF FEATURE FOR LH2 TRAPPED BETWEEN THE INBOARD AND OUTBOARD, PV18, VALVES.

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**SUBSYSTEM NAME: MAIN PROPULSION**

**LRU: LH2 RTLS DUMP VALVE, PV17, 18**

**ITEM NAME: LH2 RTLS DUMP VALVE, PV17, 18**

**CRITICALITY OF THIS**

**FAILURE MODE: 1R2**

**FAILURE MODE:**

RUPTURE/LEAKAGE OF VALVE ACTUATOR DURING ASCENT.

**MISSION PHASE: LO LIFT-OFF**

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

**CAUSE:**

FATIGUE, MATERIAL DEFECTS, DAMAGED/DEFECTIVE ACTUATOR SEALS

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

**REDUNDANCY SCREEN**

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

**PASS/FAIL RATIONALE:**

A)

B)

FAILS B SCREEN BECAUSE FAILURE CANNOT BE DETECTED DURING ASCENT; THE ACTUATOR IS UNPRESSURIZED DURING ASCENT.

C)

**- FAILURE EFFECTS -**

**(A) SUBSYSTEM:**

LOSS OF CAPABILITY TO OPEN OR MAINTAIN OPEN RTLS DUMP VALVES (PV17, 18) FOR POST MECO VENTING AND DUMP OPERATIONS. FAILURE HAS NO EFFECT DURING ASCENT SINCE ACTUATOR IS UNPRESSURIZED. ACTUATOR IS LOCATED ON HELIUM PNEUMATIC LEG DOWNSTREAM OF CHECK VALVE CV9 (ACCUMULATOR LEG). FAILURE IS NOT DETECTABLE ON GROUND SINCE ACTUATOR IS NOT PRESSURIZED.

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

SAME AS A.

**(C) MISSION:**

NOMINAL MISSION NO EFFECT.

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

SAME AS C.

**(E) FUNCTIONAL CRITICALITY EFFECTS:**

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

- 1) RTLS DUMP VALVE ACTUATOR (PV17 OR PV18) RUPTURE/LEAKAGE.
- 2) PREMATURE ACTUATION OF SOLENOID VALVE (LV72 OR LV73).

CAUSES LOSS OF PNEUMATIC ACTUATION PRESSURE RESULTING IN THE INABILITY TO CLOSE LO2 PREVALVES AT MECO. THIS RESULTS IN FAILURE TO MAINTAIN INJECTED GHE AND LO2 PRESSURE AT THE SSME PUMP, RESULTING IN POSSIBLE PUMP OVERSPEED AND EXPLOSION. POSSIBLE AFT COMPARTMENT OVERPRESSURIZATION AND FIRE/EXPLOSION HAZARD. ENGINE PURGE HELIUM RESIDUALS ARE TRANSFERRED TO VALVE ACTUATION SUPPLY AT MECO BY SOFTWARE COMMAND, WHICH MAY NOT ACTUATE LO2 PREVALVES CLOSED. POSSIBLE LOSS OF CREW/VEHICLE.

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**-DISPOSITION RATIONALE-**

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**(A) DESIGN:**

ACTUATOR FACTORS OF SAFETY: PROOF - 2.0; BURST - 4.0. DURING CERTIFICATION TESTING, ACTUATOR WAS BURST TESTED TO 3400 PSIG. ACTUATOR MAX OPERATING PRESSURE IS 850 PSIG. BOTH THE ACTUATOR BODY AND END CAP ARE MANUFACTURED FROM ALUMINUM ALLOY. STRUCTURAL ANALYSIS INDICATES POSITIVE MARGINS OF SAFETY FOR ALL CONDITIONS OF VALVE OPERATION; FRACTURE/FATIGUE ANALYSES SHOW THAT ALL CRITICAL PARTS ARE SATISFACTORY FOR FOUR TIMES EXPECTED LIFE.

EXTERNAL LEAKAGE FROM THE ACTUATOR END CAP IS PREVENTED BY THE USE OF A CREEVEY-TYPE SEAL (TEFLON COVER OVER A SANDVIK SPRING) AND A MYLAR GASKET. EXTERNAL LEAKAGE FROM THE ACTUATOR PISTON IS PREVENTED BY USE OF A KEL-F LIP SEAL.

**(B) TEST:**

ATP

EXAMINATION OF PRODUCT

AMBIENT PROOF

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL FAILURE MODE  
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VALVE BODY - 195 PSIG VALVE OPEN AND CLOSED.  
ACTUATOR - 1700 PSIG.

VALVE RESPONSE TIMES - AMBIENT AND CRYO (-300 DEG F AND -423 DEG F):  
VALVE: 55 PSIG  
ACTUATOR : 500 AND 740 PSIG

EXTERNAL LEAKAGE - AMBIENT AND CRYO (-300 DEG F AND -423 DEG F):  
VALVE BODY: 130 PSIG  
ACTUATOR: 740 PSIG

INTERNAL LEAKAGE - AMBIENT AND CRYO (-300 DEG F AND -423 DEG F):  
INLET-TO-OUTLET @ 55 PSIG  
OUTLET-TO-INLET @ 40 PSIG  
ACTUATOR: 740 PSIG

POSITION INDICATION: VERIFICATION OF OPERATION

ELECTRICAL CHARACTERISTICS - CONTACT RESISTANCE; INSULATION RESISTANCE; AND DIELECTRIC STRENGTH.

CERTIFICATION

LIFE -  
CRYO - 500 CYCLES @ -400 DEG F  
AMBIENT - 1500 CYCLES

RANDOM VIBRATION TESTS - IN ALL THREE AXES  
13.3 HOURS IN EACH AXIS WHILE PRESSURIZED TO 35 PSIG AND AT -300 DEG F.

DESIGN SHOCK (ALL THREE AXES) - 18 SHOCKS OF 15G EACH, THREE IN EACH DIRECTION.

THERMAL CYCLE TEST - PERFORMED THREE TIMES  
70 DEG F TO -400 DEG F TO 70 DEG F TO 275 DEG F TO 150 DEG F

VALVE RESPONSE TIMES - AMBIENT AND CRYO (-300 DEG F AND -423 DEG F):  
VALVE: 55 PSIG  
ACTUATOR: 500 AND 740 PSIG

EXTERNAL LEAKAGE - AMBIENT AND CRYO (-300 DEG F AND -423 DEG F):  
VALVE BODY: 130 PSIG  
ACTUATOR: 740 PSIG

INTERNAL LEAKAGE - AMBIENT AND CRYO (-300 DEG F AND -423 DEG F):  
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ELECTRICAL CHARACTERISTICS - CONTACT RESISTANCE; INSULATION RESISTANCE; AND DIELECTRIC STRENGTH.

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ELECTRICAL BONDING - LESS THAN 100 MILLIOHMS

BURST TEST - 260 PSIG VALVE BODY, 3400 PSIG ACTUATOR

OMRSD

ANY TURNAROUND CHECKOUT IS ACCOMPLISHED IN ACCORDANCE WITH OMRSD.

**(C) INSPECTION:**

RECEIVING INSPECTION

RAW MATERIAL VERIFIED BY INSPECTION FOR MATERIAL AND PROCESS CERTIFICATION. TEST REPORTS REQUIRED ON CAST MATERIAL. COMPLETION OF HOT ISOSTATIC PRESSING (HIP) PROCESS IS VERIFIED. CAST HOUSING (ROUGH MACHINED) IS INSPECTED FOR POROSITY.

CONTAMINATION CONTROL

CONTAMINATION CONTROL PROCESS AND CORROSION PROTECTION PROVISIONS ARE VERIFIED. THE INTERNAL WETTED SURFACES ARE CLEANED TO LEVEL 400A AND VERIFIED BY INSPECTION.

ASSEMBLY/INSTALLATION

ALL DETAIL PARTS ARE INSPECTED FOR CRITICAL DIMENSIONS, SURFACE FINISH, BURRS, DAMAGE, AND CORROSION. CRITICAL POPPET AND SLEEVE SURFACES ARE LAPPED AND INSPECTED WITH 40X MAGNIFICATION. TORQUES ARE VERIFIED TO BE IN ACCORDANCE WITH DRAWING REQUIREMENTS. PRIOR TO INSTALLATION, SEALS ARE VISUALLY EXAMINED WITH 10X MAGNIFICATION FOR DAMAGE AND CLEANLINESS. ALL SPRINGS ARE LOT TRACEABLE AND LOAD TESTED AT THE PIECE PART LEVEL. MANDATORY INSPECTION POINTS ARE INCLUDED IN THE ASSEMBLY PROCEDURE.

CRITICAL PROCESSES

HEAT TREATMENT OF THE VALVE BALL AFTER MACHINING IS VERIFIED. PART PASSIVATION AND HARD ANODIZING ARE VERIFIED. CERTIFICATION OF WELDING, POTTING, AND SOLDERING IS VERIFIED. PAINTING (ON BODY), ELECTRICAL BONDING, AND DRY FILM LUBRICANT ARE VERIFIED BY INSPECTION. ALL CASTINGS ARE SUBJECTED TO A HIP PROCESS.

NONDESTRUCTIVE EVALUATION

PRIOR TO FINAL MACHINING, THE HOUSING IS X-RAYED, ETCH AND DYE PENETRANT INSPECTED, AND PRESSURE LEAK CHECKED. ALL WELDS ON THE ELECTRICAL CONNECTOR ARE DYE PENETRANT INSPECTED AND VERIFIED BY INSPECTION.

TESTING

ATP VERIFIED BY INSPECTION.

HANDLING/PACKAGING

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NUMBER: 03-1-0651-10**

HANDLING, PACKAGING, STORAGE, AND SHIPPING REQUIREMENTS ARE VERIFIED BY INSPECTION.

**(D) FAILURE HISTORY:**

ATP

DURING ATP PROOF PRESSURE TEST, EXCESSIVE LEAKAGE PAST THE ACTUATOR SEAL WAS NOTED (REF CAR A9705). TEARDOWN REVEALED A SCRATCH ON THE PISTON SEAL. THE SEAL WAS REPLACED AND ACTUATOR MET LEAKAGE REQUIREMENTS. CORRECTIVE ACTION WAS TO INCORPORATE A MANDATORY INSPECTION POINT OF THE SEALS PRIOR TO INSTALLATION.

QUALIFICATION

DURING QUALIFICATION TEST, ACTUATOR LEAKAGE WAS OBSERVED (REF CAR A9894). X-RAY OF THE ACTUATOR REVEALED A BROKEN RACK/PISTON SPRING. UPON TEARDOWN, A BROKEN STATIC SEAL WAS ALSO FOUND. FAILURE ANALYSIS OF THE SPRING DETERMINED THAT THE SPRING FAILED FROM IMPACT EMBRITTLEMENT. THE ACTUATOR SPRING MATERIAL WAS CHANGED FROM TITANIUM TO ELGILOY AND REDUNDANT ACTUATOR STATIC SEALS WERE ADDED. THE QUAL UNIT WAS REWORKED AND SUCCESSFULLY RETESTED.

DURING QUALIFICATION TEST AT CRYO TEMPERATURE, THE ACTUATOR SHAFT SEAL LEAKAGE WAS 400 SCIM, MAX ALLOWABLE IS 100 SCIM (REF CAR AC6963). THE CAUSE ATTRIBUTED TO NORMAL INTERNAL WEAR IN COMBINATION WITH MIGRATING LUBRICANT. THE SPECIFICATION FOR MAXIMUM ACTUATOR SHAFT SEAL LEAKAGE WAS REVISED TO 500 SCIM (TYPE II VALVES ONLY), TO BE MEASURED AFTER EXPOSURE TO QUALIFICATION VIBRATION TEST.

DURING CRYOGENIC QUAL TESTING, ACTUATOR PISTON SEAL LEAKAGE OF 130 SCIM WAS NOTED. MAX ALLOWABLE IS 100 SCIM (REFERENCE CAR AB1806). THE LEAKAGE WAS DUE TO METALLIC PARTICLE GENERATION DURING ASSEMBLY FROM IMPROPERLY CLEANED PARTS CAUSING GALLING DURING ASSEMBLY. SUPPLIER ACTUATOR ASSEMBLY PROCEDURE PS-352M WAS CHANGED TO ADD CAUTION AND INSPECTION NOTE.

DURING QUALIFICATION TESTING, ACTUATOR PISTON SEAL LEAKAGE OF 200 SCIM WAS DETECTED. MAX ALLOWABLE IS 100 SCIM. LEAKAGE WAS DUE TO METALLIC PARTICLES GENERATED DURING ASSEMBLY WITH AN INADEQUATE ASSEMBLY TOOL. REDESIGNED TOOL ELIMINATED THE PROBLEM (REFERENCE CAR AB0197).

DURING QUALIFICATION TESTING, LEAKAGE AT THE ACTUATOR PISTON SEAL RETAINER INTERFACE WAS 560 SCIM. MAX ALLOWABLE IS 100 SCIM (REFERENCE ARE AB0088). LEAKAGE WAS DUE TO INSUFFICIENT SEAL RETAINER TORQUE OF 70 FT-LBS. ASSEMBLY TORQUE WAS INCREASED TO 95 - 100 FT-LBS WITH REPEAT APPLICATIONS AT 5 MINUTE INTERVALS UNTIL SUB-ASSEMBLY STOPS MOVING. IMPLEMENTED OV-102 AND SUBS.

FIELD

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DURING MPTA CHECKOUT, HELIUM WAS LEAKING THROUGH THE VENT PORT OF THE ACTUATOR CAUSING THE VALVE TO FAIL TO REMAIN OPEN (REF CAR A9630). DURING DISASSEMBLY, IT WAS FOUND THAT THE STATIC SEAL WAS PROTRUDING OUTSIDE ITS RETAINER AREA AND THAT THE SEAL RETAINER TORQUE WAS LOW. IT WAS CONCLUDED THAT THE ACTUATOR STATIC SEAL RETAINER TORQUE RELAXES EITHER FROM SEAL MATERIAL COLD FLOW OR RETAINER BACKING OFF. THE VALVE WAS REDESIGNED TO ADD REDUNDANT ACTUATOR SEALS AND LOCKTITE IS APPLIED TO THE RETAINER TO PREVENT TORQUE RELAXATION AND A SERIES OF RETORQUING TO MINIMIZE COLD FLOW. THE VALVE WAS REWORKED AND PASSED SUBSEQUENT LEAKAGE TESTS.

AT PALMDALE ACTUATOR LEAKAGE OCCURRED FROM UNDER THE ENDCAP OF THE ACTUATOR (REFERENCE CAR AD2446). THE ORIGIN OF THE LEAK WAS DUE TO TWO DAMAGED GASKETS P/N 1397-60 AND A SEAL P/N 1397-29-2. THE FAILURE WAS DUE TO A FAILURE TO BACK UP THE END CAP ON THE ACTUATOR WHILE TURNING A LINE FITTING DURING THE INSTALLATION OF THE VALVE. GASKETS AND SEAL REPLACED. NO FURTHER ACTION REQUIRED.

DURING CHECKOUT AT PALMDALE ON OV-099, THE ACTUATOR END CAP LEAKED EXCESSIVELY (REFERENCE CAR AC2152). NEW SEALS AND END CAP WERE INSTALLED ON THE VEHICLE BY THE SUPPLIER AND PASSED SUBSEQUENT LEAK TEST. CAUSE FOR LEAKAGE WAS NOT DETERMINED.

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:**

HELIUM BOTTLE PRESSURE IS ON DISPLAY IN COCKPIT. CREW ACTION CAN CLOSE PNEUMATIC ISOLATION VALVES (LV7,8) DURING ASCENT. PRIOR TO MECO, THE ISOLATION VALVES CAN BE REOPENED OR THE LEFT ENGINE LOW PRESSURE GHE CROSSOVER VALVE (LV10) CAN BE OPENED.

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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	: EARL HIRAKAWA	: /S/ EARL HIRAKAWA
MPS 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	: ERICH BASS	: /S/ ERICH BASS