

**FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE****NUMBER: 03-1-0403 -X****SUBSYSTEM NAME:** MAIN PROPULSION**REVISION:** 1 11/06/2000**PART DATA**

<b>PART NAME</b>	<b>PART NUMBER</b>
<b>VENDOR NAME</b>	<b>VENDOR NUMBER</b>
LRU : LH2 RECIRCULATION VALVE, TYPE 1, 2.0 INCH, NORMALLY CLOSED	MC284-0395-0051
VACCO INDUSTRIES	1397-513

**EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:**

VALVE, RECIRCULATION, LH2, 2.0 INCH, NORMALLY CLOSED. PNEUMATICALLY OPERATED.

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:** PV14  
PV15  
PV16

**QUANTITY OF LIKE ITEMS:** 3  
ONE PER ENGINE

**FUNCTION:**

THE VALVE IS MOUNTED IN PARALLEL WITH EACH LH2 PREVALVE PROVIDING A PATH FOR LH2 TO BYPASS THE PREVALVE AND FLOW THROUGH THE FEEDLINES TO THE ENGINE FOR ENGINE PRESTART CONDITIONING. VALVES ARE CLOSED PRIOR TO ENGINE START AND REMAIN CLOSED TO PROVIDE ENGINE ISOLATION WHENEVER THE PREVALVES ARE CLOSED.

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**SUBSYSTEM NAME: MAIN PROPULSION**

**LRU: LH2 RECIRCULATION VALVE, PV14, 15, 16**

**ITEM NAME: LH2 RECIRCULATION VALVE, PV14, 15, 16**

**CRITICALITY OF THIS**

**FAILURE MODE: 1/1**

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**FAILURE MODE:**

RUPTURE/EXTERNAL LEAKAGE OF THE VALVE BODY DURING LOADING, ASCENT, AND DUMP/INERT.

**MISSION PHASE:**

PL PRE-LAUNCH  
LO LIFT-OFF

**VEHICLE/PAYLOAD/KIT EFFECTIVITY:**

102 COLUMBIA  
103 DISCOVERY  
104 ATLANTIS  
105 ENDEAVOUR

**CAUSE:**

FATIGUE, MATERIAL DEFECT, DAMAGED/DEFECTIVE HOUSING SEALS

**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:**

LH2 LEAKAGE INTO THE AFT COMPARTMENT. POSSIBLE AFT COMPARTMENT OVERPRESSURIZATION AND FIRE/EXPLOSION HAZARD. PRELAUNCH GN2 PURGE OF THE AFT COMPARTMENT MAY LOWER THE GH2 CONCENTRATION BUT FIRE/EXPLOSION HAZARD STILL PRESENT. LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CRYOGENIC

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EXPOSURE. LEAKAGE IN THE AFT COMPARTMENT IS DETECTABLE DURING LOADING USING THE HAZARDOUS GAS DETECTION SYSTEM (HGDS).

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

SAME AS A.

**(C) MISSION:**

ON GROUND, VIOLATION OF HGDS LCC WILL RESULT IN LAUNCH SCRUB.

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

POSSIBLE LOSS OF CREW/VEHICLE.

**(E) FUNCTIONAL CRITICALITY EFFECTS:**

NONE.

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**-DISPOSITION RATIONALE-**

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**(A) DESIGN:**

FACTORS OF SAFETY: PROOF - 1.5 BODY; BURST - 2.0 BODY. CERTIFIED BY SIMILARITY TO THE TYPE V BALL VALVE WHICH WAS BURST TESTED TO 800 PSIG. VALVE OPERATING PRESSURE IS 55 PSIG. 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. THE VALVE BODY IS CONSTRUCTED OF A356 MACHINED ALUMINUM.

SHAFT LEAKAGE IS CONTROLLED BY DUAL DYNAMIC SEALS; ONE MYLAR AND THE OTHER TEFLON (SPRING LOADED AGAINST THE PINION SHAFT). LEAKAGE PAST THE LOWER TRUNION IS CONTROLLED PRIMARILY BY A CREEVY SEAL (TEFLON JACKET OVER A CRES SPRING), BACKED UP BY A TEFLON STATIC SEAL.

**(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

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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 AT -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 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  
ACTUATOR: 740 PSIG

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

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

ELECTRICAL BONDING - LESS THAN 100 MILLIOHMS

BURST - 260 PSIG VALVE BODY, 3400 PSIG ACTUATOR

OMRSD

ANY TURNAROUND CHECKOUT IS ACCOMPLISHED IN ACCORDANCE WITH OMRSD.

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**(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 400 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.

HANDLING/PACKAGING

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

**(D) FAILURE HISTORY:**

ATP

DURING ATP, SHAFT SEAL LEAKAGE WAS 12 SCIM, MAX ALLOWABLE IS 2 SCIM (REFERENCE CAR AC6593). THE SHAFT SEAL WAS REMOVED AND REPLACED AND PASSED SUBSEQUENT LEAKAGE TESTS. FAILURE IS ATP SCREENABLE.

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DURING ATP WITH VALVE PRESSURIZED AT 130 PSIG, THE EXTERNAL LEAKAGE WAS 41.6 SCIM, MAX ALLOWABLE 5 SCIM (REF CAR A4821). DURING DISASSEMBLY, IT WAS FOUND THAT BOTH THE PRIMARY AND SECONDARY SHAFT SEALS WERE OFF CENTER FROM THEIR INSTALLATION POSITIONS. IN ADDITION, THE SHAFT END THAT ENGAGES THE BALL HAD SPLINES WITH SHARP EDGES WHICH RESULTED IN SCRATCHES ON THE PRIMARY SHAFT SEAL WHEN THE SEAL PASSED OVER THE SPLINES. THE VALVE WAS REWORKED AND PASSED ATP. SHAFT DRAWINGS HAVE BEEN REVISED TO REMOVE SHARP EDGES ON THE SPLINES AND USE OF PROPER TOOLING TO OBTAIN THE CORRECT ALIGNMENT OF THE SEALS WAS IMPLEMENTED.

DURING ATP, EXTERNAL LEAKAGE OF THE SHAFT SEAL AT CRYO TEMPERATURE WAS 6.3 SCIM, MAXIMUM ALLOWABLE OF 5 SCIM (REF CAR A7202). THE SEAL WAS REPLACED AND VALVE MET LEAKAGE REQUIREMENTS AT CRYO TEMPS.

DURING ATP, THE EXTERNAL LEAKAGE AT CRYO TEMPS WAS AT 22 SCIM, MAX ALLOWABLE 2 SCIM (REF CAR A5438). INSPECTION OF THE VALVE REVEALED A CRACK IN THE TRUNION BEARING SEAL. THE SEAL WAS REPLACED AND THE VALVE PASSED SUBSEQUENT LEAKAGE TESTS.

DURING ATP, THE EXTERNAL LEAKAGE AT CRYO TEMPERATURE WAS 2.87 SCIM, MAX ALLOWABLE 2 SCIM (REF CAR A9706). DISASSEMBLY OF THE VALVE REVEALED THAT THE TRUNION BEARING SEALING SURFACE WAS DAMAGED DURING ASSEMBLY. THE VALVE WAS REWORKED AND MET LEAKAGE REQUIREMENTS AT CRYO TEMPERATURES.

DURING ATP, THE SHAFT SEAL LEAKAGE WAS 25 SCIM, MAX ALLOWABLE 10 SCIMS (REF CAR A9674). THE VALVE WAS DISASSEMBLED AND SCRATCHES WERE FOUND ON THE SHAFT SEAL. NEW SEALS WERE INSTALLED AND THE VALVE PASSED ATP.

**QUALIFICATION**

DURING QUALIFICATION TESTING AT CRYO TEMPERATURE, SHAFT SEAL LEAKAGE WAS 13 SCIM, MAX ALLOWABLE 10 SCIM (REF CAR AB0141). DISASSEMBLY FOUND SMALL SLIVERS OF TEFLON MATERIAL ON THE SEALING SURFACE. IT WAS DETERMINED THAT THE CONTAMINATION WAS GENERATED WITHIN THE VALVE DURING QUAL TEST. CORRECTIVE ACTION RESULTED IN RELAXATION OF QUALIFICATION LEAKAGE REQUIREMENTS TO ALLOW 20 SCIM. VALVE WAS REASSEMBLED AND PASSED LEAKAGE TESTS.

DURING QUALIFICATION TEST, LEAKAGE OF THE SHAFT SEAL AT CRYO TEMPERATURE, THE SHAFT SEAL LEAKAGE WAS 27 SCIM, MAX ALLOWABLE IS 20 SCIM (REF CAR AC6963). THE CAUSE ATTRIBUTED TO NORMAL INTERNAL WEAR IN COMBINATION WITH MIGRATING LUBRICANT. THE SPECIFICATION FOR MAXIMUM SHAFT SEAL LEAKAGE WAS REVISED TO 30 SCIM (TYPE II VALVES ONLY), TO BE MEASURED AFTER EXPOSURE TO QUALIFICATION VIBRATION TEST.

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.

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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	: 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