

INTRODUCTION TO APPENDIX C

- ITEM 1 - HYBRID RELAY MC455-0135
- ITEM 2 - GENERAL PURPOSE RELAY MC455-0129
- ITEM 3 - LATCHING RELAY MC455-0128
- ITEM 4 - RELAY MODULE MC455-0131
- ITEM 5 - GENERAL PURPOSE CONTACTOR MC455-0134
- ITEM 6 - POWER CONTACTOR MC455-0126

THE FOLLOWING TABLE LISTS FAILURE MODES AND CAUSES WHICH WERE CONSIDERED IN DERIVING THE FAILURE MODES AND EFFECTS ANALYSIS (PARA 9) FOR THE ITEMS LISTED ABOVE:

FAILURE MODE / Failure Cause	HYBRID RELAY	GEN PURP RELAY	LATCHING RELAY	RELAY MODULE	GEN PURP CONTACTOR	POWER CONTACTOR
OPEN, FAILS TO CONTACT, INADEQUATELY OFFERS, FAILS TO TRANSFER (a) Piece Part Failure (b) Contamination (c) Vibration (d) Mechanical Shock (e) Processing Anomaly (f) Thermal Stress	X X X X X X	X X X X X X	X X X X X X	X X X X X X	X X X X X	X X X X X
CLOSED, FAILS TO OPEN, PREMATURELY CLOSSES, SHORTS CONTACT-TO-CONTACT (a) Piece Part Failure (b) Contamination (c) Vibration (d) Mechanical Shock (e) Processing Anomaly (f) Thermal Stress	X X X X X X	X X X X X X	X X X X X X	X X X X X X	X X X X	X X X X X
SHORT TO STRUCTURE (GROUND) (a) Piece Part Failure (c) Vibration (d) Mechanical Shock (e) Processing Anomaly	X X X X	X X X X	X X X X	X X X X	X X X X	
SHORT POLE-TO-POLE (a) Piece Part Failure (c) Vibration (d) Mechanical Shock (e) Processing Anomaly	X X X X	X X X X	X X X X	X X X X		

11/03/87

APPENDIX C ITEM 1 - HYBRID RELAY (12 AMP)
 MC455-0135-0001 & -0002

DISPOSITION & RATIONALE

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

(A) DESIGN

A FOUR POLE DOUBLE THROW RELAY WITH ATTACHED HYBRID MODULE HOUSED WITHIN A HERMETICALLY-SEALED, STEEL CASE. THE HYBRID MODULE IS HERMETICALLY-SEALED PRIOR TO ATTACHMENT TO THE RELAY SUB ASSEMBLY. THE RELAY CONTACTS ARE SILVER ALLOY DESIGNED TO THE REQUIREMENTS OF MIL-R-6106.

DESIGN EVOLUTION

BASIC RELAY USED ON PRIOR PROGRAMS. THE -0001 CONFIGURATION (USED ON THE OV-102 ORIGINAL NEXT ASSEMBLY BUILD) WAS IDENTIFIED AS HAVING A POSSIBLE MANUFACTURING DEFECT WITHIN THE HYBRID DRIVER. THE PROBLEM WAS DUE TO AN INTERFERENCE FIT BETWEEN THE DRIVER CASE COVER AND HYBRID CIRCUIT SUBSTRATE WHICH CAUSED AN INTERMITTENT OR OPEN CIRCUIT OF THE HYBRID. SCREEN TESTING PERFORMED AT LINE REPLACEABLE UNIT (LRU) LEVEL (NEXT ASSEMBLY) HAS PROVEN TO BE A SATISFACTORY SCREEN TO DETECT THIS DEFECT. ONLY TWO FIELD FAILURES OF THIS TYPE HAS BEEN DETECTED (REF CAR'S AC9649 AND 03F044) SUBSEQUENT TO INVOKING THIS SCREEN TEST. THE MANUFACTURING DEFECT WAS ELIMINATED IN THE -0002 DESIGN.

(B) TEST

QUALIFICATION/CERTIFICATION

QUALIFICATION/CERTIFICATION TEST AND ANALYSIS COMPLETE.
 CERTIFICATION TEST INCLUDE:

TEST	CAUSE CONTROL					
	a	b	c	d*	e	f
ACCEPTANCE	X					
FUNCTIONAL	X	X			X	
VIBRATION (0.15 g ² /HZ)	X		X			
THERMAL/VACUUM (ROOM AMBIENT TO -65 TO +160 TO -65 °F FOR 5 CYCLES TOTAL AT 300K FOOT PRESSURE)	X				X	X
TRANSIENT SURGE (50 VDC) AND SPIKES (56 VDC)					X	

* MIL-R-6106 SHOCK TEST (200 G'S)

11/03/87

APPENDIX C ITEM 1 CONT'D

ACCEPTANCE AND SCREENING

ALL RELAYS ARE SUBJECTED TO 100% ACCEPTANCE TESTING WHICH INCLUDE PERFORMANCE AND SCREENING:

TEST	CAUSE CONTROL					
	a	b	c	d	e	f
PRECAP VISUAL		X			X	
VISUAL EXAMINATION		X			X	
RUN-IN (1000 CYCLES)	X				X	
VIBRATION (0.04 g ² /HZ)	X		X		X	
THERMAL AND LOGIC TEST (AT -45 AND 140 °F)	X				X	X
PIND		X			X	
LEAKAGE (FINE < 1X10 ⁻⁸ SCC/SEC AND GROSS < 1X10 ⁻⁶ SCC/SEC)		X			X	
DIELECTRIC STRENGTH (DWV AT 1250 Vrms)		X			X	
INSULATION RESISTANCE (IR AT 500 VDC)		X			X	
CONTACT VOLTAGE DROP	X				X	
OPERATING CHARACTERISTICS	X				X	

IN ADDITION ALL HYBRID CIRCUITRY IS 100% SCREENED TO MIL-STD-883 AS FOLLOWS PRIOR TO ASSEMBLY WITHIN THE BASIC RELAY:

TEST	CAUSE CONTROL					
	a	b	c	d	e	f
VISUAL					X	
PIND TESTS		X				
STABILIZATION (125 °C FOR 48 HRS)	X				X	X
TEMPERATURE CYCLE (-55 TO 125 °C, 10 CYCLES)	X				X	X
BURN-IN (160 HZ AT 125 °C)	X				X	
ACCELERATION (5000 G'S)	X				X	
LEAK		X			X	
INTERIM ELECTRICAL PARAMETERS	X				X	
FINAL VISUAL EXAMINATION					X	

11/03/87

APPENDIX C ITEM 1 CONT'D

ACCEPTANCE TEST AT THE NEXT ASSEMBLY:

TEST	CAUSE CONTROL					
	a	b	c	d	e	f
FUNCTIONAL	X				X	
CONTINUITY	X	X			X	
INSULATION RESISTANCE		X			X	
VIBRATION TEST (0.04 g ² /HZ)	X		X		X	

(C) INSPECTION

RECEIVING INSPECTION (FAILURE CAUSE a,b)

TEST REPORTS AND RECORDS ARE MAINTAINED CERTIFYING MATERIALS AND PHYSICAL PROPERTIES (RAW MATERIAL, PLATING, BRAZING, AND COATING). VERIFIES OPERATIONS (BRAZING, WELDING, AND PLATING) PERFORMED ON PROCURED ITEMS FROM SUBCONTRACTORS.

CONTAMINATION CONTROL (FAILURE CAUSE b)

PARTS ARE ULTRASONICALLY CLEANED PRIOR TO AND AFTER RELAY HEADER ASSEMBLY AND VERIFIED BY INSPECTION. HERMETIC SEALING OF COMPONENTS AND ASSEMBLY IS VERIFIED BY INSPECTION AND TEST.

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

SOLDERING WITHIN HYBRID IS VERIFIED BY INSPECTION. RELAY HEADER BUILD UP IS VERIFIED BY INSPECTION. HYBRID AND HEADER ASSEMBLY PRECAP VISUAL INSPECTION VERIFIED AT 10X MAGNIFICATION.

CRITICAL PROCESSES (FAILURE CAUSE a,b,e)

ALL CRITICAL PROCESSES INCLUDING SOLDERING, WELDING, HYBRID COMPONENT ATTACHMENT, AND WIRE BONDING, ARE MONITORED AND VERIFIED BY INSPECTION.

TESTING (FAILURE CAUSE a,b,c,e,f)

ACCEPTANCE TESTING IS OBSERVED AND VERIFIED BY QUALITY CONTROL (QC), INCLUDING VIBRATION, THERMAL AND PIND.

11/03/87

APPENDIX C ITEM 1 CONT'D

HANDLING/PACKAGING (FAILURE CAUSE c,d)

HARDWARE IS ISOLATED FROM OTHER CUSTOMER'S PARTS AND IS CONTROLLED BY SPECIAL CONTAINERS AND SPECIALLY IDENTIFIED (COLOR) WORK TRAVELERS. PARTS PROTECTED AND CONTROLLED DURING MANUFACTURING. IN-PROCESS OPERATIONS TO PRECLUDE ANY MISHANDLING. PARTS PACKAGED TO APPLICABLE REQUIREMENTS AS VERIFIED BY INSPECTION.

(D) FAILURE HISTORY

NEXT ASSEMBLY FABRICATION AND ACCEPTANCE FAILURES FOR -0001:

FAILURE MODE: OPEN/FAILS TO TRANSFER FROM UNENERGIZED POSITION,
FAILED TO RELEASE VIA INHIBIT

CAR'S AB0937 (PRIME)

DURING THE NEXT ASSEMBLY VERIFICATION AND ACCEPTANCE TESTS, SEVENTEEN FAILURES WERE EXPERIENCED WHERE A HYBRID RELAY FAILED TO TRANSFER TO THE ENERGIZED POSITION (CONTROL SIGNAL APPLIED) OR FAILED TO RELEASE FROM ENERGIZED POSITION WITH THE INHIBIT SIGNAL APPLIED. THESE FAILURES WERE ISOLATED TO A CRACK IN THE SOLDER JOINT BETWEEN EITHER PIN 4 (CONTROL SIGNAL) OR PIN 5 (INHIBIT SIGNAL) AND THE PRINTED CIRCUIT BOARD OF THE HYBRID DRIVER MODULE. THIS WAS CAUSED BY AN INTERFERENCE FIT OF THE HYBRID DRIVER MODULE COVER AND PRINTED CIRCUIT BOARD. THIS CONDITION WAS CORRECTED BY A DESIGN CHANGE OF THE HYBRID DRIVER MODULE WHICH RESULTED IN THE -0002 HYBRID RELAY CONFIGURATION.

THE -0001 HYBRID RELAY CONFIGURATION PRESENTLY DELIVERED WERE CONSIDERED SATISFACTORY FOR THEIR INTENDED USAGE. THIS WAS BASED UPON THE FACT THAT THE NEXT ASSEMBLY ACCEPTANCE TEST SERVED AS AN EFFECTIVE SCREEN AND ON THE CRITICALITY OF THE RELAY APPLICATION. THERE HAVE BEEN TWO ESCAPES, REFERENCE CAR'S AC9649 AND 03F044; CAR AC9649 WAS EXPERIENCED ON OV-099 AT KSC IN 1982 AND 03F044 WAS EXPERIENCED ON OV-102 DURING THE STS 3 MISSION IN 1981.

FAILURE MODE: OPEN, CLOSED

CAR'S AB0075, AB0447, AB3316, AB5628, AB6844, AB8942, AB9603 AND AC1591

DURING THE NEXT ASSEMBLY VERIFICATION AND ACCEPTANCE TESTS, FIVE FAILURES WERE EXPERIENCED WHERE THE RELAY FAILED TO OPERATE PROPERLY: FAILED OPEN, FAILED CLOSED OR EXHIBITED INTERMITTENT OPERATION. THREE OTHER SIMILAR FAILURES WERE EXPERIENCED IN THE FIELD; ONE IN OV-102, ONE IN SAIL AND ONE AT WHITE SANDS TEST FACILITY.

11/03/87

APPENDIX C ITEM 1 CONT'D

THESE FAILURES WERE ISOLATED TO PARTICLE CONTAMINATION, PRIMARILY WELD EXPULSION, HOWEVER, THERE WERE TWO NON - METALLIC CONTAMINANTS. THE SUPPLIER INITIATED IMPROVED CLEANLINESS CONTROLS OF THE ASSEMBLY AREA (CREATED A CLASS 100 CONTAMINATION FREE AREA), INSTALLED USAGE OF A GLOVE BOX CHAMBER FOR THE EVACUATION FOR FINAL SEAL CLOSURE PROCESS AND IMPROVED THE ULTRASONIC CLEANING EQUIPMENT. THESE STEPS WERE INITIATED IN NOVEMBER OF 1977. THE SUPPLIER ALSO INCREASED THE MAGNIFICATION OF THE VISUAL INSPECTION.

THE -0001 HYBRID RELAY CONFIGURATIONS PRESENTLY DELIVERED WERE CONSIDERED SATISFACTORY FOR THEIR INTENDED USAGE. THIS WAS BASED UPON THE FACT THAT THE NEXT ASSEMBLY ACCEPTANCE SERVED AS AN EFFECTIVE SCREEN. THERE WAS ONLY ONE TRUE ESCAPE, CAR AB0447 (OV-102). THE NEXT ASSEMBLIES FOR SAIL AND THE WHITE SANDS TEST FACILITY WERE NOT SUBJECTED TO ACCEPTANCE VIBRATION AS THEY WERE NONFLIGHT ASSEMBLIES.

FAILURE MODE: SHORT-TO-GROUND

CAR'S AB1130 AND AB1453

DURING THE NEXT ASSEMBLY ACCEPTANCE TESTS, TWO SHORT-TO-GROUND FAILURES WERE EXPERIENCED WHICH WERE ISOLATED TO THE HYBRID RELAYS. ANALYSIS REVEALED METALLIC PARTICLE CONTAMINATION. REFER TO PRECEDING PARAGRAPH FOR ACTION TAKEN.

FAILURE MODE: OPEN/FAILS TO TRANSFER

CAR AB3432

DURING THE QUALIFICATION THERMAL TEST OF MID MOTOR CONTROL ASSEMBLY -#3, A HYBRID RELAY FAILED TO TRANSFER TO ENERGIZED POSITION. THE FAILURE WAS ISOLATED TO AN OPEN COIL CIRCUIT WIRE. THIS WAS CONSIDERED TO BE AN ISOLATED INSTANCE.

FAILURE MODE: OPEN

CAR'S AB3209 AND AB8448

TWO FAILURES WERE EXPERIENCED WHERE AN OPEN CIRCUIT OF ONE POLE WAS OBSERVED. ONE WAS EXPERIENCED DURING ACCEPTANCE OF THE NEXT ASSEMBLY AND ONE WAS EXPERIENCED IN ORBITER OV-102. THESE FAILURES WERE ISOLATED TO A BROKEN CONTACT WELD WITHIN THE HYBRID RELAY. THE SUPPLIER TIGHTENED THE SURVEILLANCE ON THEIR WELDING SCHEDULES. THEY ALSO INCREASED THE PERIODIC CONTACT TO TERMINAL WELD TORQUE CRITERIA FROM 5 INCH OUNCES TO 7. RELAYS DELIVERED WERE CONSIDERED SATISFACTORY FOR THEIR INTENDED USAGE BASED UPON AVAILABLE HISTORY, THE ADDITIONAL TESTING AT THE NEXT ASSEMBLY LEVEL AND THE CRITICALITY.

11/03/87

APPENDIX C ITEM 1 CONT'D

FAILURE MODE: CLOSED/REMAINED IN ENERGIZED POSITION

CAR'S AB1139 AND AB7461

DURING SUBSYSTEM CHECKOUT TESTS, ONE IN OV-099 AND ONE IN SAIL, TWO FAILURES WERE EXPERIENCED WHERE THE HYBRID RELAY FAILED TO RELEASE OR TRANSFER FROM THE ENERGIZED POSITION. THESE FAILURES WERE ISOLATED TO FAILED COMPONENTS WITHIN THE HYBRID DRIVER MODULE. INVESTIGATION CONCLUDED THAT THE WELDING SEQUENCE PROBABLY SUBJECTED THE HYBRID DRIVER MODULE TO EXCESSIVE VOLTAGE TRANSIENT DURING A DEMAGNIFICATION PROCESS. THE WELDING SEQUENCE WAS REVISED TO PRECLUDE THE POSSIBLE VOLTAGE OVERSTRESS. THIS ACTION WAS IMPLEMENTED IN MARCH OF 1979.

RELAYS DELIVERED WERE CONSIDERED SATISFACTORY FOR THEIR INTENDED USAGE BASED UPON AVAILABLE HISTORY (LIKELIHOOD OF INDUCED DAMAGE), SUBSEQUENT TESTING PRIOR TO ACTUAL LAUNCH AND CRITICALITY.

FAILURE MODE: CONTACT CHATTER

CAR'S AB1650 AND AB6297

DURING THE ACCEPTANCE VIBRATION TEST OF THE NEXT ASSEMBLY, TWO HYBRID RELAYS EXHIBITED CONTACT CHATTER (MOMENTARY OPENINGS OR INCREASE IN CONTACT RESISTANCE FOR GREATER THAN TEN MICROSECONDS). INVESTIGATION CONCLUDED THAT THE SPRING FORCE OF THE SPRING BETWEEN COMMON TERMINAL AND MOVEABLE CONTACTS WAS ON THE LOW SIDE OF THE TOLERANCE LEVEL. THIS CONDITION COMBINED WITH THE MINOR VIBRATION AMPLIFICATION FACTOR OF THE NEXT ASSEMBLY RESULTED IN THE EXPERIENCED CONTACT CHATTER. THIS CONDITION IS CONSIDERED SCREENABLE AT THE NEXT ASSEMBLY LEVEL, THUS NO SPECIFIC ACTION WAS INITIATED.

NEXT ASSEMBLY FABRICATION AND ACCEPTANCE FAILURES FOR THE -0002

FAILURE MODE: CLOSED/FAILED TO RELEASE FROM ENERGIZED POSITION

CAR'S AC2109, AC8193, 24F015 AND A00015 (PRIME)

FOUR FAILURES HAVE BEEN EXPERIENCED WHERE THE HYBRID RELAY FAILED TO RELEASE FROM THE ENERGIZED POSITION OR REMAINED CLOSED. ONE FAILURE WAS EXPERIENCED DURING ORBITER OV-099 SUBSYSTEM CHECKOUT IN PALMDALE, TWO WERE EXPERIENCED DURING ORBITER SYSTEMS CHECKOUT TESTS AT KSC AND THE FOURTH WAS EXPERIENCED DURING ORBITER OV-099 51-B MISSION.

11/03/87

APPENDIX C ITEM 1 CONT'D

THESE FAILURES WERE ALL ATTRIBUTED TO THE HYBRID DRIVER MODULE. THE ANALYSIS REVEALED THAT THE EMITTER BALL BOND LEADS ON ONE OF THE TRANSISTOR CHIPS WAS OVER THE COLLECTOR GUARD RING. THIS RESULTED IN SIGNIFICANT CURRENT LEAKAGE KEEPING THE OUTPUT TRANSISTOR PARTIALLY TURNED "ON" THEREBY PROVIDING ENOUGH VOLTAGE APPLIED TO THE RELAY COIL SO AS TO KEEP IT IN THE ENERGIZED POSITION.

THE SUPPLIER HAD RECOGNIZED THIS PROBLEM EARLIER AND HAD REVISED THE BONDING REQUIREMENTS TO NOT ALLOW ANY OF THE BALL BOND TO EXTEND OVER ANY ADJACENT METAL. THIS ACTION WAS IMPLEMENTED BEGINNING WITH RELAYS IN LOT NUMBER 8 (LOOS IN THE SERIAL NUMBER). LOTS 3 AND 4 WERE SUBJECTED TO A SPECIAL THERMAL SCREENING TEST. THE MAJORITY OF LOT 3 WAS UTILIZED ON OV-099. LOTS 4 AND 5 WERE DELIVERED TO GODDARD FOR TEST. LOTS 6 AND 7 ARE INSTALLED IN FORWARD AND MID MOTOR CONTROL ASSEMBLIES MANUFACTURED FOR OV-103. THEY WERE CONSIDERED SATISFACTORY FOR THEIR INTENDED USAGE BASED UPON THE ACCUMULATED OPERATING TIME AND CRITICALITY.

FAILURE MODE: CLOSED/FAILED TO RELEASE FROM ENERGIZED POSITION,
OPEN (BOTH POSITIONS)

CAR'S AC7102, AC7227 AND 13F013

THREE FAILURES HAVE BEEN EXPERIENCED WHERE THE HYBRID RELAY FAILED TO RETURN TO THE UNENERGIZED POSITION; ONE REMAINED IN THE ENERGIZED POSITION AND TWO HUNG-UP BETWEEN POSITIONS (OPEN OF BOTH POSITIONS). TWO OF THESE FAILURES WERE EXPERIENCED DURING TESTING OF THE NEXT ASSEMBLY AND ONE WAS EXPERIENCED DURING OV-099 41-C MISSION.

THESE FAILURES WERE ISOLATED PARTICLES; TWO METALLIC AND ONE NON-METALLIC (THE INFLIGHT FAILURE). NO SPECIFIC CORRECTIVE ACTION WAS TAKEN. CLEANLINESS CONTROL PROCEDURES IN PLACE ARE CONSIDERED GOOD. HYBRID RELAYS DELIVERED ARE CONSIDERED SATISFACTORY FOR THEIR INTENDED USAGE. THIS IS BASED UPON THE FACT THAT THE ACCEPTANCE TESTS, BOTH AT THE RELAY LEVEL AND THE NEXT ASSEMBLY LEVEL ARE CONSIDERED GOOD SCREENS. ONLY ONE RELAY HAS ESCAPED THESE TESTS. FURTHER, THERE ARE NO SINGLE HYBRID RELAY APPLICATIONS THAT WOULD RESULT IN LOSS OF AN ORBITER.

FAILURE MODE: POLE-TO-POLE SHORT

CAR AC7833

DURING THE NEXT ASSEMBLY ACCEPTANCE TEST AN ISOLATION FAILURE WAS EXPERIENCED WHICH WAS ISOLATED TO A POLE-TO-POLE SHORT WITHIN A HYBRID RELAY (B1 TO C1).

11/02/87 (8:24pm)

APPENDIX C ITEM 1 CONT'D

THIS FAILURE WAS ISOLATED TO OUT OF POSITION CONTACT SPRINGS. INVESTIGATION REVEALED THAT THE RELAY WAS ADJUSTED BY AN INEXPERIENCED OPERATOR AND IT WAS ASSUMED THAT THE SPRINGS WERE NOT PROPERLY INSTALLED. THIS WAS CONSIDERED TO BE AN ISOLATED WORKMANSHIP ESCAPE. THE ACCEPTANCE TESTS AT THE RELAY AND NEXT ASSEMBLY LEVEL SERVE AS SCREENS FOR FAILURES OF THIS NATURE.

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