

SHUTTLE CRITICAL ITEMS LIST - ORBITER

SYSTEM : ELECT POWER DIST & CONT FMEA NO 05-6 -2015 -4 REV:05/16/88

ASSEMBLY : AVIONICS BAY 1,2,3
 P/N RI : MC495-0012-0004
 P/N VENDOR:
 QUANTITY : 9
 : NINE REQUIRED
 : SETS OF THREE EACH

ABORT: RTLS
 CRIT.FUNC: 1R
 CRIT. HDW: 2

VEHICLE: 102 103 104
 EFFECTIVITY: X X X
 PHASE(S): PL LO X OO X DO X LS

PREPARED BY: REDUNDANCY SCREEN: A-PASS B-PASS C-PASS
 DES R PHILLIPS APPROVED BY: APPROVED BY (NASA):
 REL M HOVE DES *[Signature]* SSM *[Signature]*
 QE J COURSEN REL *[Signature]* 7-22-88 REL *[Signature]* 7-24-88
 QE *[Signature]* 7-25-88 QE *[Signature]* 7-25-88

ITEM:
 INVERTER - SINGLE PHASE, 400HZ, 117 VAC

FUNCTION:
 CONVERTS NOMINAL 28 VDC POWER TO 400 HZ, 117 VAC DURING ALL MISSION PHASES. THREE SINGLE-PHASE INVERTERS ARE INTERCONNECTED WITH FREQUENCY SYNC AND PHASE DISPLACEMENT TO SUPPLY A THREE-PHASE BUS. 81V76A1, A2, A3; 82V76A4, A5, A6; 83V76A7, A8, A9

FAILURE MODE:
 PHASE IDENTITY CHANGE, SHORTED OR OPEN ZENER DIODE (PHASE REF CIRCUIT)

USE(S):
 PIECE PART FAILURE, CONTAMINATION, VIBRATION, MECHANICAL SHOCK, PROCESSING ANOMALY, THERMAL STRESS

EFFECT(S) ON:
 (A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE (E) FUNCTIONAL CRITICALITY EFFECT:

- (A) THE ARRAY'S NORMAL PHASE RELATIONSHIP IS DISRUPTED.
- (B) DUE TO THE RANDOM PHASE RELATIONSHIP, ALL THREE PHASE MOTORS, INCLUDING THE FUEL CELL COOLANT PUMP, POWERED FROM THE AFFECTED BUS WILL STALL. THE FUEL CELL PUMPS MUST BE QUICKLY RESTARTED OR POWER REMOVED AND THE FUEL CELL SHUT DOWN WITHIN 6 MINUTES. LOSS OF REDUNDANCY-FAILED INVERTER AND POSSIBLE DAMAGE TO CONNECTED THREE PHASE MOTORS. ALL MOTORS EXCEPT THE CABIN FAN CAN BE RESTARTED ON TWO PHASES AFTER ISOLATING THE FAILED INVERTER PHASE FROM THE AC BUS. LOSS OF MAIN ENGINE CONTROLLER REDUNDANCY.
- (C) POSSIBLE EARLY MISSION TERMINATION (MINIMUM DURATION FLIGHT) IF ONE OF THE TWO CABIN FANS IS POWERED FROM THE AFFECTED 3 PHASE BUS AND CANNOT BE STARTED ON 2 PHASES.

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EFFECT(S) ON (CONTINUED):

(A) SUBSYSTEM (B) INTERFACES (C) MISSION (D) CREW/VEHICLE (E) FUNCTIONAL
CRITICALITY EFFECT:

(D) NO EFFECT FIRST FAILURE. ALSO, CRIT 1 FOR RTLS ABORT. LOSS OF ANY AC BUS PRIOR TO OMS/RCS INTERCONNECT LEAVES ONE AFT RCS TANK ISOLATION VALVE OPEN DURING OMS PROPELLANT DUMP. SINCE DUMPING OMS PROPELLANTS THROUGH RCS JETS NORMALLY SUPPLIED FROM THE AFFECTED OPEN TANK ISOLATION VALVE WOULD RESULT IN DUMPING RCS PROPELLANTS ALONG WITH OMS PROPELLANTS, AND MANUALLY CLOSING THE ASSOCIATED MANIFOLD ISOLATION VALVES AFTER THE OMS PROPELLANT DUMP BEGINS WOULD RENDER THOSE RCS MANIFOLDS UNUSABLE FOR ET SEPARATION, "SMART INTERCONNECT" SOFTWARE (CR'S 59126H AND 89210B, EFFECTIVITY 01-8B, STS-26) PROTECTS AGAINST LOSS OF AFT RCS MANIFOLDS BY Deselecting the affected RCS jets for the OMS propellant dump. Disabling half of the aft RCS jets for OMS propellant dump reduces the dump capability and may result in an incomplete OMS RTLS propellant dump with a possible violation of landing constraints for weight and/or center of gravity.

(E) POSSIBLE LOSS OF VEHICLE AND CREW WITH THE SECOND FAILURE (LOSS OF ANOTHER THREE PHASE AC ARRAY) DUE TO THE POSSIBLE LOSS OF BOTH CABIN FANS, ET UMBILICAL DOOR CLOSURE, PAYLOAD BAY DOOR CLOSURE, OR VENT DOOR OPERATION. ALSO SECOND FAILURE WILL RESULT IN LOSS OF ONE MAIN ENGINE DURING ASCENT AND A SECOND FUEL CELL COOLANT PUMP. THE FUEL CELL COOLANT PUMP MUST BE RESTORED TO NOMINAL OPERATION WITHIN SIX MINUTES OR THE FUEL CELL MUST BE SHUT DOWN.

DISPOSITION & RATIONALE:

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

(A, B, C, D) DISPOSITION AND RATIONALE

(A) DESIGN

CONFIGURATION DESCRIPTION

THE POWER STATIC INVERTER IS A SOLID STATE, MODULARIZED DESIGN ENCLOSED IN A NON-POTTED, VENTED HOUSING THAT MEETS ALL DESIGN REQUIREMENTS OF SPECIFICATION MC495-0012. IT IS AN ASSEMBLY OF STATIC COMPONENTS WITHOUT THEORETICAL WEAROUT. ALL ELECTRICAL AND ELECTRONIC COMPONENTS ARE SELECTED FROM OR IN ACCORDANCE WITH THE ORBITER PREFERRED PART LIST (CPPL) REQUIREMENTS AND THEIR APPLICATIONS WERE EVALUATED FOR COMPLIANCE WITH THE DERATING AND MORTALITY (OPPL) REQUIREMENTS.

FUNCTIONAL DESCRIPTION

THE POWER STATIC INVERTER IS COLD PLATE MOUNTED AND RECEIVES AN INPUT OF 28 VDC FROM A MAIN DC BUS AND CONVERTS THE OUTPUT POWER TO 117 VAC, 400 HZ SINGLE PHASE POWER SOURCE AT 750 VA. THREE INVERTERS ARE ELECTRICALLY INTERCONNECTED TO FORM A THREE PHASE AC BUS SET. NINE INVERTERS, IN GROUPS OF THREE (3 AC BUS SETS) FURNISH FULL AC POWER FOR EACH ORBITER. EACH INVERTER HAS INTERNAL CIRCUITRY FOR OVERLOAD DETECTION. THE INVERTER FUNCTIONAL PERFORMANCE MEETS THE REQUIREMENTS OF MC495-0012 SPECIFICATION.

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(A) DESIGN (CONTINUED)

DESIGN EVOLUTION

DURING THE SUPPLIER ACCEPTANCE TESTS ON THE MC495-0012-0001 INVERTERS, FAILURES OCCURRED WHICH WERE RELATED TO POOR WORKMANSHIP, DESIGN DEFICIENCIES, INADEQUATE MANUFACTURING PROCEDURES AND PROCESSES. ALL FAILURES HAD BEEN DETECTED BY THE SCREENING PROCEDURES OF THE ACCEPTANCE TESTS. A SHORT BETWEEN TWO SINGLE BOARDS WITHOUT PLATED-THROUGH HOLES ALLOWED A SOLDER BRIDGE TO SHORT THE TWO BOARDS ON THE -0001 CONFIGURATION. THIS FAILURE INITIATED A DESIGN CHANGE AND THE MC495-0012-0003 CONFIGURATION WAS GENERATED (THE -0002 PART NUMBER WAS ESTABLISHED BY THE PROCUREMENT SPECIFICATION AS PROTOTYPE HARDWARE). THE -0003 IS IDENTICAL TO THE -0001 EXCEPT IT CONTAINS TRUE MULTI-LAYER PRINTED CIRCUIT BOARD WITH PLATED-THROUGH HOLES WHICH PREVENTS SOLDER FROM BRIDGING THE CIRCUITS AND CAUSING SHORTS. THE -0003 CONFIGURATION WAS FLOWN ON THE OV-101 APPROACH AND LANDING TEST FLIGHTS.

QUALIFICATION TEST FAILURES -0003 HARDWARE RESULTED IN CORRECTIVE ACTION REQUIRING UPGRADING OF OBSOLETE CAPACITORS, INCORPORATING IMPROVED TIE DOWNS, LEAD STRESS RELIEF AND BONDING TECHNIQUES OF COMPONENTS TO THE CIRCUIT BOARDS TO PRECLUDE BROKEN WIRES AND LEADS, AND STRUCTURAL IMPROVEMENTS TO ELIMINATE VIBRATION AMPLIFICATION THAT WAS CAUSING COMPONENT LEAD FATIGUE FAILURES. MCR 3506 AUTHORIZED THESE CHANGES AND CREATED THE MC495-0012-0004 INVERTER, EFFECTIVE ON OV-102 AND SUBS.

(B) TEST

QUALIFICATION/CERTIFICATION

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

TEST	CAUSE CONTROL					
	a	b	c	d	e	f
ACCEPTANCE	X	X	X		X	X
BONDING RESISTANCE		X			X	
BENCH HANDLING SHOCK (4 DROPS/SIDE)				X		
DESIGN SHOCK (20G, 3 DROPS/AXIS)				X		
RANDOM VIBRATION (0.09 g ² /HZ, 48 MIN)	X		X		X	
QUAL/ACCEPTANCE (QAVT AT 0.067 g ² /HZ)	X		X		X	
ACCELERATION (5 g's, 5 MIN/AXIS)	X		X		X	
ACOUSTIC NOISE	X	X			X	

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(B) TEST (CONTINUED)

TEST	CAUSE CONTROL					
	a	b	c	d	e	f
HIGH TEMPERATURE (160 °F, 750VA, 0.7 PF lagging)					X	X
VOLTAGE AND FREQUENCY REGULATION WAVEFORM	X				X	
OUTPUT VOLTAGE MODULATION	X				X	
OUTPUT FREQUENCY MODULATION	X				X	
PHASE DISPLACEMENT ANGLE	X				X	
MOTOR START	X				X	
TRANSIENT VOLTAGE RECOVERY	X				X	
SINGLE-PHASE 1/2-WAVE LOAD CAPACITY	X				X	
PHASE UNBALANCE	X				X	
ELECTROMAGNETIC COMPATIBILITY	X				X	
LIGHTNING	X				X	
LIFE (4500 HOURS)	X				X	

ACCEPTANCE AND SCREENING

ALL PRODUCTION UNITS ARE SUBJECTED TO 100% ACCEPTANCE TESTING WHICH INCLUDE:

TEST	CAUSE CONTROL					
	a	b	c	d	e	f
VISUAL EXAMINATION	X	X			X	
FUNCTIONAL	X				X	
INSULATION RESISTANCE		X			X	
DIELECTRIC WITHSTANDING VOLTAGE		X			X	
PHASE ROTATION	X				X	
THERMAL						
VIBRATION	X		X		X	X

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(B) TEST (CONTINUED)

GROUND TURNAROUND TEST

PERFORM MANUAL AC BUS 1 (2,3) ACTIVATION/DEACTIVATION WITH FREQUENCY AND PHASE ANGLE VERIFICATION. MONITOR THE POWER "ON/OFF" SWITCH STIMULI COMMANDS, "ON/OFF" EVENT DISCRETE INDICATORS, SWITCH SCAN DISCRETE, AND PHASE A, B AND C VOLTAGES. TEST IS PERFORMED FOR ALL FLIGHTS.

(C) INSPECTION

RECEIVING INSPECTION (FAILURE CAUSE e)

ALL INCOMING PARTS AND MATERIALS RECEIVED THROUGH THE RECEIVING INSPECTION DEPARTMENT ARE SUBJECTED TO A VISUAL INSPECTION AND DIMENSIONAL EXAMINATIONS WHERE APPLICABLE. RECORDS OF THE INSPECTIONS ARE MAINTAINED. ALL CERTIFICATION RECORDS AND TEST REPORTS AS RECEIVED FROM THE SUB-TIER SUPPLIERS ARE REVIEWED AND MAINTAINED IN THE RECEIVING INSPECTION FILES FOR ONE YEAR. AT THE END OF THAT YEAR ALL RECORDS ARE PLACED IN THE RECORDS VAULT.

CONTAMINATION CONTROL (FAILURE CAUSE b)

ALL REQUIRED PROCEDURES AND SHOP PRACTICES FOR GENERAL HOUSEKEEPING AND CONTAMINATION CONTROL ARE AUDITED ON A PERIODIC BASIS.

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

DETAIL INSPECTION IS PERFORMED ON ALL ASSEMBLIES AND SUBASSEMBLIES PRIOR TO THE NEXT ASSEMBLY OPERATION. THIS DETAIL INSPECTION IS PERFORMED AS INDICATED ON INSPECTION CHECK SHEETS. RECORDS OF THIS DETAIL INSPECTION ARE MAINTAINED AT THE SUPPLIER.

CRITICAL PROCESSES (FAILURE CAUSE b,e)

ALL CRITICAL PROCESSES AND CERTIFICATIONS ARE MONITORED AND VERIFIED BY QUALITY CONTROL (QC). THE CRITICAL PROCESSES ARE SOLDERING, CRIMPING, CONFORMAL COATING AND ADHESIVE BONDING.

TESTING (FAILURE CAUSE c,e)

A DCAS QUALITY ASSURANCE REPRESENTATIVE IS PRESENT DURING ATP FINAL PERFORMANCE TESTS. ALL TEST RECORD SHEETS ARE REVIEWED BY THE SUPPLIER'S QC DEPARTMENT PRIOR TO FINAL ACCEPTANCE OF THE UNITS.

HANDLING/PACKAGING (FAILURE CAUSE c,d)

ALL IN-PROCESS AND FINAL OPERATIONS ARE VERIFIED BY QC FOR PART HANDLING AND PROTECTION. THE CORRECT METHODS OF PART HANDLING AND PROTECTION ARE OUTLINED IN THE SUPPLIER'S WORKMANSHIP STANDARDS. PACKAGING IS PER SUPPLIER PACKING PROCEDURE WHICH SPECIFIES PRESERVATION AND PACKAGING PER MIL-P-116. THE SELECTION OF SAMPLES AND THE PERFORMANCE OF INSPECTIONS AND TESTS BY THE INSPECTOR ARE IMPLEMENTED AND VERIFIED IN ACCORDANCE WITH DOCUMENTED QC INSTRUCTION.

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(D) FAILURE HISTORY

THERE HAVE BEEN NO FAILURES OF A FLIGHT CONFIGURATION POWER STATIC INVERTER THAT HAS RESULTED IN PHASE IDENTITY CHANGE.

MC495-0012-0003 CONFIGURATION

CAR A4581

DURING QUALIFICATION VIBRATION TEST, THE OUTPUT VOLTAGE WAS ERRATIC. THE FAILURE WAS CAUSED BY BROKEN COMPONENT LEADS. THIS CONDITION WAS THE RESULT OF INADEQUATE SECURING OF COMPONENTS TO THE PCB'S (WIRING). THE CORRECTIVE/REMEDIAL ACTION WAS TO BOND ALL COMPONENTS TO THE PCB'S. ALL BOARDS WERE TO BE COATED WITH SILICONE RUBBER. MCR 3506 AUTHORIZED CHANGES, UPGRADING THE -0003 TO THE -0004 CONFIGURATION (THE FINAL FLIGHT CONFIGURATION).

MC495-0012-0004 CONFIGURATION (FINAL FLIGHT CONFIGURATION)

CAR'S AB2946 AND AD2427

DURING OV-099 SYSTEMS CHECKOUT TESTS, AN INVERTER OUTPUT VOLTAGE WAS ERRATIC AND FINALLY DROPPED TO ZERO. THE FAILURE WAS ISOLATED TO A ZENER DIODE WITHIN THE INVERTER'S POWER SUPPLY. THE DIODE (JANTXV1N758A) FAILURE WAS ANALYZED BY ITS MANUFACTURER (CODI) AS A INTERNAL CRACK IN THE SILICON WHICH ACCOUNTS FOR ITS EXCESSIVE ELECTRICAL CURRENT LEAKAGE. THE EXACT CAUSE OF CRACK COULD NOT BE DETERMINED; THE MANUFACTURER IDENTIFIED THE MOST PROBABLE CAUSE AS A MECHANICAL STRESS CREATED BY A SLIGHT MISALIGNMENT WITH THE S-WHISKER, AGGRAVATED BY HANDLING AND PROPAGATED WITH TIME UNTIL THE LEAKAGE CURRENT LEVEL BECAME SUFFICIENT TO FAIL THE INVERTER. THE MANUFACTURER RECORDS THE FIRST FAILURE OF THIS NATURE ON THIS JANTXV DEVICE AS AN ISOLATED, NON-GENERIC PROBLEM. THIS IS SUPPORTED BY THE FACT THAT ALL INVERTERS DELIVERED HAVE ZENER DIODES FROM THE SAME LOT AND HAVE ACCUMULATED THOUSANDS OF COMPONENT HOURS WITH NO FURTHER ANOMALIES.

THE POWER STATIC INVERTERS ARE CONSIDERED SATISFACTORY FOR THEIR INTENDED USAGE, BACKED BY NUMEROUS HOURS OF SATISFACTORY OPERATION ACCUMULATED DURING SAIL AND JSC TESTING AS WELL AS ALL ORBITER FLIGHTS TO DATE.

(E) OPERATIONAL USE

FLIGHT CREW REQUIRED TO DISABLE AFFECTED INVERTER, AND RECONFIGURE LOADS. FUEL CELL PUMPS MUST BE RESTARTED, OR FUEL CELL SHUTDOWN.