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PRINT DATE: 04/10/90

FAILURE MODES EFFECTS ANALYSIS (FMEA) -- CRITICAL HARDWARE

NUMBER: 03-3-2008-X

SUBSYSTEM NAME: ORBITAL MANEUVERING SYSTEM (OMS)

REVISION : 2 04/10/90

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|       | PART NAME<br>VENDOR NAME                    | PART NUMBER<br>VENDOR NUMBER   |
|-------|---|--------------------------------|
| LRU : | VALVE, AC MOTOR OPERATED<br>PARKER HANNIFIN | MC284-0430-0011<br>5750025-103 |
| LRU : | VALVE, AC MOTOR OPERATED<br>PARKER HANNIFIN | MC284-0430-0012<br>5750026-103 |

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PART DATA

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EXTENDED DESCRIPTION OF PART UNDER ANALYSIS:

VALVE, CROSSFEED, A.C. MOTOR ACTUATED, 115/200 V. AC, 3-PHASE,  
1.0 AMP MAX. (2-PHASE), 1.0 AMP (3-PHASE).

QUANTITY OF LIKE ITEMS: 8

4 RIGHT POD

4 LEFT POD

FUNCTION:

PARALLEL REDUNDANT CROSSFEED VALVES PROVIDE ISOLATION OF OMS PROPELLANT FOR LEAK ISOLATION & FEED SYSTEM CONFIGURATION. THEY ALSO ALLOW CROSSFEED OF OMS PROP BETWEEN PODS, AND ISOLATE THE OMS FROM THE CROSSFEED LINE DURING RCS INTERCONNECT FOR RCS CROSSFEED OPERATIONS. AUTOMATIC OPERATION (WITH MANUAL OVERRIDE) IS PROVIDED THROUGH THE GPC FOR VALVE SEQUENCING DURING RTLS. THE FUEL AND OXIDIZER VALVE CAN BE OPERATED INDEPENDENTLY FOR C/O. THE FLOW ASSEMBLY CONSISTS OF A LIFT-OFF BALL VALVE ACTUATED THROUGH A ROTATING FINGER DRIVEN BY THE ACTUATOR. AN INTERNAL RELIEF DEVICE IS PROVIDED. THE ACTUATOR ASSEMBLY CONSISTS OF 115V.AC, 400 HZ, 3-PHASE MOTOR (CAPABLE OF 2 PHASE OPERATION) OPERATING THROUGH A PLANETARY GEAR TRAIN & MICRO SWITCHES TO CONTROL MOTOR POWER.

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NUMBER: 03-3-2008-03

SUBSYSTEM: ORBITAL MANEUVERING SYSTEM (OMS) REVISION# 2 04/10/90  
LRU :VALVE, AC MOTOR OPERATED  
ITEM NAME: VALVE, AC MOTOR OPERATED CRITICALITY OF THIS FAILURE MODE:1/1

FAILURE MODE:  
STRUCTURAL FAILURE, EXTERNAL LEAK.

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:  
BELLOWS LEAKAGE, PROPELLANT REACTION IN ACTUATOR ASSEMBLY, POTENTIAL AUTO-DECOMPOSITION OF FUEL WITH HEAT IN ACTUATOR ASSEMBLY, EXCESSIVE SURGE PRESSURE.

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:  
POTENTIAL PROPELLANT REACTION IN VALVE ACTUATOR COULD CAUSE VALVE/ LINE STRUCTURAL DAMAGE, RESULTING IN EXTERNAL LEAK.

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(B) INTERFACING SUBSYSTEM(S):

DECREASED DELTA V CAPABILITY. POSSIBLE INABILITY TO UTILIZE INTERCONNECT (IF CROSSFEED VALVES IN ALTERNATE POD MUST BE CLOSED). POTENTIAL UNACCEPTABLE CG OFFSET. CORROSION DAMAGE WITHIN POD.

(C) MISSION:

ABORT DECISION.

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

POSSIBLE CREW/VEHICLE LOSS IF LEAK RESULTS IN EXCESSIVE LOSS OF PROPELLANT OR EXPLOSIVE HAZARD.

(E) FUNCTIONAL CRITICALITY EFFECTS:

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- DISPOSITION RATIONALE -  
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(A) DESIGN:

DESIGN FACTOR OF SAFETY IS 2.0. INTERNAL RELIEF DEVICE PREVENTS EXCESSIVE PRESSURE BUILDUP FROM THERMAL EFFECTS. 2-PLY BELLOWS IN VALVE FLOW SECTION ISOLATES PROPELLANT FROM ACTUATOR ELECTRICAL COMPONENTS. THE BELLOWS IS FILLED WITH KRYTOX TO PROVIDE INTERNAL STRUCTURAL SUPPORT FOR THE BELLOWS. THERMAL SWITCH ON MOTOR INTERRUPTS POWER FOR FAIL ON. REDUNDANT PARALLEL VALVES ARE PROVIDED.

■ (B) TEST:

QUALIFICATION TEST

SHOCK, ENDURANCE (2500 CYCLES), THERMAL CYCLING (+20 TO -150 DEG F), RANDOM VIBRATION, PROPELLANT EXPOSURE, SURGE PRESSURE, BURST (2000 PSI). ALSO QUALIFIED AS PART OF POD ASSEMBLY. VIBRO-ACOUSTIC TESTING AT JSC (131 EQUIVALENT MISSIONS). HOT-FIRE TEST PROGRAM AT WSTF - 517 TESTS (24 EQUIVALENT MISSIONS). APPROX. 7 YEARS PROPELLANT EXPOSURE. LINE SURGE PRESSURE TESTING. ADDITIONAL QUALIFICATION TESTING TO BE PERFORMED FOR BELLOWS PROBLEMS - 100-MISSION LIFE TEST (ACTUATING CYCLES AND SURGE PRESSURES) ON VALVES WITH DAMAGED BELLOWS. THESE TESTS DISCLOSED THAT DEFORMED BELLOWS CRACKED DUE TO FATIGUE BETWEEN 11 AND 50 MISSIONS. SUBSEQUENT TO THE DISCOVERY OF PROPELLANT LEAKAGE INTO THE BELLOWS, SPECIAL TESTS HAVE BEEN CONDUCTED TO DETERMINE THE POTENTIAL FOR AUTO DECOMPOSITION WITH SIMULATED LEAKAGE INTO THE ACTUATOR CAVITY. NO AUTO DECOMPOSITION OCCURRED.

ACCEPTANCE TEST

SUBASSEMBLY, INLET/OUTLET SCREEN RATING, POSITIVE ACTUATION BARRIER LEAKAGE, THERMAL PROTECTION SWITCH ACTIVATION, PROOF PRESSURE AND EXTERNAL LEAKAGE, INTERNAL LEAKAGE, RELIEF VALVE FUNCTION, ACCEPTANCE VIBRATION, ELECTRICAL PERFORMANCE, PRESSURE DROP, CLEANLINESS.

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ADDITIONAL ACCEPTANCE TESTING FOR NEW VALVE BUILDS - BELLOWS LEVEL HELIUM LEAK CHECK, HELIUM LEAK CHECK OF BELLOWS ASSEMBLY AFTER INSTALLATION INTO VALVE BODY BUT PRIOR TO KRYTOX FILL, REPEATED FILL WEIGH AND CLEAN PROCESSES TO VERIFY KRYTOX FILL LEVEL.

GROUND TURNAROUND

- V43C80.165 REQUIRES SNIFF TEST OF ALL VALVE ACTUATOR CAVITIES EACH FLIGHT. PCDS HAVE BEEN MODIFIED TO ENABLE SNIFF TESTS TO BE PERFORMED WITH PCDS INSTALLED ON ORBITER.
- V43C80.210 VERIFIES NO EXTERNAL LEAKAGE FIRST FLIGHT.
- V43C80.240 TOXIC VAPOR LEAK CHECK OF PROP FEED SYSTEM FIRST FLIGHT AND ON CONTINGENCY.
- V43CF0.010 PERFORMS PROPELLANT SERVICING TO FLIGHT LOAD EVERY FLIGHT AND VERIFIES PROPELLANT CONFORMANCE TO SE-S-0073.
- S00F80.285 PERFORMS FUNCTIONAL TEST OF CRITICALITY 1 VALVES PRE-LAUNCH.

■ (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, INSPECTION OF EACH COLLAR AFTER TRIMMING AND BELLOWS KRYTOX FILL VERIFICATION.

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 DEFORMED.

CRITICAL PROCESSES

THE WELDING PROCESS AND VERIFICATION THAT WELDS MEET SPECIFICATION REQUIREMENTS ARE VERIFIED BY INSPECTION. WELDING PER EPS 5750023, SOLDERING PER NH85300.4 (3A) AND KRYTOX FILL PER 2 EPS 5750023 ARE VERIFIED BY INSPECTION.

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## TESTING

TEST EQUIPMENT AND TOOL CALIBRATION ARE VERIFIED BY INSPECTION.  
ACCEPTANCE TEST IS VERIFIED BY INSPECTION.

## HANDLING/PACKAGING

HANDLING, PACKAGING, STORAGE AND SHIPPING REQUIREMENTS 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 VAPORS IN THE ACTUATOR ASSEMBLY, AND IN SEVEN CASES RESULTED IN THE FAILURES OF THE VALVE TO FUNCTION. THE REMAINDER OF THESE FAILURES WERE DETECTED BY A SNIFF TEST OF THE ACTUATOR CAVITY.

(1) CAR AC9013 RECORDS EIGHT BELLOWS FAILURES DUE TO POROSITY (POROUS WELDS) AT THE ENDS OF END COLLAR OR IN THE 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 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 A03375 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 ACCEPTABLE LEVEL OF DEFORMATION (CRITERIA DEFINED BY RI SPEC MPP501MT507M08) 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 WELDS PROCESSES AND TIGHTER BELLOWS LEAK CHECK CRITERIA ALONG WITH AN IMPROVED PROCESS FOR FILLING THE BELLOWS LEAKS 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 TEST, 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

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INDICATED A LOCAL TEMP. OF APPROX. 1900 DEG. F. WHILE NO IGNITION OCCURRED, TEST 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 A01637) DURING THE TEST.

ONE VALVE COMPLETED 50 MISSIONS; THE OTHER 2 HAD COMPLETED 5 MISSIONS AT THE TIME THE LEAKAGE WAS DETECTED. THE LEAKAGE WAS LESS THAN  $1 \times 10^{-6}$  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 .5 SCCH THROUGH THREE DIFFERENT LEAK PATHS. THE FAILURE WAS ATTRIBUTED TO FATIGUE.

THE TWO VALVES THAT FAILED AT 5 - MISSIONS HAD PREVIOUSLY COMPLETED 5 AND 6 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 IMPAIRING OR A DETONATION HAZARD EXISTS.

- (E) OPERATIONAL USE:  
USE PERIGEE ADJUST BURN TO DEplete PROPELLANT FROM LEAKING POD (OUT OF

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PLANE COMPONENT IF NECESSARY) AND REDUCE DELTA V REQUIREMENTS FOR  
DEORBIT. AFTER LEAKED PROPELLANT HAS DISPERSED, PERFORM DEORBIT BURN  
WITH GOOD PGJ.

- APPROVALS -

|                          |                 |   |                             |
|--------------------------|-----------------|---|-----------------------------|
| RELIABILITY ENGINEERING: | J. N. HART      | : | <u>                    </u> |
| DESIGN ENGINEERING       | : D. W. CARLSON | : | <u>                    </u> |
| QUALITY ENGINEERING      | : O. J. BUTTNER | : | <u>                    </u> |
| NASA RELIABILITY         | :               | : | <u>                    </u> |
| NASA SUBSYSTEM MANAGER   | :               | : | <u>                    </u> |
| NASA QUALITY ASSURANCE   | :               | : | <u>                    </u> |