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PRINT DATE: 01/09/90

SHUTTLE CRITICAL ITEMS LIST - ORBITER NUMBER: 03-2A-202111-X

SUBSYSTEM NAME: AFT REACTION CONTROL SYSTEM (RCS)

REVISION : 2 01/09/90

	PART NAME VENDOR NAME	PART NUMBER VENDOR NUMBER
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, INTERCONNECT, 3 PHASE 400 HZ AC MOTOR OPERATED (115-200V),
OMS/RCS (1-1/2") (LV271, 272, 273, 274, 371, 372, 373, 374).

QUANTITY OF LIKE ITEMS: 8
TWO INTERCONNECT LINES PER PROPELLANT TANK

FUNCTION:
TO PROVIDE CONTROL OF INTERCONNECT LINES FOR VARIOUS MODES OF PROPELLANT
FEED: 1) OPEN FOR OMS TO RCS 2) OPEN FOR RCS TO RCS 3) CLOSED FOR RCS
TO SAME SIDE RCS AND OMS TO OMS. TWO INTERCONNECT VALVES PER PROP TANK
ARE USED. EACH GOES INDEPENDENTLY TO SEPARATE MANIFOLD BANKS. LINE
PRESSURE RELIEF TOWARDS PROP TANK IS PROVIDED. LINE PRESS RELIEF TO
TANK IS PROVIDED. THERMAL SWITCHES ON EACH AC PHASE INTERRUPT
ELECTRICAL POWER WHEN VALVE HOUSING TEMPERATURE REACHES 255 DEGREES
FAHRENHEIT.

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SUBSYSTEM: AFT REACTION CONTROL SYSTEM (RCS)
LRU : VALVE, AC MOTOR OPERATED
ITEM NAME: VALVE, AC MOTOR OPERATED

CRITICALITY OF THIS
FAILURE MODE: 1R2

FAILURE MODE:
FAILS CLOSED, FAILS TO REMAIN OPEN

MISSION PHASE:
00 ON-ORBIT

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

CAUSE:
LIMIT SWITCH FAILURE, VIBRATION, SEAT CRACKS, MATERIAL DEFECT, RELIEF
DEVICE FAILURE, ELECTRICAL SHORT, JAMMING OF CAM, MOTOR FAILURE,
BELLOWS FAILURE, STRUCTURAL FAILURE, CONTAMINATION, CORROSION, LOSS OF
POWER, THERMAL SWITCHES FAILED OPEN OR CLOSED.

CRITICALITY 1/1 DURING INTACT ABORT ONLY? Y
RTLS RETURN TO LAUNCH SITE
TAL TRANS ATLANTIC ABORT

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

PASS/FAIL RATIONALE:

A)

B)

C)

- FAILURE EFFECTS -

(A) SUBSYSTEM:
LOSS OF REDUNDANCY.

(B) INTERFACING SUBSYSTEM(S):
DEGRADATION OF INTERFACE FUNCTION-CROSSFEED PROP CAN BE UTILIZED BY
ONLY 2 OF 4 MANIFOLD BANKS.

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(C) MISSION:

EARLY MISSION TERMINATION DECISION - PROPELLANT MANAGEMENT PROBLEMS DURING CROSSFEED. INABILITY TO USE RCS THRUSTERS IN INTERCONNECT FROM OMS MAY PREVENT COMPLETION OF SOME MISSION OBJECTIVES DUE TO REDUCTION OF AVAILABLE PROPELLANT AND/OR INABILITY TO USE VERNIER THRUSTERS IN INTERCONNECT.

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

CRIT 1 FOR RTLS AND TAL. CLOSED CROSSFEED VALVES DURING RTLS OR TAL ABORT PROHIBITS DUMPING OMS PROPELLANT THROUGH HALF THE RCS THRUSTERS RESULTING IN EXCESSIVE LANDING WEIGHTS. SMART INTERCONNECT REDUCES THE RISK OF THIS SCENARIO OCCURRING TO ONLY A LATE RTLS OR A TAL ABORT.

(E) FUNCTIONAL CRITICALITY EFFECTS:

POSSIBLE CREW/VEHICLE LOSS, 1R EFFECT ASSUMES LOSS OF BOTH INTERCONNECT VALVES FAILING CLOSED AND INSUFFICIENT PROPELLANT TO PERFORM DEORBIT MANEUVER.

 - DISPOSITION RATIONALE -

(A) DESIGN:

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 ISOLATES PROPELLANT FROM ACTUATOR ELECTRICAL COMPONENTS. BELLOWS IS TWO PLY .003" THICK RESISTANCE WELDED TOGETHER, AND THEN E.B. WELDED TO TWO END PIECES, WHICH ARE THEN E.B. WELDED INTO THE VALVE. THE BELLOWS IS 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:

THE QUALIFICATION TEST PROGRAM UTILIZED 4 UNITS. THE TESTING INCLUDED: SHOCK, ENDURANCE (2500 CYCLES), THERMAL CYCLING (+20 TO +150 DEG F), RANDOM VIBRATION, PROPELLANT EXPOSURE, SURGE PRESSURE AND BURST (2000 PSI). THE VALVE WAS CONTINUOUSLY POWERED FOR SEVEN DAYS WITH

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THERMAL SWITCHES CYCLING ON AND OFF (TEMP NOT ALLOWED TO EXCEED 300 DEGREES FAHRENHEIT).

THE UNIT WAS ALSO QUALIFIED AS PART OF THE VIBRO-ACOUSTIC TESTING AT JSC (131 MISSION EQUIVALENT), AND THE HOT FIRE TEST PROGRAM AT WSTF (24 EQUIVALENT MISSION DUTY CYCLES AND APPROXIMATELY 7 YEARS OF PROPELLANT EXPOSURE).

ADDITIONAL QUALIFICATION TESTING TO BE PERFORMED FOR BELLOWS PROBLEMS CONSISTS 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).

ACCEPTANCE TESTING INCLUDES INLET/OUTLET SCREEN RATING, POSITIVE ACTUATION BARRIER LEAKAGE, AND A THERMAL PROTECTION SWITCH TEST DURING SUBASSEMBLY.

IN ADDITION, TESTING AT THE UNIT LEVEL INCLUDES: PROOF AND EXTERNAL LEAKAGE, INTERNAL LEAKAGE, RELIEF VALVE FUNCTION, ACCEPTANCE VIBRATION, ELECTRICAL PERFORMANCE, PRESSURE DROP, CLEANLINESS, AND LIMIT SWITCH PIND TESTING.

ADDITIONAL ACCEPTANCE TESTS FOR REWORKED VALVES AND NEW VALVES ARE: 1) HE 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.

OMRSD PERFORMS THE FOLLOWING: ISOLATION VALVE ELECTRICAL VERIFICATION OF MOD/POD ON A CONTINGENCY BASIS. A REDUNDANT CIRCUIT VERIFICATION THE 1ST, 5TH, AND EVERY 5 FLIGHTS THEREAFTER, AND ON A CONTINGENCY BASIS. CROSSFEED ISOLATION VALVE LEAKAGE TEST THE FIRST AND TENTH AND EVERY TEN FLIGHTS THEREAFTER AND ON A CONTINGENCY BASIS. CROSSFEED ISOLATION VALVE RELIEF DEVICE C/O ON A CONTINGENCY BASIS. AN ACTUATOR SNIFF TEST ON ALL AC MOTOR VALVES EVERY FLIGHT. REDUNDANT CIRCUIT VERIFICATION O/P AND O/M EVERY FLIGHT. LIQUID FILLED MANIFOLDS ON A CONTINGENCY BASIS. THE PROPELLANT LOADING FOR EACH FLIGHT. A FUNCTIONAL CHECK OF CRIT 1 AC MOTOR VALVE EVERY FLIGHT.

(C) INSPECTION:

CONTAMINATION CONTROL

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

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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. THE 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:

EIGHTEEN CASES OF VALVES 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 MISSION 51L STAND DOWN PERIOD. ACTUATORS WITH PIND-TESTED SWITCHES ARE IN PRODUCTION, PLAN CHANGEOUT ON ATTRITION BASIS (EXCEPT VALVES CRITICAL FOR ABORT).

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 ADO035 RECORDS FOUR BELLOWS FAILURES DUE TO COLLAPSED BELLOWS (INCLUDES ONE FAILURE FROM ITEM (1) ABOVE WHICH ALSO EXHIBITED 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

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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 MPP50JMT507MOB) 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 BY 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} SCCH 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 SCCS THROUGH THREE DIFFERENT LEAK PATHS. THE 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

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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:

NO CREW ACTION AVAILABLE FOR RTLS AND TAL ABORTS. SMART INTERCONNECT HANDLES VALVE FAILURES. PROPELLANT BUDGET MUST BE MANAGED TO AVOID OMS INTERCONNECT. LOSS OF INTERCONNECT CAPABILITY MAY RESULT IN EARLY MISSION TERMINATION.

- APPROVALS -

RELIABILITY ENGINEERING: F.E. BARCENAS
 DESIGN ENGINEERING : B. DIPONTI
 QUALITY ENGINEERING : M. SAVALA -
 NASA RELIABILITY :
 NASA SUBSYSTEM MANAGER :
 NASA QUALITY ASSURANCE :

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