INTRODUCTION TO APPENDIX A

ITEM 1 - TOGGLE SWITCH - ME452-0102-7XXX
ITEM 2 - ROTARY SWITCH - ME452-0093
ITEM 3 - PUSHBUTTON 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
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
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
POLE-TO-POLE SHORT	(a) Piece Part Structural Failure	X	X		
	(b) Contamination	X	X		
	(c) Vibration	X	X		
	(d) Mechanical Shock	X	X		
	(e) Processing Anomaly	X	X		
BROKEN STOP	(a) Piece Part Structural Failure		X		
	(e) Processing Anomaly		X		
LOSS OF ANNUNCIATOR / LENS ILLUMINATION, FAILS TO ILLUMINATE	(a) Piece Part Structural Failure			X	
	(b) Contamination			X	
	(c) Vibration			X	
	(d) Mechanical Shock			X	
	(e) Processing Anomaly			X	
	(f) Thermal Stress			X	

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

INTRODUCTION TO APPENDIX A (CONT'D)

ITEM 5 - TOGGLE SWITCH - ME452-0102-8XXX

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 ITEM.

FAILURE MODE	FAILURE CAUSE	TOGGLE SWITCH ON-ON, ON-OFF-ON TYPES	TOGGLE SWITCH ON-ON-ON TYPES
FAILS OPEN, PREMATURE OPEN	(a) Piece Part Structural Failure	X	X
	(b) Contamination	X	X
	(c) Vibration	X	X
	(d) Mechanical Shock	X	X
	(e) Processing Anomaly	X	X
	(f) Thermal Stress		
FAILS CLOSED, PREMATURE CLOSURE, CONTACT-TO-CONTACT SHORT	(a) Piece Part Structural Failure	X	X
	(b) Contamination	X	X
	(c) Vibration	X	X
	(d) Mechanical Shock	X	X
	(e) Processing Anomaly	X	X
	(f) Thermal Stress		
SHORT-TO-CASE (GROUND)	(a) Piece Part Structural Failure		
	(b) Contamination		
	(c) Vibration		
	(d) Mechanical Shock		
	(e) Processing Anomaly		
POLE-TO-POLE SHORT	(a) Piece Part Structural Failure		
	(b) Contamination		
	(c) Vibration		
	(d) Mechanical Shock		
	(e) Processing Anomaly		

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

APPENDIX A ITEM 5 - TOGGLE SWITCH
ME452-0102-0XXX

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 SELF-WIPING CONTACT(S). DETENT SPRING ENDS HAVE DOUBLE LOOP FOR POSITIVE RETENTION IN CASE OF SPRING BREAKAGE. EACH POLE IS ISOLATED FROM EVERY OTHER POLE BY KAPTON BARRIERS. APPLICATIONS MEET ORBITER PROJECT PARTS LIST (OPPL) CURRENT DERATING REQUIREMENTS FOR 2 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	X	X			
PERFORMANCE	X	X			
CONTACT RESISTANCE	X	X	X	X	X
VOLTAGE DROP AT RATED CURRENT	X	X			X
FLIGHT VIBRATION (0.2 g^2/HZ)	X		X		
ENDURANCE (5,000 CYCLES AT 2 AMPS)	X				X
SHORT CIRCUIT CLOSURE (2 CYCLES AT 50 AMPS)					
TERMINAL STRENGTH (12 INCH-OZ RADIAL AND LONGITUDINAL TORQUE FOR 1 MINUTE)	X				
OVERLOAD (10 CYCLES AT 150 PERCENT OF THE RATED RESISTIVE LOAD)					

APPENDIX A ITEM 5 CONT'D

QUALIFICATION/CERTIFICATION, CONT'D

TEST	CAUSE CONTROL				
	a	b	c	d	e
TOGGLE LEVER STRENGTH					
(16 LB., 2 AXES - LOCK TYPE SWITCHES)	X				X
(25 LB., 2 AXES - NONLOCK TYPE SWITCHES)	X				X
LEAKAGE					
(FINE TO $1X10^{-6}$ CC/SEC)		X			
SHOCK TEST					
(78-G, ONE IMPACT IN EACH OF 3 AXES)				X	

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	X	X			
PERFORMANCE	X	X			
VOLTAGE DROP AT RATED CURRENT	X	X			X
INSULATION RESISTANCE					
(IR AT 500 VDC, 1000 MEGOHM MINIMUM)		X			X
DIELECTRIC WITHSTANDING VOLTAGE					
(DWV AT 500 V RMS)		X			X
CONTACT RESISTANCE	X	X	X	X	X
VIBRATION (0.04 g^2/HZ)			X		
LEAKAGE					
(GROSS TO $1X10^{-4}$ CC/SEC)		X			X
(FINE TO $1X10^{-6}$ 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	X	X			
CONTINUITY	X	X			X
INSULATION RESISTANCE		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.

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 -7XXX TOGGLE SWITCHES WHICH HAVE BEEN ATTRIBUTED TO "TEASING" WHICH ALSO CAN OCCUR WITH THE -8XXX TOGGLE SWITCHES. "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.

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 (WIPER) AND THE FIXED CONTACT 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).

APPENDIX A ITEM 5 CONT'D

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.

THE FOLLOWING FAILURES OCCURRED AND WERE RESOLVED DURING QUALIFICATION TESTING:

CAR ADS119
THE INSULATION RESISTANCE WAS LESS THAN THE SPECIFIED 1000 MEG OHMS WHEN THE SWITCH WAS ENGAGED. MOST LIKELY CAUSE WAS A METAL SLIVER FORMED BY THE GRINDING OF THE HEADER ASSEMBLY TO CASE AREA WHERE THE WELD JOINT WAS TO BE MADE. THE METAL SLIVER THEN PENETRATED INTO THE CASE THROUGH A GAP BETWEEN THE CASE AND COVER ASSEMBLIES DURING THE LASER WELDING OPERATION.

THE MANUFACTURING PROCESS WAS REVISED TO ELIMINATE THE GRINDING OPERATION, TIG WELDING REPLACED LASER WELDING AND PROPER LENGTH CASES AND BRACKET OVERHANG KAPTON HEAT PROTECTION WERE UTILIZED FOR SUBSEQUENT UNITS.

CAR ADS136
DURING HUMIDITY TESTING, AFTER VIBRATION, THE WELD BETWEEN THE SWITCH BUSHING AND CASE WAS OBSERVED TO BE BROKEN. EXAMINATION OF THE SWITCH SHOWED THAT THE SPOT WELD WAS MISSING.

THE WELDING PROCESS HAS BEEN REVISED TO INCLUDE A SAMPLE SPOT WELD BEFORE AND AFTER WELDING A DAILY LOT OF BUSHING/CASE ASSEMBLIES. THE SAMPLE SPOT WELD WILL BE DESTRUCTIVELY TESTED. IN ADDITION, X-RAY INSPECTION WILL BE REVISED TO INCLUDE A SPOT WELD CHECK. ALL -8XXX SERIES SWITCHES DELIVERED TO THE BUYER WILL BE MANUFACTURED TO THESE REVISIONS.

CAR AD5345
HANDLE OF MOM-ON-MOM SWITCH WOULD NOT RETURN TO THE CENTER POSITION FROM THE MOMENTARY POSITIONS WHEN RELEASED. THE PROBLEM WAS CAUSED BY A BUILD UP OF FRICTION IN THE BUSHING ASSEMBLY AFTER 5400 CYCLES OF OPERATION. NO MOLYKOTE LUBRICANT OR INSUFFICIENT LUBRICANT WAS APPLIED DURING ASSEMBLY.

AFTER MOLYKOTE LUBRICANT WAS PROPERLY APPLIED, THREE OTHER SWITCHES WERE SUCCESSFULLY CYCLED IN EXCESS OF 100,000 CYCLES. THE SUPPLIER CHANGED THE PRE-CAP VISUAL INSPECTION TO VERIFY THAT PROPER APPLICATION OF MOLYKOTE LUBRICANT WAS PERFORMED ON ALL SWITCHES.

A TOGGLE SWITCH FAILURE OCCURRED AFTER ATP AS DESCRIBED BY THE FOLLOWING:

FAILURE MODE: SHORT-TO-CASE (GROUND)

CAR AD7317
AFTER INSTALLATION OF TOGGLE SWITCH PART NUMBER ME452-0102-8306, SERIAL NUMBER 686 INTO A PANEL AT ROCKWELL INTERNATIONAL, DOWNEY AND DURING FUNCTIONAL TEST, IT WAS DISCOVERED THAT TERMINAL 17 OF THE TOGGLE SWITCH HAD A 90 OHM SHORT TO THE SWITCH CASE.

MICROSCOPIC EXAMINATION OF TERMINAL 17 SHOWED GOLD COLOR CONTAMINATION ON ITS INSULATION FROM THE TERMINAL TO THE CASE. CHEMICAL ANALYSIS DETERMINED THAT THE CONTAMINATION WAS COMPOSED OF COPPER, NICKEL AND ZINC.

THE MANUFACTURER, APPLIED RESOURCES CORPORATION (ARC), INVESTIGATED THEIR DATA ON THIS SWITCH AND NOTED THAT THE CERAMIC HEADER ASSEMBLY WAS 100 PERCENT TESTED PIN TO PIN AND PIN TO CASE FOR DIELECTRIC WITHSTANDING VOLTAGE WITH NO FAILURES. THE SWITCH ALSO PASSED TESTS SIX TIMES FOR BOTH INSULATION RESISTANCE AND CIRCUIT RESISTANCE WITH NO FAILURES AS WELL AS FINAL ACCEPTANCE TESTS FOR DIELECTRIC STRENGTH AND INSULATION RESISTANCE WITH NO FAILURES OR LEAKAGE.

ARC IN CONSULTATION WITH THE CERAMIC HEADER MANUFACTURER CONCLUDED THAT THE GOLD-COLORED CONTAMINATION WAS EXCESS BRAZE MATERIAL. THE MOST PROBABLE CAUSE OF THIS FAILURE WAS THAT THE GOLD-COLORED CONTAMINATION IN COMBINATION WITH FLUX PROVIDED A CONDUCTIVE PATH FROM THE AFFECTED PIN TO THE CASE (NEITHER THE METALLIC CONTAMINATION NOR THE FLUX BY THEMSELVES WOULD HAVE CAUSED THE FAILURE).

10/29/90

APPENDIX A ITEM 5 CONT'D

ARC HAS ADDED A VISUAL INSPECTION POINT TO THEIR INCOMING INSPECTION PLAN TO ENSURE THAT EXCESS BRAZE MATERIAL IS NOT PRESENT. THIS FAILURE MECHANISM OF SHORT TO CASE (GROUND) FROM THIS CONTAMINATION SOURCE HAS BEEN REMOVED BECAUSE OF ADDED INSPECTION AND SCREENING AT THE NEXT ASSEMBLY ACCEPTANCE TEST LEVEL.

THERE ARE NO UNRESOLVED SWITCH FAILURES.

PREPARED BY:		**APPROVED BY:**
EPD&C DESIGN	D BUENDIA DB	DES
EPD&C RELIABILITY	T KIMURA TK	REL 5-8-91
QUALITY	W HIGGINS WH	QE 5-6-91
NASA QUALITY		QE 6/5/91
NASA RELIABILITY		REL 6/6/91
NASA Subsystem Manager		SSM 6/3/91