

## FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CRITICAL HARDWARE

NUMBER: 03-3-2007-X

SUBSYSTEM NAME: ORBITAL MANEUVERING SYSTEM (OMS)

REVISION : 6 03/05/91

	PART NAME VENDOR NAME	PART NUMBER VENDOR NUMBER
■ LRU :	VALVE, TANK ISOLATION, OX PARKER HANNIFIN	MC284-0430-0023/0047 5750029-103/106
■ LRU :	VALVE, TANK ISOLATION, FUEL PARKER HANNIFIN	MC284-0430-0024/0048 5750030-103/106

## PART DATA

## EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:

VALVE, TANK ISOLATION, A.C. MOTOR ACTUATED, 115/200 V, AC, 3-PHASE, 400 HZ, 1.0 AMP MAX (2-PHASE), 1.0 AMP (3 PHASE). (L7462, 464, 461, 463, 562, 564, 561, 563)

QUANTITY OF LIKE ITEMS: 8  
4 PER POD (PARALLEL)

## FUNCTION:

TWO PARALLEL REDUNDANT ISOLATION VALVES ARE USED PER TANK TO ISOLATE OMS PROPELLANT DURING OMS CROSS-FEED. THEY ARE ALSO USED TO PREVENT HELIUM INGESTION TO ENGINE AT PROPELLANT RUN OUT, TO ISOLATE LEAKS BY MANUAL SWITCH ACTUATION, AND ARE ALSO USED DURING GROUND OPERATIONS. FUEL AND OXIDIZER VALVE ARE OPERATED INDEPENDENTLY FOR C/O. THE ACTUATOR ASSEMBLY CONSISTS OF 115 V.A.C., 400 HZ, THREE PHASE MOTOR (CAPABLE OF 2-PHASE OPERATION) OPERATING THROUGH A PLANETARY GEAR TRAIN WITH MICROSWITCHING TO CONTROL MOTOR POWER. THE FLOW ASSEMBLY CONSISTS OF LIFT-OFF BALL VALVE ACTUATED THROUGH A ROTATING FINGER DRIVEN BY THE ACTUATOR. AN INTERNAL RELIEF DEVICE IS PROVIDED. THERMAL SWITCHES ON EACH AC PHASE INTERRUPT ELECTRICAL POWER WHEN VALVE HOUSING REACHES A TEMPERATURE OF 255 F.

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LRU : VALVE, TANK ISOLATION, OX  
ITEM NAME: VALVE, TANK ISOLATION, FUEL

CRITICALITY OF THIS  
FAILURE MODE: 1R2

- FAILURE MODE:  
INTERNAL LEAKAGE, FAIL OPEN, FAILS TO CLOSE, FAILS TO REMAIN CLOSED

MISSION PHASE:

LD LIFT-OFF  
DO DE-ORBIT

- VEHICLE/PAYLOAD/KIT EFFECTIVITY: 102 COLUMBIA  
: 103 DISCOVERY  
: 104 ATLANTIS  
: 105 ENDEAVOUR

CAUSE:

CONTAMINATION, CORROSION, MATERIAL DEFECT, SEAT CRACKS, PREMATURE  
SIGNAL, RELIEF DEVICE FAILURE, JAMMING OF BALL SHAFT OR CAMS, CONTROL  
SWITCH FAILURE, MOTOR FAILURE, PROPELLANT LEAK INTO ACTUATOR CAVITY.  
TWO OF 3 THERMAL SWITCHES FAIL ON OR OFF DEPENDENT ON VALVE POSITION.

CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO

- REDUNDANCY SCREEN A) PASS  
B) PASS  
C) PASS

PASS/FAIL RATIONALE:

- A)
- B)
- C)

- FAILURE EFFECTS -

(A) SUBSYSTEM:

SUBSYSTEM DEGRADATION - LOSS OF REDUNDANCY, LOSS OF ABILITY TO ISOLATE  
TANK IN REACTION TO FAILURE.

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

LOSS OF REDUNDANCY FOR LEAK ISOLATION (BACK-UP TO OMS CROSSFEED VALVE FOR INTERCONNECT OR RCS CROSSFEED).

**(C) MISSION:**

NO EFFECT.

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

SAME AS (C)

**(E) FUNCTIONAL CRITICALITY EFFECTS:**

POTENTIAL LOSS OF CREW/VEHICLE. EXCESSIVE LOSS OF PROPELLANT DUE TO INABILITY TO ISOLATE EXTERNAL LEAK. INABILITY TO ISOLATE OMS FROM RCS FOR INTERCONNECT OR RCS CROSSFEED. INABILITY TO UTILIZE PROPELLANT FROM OPPOSITE POD IN OMS CROSSFEED. GAS INGESTION INTO OMS ENGINE AT PROPELLANT RUN-OUT.

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- DISPOSITION RATIONALE -  
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**(A) DESIGN:**

AC MOTOR VALVE IS 3-PHASE - 2 OF 3 WINDINGS ARE ADEQUATE FOR VALVE FUNCTION. SERIES (HYBRID) RELAYS PROVIDE REDUNDANCY FOR ELECTRICAL POWER SIGNAL. SERIES REDUNDANT MICRO SWITCHES ARE PROVIDED FOR CLOSING. A 400-MICRON FILTER IS UTILIZED ON THE INLET AND OUTLET TO LIMIT THE POTENTIAL FOR CONTAMINATION CAUSED FAILURE OR JAMMING OF MOVING PARTS. GPC OR MANUAL COMMAND CAPABILITY IS PROVIDED. DUAL BALL SEALS ARE PROVIDED FOR BI-DIRECTIONAL SEALING. BELLOWS IN VALVE FLOW SECTION ISOLATES PROPELLANT FROM ACTUATOR ELECTRICAL COMPONENTS. BELLOWS ARE TWO PLY .003" THICK RESISTANCE WELDED TOGETHER, AND THEN EB WELDED TO TWO END PIECES, WHICH ARE THEN EB WELDED INTO THE VALVE. THE BELLOWS ARE FILLED WITH KRYTOX GREASE. SWITCHES ARE HERMETICALLY SEALED TO PREVENT PROPELLANT FROM REACHING CONTACTS. MATERIALS ARE SELECTED THAT ARE COMPATIBLE WITH PROPELLANTS. ALL THREE PHASES OF THE MOTOR CONTAIN A THERMAL SWITCH. THE THERMAL SWITCH PROVIDES OVERTEMPERATURE PROTECTION FOR THE VALVE'S ACTUATOR. THE SWITCH IS DESIGNED TO OPEN AT 255 DEGREES FAHRENHEIT AND CLOSE AT 225 DEGREES FAHRENHEIT.

**(B) TEST:****QUALIFICATION TEST**

(4 UNITS), SHOCK, ENDURANCE (2500 CYCLES), THERMAL CYCLING (+20 TO +150 DEGREES F.), RANDOM VIBRATION, PROPELLANT EXPOSURE, SURGE PRESSURE, BURST (2000 PSI). THE VALVE WAS CONTINUOUSLY POWERED FOR SEVEN DAYS WITH THERMAL SWITCHES CYCLING ON AND OFF (TEMPERATURE IS NOT

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ALLOWED TO EXCEED 300 DEGREES FAHRENHEIT). ALSO QUALIFIED AS PART OF POD ASSEMBLY - VIBRO-ACOUSTIC TESTING AT SSC (131 EQUIVALENT MISSIONS). HOT-FIRE TEST PROGRAM AT WSTF - 517 TESTS (24 EQUIVALENT MISSIONS). APPROX. 7 YEARS PROPELLANT EXPOSURE.

ADDITIONAL QUALIFICATION TESTING WAS PERFORMED TO EVALUATE BELLOWS PROBLEMS. THE TESTING CONSISTED OF A 100-MISSION LIFE TEST (ACTUATING CYCLES AND SURGE PRESSURES) ON VALVES WITH DAMAGED BELLOWS. THREE UNITS HAVING BELLOWS WITH THE MAXIMUM DISTORTION ALLOWED WERE USED FOR THIS TESTING. (TWO UNITS WERE REMOVED FROM A VEHICLE AND ONE FROM SPARES). TWO UNITS COMPLETED 5 MISSIONS AND 1 COMPLETED 50 MISSIONS. AS A RESULT FLIGHT UNITS ARE TO BE CHECKED FOR BELLOWS LEAKAGE PRIOR TO EACH MISSION. ADDITIONAL ACCEPTANCE TESTS FOR REWORKED VALVES AND NEW VALVES ARE:

- 1) HELIUM MASS SPEC OF THE BELLOWS FOR 30 MINUTES AT A MAX LEAK RATE OF 10-8 SCCS.
- 2) HELIUM MASS SPEC OF THE BELLOWS ASSEMBLY AFTER INSTALLATION INTO THE VALVE BODY, BUT PRIOR TO KRYTOX FILL FOR 30 MINUTES AT A MAX LEAK RATE OF 10-7 SCCS.
- 3) REPEATED FILL, WEIGH, AND CLEAN PROCESSES TO VERIFY KRYTOX LEVEL IS OVER 95% FULL.
- 4) X-RAY BEFORE AND AFTER PROOF PRESSURE TO DEMONSTRATE NO BELLOWS DAMAGE.

## ACCEPTANCE TEST

IN PROCESS BELLOWS LEAK TEST, THERMAL PROTECTION SWITCH ACTUATION, PROOF AND EXTERNAL LEAKAGE, INTERNAL LEAKAGE, RELIEF VALVE FUNCTION, ACCEPTANCE VIBRATION, ELECTRICAL PERFORMANCE, PRESSURE DROP, CLEANLINESS.

## GROUND TURNAROUND

- V43CA0.045 PERFORMS FIRST FLIGHT ELECTRICAL VERIFICATION.
- V43CB0.130 PERFORMS INTERNAL LEAK CHECKS ON 10 FLIGHT INTERVALS.
- V43CB0.140 (TANK ISOLATION VALVE RELIEF DEVICE C/O) VERIFIES PROPER FUNCTION OF RELIEF DEVICE AT 10 FLIGHT INTERVALS.
- V43CB0.165 REQUIRES EACH FLIGHT SNIFF TEST TO VERIFY NO PROPELLANT VAPOR IN VALVE ACTUATOR.
- V43CA0.070 PERFORMS REDUNDANT CIRCUIT VERIFICATION ORBITER/POD EVERY 5TH FLIGHT.
- V43CA0.072 PERFORMS REDUNDANT CIRCUIT VERIFICATION ORBITER/POD EVERY FLIGHT.
- V43CA0.075 PERFORMS ELECTRICAL INTERFACE VERIFICATION ORBITER/POD ON A CONTINGENCY BASIS.
- V43CF0.010 PERFORMS PROPELLANT SERVICING TO FLIGHT LOAD EVERY FLIGHT AND VERIFIES PROPELLANT CONFORMANCE TO SE-S-0073.

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## ■ (C) INSPECTION:

## RECEIVING INSPECTION

MATERIALS AND PROCESSES CERTIFICATIONS ARE VERIFIED BY INSPECTION.

## CONTAMINATION CONTROL

CLEANLINESS TO LEVEL 200 FOR MMH AND 200A FOR NTO AND CORROSION PROTECTION PROVISIONS ARE VERIFIED BY INSPECTION.

## ASSEMBLY/INSTALLATION

MANUFACTURING ASSEMBLY AND INSTALLATION PROCEDURES ARE VERIFIED BY INSPECTION. CRITICAL DIMENSIONS AND SURFACE FINISHES ARE VERIFIED BY INSPECTION. ADDITIONAL INSPECTIONS HAVE BEEN ADDED FOR NEW VALVE BUILDS INCLUDING 100% INSPECTION OF BELLOWS WELD, WELD SAMPLES AT BEGINNING OF EACH SHIFT, AND INSPECTION OF EACH COLLAR AFTER TRIMMING. BELLOWS KRYTOX FILL VERIFICATION IS ALSO PERFORMED.

## NONDESTRUCTIVE EVALUATION

CASTINGS ARE PENETRANT AND X-RAY INSPECTED ON THE DETAIL LEVEL. WELDS RECEIVE VARIOUS COMBINATIONS OF X-RAY, PENETRANT, VISUAL AND LEAK TEST. SOME WELDS SUCH AS BELLOWS END WELDS ARE NOT X-RAYED. BELLOWS END WELDS ARE LEAK TESTED AND VISUALLY EXAMINED. THE VALVE IS X-RAY INSPECTED AFTER PROOF PRESSURE TEST TO VERIFY THAT THE BELLOWS HAS NOT COLLAPSED.

## CRITICAL PROCESSES

THE WELDING PROCESS AND VERIFICATION THAT WELDS MEET SPECIFICATION REQUIREMENTS ARE VERIFIED BY INSPECTION. WELDING PER 2 EPS S750023, SOLDERING PER NHBS300.4 (3A) AND KRYTOX FILL PER 2 EPS S750023 ARE VERIFIED BY INSPECTION.

## TESTING

TEST EQUIPMENT AND TOOL CALIBRATION ARE VERIFIED BY INSPECTION. ACCEPTANCE TEST IS VERIFIED BY INSPECTION. THERMAL SWITCH ACTUATION VERIFIED AT PRE-ACCEPTANCE TEST LEVEL (PRIOR TO ASSEMBLY INTO VALVE).

## HANDLING/PACKAGING

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

## ■ (D) FAILURE HISTORY:

THIS FAILURE HISTORY REFERS TO AND IS APPLICABLE TO BOTH THE GMS AND RCS. NUMEROUS CASES OF OUT-OF-SPEC INTERNAL LEAKAGE, MOST WERE RELATIVELY MINOR AND WOULD NOT CAUSE TYPE OF PROBLEM REFERENCED IN FAILURE EFFECTS. MOST DECREASE SIGNIFICANTLY UPON PROPELLANT EXPOSURE, EXCEPTION IS LEAKAGE DUE TO RELIEF DEVICE DAMAGE. PROCEDURES WERE REVISED TO MINIMIZE POTENTIAL FOR RELIEF DEVICE DAMAGE

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DURING CHECKOUT AND GROUND OPS.

THIS FAILURE HISTORY REFERS TO AND IS APPLICABLE TO BOTH THE OMS AND RCS. EIGHTEEN CASES OF VALVE FAIL TO FUNCTION DUE TO FAILED VALVE POSITION INDICATOR (VPI) SWITCHES (16 FLIGHT, 2 GROUND).

CAR 13F001 ADDRESSES LIMIT SWITCH FAILURES. THE CRITICAL TANK AND CROSSFEED VALVE SWITCHES ARE BEING REPLACED WITH "PIND" TESTED SWITCHES DURING THE POST STS-51L STAND DOWN PERIOD. ACTUATORS WITH PIND-TESTED SWITCHES ARE IN PRODUCTION, PLAN CHANGEDOUT ON ATTRITION BASIS (EXCEPT VALVES CRITICAL FOR ABORT).

THIS FAILURE HISTORY REFERS TO AND IS APPLICABLE TO BOTH THE OMS AND RCS. A TOTAL OF 13 BELLOW FAILURES HAVE BEEN RECORDED TO DATE FOR OMS AND RCS.

- (1) 2 FAILURES WHICH HAVE NOT BEEN EVALUATED ARE RECORDED ON AD3375.
- (2) 8 WERE DUE TO POROSITY (POROUS WELD AT END COLLAR AND ARE RECORDED ON AC9013).
- (3) 4 WERE DUE TO COLLAPSED BELLOWS (DEFORMED BELLOWS CONVOLUTES) AND ARE RECORDED ON A00035 (INCLUDES 1 FAILURE FROM ITEM 2) ABOVE WHICH ALSO EXHIBITED POROSITY.

DEFORMATION OF THE BELLOWS HAS BEEN ATTRIBUTED TO INSUFFICIENT FILL OF THE BELLOWS WITH KRYTOX DURING ASSEMBLY. THE DEFORMATION OCCURS DURING SUBSEQUENT PROOF PRESSURE TESTING. THREE DELTA VERIFICATION TESTS WERE CONDUCTED ON VALVES WITH DEFORMED BELLOWS. ALL THREE VALVES DEVELOPED LEAKS (REF AD1637) ACROSS THE BELLOWS DURING TEST. TWO VALVES COMPLETED 5 MISSIONS AND ONE VALVE COMPLETED 50 MISSIONS. THE LEAKAGE WAS LESS THAN  $1 \times 10^{-6}$  SCCS. HOWEVER THIS LEAK RATE CAN RESULT IN A NON-FUNCTIONING VALVE AFTER AN EXTENDED PROPELLANT EXPOSURE TIME IN THE ACTUATOR. THE ALLOWABLE LEAK RATE FOR THE BELLOWS HAS BEEN CHANGED TO  $1 \times 10^{-8}$  EXP-8 SCCS. IMPROVED PROCESSES AND PROCEDURES INCLUDING VERIFICATION OF PROPER FILL OF THE BELLOWS WITH KRYTOX HAVE BEEN IMPLEMENTED FOR FUTURE BUILDS. ALL INSTALLED VALVES WERE INSPECTED BY X-RAY FOR BELLOWS DEFORMATION. VALVES WITH UNACCEPTABLE BELLOWS WERE REPLACED. A SNIFF TEST OF ALL VALVE ACTUATORS IS ALSO REQUIRED FOR EACH FLIGHT.

(E) OPERATIONAL USE:

USE OPPOSITE POD'S PROPELLANT FIRST AND COMPLETE IN STRAIGHT FEED IF OMS CROSSFEED IS NECESSARY.

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- APPROVALS -  
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RELIABILITY ENGINEERING: J. N. HART  
DESIGN ENGINEERING : V. F. ROZNOŠ  
QUALITY ENGINEERING : O. J. BUTTNER  
NASA RELIABILITY :  
NASA SUBSYSTEM MANAGER :  
NASA QUALITY ASSURANCE :

*J. N. Hart* 1/24/91  
: *V. F. Roznos*  
: *O. J. Buttner* 1/8/91  
: *Reliability - Jones* 3/2/91  
: *Samuel K. Jones* 8-21-91  
: *Orney* 3-20-91