

SHUTTLE CRITICAL ITEMS LIST - ORBITER

SUBSYSTEM :ELECT POWER DIST & CONT FMEA NO 05-6 -2015 -5 REV:05/16/88

ASSEMBLY :AVIONICS BAY 1,2,3 CRIT.FUNC: 1R  
 P/N RI :MC495-0012-0004 CRIT. HDW: 3  
 P/N VENDOR: VEHICLE 102 103 104  
 QUANTITY :9 EFFECTIVITY: X X X  
 :NINE REQUIRED PHASE(S): PL X LO X OO X DO X LS X  
 :SETS OF THREE EACH

REDUNDANCY SCREEN: A-FAIL B-FAIL C-PASS  
 PREPARED BY: APPROVED BY: APPROVED BY (NASA):  
 DES R PHILLIPS DES *[Signature]* SSM *[Signature]*  
 REL M HOVE REL *[Signature]* 7-23-88 REL *[Signature]*  
 QE J COURSEN QE *[Signature]* 7-25-88 QE *[Signature]*

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:  
 LOSS OF SYNC, LOSS OF FREQUENCY SYNCHRONIZATION FOR ONE PHASE

CAUSE(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) FIRST FAILURE - NO EFFECT. THE INVERTER'S FREQUENCY REFERENCE CIRCUITRY IS DESIGNED SUCH THAT WITH THE LOSS OF FREQUENCY REFERENCE SIGNAL TO OR FROM A SINGLE-PHASE INVERTER, THE THREE-PHASE ARRAY WILL CONTINUE TO OPERATE WITH THE PROPER FREQUENCY AND PHASE RELATIONSHIPS.

(B) POSSIBLE SLIGHT INCREASE IN HARMONIC DISTORTION AT THE OUTPUT OF THE THREE-PHASE ARRAY RESULTING IN SLIGHT OR NEGLIGIBLE INCREASED HEATING EFFECT IN MOTOR LOADS.

(C,D) FIRST FAILURE - NO EFFECT.

(E) POSSIBLE LOSS OF CREW/VEHICLE DUE TO LOSS OF POWER TO CRITICAL AC LOADS VIA THE FOLLOWING SCENARIO:

(1) LOSS OF FREQUENCY SYNCHRONIZATION TO OR FROM A SINGLE-PHASE INVERTER IN A THREE-PHASE ARRAY.

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EFFECT(S) ON (CONTINUED):

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

(2) LOSS OF FREQUENCY SYNCHRONIZATION TO OR FROM A SECOND PHASE IN THE SAME THREE-PHASE ARRAY RESULTING IN ONE PHASE OF THE ARRAY OPERATING AT A DIFFERENT FREQUENCY THAN THE OTHER TWO PHASES. RESULTS IN THREE-PHASE MOTORS CONNECTED TO THE ARRAY OPERATING AT OR NEAR STALL CONDITIONS WITH CONSEQUENT SEVERE HEATING IN THE MOTORS. THIS CONDITION IS CONSIDERED TO BE EQUIVALENT TO LOSS OF AN AC BUS.

(3) LOSS OF A SECOND AC BUS RESULTING IN LOSS OF CRITICAL AC LOADS SUCH AS CABIN FANS, ET UMBILICAL DOOR CLOSURE, PAYLOAD BAY DOOR CLOSURE OR VENT DOOR OPERATION. ALSO LOSS OF A SECOND AC BUS WILL RESULT IN THE LOSS OF ONE MAIN ENGINE DURING ASCENT AS WELL AS LOSS OF A SECOND FUEL CELL COOLANT PUMP. FUEL CELL COOLANT PUMPS MUST BE RESTORED TO NORMAL OPERATION WITHIN SIX MINUTES OR THE AFFECTED FUEL CELL MUST BE SHUT DOWN.

FAILS "A" AND "B" SCREENS BECAUSE THE FIRST FAILURE DOES NOT AFFECT NORMAL AC BUS OPERATION AND THUS CANNOT BE DETECTED DURING GROUND TURNAROUND OR IN FLIGHT.

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 (OPPL) 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 AND SENSORS FOR INTERNAL TEMPERATURE MEASUREMENTS. ITS 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.

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(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
<b>CAUSES</b>						
a Piece part failure				d Mechanical shock		
b Contamination				e Processing anomaly		
c Vibration				f Thermal stress		
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 <sup>2</sup> /HZ, 48 MIN)	X		X		X	
QUAL/ACCEPTANCE (QAVT AT 0.067 g <sup>2</sup> /HZ)	X		X		X	
ACCELERATION (5 g's, 5 MIN/AXIS)	X		X		X	
ACOUSTIC NOISE	X	X			X	
HIGH TEMPERATURE (160 °F, 750VA, 0.7 PF lagging)					X	X
VOLTAGE AND FREQUENCY REGULATION	X				X	
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	

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**(B) TEST (CONTINUED)**

**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					X	
VIBRATION	X		X		X	X

**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.

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(C) INSPECTION (CONT)

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.

(D) FAILURE HISTORY

THERE HAVE BEEN NO FAILURES OF A FLIGHT CONFIGURATION POWER STATIC INVERTER THAT HAS RESULTED IN LOSS OF FREQUENCY SYNCHRONIZATION.

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

NONE.

05-6-48