

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE****NUMBER: 03-1-0651 -X****SUBSYSTEM NAME:** MAIN PROPULSION**REVISION:** 2

11/07/00

**PART DATA**

	<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)	MC284-0395-0053
	VACCO INDUSTRIES	1440-511
LRU	: LH2 OUTBOARD RTLS DUMP VALVE, TYPE 4 (PV18)	MC284-0395-0054
	VACCO INDUSTRIES	1441-511

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

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

**CRITICALITY OF THIS**

**FAILURE MODE: 1R2**

**FAILURE MODE:**

FAIL TO REMAIN CLOSED/INTERNAL LEAKAGE (INCLUDES BUILT-IN RELIEF VALVE) DURING LOADING AND ASCENT.

**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**

**REDUNDANCY SCREEN**

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

**PASS/FAIL RATIONALE:**

A)

B)

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

C)

**- FAILURE EFFECTS -**

**(A) SUBSYSTEM:**

FIRST FAILURE RESULTS IN LOSS OF REDUNDANCY. SERIES REDUNDANT VALVE WILL PREVENT LOSS OF LH2 OVERBOARD.

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**(B) INTERFACING SUBSYSTEM(S):**  
SAME AS A.

**(C) MISSION:**  
NO EFFECT.

**(D) CREW, VEHICLE, AND ELEMENT(S):**  
SAME AS C.

**(E) FUNCTIONAL CRITICALITY EFFECTS:**

CASE 1:

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

1,2) BOTH RTLS DUMP VALVES (PV17,18) FAIL TO REMAIN CLOSED.

FAILURE RESULTS IN LH2 LEAKAGE OVERBOARD, CAUSING FIRE/EXPLOSION HAZARD.  
POSSIBLE LOSS OF CREW/VEHICLE.

A MAXIMUM OF 1800 LBM OF LH2 COULD BE LOST BETWEEN LIFTOFF AND MECO. POSSIBLE VIOLATION OF ET MINIMUM STRUCTURAL REQUIREMENT DUE TO REDUCED ULLAGE PRESSURE. POSSIBLE LOW LEVEL CUTOFF (MAY CAUSE ATO OR AOA).

CASE 2:

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

1) INBOARD RTLS DUMP VALVE (PV17) FAILS TO REMAIN CLOSED.

2) RUPTURE/LEAKAGE OF LINE BETWEEN INBOARD AND OUTBOARD RTLS DUMP VALVES.

FAILURE RESULTS IN LH2 LEAKAGE INTO THE AFT COMPARTMENT, CAUSING FIRE/EXPLOSION HAZARD. POSSIBLE LOSS OF CREW/VEHICLE.

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**-DISPOSITION RATIONALE-**

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**(A) DESIGN:**

FAILURE OF THE VALVE TO REMAIN CLOSED CAN OCCUR DUE TO ACTUATOR SPRING FAILURE OR A STRUCTURAL FAILURE AT THE BALL CLOSURE TO SHAFT ATTACH INTERFACE.

THE VALVE AND ACTUATOR BODIES ARE MADE FROM MACHINED A356 ALUMINUM CASTING. THE VALVE ACTUATOR IS SPRING LOADED TO THE CLOSED POSITION AND IS DESIGNED TO OPEN WITH THE APPLICATION OF 500 TO 800 PSIG OF HELIUM PRESSURE TO THE VALVE ACTUATOR. THE ACTUATOR PISTON DRIVES A SPRING LOADED RACK WHICH DRIVES A PINION GEAR, THE SHAFT OF WHICH ROTATES THE VALVE BALL (CLOSURE). THE PISTON IS

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OF 304 CRES AND THE RACK AND PINION ARE OF INCONEL 718. THE PINION GEAR/SHAFT IS MACHINED FROM A SINGLE PIECE OF STOCK.

THE SPRING IS MANUFACTURED FROM 0.177 INCH DIAMETER ELGILOY WIRE AND HAS A SPRING RATE OF 96 POUNDS PER INCH. IN THE INSTALLED POSITION, WITH THE ACTUATOR VENTED, THE SPRING EXERTS A FORCE OF 275 POUNDS. IF THE SPRING SHOULD BREAK WITH THE VALVE CLOSED, THE INTERNAL FRICTION OF THE ACTUATOR AND VALVE WOULD PREVENT THE VALVE FROM LEAVING THE CLOSED POSITION. PRESSURE LOADS ON THE VALVE BALL, FROM EITHER DIRECTION, ARE EVENLY DISTRIBUTED AND WOULD NOT TEND TO OPEN THE VALVE.

THE RELIEF VALVE WITHIN PV17 WILL RELIEVE AND RESEAT IN THE RANGE OF 15 TO 40 PSID WITH A MAXIMUM FLOWRATE OF 1 POUND PER SECOND. THE RELIEF VALVE'S SIMPLE DESIGN EMPLOYS A SPHERICAL KEL-F POPPET ATTACHED TO A 6061-T651 PISTON. THE PISTON IS SPRING (ELGILOY) LOADED, HOLDING THE POPPET ONTO ITS SEAT. ANY PRESSURE BUILDUP ON THE UPSTREAM (MANIFOLD) SIDE OF THE VALVE WILL AUGMENT THE SPRING FORCE HOLDING THE POPPET ONTO ITS SEAT. THE PISTON IS GUIDED BY A 6061-T651 CAP AND, TO PREVENT BINDING, THE TOLERANCES BETWEEN PISTON AND CAP ARE CLOSELY CONTROLLED (0.002 TO 0.009 ON THE DIAMETER). ADDITIONALLY, THE PISTON IS HARD ANODIZED.

INTERNAL LEAKAGE THROUGH THE VALVE IS CONTROLLED BY A FLUOROGOLD BALL SEAL WHICH IS LOADED BY A BELLEVILLE SPRING. INTERNAL LEAKAGE CAN OCCUR DUE TO ENTRAPMENT OF CONTAMINANT PARTICLES BETWEEN THE BALL SEAL AND THE BALL CLOSURE, AND/OR THE RELIEF VALVE POPPET AND SEAT. HOWEVER, SYSTEM CONTAMINATION IS MINIMIZED DUE TO THE PRESENCE OF AN ET SCREEN, A GSE DEBRIS PLATE, A GSE FILTER, AND MAINTAINING THE SYSTEM CLEANLINESS AT LEVEL 400.

FACTORS OF SAFETY: PROOF - 1.5 BODY, 2.0 ACTUATOR; BURST - 2.0 BODY, 4.0 ACTUATOR. STRUCTURAL ANALYSIS INDICATES POSITIVE MARGINS OF SAFETY FOR ALL CONDITIONS OF VALVE OPERATIONS; FRACTURE/FATIGUE ANALYSES SHOW THAT ALL CRITICAL PARTS ARE SATISFACTORY FOR FOUR TIMES EXPECTED LIFE.

**(B) TEST:**

ATP

EXAMINATION OF PRODUCT

AMBIENT PROOF:

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

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

POSITION INDICATION: VERIFICATION OF OPERATION

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

RELIEF VALVE CRACK AND RESEAT (PV17 ONLY)  
AMBIENT AND CRYO (-300 DEG F): 15-40 PSID

CERTIFICATION

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

RANDOM VIBRATION TESTS - IN ALL THREE AXES  
13.3 HOURS IN EACH AXIS WHILE PRESSURIZED TO 105 PSIG AND AT -300 DEG F.

DESIGN SHOCK (ALL THREE AXES) - 18 SHOCKS OF 15G EACH, THREE IN EACH DIRECTION.  
THERMAL CYCLE TESTS - 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  
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INTERNAL LEAKAGE - AMBIENT AND CRYO (-300 DEG F AND -423 DEG F):  
INLET-TO-OUTLET @ 55 PSIG  
ACTUATOR: 740 PSIG

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

ELECTRICAL BONDING - LESS THAN 100 MILLIOHMS

BURST - BY SIMILARITY TO THE TYPE V VALVE. 800 PSIG VALVE BODY, 3400 PSIG  
ACTUATOR

OMRSD  
ANY TURNAROUND CHECKOUT IS ACCOMPLISHED IN ACCORDANCE WITH OMRSD.

**(C) INSPECTION:**  
RECEIVING INSPECTION

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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 LEAK CHECKED AT PROOF PRESSURE. ALL WELDS ON THE ELECTRICAL CONNECTOR ARE DYE PENETRANT INSPECTED AND VERIFIED BY INSPECTION.

**TESTING**

ATP VERIFIED BY INSPECTION.

**PACKAGING/HANDLING**

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

**(D) FAILURE HISTORY:**

INTERNAL LEAKAGE:

MINOR INTERNAL LEAKAGES HAVE OCCURRED AT THE SUPPLIER DURING ATP. CORRECTIVE ACTIONS WERE DESIGN CHANGES TO THE BALL SEAL AND RETAINER. DISCREPANT PARTS WERE REPLACED, MANUFACTURING ASSEMBLY PROCEDURES WERE CHANGED, AND ALLOWABLE ACTUATOR AND SHAFT SEAL LEAKAGE RATE REQUIREMENTS WERE RELAXED (REFERENCE CARS AC5714, AC6963, AB3341).

INTERNAL LEAKAGE DURING ATP WAS CAUSED BY BURRS AT THE SEALING CONTACT AREA OF THE BALL SEAL (REFERENCE CAR AB9088). SUPPLIER INITIATED A DEBURRING

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OPERATION UNDER 30X MAGNIFICATION. CORRECTIVE ACTION IS EFFECTIVE FOR TYPE I THRU TYPE V VALVES.

INTERNAL LEAKAGE DURING ATP WAS DETERMINED TO BE CAUSED BY INSUFFICIENT SEALING PRESSURE BETWEEN THE BALL SEAL AND THE BALL (REFERENCE CAR AC5985). THE SEAL RETAINER WAS FOUND TO BE DIMENSIONALLY DISCREPANT, CAUSING THE LACK OF SEALING PRESSURE. ALL EXISTING SEAL RETAINERS (P/N 80692) HAVE BEEN INSPECTED AND REWORKED TO THE CORRECT ANGLE OF 26 DEGREES.

DURING ATP AT ROCKWELL-DOWNEY, THE TYPE IV BALL VALVE EXHIBITED EXCESSIVE OUTLET-TO-INLET LEAKAGE AT LH2 TEMPERATURES (REFERENCE CAR AD1422). THE LEAKAGE WAS DUE TO HIGH POROSITY OF THE VALVE BODY (A356 ALUMINUM) AT THE BALL SEAL BODY CONTACT AREA. CORRECTIVE ACTION WAS TO IMPLEMENT A HOT ISOSTATIC PRESSING (HIP) PROCESS WHICH REDUCES THE POROSITY OF THE PARENT METAL. THE PROBLEM IS ATP SCREENABLE DURING THE HYDROGEN ATP.

DURING ATP, THE INLET TO OUTLET LEAKAGE AT CRYO TEMPERATURES EXCEEDED THE LEAKAGE REQUIREMENT (REFERENCE CAR A6441). DURING DISASSEMBLY, IT WAS NOTED THAT THE TORQUE ON THE BALL SEAL ASSEMBLY RETAINER WAS LOW. THE RETAINER WAS RETORQUED AND THE VALVE WAS RETESTED AT CRYO TEMPERATURES AND LEAKAGE REQUIREMENTS WERE MET. ASSEMBLY PROCEDURES WERE CHANGED TO INCORPORATE AN INSPECTION POINT TO VERIFY PROPER RETAINER TORQUE.

DURING ATP CRYO TESTS, LEAKAGE PAST THE BALL SEAL WAS NOT WITHIN THE LEAKAGE REQUIREMENTS (REF CAR A5402). DIS-ASSEMBLY OF THE VALVE SHOWED NO OBVIOUS LEAK PATHS. THE ATP WAS REVISED TO ESTABLISH A ONE HOUR COLD SOAK STABILIZATION TIME PRIOR TO FUNCTIONAL TESTING. ALSO, THE PROCEDURES WERE ESTABLISHED TO OBTAIN CORRECT SEAL LOADING DURING ASSEMBLY. THE VALVE HAS BEEN REDESIGNED AND THIS SEAL CONFIGURATION IS NO LONGER IN USE.

DURING ATP, THE INLET-TO-OUTLET LEAKAGE (125 AND 162 SCIM - MAX ALLOWABLE 100 SCIM) EXCEEDED THE REQUIREMENT ON TWO VALVES (REF CAR A9672). DUE TO MPTA TEST SCHEDULE DEMANDS, BOTH VALVES WERE WAIVED AND APPROVED FOR MPTA TESTING. NO FAILURE ANALYSIS WAS PERFORMED ON EITHER VALVE.

DURING ATP, THE INLET-TO-OUTLET LEAKAGE (820 SCIM - MAX ALLOWABLE 400 SCIM) EXCEEDED THE REQUIREMENT (REF CAR A8502). ALSO, THE RELIEF VALVE FLOW REQUIREMENTS WERE NOT MET. DUE TO MPTA TEST SCHEDULE DEMANDS, THE VALVE WAS WAIVED AND APPROVED FOR MPTA TESTING. NO FAILURE ANALYSIS WAS PERFORMED.

DURING ATP, EXCESSIVE INLET-TO-OUTLET LEAKAGE ON TWO VALVES OCCURRED AT CRYO TEMPERATURES (REF CARS AC6753 AND AC5201). THE VALVES WERE DISASSEMBLED AND THE BALL SEAL REVEALED HAIRLINE CRACKS AT SEVERAL POINTS ON THE INNER DIAMETER. TESTING INDICATED THAT THE CRACKS WERE CAUSED BY THE GEOMETRY OF THE BALL SEAL. THE BALL SEAL WAS REDESIGNED TO INCORPORATE A LARGER INNER DIAMETER; THE VALVE PASSED SUBSEQUENT LEAKAGE TESTS. THIS DESIGN CHANGE WAS INCORPORATED ON ALL FIVE BALL VALVE CONFIGURATIONS.

DURING LEAK TEST AT KSC, THE RTLS INBOARD DUMP VALVE LEAKED INTERNALLY (REFERENCE CAR AB5689). LEAKAGE WAS DUE TO CONTAMINATION ON THE RELIEF

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VALVE POPPET. THE VALVE WAS REPLACED AND SUBSEQUENTLY PASSED THE VEHICLE LEAK CHECK REQUIREMENTS.

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: WHEN THE ULLAGE PRESSURE DROPS BELOW 28 PSI, THE CREW WILL OPEN THE LH2 FLOW CONTROL VALVE WITH THE COCKPIT SWITCH. WHEN THIS IS INEFFECTIVE AND THE NPSP DROPS BELOW A PREFLIGHT ACCEPTED VALUE, THE CREW WILL ABORT TO TAL OR ACLS.

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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