

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CIL HARDWARE

NUMBER: 03-1-0304 -X

SUBSYSTEM NAME: MAIN PROPULSION

REVISION: 2 11/07/00

PART DATA

	PART NAME	PART NUMBER
	VENDOR NAME	VENDOR NUMBER
LRU	: LH2 TOPPING VALVE, 2.0 INCH, NC, TYPE 1 VACCO INDUSTRIES	MC284-0395-0051 1397-513

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:

LH2 TOPPING VALVE, 2 INCH, 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: PV13

QUANTITY OF LIKE ITEMS: 1

FUNCTION:

PROVIDES CONTROL OF REPLENISH/TOPPING OF LH2 DURING COMPLETION OF PROPELLANT LOADING. OPENED AT THE START OF LH2 SLOW FILL. CLOSED FOR LH2 TANK PREPRESSURIZATION AND DRAINBACK OF LH2 FILL LINE. REMAINS CLOSED DURING ENGINE OPERATION. OPENED DURING DUMP/INERTING OPERATIONS.

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FAILS TO REMAIN CLOSED/INTERNAL LEAKAGE DURING ASCENT

MISSION PHASE: 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 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)

- FAILURE EFFECTS -**(A) SUBSYSTEM:**

LH2 WILL ENTER FILL LINE. LOSS OF REDUNDANCY FOR OVERBOARD LEAKAGE WITH OUTBOARD FILL AND DRAIN VALVE (PV11).

(B) INTERFACING SUBSYSTEM(S):

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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 - ASCENT.

- 1) TOPPING VALVE (PV13) FAILS TO REMAIN CLOSED.
- 2) OUTBOARD FILL AND DRAIN VALVE (PV11) FAILS TO REMAIN CLOSED.

LH2 WILL DUMP OVERBOARD (3200 LBM MAXIMUM) RESULTING IN LOSS OF PROPELLANT AND PREMATURE ENGINE SHUTDOWN. FIRE/EXPLOSION HAZARD BOTH INTERIOR (FILL AND DRAIN LINE) AND EXTERIOR TO THE VEHICLE. POSSIBLE VIOLATION OF ET MINIMUM STRUCTURAL REQUIREMENTS DUE TO REDUCED ULLAGE PRESSURE. POSSIBLE LOSS OF CREW/VEHICLE.

CASE 2:

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

- 1) TOPPING VALVE (PV13) FAILS TO REMAIN CLOSED.
- 2) LH2 FILL & DRAIN LINE (FH6) RUPTURE/LEAKAGE.

LH2 WILL LEAK INTO THE AFT FUSELAGE CAUSING POSSIBLE AFT COMPARTMENT OVERPRESS AND FIRE/EXPLOSION HAZARD. POSSIBLE LOSS OF CRITICAL ADJACENT COMPONENTS DUE TO CRYO EXPOSURE. POSSIBLE LOSS OF CREW/VEHICLE.

-DISPOSITION RATIONALE-

(A) DESIGN:

THE VALVE ACTUATOR IS SPRING LOADED TO THE CLOSED POSITION. THE ACTUATOR PISTON DRIVES A SPRING LOADED RACK WHICH, IN TURN, DRIVES A PINION GEAR SHAFT WHICH ROTATES THE VALVE BALL CLOSURE DEVICE. 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 DRIFTING OUT OF THE CLOSED POSITION.

THE RACK AND PINION ARE OF INCONEL 718 AND THE PINION GEAR/SHAFT IS MACHINED FROM A SINGLE PIECE OF STOCK. PRESSURE LOADS ON THE VALVE BALL, FROM EITHER DIRECTION, ARE EVENLY DISTRIBUTED AND WOULD NOT TEND TO OPEN THE VALVE.

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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.

INTERNAL LEAKAGE IS CONTROLLED BY A FLUOROGOLD BALL SEAL WHICH IS LOADED BY A BELLEVILLE SPRING.

FACTORS OF SAFETY FOR INTERNAL PRESSURE: PROOF - 1.5 BODY, 2.0 ACTUATOR;
BURST - 2.0 BODY, 4.0 ACTUATOR.

(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

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

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

ELECTRICAL BONDING - LESS THAN 100 MILLIOHMS

BURST - 260 PSIG VALVE BODY, 3400 PSIG ACTUATOR

GROUND TURNAROUND TEST
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

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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 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. OV103 AND OV104 BALL VALVES (LH2 ATPPED BUT NOT HIPPED) HAVE EXHIBITED NO LEAKAGE. THE OV102 VALVES WERE NOT ACCEPTANCE TESTED WITH LH2. THE OV102 LH2 VALVES ARE SCHEDULED FOR REMOVAL AND REWORK FOR OTHER DESIGN CHANGES.

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

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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 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:

NO CREW ACTION CAN BE TAKEN.

- APPROVALS -

S&R ENGINEERING	: W.P. MUSTY	: /S/ W. P. MUSTY
S&R ENGINEERING ITM	: P. A. STENGER-NGUYEN	: /S/ P. A. STENGER
DESIGN ENGINEERING	: EARL HIRAKAWA	: /S/ EARL HIRAKAWA
MPS SUBSYSTEM MGR.	: TIM REITH	: /S/ TIM REITH

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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