

INTRODUCTION TO APPENDIX A

- ITEM 1 - TOGGLE SWITCH - ME452-0102-7XXX
- ITEM 2 - ROTARY SWITCH - ME452-0093
- ITEM 3 - POSITION SWITCH - ME452-0060 AND ME452-0061
- ITEM 4 - LIMIT SWITCH - MC452-0123

FAILURE MODES AND CAUSES

THE FOLLOWING TABLE LISTS FAILURE MODES AND CAUSES WHICH WERE CONSIDERED IN DERIVING THE FAILURE MODES AND EFFECTS ANALYSIS (FMEA'S) FOR THE ABOVE ITEMS.

FAILURE MODE	FAILURE CAUSE	TOGGLE SWITCH	ROTARY SWITCH	P/B SWITCH	LIMIT SWITCH
FAILS OPEN, PREMATURE OPEN	{a} Piece Part Structural Failure	X	X	X	X
	{b} Contamination	X	X	X	X
	{c} Vibration	X	X	X	X
	{d} Mechanical Shock	X	X	X	X
	{e} Processing Anomaly	X	X	X	X
	{f} Thermal Stress	X	X	X	X
FAILS CLOSED, PREMATURE CLOSURE, CONTACT-TO-CONTACT SHORT	{a} Piece Part Structural Failure	X	X	X	X
	{b} Contamination	X	X	X	X
	{c} Vibration	X	X	X	X
	{d} Mechanical Shock	X	X	X	X
	{e} Processing Anomaly	X	X	X	X
	{f} Thermal Stress	X	X	X	X
SHORT-TO-CASE (GROUND)	{a} Piece Part Structural Failure	X	X	X	X
	{b} Contamination	X	X	X	X
	{c} Vibration	X	X	X	X
	{d} Mechanical Shock	X	X	X	X
	{e} Processing Anomaly	X	X	X	X
SOLE-TO-POLE SHORT	{a} Piece Part Structural Failure	X	X	X	X
	{b} Contamination	X	X	X	X
	{c} Vibration	X	X	X	X
	{d} Mechanical Shock	X	X	X	X
	{e} Processing Anomaly	X	X	X	X
BROKEN STOP	{a} Piece Part Structural Failure	X	X	X	X
	{e} Processing Anomaly	X	X	X	X
LOSS OF ANNUNCIATOR / LENS ILLUMINATION, FAILS TO ILLUMINATE	{a} Piece Part Structural Failure		X	X	X
	{b} Contamination		X	X	X
	{c} Vibration		X	X	X
	{d} Mechanical Shock		X	X	X
	{e} Processing Anomaly		X	X	X
	{f} Thermal Stress		X	X	X

NOTE: PREMATURES CREATED BY THE TEARING OF TOGGLE SWITCHES ARE REVERSIBLE OR TEMPORARY CONDITIONS.

11/19/87

APPENDIX A ITEM 1 - TOGGLE SWITCH
ME452-0102-7XXX

DISPOSITION & RATIONALE

(A) DESIGN, (B) TEST, (C) INSPECTION, (D) FAILURE HISTORY:

(A) DESIGN

HERMETICALLY-SEALED, INERT GAS BACK-FILLED, STAINLESS STEEL CASE. POSITIVE MECHANICAL LINKAGE BETWEEN TOGGLE AND MOVABLE CONTACT(S). DETENT SPRING ENDS HAVE DOUBLE LOOP FOR POSITIVE RETENTION IN CASE OF SPRING BREAKAGE. APPLICATIONS MEET ORBITER PROJECT PARTS LIST (CPPL) CURRENT DERATING REQUIREMENTS FOR 15 AMPS RATING. THE SWITCH IS DESIGNED, TESTED AND INSPECTED TO MEET THE REQUIREMENTS OF SPACE SHUTTLE PROGRAM BY ROCKWELL INTERNATIONAL SPECIFICATION MC452-0102.

(B) TEST

QUALIFICATION/CERTIFICATION

CERTIFICATION TESTING AND ANALYSIS ARE COMPLETED AND APPROVED. TESTS INCLUDED THE FOLLOWING:

TEST	CAUSE CONTROL				
	a	b	c	d	e
FUNCTIONAL PERFORMANCE	X	X			
CONTACT RESISTANCE	X	X			
VOLTAGE DROP AT RATED CURRENT	X	X	X	X	X
FLIGHT VIBRATION (0.2 g ² /HZ)	X		X		X
ENDURANCE (5,000 CYCLES AT 15 AMPS, 20,000 CYCLES AT 10 AMPS (40M38202))	X				X
SHORT CIRCUIT CLOSURE (2 CYCLES AT 95 AMPS)					
TERMINAL STRENGTH (10 LBS PULL)	X				
OVERLOAD (10 CYCLES AT 150% OF THE RATED RESISTIVE LOAD)					
TOGGLE LEVER STRENGTH (25 LB., 3 AXES)	X				X
LEAKAGE (GROSS AND FINE TO 1X10 ⁻⁷ CC/SEC)		X			
SHOCK TEST (78-G, ONE IMPACT IN EACH OF 3 AXES)				X	

11/19/87

APPENDIX A ITEM 1 CONT'D

ACCEPTANCE AND SCREENING

ALL SWITCHES ARE SUBJECTED TO ACCEPTANCE AND SCREENING TESTS ON A 100% BASIS AND INCLUDE THE FOLLOWING:

TEST	CAUSE CONTROL				
	a	b	c	d	e
FUNCTIONAL PERFORMANCE	X	X			
VOLTAGE DROP AT RATED CURRENT	X	X			X
INSULATION RESISTANCE (IR AT 500 VDC, 100 MEGOHM MINIMUM)		X			X
DIELECTRIC WITHSTANDING VOLTAGE (DWV AT 800 V RMS)		X			X
CONTACT RESISTANCE	X	X	X	X	X
VIBRATION (0.04 g ² /HZ)			X		
LEAKAGE (1X10 ⁻⁶ CC/SEC)		X			X
RADIOGRAPHIC (X-RAY)		X			
PREACCEPTANCE RUN-IN (250 ACTUATIONS)	X	X			X

ACCEPTANCE TEST AT THE NEXT ASSEMBLY:

TEST	CAUSE CONTROL				
	a	b	c	d	e
FUNCTIONAL CONTINUITY	X	X			X
INSULATION RESISTANCE	X	X			X

(C) INSPECTION

RECEIVING INSPECTION

UPON RECEIPT, INSPECTION PERFORMS VISUAL AND DIMENSIONAL EXAMINATION OF ALL INCOMING PARTS AND VERIFIES THE MATERIAL USED. CERTIFICATION RECORDS AND TEST REPORTS ARE MAINTAINED CERTIFYING MATERIALS AND PHYSICAL PROPERTIES.

11/19/87

APPENDIX A ITEM 1 CONT'D

CONTAMINATION CONTROL (FAILURE CAUSE b)

SWITCHES ARE ASSEMBLED IN AN ENVIRONMENTALLY CONTROLLED AREA WITH AIR FILTRATION SYSTEM. LAMINAR FLOW BENCHES ARE UTILIZED DURING FINAL ASSEMBLY. EACH SWITCH IS PLACED IN AN INDIVIDUAL BOX THROUGHOUT ASSEMBLY PROCESS. EACH SWITCH IS WASHED (WITH CHLOROTHENE VAPOR DEGREASER) AND INSPECTED UNDER 10X MAGNIFICATION.

ASSEMBLY/INSTALLATION (FAILURE CAUSE a,b,e)

DETAILED INSPECTION IS PERFORMED ON ALL ASSEMBLIES PRIOR TO NEXT OPERATION. INSPECTION UNDER 10X MAGNIFICATION IS PERFORMED PRIOR TO CLOSEOUT WELD.

NONDESTRUCTIVE EVALUATION (NDE) (FAILURE CAUSE a,b,e)

RADIOGRAPHIC INSPECTION (X-RAY) PERFORMED PRIOR TO PRODUCTION RUN-IN AND SUBSEQUENT TO VIBRATION FOR EVIDENCE OF SOLDER MIGRATION, LOOSE PARTS, AND ASSEMBLY ANOMALIES.

CRITICAL PROCESSES (FAILURE CAUSE b,e)

ALL OPERATIONS INCLUDING ROTOR SUB-ASSEMBLY, ROTOR ASSEMBLY, LEVER SUB-ASSEMBLY, ROTOR DETENT ASSEMBLY, SWITCH MAIN ASSEMBLY, AND HERMETICALLY SEALED SWITCH ASSEMBLY ARE VERIFIED AND INSPECTED BY QUALITY CONTROL (QC).

TESTING

ACCEPTANCE TESTS, INCLUDING RUN-IN, PERFORMANCE, VIBRATION, AND HERMETICITY, IS OBSERVED AND VERIFIED BY QC.

HANDLING/PACKAGING (FAILURE CAUSE c,d)

PARTS ARE PACKAGED, PROTECTED, AND VERIFIED BY INSPECTION TO APPLICABLE REQUIREMENTS.

(D) FAILURE HISTORY

THERE HAVE BEEN A NUMBER OF DISCREPANCIES REPORTED AGAINST THE TOGGLE SWITCHES WHICH HAVE BEEN ATTRIBUTED TO "TEASING". "TEASING" IS A CONDITION WHERE THE OPERATOR MOVES THE SWITCH ACTUATOR TO A POSITION HE BELIEVES IS PROPER, HOWEVER, THE INTERNAL MECHANISM HAS NOT COMPLETED THE TRANSFER AS REQUIRED.

11/19/87

APPENDIX A ITEM 1 CONT'D

THIS CONDITION IS ESPECIALLY TRUE FOR THE MOMENTARY AND LEVER LOCK TOGGLE SWITCHES.

a) MOMENTARY SWITCHES: WHEN OPERATING A MOMENTARY SWITCH, THE INITIAL CONTACT OF THE MOVABLE CONTACT (ROLLER) AND THE FIXED CONTACT (CONTACT SHOE) MAY BE "FELT". IF MOVEMENT OF THE SWITCH HANDLE IS STOPPED AT THIS POINT, POSITIVE CONTACT WILL NOT BE MADE. IN A MULTIPLE POLE SWITCH, SOME OF THE POLES MAY BE COMPLETING THE CIRCUIT AND OTHERS NOT, DUE TO MOVABLE AND/OR FIXED CONTACT MISALIGNMENTS.

THIS IS AN INHERENT CHARACTERISTIC OF THE SWITCH DESIGN, AND IS MORE PREVALENT IN A FOUR POLE THAN IN A SINGLE POLE SWITCH. IN ADDITION, A SLIGHT RELAXATION OF PRESSURE ON THE SWITCH HANDLE COULD ALLOW ONE OR MORE CIRCUITS TO OPEN. "TEASING" THIS TYPE OF SWITCH CAN BE ELIMINATED BY MOVING THE SWITCH HANDLE TO THE FULL EXTENT, INTO THE MECHANICAL STOP AND HOLDING IT THERE FOR A PERIOD OF TIME (2 TO 3 SECONDS).

b) LEVER LOCK SWITCHES: IN A THREE POSITION LEVER LOCK SWITCH, "TEASING" OCCURS WHEN THE LEVER LOCK HANDLE IS PULLED, TRANSFER ACTION STARTED, AND THEN THE LEVER LOCK HANDLE IS RELEASED BEFORE TRANSFER ACTION IS COMPLETED. UNDER THESE CONDITIONS, THE FRICTIONAL DRAG FORCE OF THE LOCKING MECHANISM ON THE LOCK CAM SIGNIFICANTLY AFFECTS THE "FEEL" OF THE SWITCH TRANSFER ACTION, AND THE SWITCH IS NOT IN THE PROPER POSITION. INTERNALLY, WITH THE SWITCH NOT IN THE PROPER DETENT POSITION, THE SAME SET OF CONDITIONS EXIST AS DESCRIBED ABOVE FOR MOMENTARY SWITCHES. TO ELIMINATE "TEASING", THE HANDLE MUST BE PLACED INTO ITS GROOVE IN THE BUSHING OR MOVED TO THE DESIRED POSITION BEFORE RELEASING THE LEVER LOCK HANDLE.

"TEASING" IS A FUNCTION OF THE OPERATOR'S PROCEDURE AND THE SWITCH DESIGN AND CAN BE ELIMINATED WITH PROPER SWITCH OPERATION.

OTHER PERTINENT TOGGLE SWITCH FAILURES INCLUDE THE FOLLOWING:

FAILURE MODE: CONTACT-TO-CONTACT SHORT, SHORT-TO-CASE (GROUND), POLE-TO-POLE SHORT, OPEN, CLOSE

CAR A7791 AND DR AC6872 (NON-FLIGHT SWITCH CONFIGURATION) DURING SYSTEMS TEST IN THE SHUTTLE AVIONICS INTEGRATED LAB(SAIL) IN SEPTEMBER OF 1977, THE CREW WAS NOT ABLE TO INITIAL PROGRAM LOAD(IPL) FROM MASS MEMORY NO. 2. THIS WAS ISOLATED TO IPL/NORMAL TOGGLE SWITCH, S24 (P/N MEAS2-0102-6101) ON PANEL C7 (AN ALT PANEL CONFIGURATION). AGAIN DURING SAIL SYSTEMS TEST IN

11/19/87

APPENDIX A ITEM 1 CONT'D

OCTOBER OF 1983, THE CREW WAS NOT ABLE TO IPL GENERAL PURPOSE COMPUTER(GPC) NUMBER 5. TROUBLESHOOTING ISOLATED THE FAILURE TO THE BACKUP FLIGHT CONTROLLER(BFC) CATHODE RAY TUBE(CRT) DISPLAY ON/OFF SWITCH, S17 (P/N ME452-0102-6101) ON PANEL C3A1.

FAILURE ANALYSIS OF BOTH OF THESE SWITCHES DETERMINED THAT THE FAILURE WAS CAUSED BY A FRACTURED ROLLER RETAINER. FURTHER INVESTIGATION REVEALED EXCESSIVE WEAR CAUSED THE RETAINER TO FRACTURE IN BOTH OF THE SWITCHES. AVAILABLE DATA, INCLUDING DISASSEMBLY OF QUALIFICATION TEST SAMPLES AND OTHER TOGGLE SWITCHES SUBJECTED TO VARIOUS CYCLIC LIFE TESTS INDICATES THAT BOTH SWITCHES HAD SEEN IN EXCESS OF 40,000 CYCLES; THE SECOND SWITCH PROBABLY IN EXCESS OF 100,000 CYCLES. IN BOTH CASES THE SWITCHES WERE FABRICATED USING A RETAINER DESIGN WHICH HAD FOUR DIMPLES; TWO ON EACH SIDE OF THE RETAINER. THESE WERE INITIALLY INCLUDED TO HELP CENTER THE ROLLER AND PREVENT COCKING. THE FAILURE ANALYSIS CONFIRMED THAT THE FRACTURE WAS THROUGH THE DIMPLED AREA. THE RETAINER DRAWING WAS REVISED IN MID 1975 TO DELETE THESE DIMPLES. A-7101 TOGGLE SWITCH UTILIZING A RETAINER WITHOUT DIMPLES WAS SUCCESSFULLY SUBJECTED TO 220,000 CYCLES WITH NO FAILURE OR VISUAL INDICATION OF FRACTURE FATIGUE.

A REVIEW OF THE SWITCH APPLICATIONS INDICATED THAT TOGGLE SWITCHES WERE REQUIRED TO OPERATE FOR 5000 CYCLES, THAT IS 50 CYCLES PER MISSION, INCLUDING TURNAROUND FOR 100 MISSIONS. RECENT DISCUSSIONS WITH KSC INDICATE THAT THIS IS STILL A REALISTIC FIGURE WITH PERHAPS SOME WORST CASES REQUIRING 70 CYCLES. THIS IS COMPATIBLE WITH THE CERTIFICATION TESTS ACCOMPLISHED, 5000 CYCLES AT 15 AMPERES AND 20,000 CYCLES AT 10 AMPERES.

THE FAILURES OF THIS NON-FLIGHT CONFIGURATION WERE ATTRIBUTED TO WEAR OUT CONDITIONS. THE MODIFICATION OF THE ROLLER RETAINER AND SUBSEQUENT LIFE TEST OF THE 7101 SWITCH CONFIGURATION PROVIDES ASSURANCE THAT THE FLIGHT CONFIGURATION SWITCHES WILL NOT EXHIBIT THIS FAILURE MECHANISM.

CAR AC7521

DURING PANEL FUNCTIONAL TEST, ONE POLE OF A FOUR POLE SWITCH EXHIBITED INTERMITTENT CONTINUITY WITH THE SWITCH IN THE CENTER POSITION. THE FAILURE WAS CAUSED BY A METAL RIDGE ON THE PLUNGER RESULTING IN UNEVEN PRESSURE ON THE ROLLER ON ONE SET OF CONTACT SHOES. THIS IS CONSIDERED TO BE AN ISOLATED INSTANCE. THERE HAVE BEEN NO SIMILAR INSTANCES OF THIS NATURE. RECEIVING INSPECTION WAS UPGRADED TO INCLUDE 10X MICROSCOPIC EXAMINATION TO CHECK PARTS TO PRECLUDE RECURRENCE. THIS WAS IMPLEMENTED IN MARCH, 1984.

11/19/87

APPENDIX A ITEM 1 CONT'D

CAR AC8953
DURING SAIL SYSTEMS TEST, SWITCH EXHIBITED ERRATIC OPERATION OR CONTINUITY THROUGH ONE POLE OF THE SWITCH. THE FAILURE WAS ATTRIBUTED TO EXCESSIVE LUBRICANT ON THE CONTACTS ALONG WITH A SPRING FORCE ON THE LOW SIDE OF THE TOLERANCE LIMITS. THIS IS CONSIDERED TO BE AN ISOLATED INSTANCE. THERE HAVE BEEN NO SIMILAR INSTANCES OF THIS NATURE. NO CORRECTIVE ACTION WAS TAKEN AS NO PRODUCTION WAS IN PROCESS.

FAILURE MODE: FAILS OPEN, FAILS CLOSED

CAR AC9012
DURING OV-099 CHECKOUT TESTS THE TECHNICIAN OBSERVED THAT A TOGGLE SWITCH LEVER LOCK HANDLE WAS MISSING - APPLICATION OF LOCKING COMPOUND WAS NOT USED TO RETAIN THE LEVER LOCK HANDLE WHEN IT WAS INSTALLED. ASSEMBLY PERSONNEL AT KSC WERE INSTRUCTED TO FOLLOW INSTALLATION PROCEDURES.

CAR AD1527
DURING ORBITER OV-102 CHECKOUT TESTS, THE TECHNICIAN WAS UNABLE TO PULL THE LEVER LOCK ACTUATOR OUT OF THE LOCKED POSITION, THEREFORE, WAS UNABLE TO TRANSFER THE SWITCH. THIS CONDITION WAS CAUSED BY EXCESSIVE APPLICATION OF LOC-TITE, WHICH CONTAMINATED THE LEVER LOCK MECHANISM. ASSEMBLY PERSONNEL AT KSC WERE INSTRUCTED TO BE MORE CAREFUL AND TO ADHERE TO THE REQUIREMENTS OF PROCESS SPECIFICATION MA0106-333.

THERE ARE NO UNRESOLVED SWITCH FAILURES.

PREPARED BY:

DESIGN H. TURNER
RELIABILITY M. HOVE
QUALITY J. COURSEN

APPROVED BY: APPROVED BY (NASA):

DES *St. Turner* 11/20/87 SSM *Robert* 12/3/87
REL *Robert* 11/20/87 REL *St. Turner*
QE *J. Coursen* 11/20/87 QE *St. Turner* 12/3/87