

SHUTTLE CRITICAL ITEMS LIST - ORBITER

SUBSYSTEM : ACTUATION MECH-PBD FMEA NO 02-4B -209 -2 REV:03/08/88

ASSEMBLY : DRIVE MECHANISM, PBD		CRIT. FUNC: LR
P/N RI : V070-594126		CRIT. HDW: 2
P/N VENDOR: V070-594130,131	VEHICLE	102 103 104
QUANTITY : 12	EFFECTIVITY:	X X X
: 6 PER DOOR	PHASE(S):	PL LO OO X DO LS

PREPARED BY:	DES M. A. ALLEN	APPROVED BY:	DES <i>[Signature]</i>	REDUNDANCY SCREEN: A-PASS B-N/A C-PASS	APPROVED BY (NASA):
REL M. B. MOSKOWITZ	REL <i>[Signature]</i>	SSM <i>[Signature]</i>	REL <i>[Signature]</i>		3/18/88
QE W. J. SMITH	QE <i>[Signature]</i>	QE <i>[Signature]</i>	QE <i>[Signature]</i>		

ITEM:  
LINKAGE, DRIVE

FUNCTION:  
TRANSMITS MOTION FROM ROTARY ACTUATORS TO PAYLOAD BAY DOOR BY PUSH-PULL ROD, BELLCRANK AND LINK AT SIX PLACES ON EACH DOOR, TO OPEN AND CLOSE DOOR.

FAILURE MODE:  
STRUCTURAL FAILURE

CAUSE(S):  
ADVERSE TOLERANCES/WEAR, STRESS CORROSION, DEFECTIVE PART/MATERIAL OR MANUFACTURING DEFECT, EXCESSIVE LOAD, FATIGUE, FAILURE/DEFLECTION OF INTERNAL PART, IMPROPER RIGGING/ADJUSTMENT

EFFECTS ON:  
(A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE

(A,B) LOSS OF TORQUE TRANSMISSION FROM ONE OF SIX ROTARY ACTUATORS TO DOOR HINGE LINE. FIRST FAILURE - NO EFFECT ON OPENING/CLOSING DOOR.

(C,D) SECOND FAILURE OF LINKAGE WILL RESULT IN POSSIBLE LOSS OF MISSION IF DOOR CANNOT BE OPENED. POSSIBLE LOSS OF CREW/VEHICLE IF DOOR CANNOT BE CLOSED.

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DISPOSITION & RATIONALE:

(A) DESIGN (B) TEST (C) INSPECTION (D) FAILURE HISTORY (E) OPERATIONAL USE

(A) DESIGN

LINKAGE DESIGNED WITH POSITIVE MARGIN OF SAFETY FOR ALL DESIGN LOAD CONDITIONS WHICH INCLUDE STALL NEAR ON CENTER POSITION. MATERIALS INCONEL 718 PUSH RODS AND TITANIUM BELLCRANK, ARE ACCEPTABLE AS INSTALLED TO STRESS AND GALVANIC CORROSION STANDARDS. PAYLOAD BAY DOOR DRIVE ROTARY ACTUATOR TORQUE LIMITERS CONTROL LOAD TRANSMITTED THROUGH THIS LINKAGE. DESIGN OF THE ACTUATION SYSTEM PERMITS PARTIAL WORKAROUND OF MULTIPLE FAILURES OR JAMMED CONDITION BY EXTRAVEHICULAR ACTIVITY (EVA) CREW IF PAYLOAD DOES NOT LIMIT ACCESS.

(B) TEST

QUALIFICATION TESTS: THE QUALIFICATION DRIVE SYSTEM IS CERTIFIED PER CR-29-162-0008-0001E AND THE QUALIFICATION ACTUATION MECHANISM INSTALLATION CERTIFIED PER CR-29-594125-001G. THE DRIVE SYSTEM QUALIFICATION TEST INCLUDES: HUMIDITY TEST - PER MIL-STD-810B METHOD 507 PROCEDURE IV, CYCLE PDU DURING SECOND AND FOURTH HUMIDITY CYCLE; QUALIFICATION VIBRATION TEST (QAVT) - 20 TO 2,000 HZ RANGE WITH MAXIMUM OF 0.067  $g^2$ /HZ FROM 80 TO 350 HZ FOR 2 1/2 MINUTES/AXIS IN ACCORDANCE WITH SP-T-0023B, MONITOR ELECTRICAL CONTINUITY DURING VIBRATION; FLIGHT VIBRATION - 20 TO 2,000 HZ RANGE WITH MAX OF 0.03  $g^2$ /HZ FROM 100 TO 250 HZ FOR 4.5 MINUTES/AXIS LEVEL "A", AND 0.008  $g^2$ /HZ FROM 100 TO 250 HZ FOR 94 MINUTES/AXIS LEVEL "B"; SHOCK TEST - BASIC DESIGN SHOCK PER MIL-STD-810B METHOD 516.1, PROCEDURE I AND TRANSIENT SHOCK AT 5 TO 35 HZ +/- 0.25 g PEAK.

QUAL TESTS ALSO INCLUDE: THERMAL VACUUM TEST - THERMALLY CYCLED 5 TIMES BETWEEN -100 DEG F AND +157 DEG F AT A VACUUM OF  $1 \times 10^{-6}$  TORR FOR 55 HOURS, DRIVE SYSTEM CYCLED AT EACH -65 DEG F AND +157 DEG F; THERMAL CYCLING TEST - CYCLED 5 TIMES BETWEEN -100 DEG F AND +340 DEG F WITH DRIVE SYSTEM CYCLED AT EACH -100 DEG F AND +157 DEG F WITH 60 MINUTES DWELL AT EACH TEMPERATURE EXTREME; OPERATING LIFE TEST - DRIVE SYSTEM CYCLED 1,800 TIMES AT ROOM TEMPERATURE, INCLUDES MOTOR 1 AND 2 CYCLED 150 TIMES EACH INDIVIDUALLY WITHIN 126 SECONDS/STROKE AND 1,500 TIMES WITH BOTH MOTORS DRIVING TOGETHER WITHIN 63 SECONDS/STROKE; MECHANICAL STOPS TEST - 100 TIMES WITH BOTH MOTORS INTO HARD STOP IN EACH DIRECTION AT NO LOADS; STIFFNESS TEST - MEASURED SPRING RATE OF ROTARY ACTUATOR, TORQUE SHAFT, PDU AND SHAFT HANGER - GREATER THAN  $0.5 \times 10^{-6}$  INCH-LB/RADIAN AT ROTARY ACTUATOR ARM); POWER CONSUMPTION TEST, IRREVERSIBILITY TEST, FREEPLAY TEST WAS CONDUCTED AS DEFINED IN THE ACCEPTANCE TESTS.

CERTIFICATION BY ANALYSIS/SIMILARITY INCLUDED: FUNGUS, OZONE, PACKAGING, LIMIT/ULTIMATE LOAD, ACCELERATION, LANDING SHOCK, SYSTEM STIFFNESS, TEMPERATURES, HUMIDITY, LIFE, PRESSURE, SHOCK AND VIBRATION FOR ITEMS OF DRIVE SYSTEM NOT TESTED. THE PBD ACTUATING MECHANISM INSTALLATION WAS SUBJECTED TO SYSTEM QUALIFICATION TESTS ON THE 15 FOOT PBD TEST ARTICLES (087) AND ON A 60 FOOT TEST RIG, TESTS INCLUDED: ACCEPTANCE - TO CONFIRM ALL COMPONENTS HAVE BEEN ASSEMBLED AND RIGGED PER ML0308-0032 ON THREE TEST SPECIMENS.

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TESTS ON FORWARD 15 FOOT PANEL INCLUDED: ORBITAL FUNCTIONS - 3 THERMAL CONDITIONS WITH SIMULATED THERMAL DISTORTIONS OF THE FORWARD BULKHEAD AND THE LH AND RH LONGERON SILLS, 2 MOTOR OPERATIONS 22 CYCLES AT LESS THAN 63 SECONDS PER STROKE, EACH MOTOR OPERATION 3 CYCLES AT LESS THAN 126 SECONDS/STROKE FOR EACH OF THE 3 ORBITAL FUNCTIONS; OPERATING LIFE TESTS - PBD MECHANISM CYCLED 93 TIMES, 55 TIMES WITH TWO MOTOR OPERATION AND 19 TIMES WITH SINGLE MOTOR OPERATIONS; ACOUSTIC TEST - 25 HZ TO 8,000 HZ FOR 5 MINUTES.

TESTS ON AFT 15 FOOT PANEL INCLUDED: ORBITAL FUNCTIONS - 3 THERMAL CONDITIONS WITH SIMULATED THERMAL DISTORTIONS OF THE AFT BULKHEAD AND THE LH AND RH LONGERON SILL, 2 MOTOR OPERATIONS 27 CYCLES AT LESS THAN 63 SECONDS/STROKE, EACH MOTOR OPERATION 3 CYCLES AT LESS THAN 126 SECONDS/STROKE FOR EACH OF THE 3 ORBITAL FUNCTIONS; OPERATING LIFE TESTS - MECHANISM CYCLED 243 TIMES 205 TIMES WITH TWO MOTOR OPERATION AND 19 TIMES WITH SINGLE MOTOR OPERATIONS; ACOUSTIC TEST - 25 HZ TO 6,000 HZ FOR 5 MINUTES.

TESTS ON 60 FOOT TEST RIG INCLUDED: AMBIENT CYCLING - 3 THERMAL CONDITIONS WITH THERMAL DISTORTIONS OF THE SILL LONGERON, 2 MOTOR OPERATIONS 22 CYCLES AT LESS THAN 63 SECONDS/STROKE; 10 WITHOUT DISTORTION SIMULATION; EACH SINGLE MOTOR OPERATION 3 WITHOUT DISTORTION AND 6 WITH DISTORTION AT LESS THAN 126 SECONDS/STROKE; TEMPERATURE CYCLING - 3 THERMAL CONDITIONS WITH THERMAL DISTORTIONS OF THE SILL LONGERON, 2 MOTOR OPERATIONS 22 CYCLES AT -42 DEG F AT LESS THAN 63 SECONDS/STROKE; 10 WITHOUT DISTORTION SIMULATION, EACH SINGLE MOTOR OPERATION 3 WITHOUT DISTORTION SIMULATION AND WITH DISTORTION AT LESS THAN 126 SECONDS/STROKE AT -42 DEG F; ORBITAL FUNCTIONAL TEST - REPEAT THE ABOVE AMBIENT AND -42 DEG F TESTS FOR A TOTAL OF 80 MECHANISM CYCLES. CERTIFICATION BY ANALYSIS/SIMILARITY INCLUDES FUNGUS, OZONE, PACKAGING, THERMAL/VACUUM, SALT SPRAY, ACOUSTIC, SHOCK, LIMIT/ULTIMATE LOADS, ACCELERATION, SAND/DUST AND MARGIN OF SAFETY.

ACCEPTANCE TEST: TESTS ON THE MC162-0008 COMPONENTS INCLUDES: EXAMINATION OF PRODUCT - WEIGHT, WORKMANSHIP, DIMENSIONS, CONSTRUCTION, CLEANLINESS, FINISH, IDENTIFICATION, MARKINGS, TRACEABILITY AND USE OF CERTIFIED MATERIALS AND PROCESSES; ACCEPTANCE VIBRATION (AVT) - 20 TO 2,000 HZ RANGE WITH MAXIMUM OF 0.04 g<sup>2</sup>/HZ FROM 80 TO 350 HZ FOR 30 SECONDS/AXIS MINIMUM, ELECTRICAL CONTINUITY MONITORED DURING TESTS AND PDU CYCLED BEFORE AND AFTER VIBRATION; ACCEPTANCE THERMAL TEST (ATT) - THERMALLY CYCLED FROM +70 DEG F TO +320 DEG F, TO +157 DEG F, TO -80 DEG F, TO +320 DEG F, TO +157 DEG F, TO 70 DEG F WITH CONTINUITY MONITORED THROUGHOUT, PDU WAS CYCLED 6 TIMES AT EACH +157 DEG F AND 6 TIMES AT -80 DEG F AT LESS THAN 63 SECONDS/STROKE TWO MOTOR OPERATIONS AND 126 SECONDS/STROKE SINGLE MOTOR OPERATIONS; POWER CONSUMPTION TESTS -INPUT POWER MAX OF 450 WATTS/MOTOR AT RATED LOAD AND SINGLE MOTOR TIME OF 126 SECONDS/STROKE AND 63 SECONDS/STROKE DUAL MOTOR OPERATION; INSULATION RESISTANCE, DIELECTRIC STRENGTH - PER MF0004-002 EXCEPT TEST VOLTAGE WAS 750 VRMS. CYCLING TEST - SINGLE MOTOR DRIVE 20 CYCLES EACH AND DUAL MOTORS 40 CYCLES. FREEPLAY TEST - MAXIMUM OF 1.0 DEGREES WITH 10 IN LBS REVERSING TORQUE ON EACH ACTUATOR; ACTUATOR STALL - CONTINUOUS STALL FOR 126 SECONDS AT FULL INVERTOR POWER 120 VOLTS AC.

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ACCEPTANCE TESTS ALSO INCLUDE: IRREVERSIBILITY TEST - 650 INCH-LB AT PCU OUTPUT SHAFT; TRAVEL LIMIT TEST - ACTUATOR STOPPED BY LIMIT SWITCHES AND BY HARD STOPS WITH SWITCHES DEENERGIZED; MANUAL OPERATIONS - LESS THAN 100 INCH-LB TORQUE TO ENGAGE AND DISENGAGE THE PDU; BACKDRIVE - FORCE AT ACTUATOR OUTPUT ARM ROD ATTACH POINT LESS THAN 150 POUNDS; TORQUE LIMITS - ROTARY ACTUATOR OUTPUT LIMITS AT ROOM AMBIENT ARE 6,200 TO 8,950 INCH-LB, OUTPUT LIMITS AT +157 DEG F AND -65 DEG F ARE 6,200 TO 10,000 INCH-LB; PROOF LOAD TESTS - 3/4 O.D. DRIVE SHAFTS TESTED TO 325 INCH-LB AND 1.0 O.D. DRIVE SHAFTS TESTED TO 650 INCH-LB; FRICTION TORQUE TEST - TORQUE ON SHAFT SUPPORT IS LESS THAN 1.0 INCH-LB. EACH TORQUE SHAFT IS PROOF LOADED DURING ACCEPTANCE.

OMRSD: GROUND TURNAROUND INCLUDES MONITORING FUNCTIONAL CHECKS TO VERIFY NO BINDING OR JAMMING AND VISUAL INSPECTION OF HARDWARE TO ENSURE THAT PARTS ARE NOT BROKEN OR DEFORMED.

(C) INSPECTION

RECEIVING INSPECTION

MATERIALS ISSUED FOR FABRICATION OF BELLCRANK AND ROD ASSEMBLIES ARE VERIFIED BY INSPECTION. ROD ENDS ARE PURCHASED TO CONTROLLED DRAWINGS AND SPECIFICATIONS AND ARE VERIFIED FROM PURCHASE ORDERS.

CONTAMINATION CONTROL

CORROSION PROTECTION PER DRAWING AND CORROSION PROTECTION SPECIFICATION IS VERIFIED BY INSPECTION.

ASSEMBLY/INSTALLATION

BUSHING INSTALLATION IS PER DRAWING AND BUSHING INSTALLATION SPECIFICATION AND IS VERIFIED BY INSPECTION. MACHINING OPERATIONS ARE PER DRAWING AND MACHINE SPECIFICATION WHICH ARE VERIFIED BY INSPECTION ON MANUFACTURING ORDERS. ASSEMBLY IS COMPLETE PER DRAWINGS AND APPLICABLE SPECIFICATIONS WHICH ARE VERIFIED BY INSPECTION ON MANUFACTURING ORDERS. PROCESSING MATERIALS IN CONTACT WITH TITANIUM PER MF0004-018 VERIFIED BY INSPECTION.

NONDESTRUCTIVE EVALUATION

PENETRANT INSPECTION VERIFIED BY INSPECTION.

CRITICAL PROCESSES

HEAT TREATING IS VERIFIED BY INSPECTION.

TESTING

ACCEPTANCE TESTING VERIFIED BY INSPECTION.

HANDLING/PACKAGING

HANDLING AND PACKAGING REQUIREMENTS ARE VERIFIED.

(D) FAILURE HISTORY

THERE HAVE BEEN NO ACCEPTANCE TEST, QUALIFICATION TEST, FIELD OR FLIGHT FAILURES ASSOCIATED WITH THIS FAILURE MODE.

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(E) OPERATIONAL USE

EVA WORKAROUND IS POSSIBLE TO CLOSE DOOR IF PAYLOAD DOES NOT LIMIT  
ACCESS.