

SHUTTLE CRITICAL ITEMS LIST - ORBITER

BSYSTEM :ACTUATION MECH-ET/ORB DOOR FMEA NO 02-4D-012600-4 REV:02/17/88

ASSEMBLY :ET/ORBITER UMBILICAL DOOR MECHANISMS CRIT. FUNC: 1
P/N RI :MC287-0020 CRIT. HDW: 1
P/N VENDOR:15600 HOOVER ELECTRIC VEHICLE 102 103 104
QUANTITY :4 (2 LH2 & 2 LO2) EFFECTIVITY: X X X
:(2 PER ACTUATOR) PHASE(S): FL LO X OO DO X LS

PREPARED BY: REDUNDANCY SCREEN: A- B- C-
DES R. H. YEE APPROVED BY: APPROVED BY (NASA):
REL J. S. MULLEN DES ~~H. G. Ford~~ SSM ~~A. C. Mason~~ 2/24/88
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ITEM:
TORQUE LIMITER, DOOR DRIVE ACTUATOR

FUNCTION:
TO PROTECT THE DOOR STRUCTURE, DOOR DRIVE LINKAGE AND ACTUATOR BY ALLOWING PREDETERMINED SLIPPAGE DURING A STALL OR JAM CONDITION.

FAILURE MODE:
TORQUE LIMITER SLIPS AT LESS THAN MINIMUM ALLOWABLE TORQUE.

CAUSE(S):
ADVERSE TOLERANCES/WEAR, CHANGE IN MATERIAL PROPERTIES, CONTAMINATION/ FOREIGN OBJECT/DEBRIS, DEFECTIVE PART/MATERIAL OR MANUFACTURING DEFECT, TEMPERATURE, LOSS OF SPRING FORCE

EFFECT(S) ON:
(A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE
(A) LOSS OF FUNCTION - UNABLE TO CLOSE DOOR.
(B) THERMAL LEAKAGE INTO COMPARTMENT.
(C,D) POSSIBLE LOSS OF CREW/VEHICLE DUE TO DAMAGE CAUSED BY THERMAL EFFECTS IF THE DOORS CANNOT BE CLOSED AND FULLY LATCHED FOR SAFE RE-ENTRY.

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DISPOSITION & RATIONALE:

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

(A) DESIGN

EACH ORBITER/ET UMBILICAL DOOR IS OPENED OR CLOSED (TO WITHIN APPROX 2 INCHES) BY FOUR-BAR/OVER-CENTER HINGE/ACTUATION LINKAGES THAT ARE DRIVEN BY AN ELECTROMECHANICAL ACTUATOR THROUGH A TORQUE TUBE, BELLCRANKS, AND CONNECTING-RODS. EACH DOOR DRIVE ACTUATOR CONSISTS OF A PLANETARY GEARBOX/DIFFERENTIAL DRIVEN BY TWO (REDUNDANT) 3-PHASE ELECTRIC MOTORS; EACH MOTOR HAS AN INTEGRAL SPRING-LOADED FRICTION CLUTCH/BRAKE; AN INTEGRAL SPRING-LOADED DUAL-DISC PLATE FRICTION TORQUE LIMITER; WITH LIMIT SWITCHES AND MECHANICAL STOPS TO CONTROL/LIMIT ACTUATOR MOVEMENT/ROTATION. THE ACTUATOR HOUSING IS DESIGNED TO PRECLUDE THE ENTRY OF FOREIGN PARTICLES. PARTS ARE CLEANED TO LEVEL 300, PER MA0110-301 (PRIOR TO ASSEMBLY); ASSEMBLED IN A CLASS 100,000 CLEAN ROOM (PER FED-STD-209). DUAL ROTATING SURFACES ON BEARINGS. SAFETY FACTOR 1.4 MINIMUM. PROVISION EXISTS TO CYCLE THE ACTUATOR (TO LOOSEN STALLED/JAMMED MECHANISM). BRAKES MUST BE ELECTRICALLY ENERGIZED TO DISENGAGE AND ARE DESIGNED TO FAIL IN THE ENGAGED POSITION. DIFFERENTIAL IS DESIGNED TO DISTRIBUTE POWER FROM EITHER ONE OR BOTH (REDUNDANT) MOTORS. MOTORS DESIGNED TO OPERATE IN EMERGENCY 2-PHASE CONDITION. EACH TORQUE LIMITER IS DESIGNED TO PROTECT ITS MOTOR AND DRIVE TRAIN FROM AN OVERLOAD FAILURE.

(B) TEST

QUALIFICATION TESTS: QUAL-CERTIFIED PER CR-45-287-0020-0001.
QUALIFICATION TESTS INCLUDED: HUMIDITY TEST, SHOCK TEST, QUALIFICATION ACCEPTANCE VIBRATION TESTS (QAVT), THERMAL VACUUM TEST, THERMAL CYCLING TEST, OPERATING LIFE TEST (2,000 CYCLES, 100-MISSION, 10-YEAR LIFE; EXPECT 500 CYCLES PER 100 MISSIONS), MECHANICAL STOP TEST, POWER CONSUMPTION TEST, FREE-PLAY TEST, AND IRREVERSIBILITY TEST.

ACCEPTANCE TESTS: INCLUDES EXAMINATION OF PRODUCT (FOR WEIGHT, DIMENSIONS, CONSTRUCTION, CLEANLINESS AND FINISH), ACCEPTANCE VIBRATION TESTS (AVT) (20-2,000 HZ, 30 SEC TO 5 MINUTES, IN EACH OF THREE ORTHOGONAL AXES, WITH ELECTRICAL CIRCUITS MONITORED FOR CONTINUITY), ACCEPTANCE THERMAL TESTS (ATT) (CYCLED BETWEEN -80 DEG F AND +330 DEG F; MOTOR 1, MOTOR 2 AND DUAL MOTOR), POWER CONSUMPTION TEST (OPERATED AT RATED LOAD AT -50 DEG F, SINGLE MOTOR DEPLOYED WITHIN 48 SEC, DUAL MOTORS DEPLOYED WITHIN 24 SEC, 165 WATTS/MOTOR MAX, 0.75 AMPS/PHASE/MOTOR MAX; 616 WATTS/MOTOR MAX STARTING POWER AND 3.5 AMPS/PHASE/MOTOR MAX STARTING CURRENT; OPERATED AT MAXIMUM LOAD AT -50 DEG F, 186 WATTS/MOTOR MAX AND 0.77 AMPS/PHASE/MOTOR MAX), INSULATION RESISTANCE TEST AND DIELECTRIC STRENGTH TEST (PER MF0004-002), CYCLING TEST (OPERATED AT RATED LOAD; SINGLE MOTOR, 13 CYCLES EACH FROM CW-CCW-CW ROTATION AT 48 SEC/DIRECTION; DUAL MOTOR, 70 CYCLES FROM CW-CCW-CW ROTATION AT 24 SEC/DIRECTION), FREEPLAY TEST (MAX ANGULAR FREEPLAY AT OUTPUT SHAFT +/-1.0 DEGREES ROTATION, WITH 10 INCH-LB OF REVERSING TORQUE), STALL/MAXIMUM TORQUE TEST (MAX ACTUATOR OUTPUT 14,000 INCH-LB, AT -75 DEG F MINIMUM), IRREVERSIBILITY TEST (ACTUATOR MUST BE IRREVERSIBLE TO THE OPERATING LOAD OF 1,875 INCH-LB, IN EITHER DIRECTION), MECHANICAL LIMITS TEST AND ELECTRICAL LIMITS TEST (ACTUATOR CYCLED THROUGH ITS FULL TRAVEL TO VERIFY COMPLIANCE WITH MECHANICAL AND ELECTRICAL LIMITS).

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OMRSD: OPEN/CLOSE (1-"G") OPERATIONAL CHECKOUT OF RIGHT-HAND/LEFT-HAND ET DOOR; MOTOR 1, MOTOR 2 AND DUAL MOTOR OPERATION. FREQUENCY - ALL VEHICLES AT GROUND TURNAROUND. FUNCTIONAL LOADS IN 1-"G" EXCEED OPERATIONAL LOADS WITH A HIGH MARGIN OF SAFETY. THIS TEST VERIFIES THAT THE SLIP-TORQUE OF BOTH TORQUE LIMITERS (ONE FOR EACH MOTOR; TWO FOR EACH ACTUATOR) MEETS MINIMUM REQUIREMENTS.

(C) INSPECTION

RECEIVING INSPECTION

CERTIFICATION OF COMPLIANCE, TEST COUPONS, PHYSICAL AND CHEMICAL RECORDS ARE MAINTAINED IN THE MASTER FILE. RECEIVING INSPECTION PERFORMS VISUAL AND DIMENSIONAL EXAMINATION OF ALL INCOMING PARTS. QUALITY CONTROL MAINTAINS SURVEILLANCE OF RAW MATERIAL, LIMITED LIFE MATERIALS, CHEMICAL AND METALLURGICAL TESTS AND REPORTS. GEARS ARE HARDNESS CHECKED AND VERIFIED BY INSPECTION.

CONTAMINATION CONTROL

POLYETHYLENE SHEETING, USED TO BAG AND SEAL PARTS AFTER CLEANING, IS VERIFIED BY INSPECTION. A CLASS 100,000 CLEAN ROOM FACILITY IS USED FOR ASSEMBLY AND VERIFIED BY INSPECTION. ALL METAL PARTS ARE VERIFIED BY INSPECTION TO BE CLEANED. FINAL INSPECTION INCLUDES CHECKS FOR CONTAMINATION USING BORESCOPES, 5X AND 10X MAGNIFICATION DEVICES, AND FILTRATION METHODS.

ASSEMBLY/INSTALLATION

INSPECTION VERIFIES AND RECORDS DIMENSIONS OF ALL DETAIL PARTS.

NONDESTRUCTIVE EVALUATION

HIGH STRESS PARTS ARE MAGNETIC OR FLUORESCENT PENETRANT INSPECTED.

CRITICAL PROCESSES

HEAT TREATING IS VERIFIED BY INSPECTION. INSPECTION VERIFIES THAT GEARBOXES ARE PROPERLY LUBRICATED.

TESTING

ACCEPTANCE TESTING IS VERIFIED BY INSPECTION.

HANDLING/PACKAGING

HANDLING AND PACKAGING REQUIREMENTS ARE VERIFIED BY INSPECTION.

(D) FAILURE HISTORY

CAR NO. ABB309 : ENGINEERING EVALUATION TESTS WERE CONDUCTED ON THREE UMBILICAL DOOR DRIVE ACTUATORS TO DETERMINE IF ACTUATOR OUTPUT TORQUE FALLS OFF WITH AGE. STALL/MAX TORQUE WAS FOUND TO BE WELL BELOW SPECIFICATION REQUIREMENTS AND WAS ATTRIBUTED TO CHANGES IN TORQUE LIMITER CHARACTERISTICS. THIS PROBLEM WAS CLOSED ON THE BASIS THAT UMBILICAL CLOSEOUT DOOR OPERATION IS VERIFIED PER OMI V1097 DURING GROUND TURNAROUND, FOR ALL FLIGHTS.

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CAR NO. AC8413 : AT KSC, ON OV-103, THE RH UMBILICAL DOOR SLIPPED FROM FULL OPEN POSITION TO APPROXIMATELY 90 DEGREES FROM HORIZONTAL. FAILURE ANALYSIS OF THE ACTUATOR INDICATED THAT THE CAUSE OF THE BACKDRIVE IS ATTRIBUTED TO DEGRADATION IN THE TORQUE CLUTCH SETTING. EXTENSIVE TESTING HAS SHOWN THAT CLUTCH DEGRADATION LEVELS OFF AT A POINT WHERE THE ACTUATOR CAN ALWAYS DRIVE THE REQUIRED OPERATING LOAD. HOWEVER, IN THE NON-OPERATING (STATIC) CONDITION, SLIPPAGE CAN OCCUR. THE TWO TORQUE LIMIT CLUTCHES WERE READJUSTED AND THE UNIT SUCCESSFULLY PASSED AN ABBREVIATED ATP.

CAR NO. AC9886 : AT KSC, ON OV-104, DURING SINGLE MOTOR OPERATION, CLOSING THE LH ET DOOR FROM FULL OPEN TOOK LONGER THAN THE ALLOWABLE 48 SECONDS. FAILURE ANALYSIS INDICATED DEGRADATION OF THE TORQUE CLUTCH SETTING. THE TORQUE CLUTCHES WERE READJUSTED, PASSED ATP AND THE ACTUATOR WAS RETURNED TO STOCK.

CAR NO. AD3241 : ENGINEERING EVALUATION TESTS WERE PERFORMED ON A SPARE ACTUATOR FROM KSC STOCK TO DETERMINE FALL OFF IN OUTPUT TORQUE WITH AGE. STALL/MAX TORQUE WAS WELL BELOW SPECIFICATION. THE SUPPLIER (HOOVER) HAS PROPOSED CHANGES TO THE TORQUE LIMIT CLUTCH CONSTRUCTION THAT ARE BEING EVALUATED BY RI. AN ALTERNATIVE IS ACCEPTANCE OF THE CONDITION FOR FLIGHT WITH PERIODIC RE-ACCEPTANCE TEST AND RE-ADJUSTMENT FOR ATP REQUIREMENTS (REF. MCR 12154).

CAR SUMMARY: THE ORIGINAL DESIGN REQUIREMENT FOR THE DOOR DRIVE TORQUE LIMITER MINIMUM SLIP POINT WAS BASED ON A CONSERVATIVE APPROACH AND WAS FAR IN EXCESS OF ANY OPERATIONAL REQUIREMENT. SINCE 1981 THE TORQUE LIMITERS HAVE DEMONSTRATED A CHARACTERISTIC DEGRADATION OF THE MINIMUM SLIP POINT AS A FUNCTION OF TIME. BASED ON TEST DATA FROM THE AVAILABLE ACTUATORS, IT APPEARS THAT THE TORQUE OUTPUT DEGRADES TO APPROXIMATELY ONE-HALF THE ACCEPTANCE TEST VALUE, THEN LEVELS OFF AND REMAINS STABLE. RECENT ANALYSIS INDICATES THAT THE WORST CASE OPERATIONAL REQUIREMENT BASED ON RTLS ABORT IS FAR LESS THAN THE ORIGINAL DESIGN REQUIREMENT. WITH THE ASSUMPTION OF WORSE CASE TORQUE LIMITER DEGRADATION, THE ACTUATOR CAPABILITY EXCEEDS THE PRESENT OPERATIONAL REQUIREMENT BY A FACTOR OF 2. THIS FACTOR OF SAFETY IS DEMONSTRATED PRIOR TO EVERY FLIGHT BY PERFORMING AN OPEN/CLOSE FUNCTIONAL TEST. (THE WEIGHT OF THE DOOR IN 1-"G" VERIFIES THE SAFETY FACTOR)

(E) OPERATIONAL USE
NONE.