

SHUTTLE CRITICAL ITEMS LIST - ORBITER NUMBER: 03-2F-102112-X

SUBSYSTEM NAME: FORWARD REACTION CONTROL SYSTEM (RCS)

REVISION : 2 12/12/89

	PART NAME VENDOR NAME	PART NUMBER VENDOR NUMBER
LRU :	VLV, AC MOTOR OPERATED	MC284-0430-0005 5750023-103
LRU :	VLV, AC MOTOR OPERATED	MC284-0430-0006 5750024-103
LRU :	VALVE, AC MOTOR OPERATED PARKER HANNIFIN	MC284-0430-0011 5750025-103
LRU :	VALVE, AC MOTOR OPERATED PARKER HANNIFIN	MC284-0430-0012 5750026-103

EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:

VALVE, TANK AND MANIFOLD ISOLATION, 3 PHASE 400HZ, AC MOTOR OPERATED (115-200V). (LV117, 118, 127, 137, 138, 148, 161, 162, 163, AND 164)

QUANTITY OF LIKE ITEMS: 12
6 PER PROPELLANT

FUNCTION:

TWO TANK ISO VALVES ARE USED FOR EACH PROPELLANT TANK TO ISOLATE THE TANK FROM THE DOWNSTREAM SYSTEM. THE MANIFOLD ISOLATION VALVE IS USED TO ISOLATE PROPELLANT LEAKS IN EACH OF THE FOUR PRIMARY MANIFOLDS. THE VALVE BELLOWS PROVIDE A BARRIER TO PREVENT PROPELLANTS FROM REACHING THE ELECTRICAL COMPONENTS LOCATED IN THE ACTUATOR. THERMAL SWITCHES ON EACH AC PHASE INTERRUPT ELECTRICAL POWER WHEN VALVE HOUSING TEMPERATURE REACHES 255 DEGREES FAHRENHEIT.

SHUTTLE CRITICAL ITEMS LIST - ORBITER NUMBER: 03-2F-102112-01

REVISION# 2 12/12/89

SUBSYSTEM: FORWARD REACTION CONTROL SYSTEM (RCS)

LRU :VLV, AC MOTOR OPERATED

CRITICALITY OF THIS

ITEM NAME: VALVE, AC MOTOR OPERATED

FAILURE MODE:1/1

FAILURE MODE:

BELLOWS LEAK, STRUCTURAL FAILURE, EXTERNAL LEAK, THERMAL SWITCH FAILS ON

MISSION PHASE:

PL	PRELAUNCH
LO	LIFT-OFF
OO	ON-ORBIT
DO	DE-ORBIT
LS	LANDING SAFING

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

CAUSE:

PROPELLANT REACTION IN ACTUATOR ASSEMBLY, DEFORMED BELLOWS, WELD/MAT'L DEFECT, SURGE PRESSURE, SHOCK, INSUFFICIENT KRYTOX FILL LEVELS, VIBRATION, OMNI SEAL DAMAGE, JAMMED TRUKION CAUSING BELLOWS TO DEFORM, THERMAL SWITCHES FAILED CLOSED

CRITICALITY 1/1 DURING INTACT ABORT ONLY? NO

REDUNDANCY SCREEN A) N/A
 B) N/A
 C) N/A

PASS/FAIL RATIONALE:

- A)
- B)
- C)

- FAILURE EFFECTS -

(A) SUBSYSTEM:

LOSS OF VALVE FUNCTION. POSSIBLE EXTERNAL LEAK. ELECTRICAL INSULATION DAMAGE CAUSING SHORTS AND POSSIBLE AUTO DECOMPOSITION OF MMH. THE MECHANISM OF FAILURE IS THAT MMH ATTACKS THE POTTING ON THE LIMIT

SHUTTLE CRITICAL ITEMS LIST - ORBITER NUMBER: 03-2F-102112-01

SWITCHES AND CONNECTOR WHICH COULD SHORT THESE SWITCHES AND CAUSE THE POWER TO BE APPLIED CONTINUOUSLY TO THE AC MOTOR. ALTHOUGH THE MOTOR IS PROTECTED BY THERMAL SWITCHES, THE INSIDE OF THE MOTOR REACHES 450 DEG F BEFORE THEY CYCLE. THE MMH ALSO ATTACKS THE INSULATION ON MOTOR WINDINGS CAUSING THEM TO SHORT EITHER TO GROUND OR WINDING TO WINDING & DRAWING HIGH CURRENT THROUGH THE MOTOR.

(B) INTERFACING SUBSYSTEM(S):

A SHORT IN THE AC MOTOR MAY CAUSE THE CIRCUIT BREAKER TO MOTOR CONTROL ASSEMBLY TO TRIP CAUSING TEMPORARY LOSS OF CONTROL OF ALL AC MOTOR VALVES ON THAT BUSS. POSSIBLE POD CORROSION OR FIRE DAMAGE.

(C) MISSION:

IF DETECTED, ABORT DECISION REQUIRED.

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

POSSIBLE CREW/VEHICLE LOSS IF LEAK RESULTS IN EXCESSIVE LOSS OF PROPELLANT INHIBITING ET SEP/ENTRY OR OVERPRESSURIZATION OF THE MODULE.

(E) FUNCTIONAL CRITICALITY EFFECTS:

- DISPOSITION RATIONALE -

(A) DESIGN:

THE AC MOTOR VALVE IS 3-PHASE. 2 OF 3 PHASES ARE ADEQUATE FOR VALVE FUNCTION.

400 MICRON FILTER AT INLET AND OUTLET LIMITS THE POTENTIAL FOR CONTAMINATION.

THE VALVE HAS GPC, OR MANUAL COMMAND CAPABILITY. PARALLEL LIMIT SWITCHES ARE PARTICLE IMPACT NOISE DETECTION (PIND) TESTED. INTERNAL RELIEF DEVICE PREVENTS EXCESSIVE PRESSURE BUILDUP FROM THERMAL EFFECTS.

BELLOWS IN VALVE FLOW SECTION ISOLATE PROPELLANT FROM ACTUATOR ELECTRICAL COMPONENTS. THE BELLOWS DESIGN FACTOR OF SAFETY IS 2.0 FOR BURST AND 1.5 FOR PROOF. BELLOWS IS 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 IS FILLED WITH KRYTOX GREASE. SWITCHES ARE HERMETICALLY SEALED TO PREVENT PROPELLANT FROM REACHING CONTACTS.

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 CLOSES AT 225 DEGREES FAHRENHEIT.

SHUTTLE CRITICAL ITEMS LIST - ORBITER NUMBER: 03-2F-102112-01

■ (B) TEST:

THE QUALIFICATION TEST PROGRAM UTILIZED FOUR UNITS. THE TESTING INCLUDED SHOCK, ENDURANCE (2500 CYCLES), THERMAL CYCLING (+20 TO +150 DEG F), RANDOM VIBRATION, PROPELLANT EXPOSURE, SURGE PRESSURE, BURST (2000 PSI). THE VALVE WAS CONTINUOUSLY POWERED FOR 7 DAYS WITH THERMAL SWITCHES CYCLING ON AND OFF (TEMPERATURE NOT TO ALLOWED TO EXCEED 300 DEGREES FAHRENHEIT).

THE UNIT IS ALSO QUALIFIED AS PART OF THE POD ASSY IN THE VIBRO-ACOUSTIC TEST AT JSC (131 EQUIVALENT MISSIONS) AND THE HOT FIRE TEST AT WSTF (24 EQUIVALENT MISSION DUTY CYCLES AND APPROX 7 YEARS OF PROPELLANT EXPOSURE).

ADDITIONAL QUALIFICATION TESTING TO BE PERFORMED FOR BELLOWS PROBLEMS INCLUDE 100 MISSION LIFE TESTING (ACTUATING CYCLES AND SURGE PRESSURES) ON VALVES WITH DAMAGED BELLOWS. THREE UNITS WERE REMOVED FROM VEHICLES AND SPARES WITH WORST CASE BELLOWS DISTORTION ALLOWED IN THE VEHICLE FOR THIS TESTING.

ACCEPTANCE TESTING INCLUDES INLET/OUTLET SCREEN RATING, POSITIVE ACTUATION BARRIER LEAKAGE, AND THERMAL PROTECTION SWITCH (ALL AT THE SUBASSEMBLY LEVEL). IN ADDITION, ACCEPTANCE INCLUDES INTERNAL AND EXTERNAL LEAKAGE, RELIEF VALVE FUNCTION, ACCEPTANCE VIBRATION, ELECTRICAL PERFORMANCE, PRESSURE DROP, CLEANLINESS AND PIND TESTING OF LIMIT SWITCHES.

ADDITIONAL ACCEPTANCE TEST FOR NEW VALVE BUILDS: ARE 1) HELIUM MASS SPEC OF THE BELLOWS FOR 30 MINUTES AT 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 -8 SCCS, 3) REPEATED FILL WEIGH, AND CLEAN PROCESSES TO VERIFY KRYTOX IS OVER 95% FULL AND 4) X-RAY BEFORE AND AFTER PROOF PRESSURE TO DEMONSTRATE NO BELLOWS LEAK. ALL INSTALLED VALVES HAVE BEEN X-RAYED AT LEAST ONCE AND THE ACTUATOR CAVITY VERIFIED FREE OF PROPELLANT. PRIOR TO EACH FLIGHT, ALL VALVES ACTUATED THROUGH AT LEAST A COMPLETE OPENING AND CLOSING CYCLE WITH A 0.6 SEC COMMAND FROM A GROUND MDM.

OMRSD PERFORMS THE FOLLOWING: TWO PHASE OPERATION IS CHECKED AFTER THE 1ST, THE, 10TH, AND 20TH FLIGHT. A REDUNDANT CIRCUIT VERIFICATION THE 1ST, 5TH, AND EVERY 5 FLIGHTS THEREAFTER, AND ON A CONTINGENCY BASIS. AN AC MOTOR VALVE ELECTRICAL VERIFICATION TEST THE FIRST FLIGHT AND ON A CONTINGENCY BASIS. A PROPELLANT TANK ISO VALVE LEAKAGE TEST THE FIRST FLIGHT AND ON A CONTINGENCY BASIS. A TANK ISO VALVE RELIEF DEVICE CHECKOUT THE FIRST AND TENTH FLIGHT AND EVERY TEN FLIGHTS THEREAFTER. A MANIFOLD ISO VALVE (PRIMARY) RELIEF DEVICE CHECKOUT THE FIFTH FLIGHT AND EVERY FIVE FLIGHTS THEREAFTER. WHEN PROPELLANTS ARE

SHUTTLE CRITICAL ITEMS LIST - ORBITER NUMBER: 03-2F-102112-01

NOT OFF-LOADED AN OMRSD PARAGRAPH SPECIFIES VALVE POSITION FOR LIQUID FILLED MANIFOLDS TO PREVENT EXCESSIVE MANIFOLD PRESSURE. A MANIFOLD ISO VLV LEAK TEST THE 5TH FLIGHT AND EVERY 5 FLIGHTS THEREAFTER, OR AS A CONTINGENCY WHENEVER AN LRU IS REPLACED. AN ACTUATOR SNIFF TEST ON ALL AC MOTOR VALVES EVERY FLIGHT. REDUNDANT CIRCUIT VERIFICATION AND PROPER TALKBACK EVERY FLIGHT. THE PROPELLANT LOADING FOR EACH FLIGHT.

(C) INSPECTION:

CONTAMINATION CONTROL

CLEANLINESS TO LEVEL 200A FOR TYPE I (OXID) VALVE AND TO LEVEL 200 FOR TYPE II (FUEL) VALVE AND CORROSION PROTECTION ARE VERIFIED BY INSPECTION.

ASSEMBLY/INSTALLATION

RELIEF VALVE SEATS ARE VERIFIED TO BE FREE OF SURFACE DEFECTS BY INSPECTION. INSPECTION VERIFIES INSPECTION OF BALL, SHAFT, AND CAM FOR CRITICAL TOLERANCES. CRITICAL DIMENSIONS AND SURFACE FINISHES ARE VERIFIED BY INSPECTION.

NONDESTRUCTIVE EVALUATION

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

CRITICAL PROCESSES

WELDING PER EPS 5750023, SOLDERING PER NHB 5300.4(3A), AND KRYTOX FILL PER 2EPS 5750023 ARE VERIFIED BY INSPECTION.

TESTING

ATP IS WITNESSED AND VERIFIED BY INSPECTION.

HANDLING/PACKAGING

PACKAGING PROCEDURES ARE VERIFIED BY INSPECTION.

(D) FAILURE HISTORY:

A TOTAL OF 13 BELLOWS FAILURES HAVE BEEN RECORDED TO DATE FOR THE OMS AND RCS. THESE FAILURES RESULT IN AN ACCUMULATION OF PROPELLANT/PROPELLANT VAPOR IN THE ACTUATOR ASSEMBLY, AND IN 7 CASES RESULTED IN THE FAILURE OF THE VALVE TO FUNCTION. THE REMAINDER OF THE FAILURES WERE DETECTED BY A SNIFF TEST OF THE ACTUATOR CAVITY.

(1) CAR AC9013 RECORDS EIGHT BELLOWS FAILURES DUE TO POROSITY (POROUS WELDS AT END COLLAR OR IN PARENT MATERIAL OF THE BELLOWS.

(2) CAR A00035 RECORDS FOUR BELLOWS FAILURES DUE TO COLLAPSED BELLOWS (INCLUDES ONE FAILURE FROM ITEM (1) ABOVE WHICH ALSO EXHIBITED

SHUTTLE CRITICAL ITEMS LIST - ORBITER NUMBER: 03-2F-102112-01

POROSITY). THE BELLOWS COLLAPSE IS BELIEVED TO BE THE RESULT OF ATP PROOF PRESSURE TESTING FOR BELLOWS WITH AN INADEQUATE KRYTOX GREASE FILL LEVEL.

(3) CARS AD3375 AND AD1730 ARE TWO LEAKAGE FAILURES WHICH HAVE NOT BEEN EVALUATED YET, BUT ARE BELIEVED TO BE CAUSED BY CONDITION (1) SINCE THEY ARE DETECTED BY SNIFF TEST.

CORRECTIVE ACTION:

ALL INSTALLED VALVES HAVE BEEN INSPECTED BY X-RAY FOR BELLOWS DEFORMATION; VALVES WITH AN UNACCEPTABLE LEVEL OF DEFORMATION (CRITERIA DEFINED IN RI SPEC MPP501MT507MO8) WILL BE REPLACED BEFORE FLIGHT. SNIFF LINES ARE BEING ADDED TO EACH VALVE TO ALLOW A SNIFF TEST TO BE PERFORMED EACH FLIGHT WITHOUT REQUIRING POD REMOVAL. IMPROVED WELD PROCESSES AND TIGHTER BELLOWS LEAK CHECK CRITERIA, ALONG WITH AN IMPROVED PROCESS FOR FILLING THE BELLOWS WITH KRYTOX, HAVE BEEN IMPLEMENTED FOR FUTURE VALVE BUILDS.

A TEST PROGRAM WAS CONDUCTED USING TWO AC MOTORS AND TWO COMPLETE ACTUATORS TO DETERMINE IF IGNITION OF THE MMH VAPOR INSIDE THE ACTUATOR WAS POSSIBLE WITH CONDITIONS RESULTING FROM THE APPLICATION OF ELECTRICAL POWER. IN THE MOTOR ONLY TESTS, MOTOR FAILURE AS A RESULT OF MMH ATTACK OF THE MOTOR WINDING INSULATION OCCURRED AFTER 6 DAYS (9 STALL CYCLES). PEAK MOTOR TEMPERATURES WERE APPROXIMATELY 400 DEG. F EXCEPT DURING THE SHORTING, WHEN MELTING OF THE COPPER WINDINGS INDICATED A LOCAL TEMPERATURE OF APPROX. 1900 DEG F. WHILE NO IGNITION OCCURRED, TESTS SHOWED THAT SOME THERMALLY INDUCED DECOMPOSITION TOOK PLACE; HOWEVER, IT WAS NOT SUFFICIENT TO PRODUCE A SUSTAINED REACTION.

ONE ACTUATOR TEST WAS PERFORMED BY STALLING THE MOTOR; THESE TESTS SHOWED A MAX MOTOR CASE TEMP OF APPROXIMATELY 340 DEG F. THIS TEST WAS INTERRUPTED BY AN UNRELATED FAILURE AFTER LESS THAN TWO DAYS AND WILL BE RE-RUN. THE OTHER ACTUATOR WAS RUN WITH NORMAL VALVE CYCLES (NO MOTOR STALLING); THIS ACTUATOR FUNCTIONED NORMALLY THROUGHOUT THE ENTIRE 90-DAY TEST DURATION.

A DELTA VERIFICATION TEST WAS CONDUCTED ON THE THREE VALVES WITH WORST CASE BELLOWS DEFORMATION (THAT WOULD HAVE BEEN ALLOWED TO REMAIN ON THE FLIGHT VEHICLES BE THE BELLOWS X-RAY CRITERIA). THIS TEST WAS INTENDED TO DEMONSTRATE THAT THERE WAS NO BELLOWS LIFE ISSUE WITH THE DEGREE OF DEFORMATION IN THE BELLOWS LEFT ON THE FLIGHT VEHICLES. ALL THREE VALVES DEVELOPED BELLOWS LEAKS (REF CAR AD1637) DURING THE TEST.

ONE VALVE COMPLETED 50 MISSIONS; THE OTHER TWO HAD COMPLETED 5 MISSIONS AT THE TIME THE LEAKAGE WAS DETECTED. THE LEAKAGE WAS LESS THAN 1×10^{-6} SCCG OF HELIUM WITH KRYTOX IN THE BELLOWS. THE 50 - MISSION VALVE HAS BEEN TORN DOWN FOR FAILURE ANALYSIS; WHEN THE KRYTOX WAS REMOVED, THE LEAKAGE WAS OVER 0.5 SCCG THROUGH THREE DIFFERENT LEAK PATHS. THE

SHUTTLE CRITICAL ITEMS LIST - ORBITER NUMBER: 03-2F-102112-01

FAILURE WAS ATTRIBUTED TO FATIGUE.

THE TWO VALVES THAT FAILED AT 5 MISSIONS HAD PREVIOUSLY COMPLETED FIVE AND SIX ACTUAL MISSIONS RESPECTIVELY; THESE VALVES COMPLETED AN ADDITIONAL 5 MISSIONS AFTER THE FAILURES WERE DETECTED. THESE VALVES HAVE BEEN PLACED IN A PROPELLANT COMPATIBILITY TEST TO (A) DETERMINE THE RELATIONSHIP BETWEEN HELIUM AND PROPELLANT LEAKAGE AND (B) VERIFY THAT A FAILED BELLOWS WOULD BE DETECTABLE BY SNIFF TEST BEFORE THE PROPELLANT CAUSED THE VALVE TO FAIL TO FUNCTION. THE VALVE EXPOSED TO OXIDIZER SHOWED SIGNS OF LEAKAGE WITHIN THE FIRST DAY (288 PPM) AND AFTER 30 DAYS THE LEVEL OF OXIDIZER CONCENTRATION WAS 19000 PPM.

THE OXIDIZER VALVE WAS CYCLED OPEN AND CLOSED EVERY THREE TO FIVE DAYS DURING THIS PERIOD AND THE ONLY DEGRADATION WAS A SLIGHTLY SLOWER ACTUATION TIME. THE VALVE EXPOSED TO FUEL HAS SHOWN NO DETECTABLE MMH VAPOR, AND HAS SUFFERED NO DEGRADATION IN FUNCTION.

TO DATE, THE DATA ACCUMULATED DEMONSTRATES THAT THE EACH-FLIGHT SNIFF TEST WILL IDENTIFY A FAILED BELLOWS BEFORE THE PROPELLANT VAPOR CAN ACCUMULATE IN THE ACTUATOR TO THE EXTENT THAT THE VALVE FUNCTION IS IMPAIRED OR A DETONATION HAZARD EXISTS.

(E) OPERATIONAL USE:

MANIFOLD VALVE FAILURES CAN BE ISOLATED WITH TANK ISO VALVES. IF THE AC POWER TO THE VALVE IS TURNED ON WITHOUT A COMMAND OR REMAINS ON, SWITCH AFFECTED VALVES TO GPC TO REMOVE POWER.

IF AC CIRCUIT BREAKER IS TRIPPED, REMOVE POWER FROM THE EFFECTED VALVE BY PLACING SWITCH IN GPC AND RESETTING BREAKER.

DURING ASCENT IF LEAK RATE DOES NOT PERMIT ET SEP A CONTINGENCY AFT ONLY SEPARATION WILL BE PERFORMED.

- APPROVALS -

RELIABILITY ENGINEERING :	F. B. BARCENAS	: <u><i>F. B. Barcenas</i></u>
DESIGN ENGINEERING :	B. DIPONTI	: <u><i>B. Diponti</i></u>
QUALITY ENGINEERING :	M. SAVALA	: <u><i>M. Savala</i></u>
NASA RELIABILITY :		: <u><i>M. H. Blum 4/15/90</i></u>
NASA SUBSYSTEM MANAGER :		: <u><i>M. H. Blum 2/22/90</i></u>
NASA QUALITY ASSURANCE :		: <u><i>R. S. Alcorn 3/01/90</i></u>
		: <u><i>R. S. Alcorn 3/1/90</i></u>