

FINAL REPORT
DESIGN AND MANUFACTURE
OF
STATIC INVERTER
FOR
BRAYTON POWER CONVERSION SYSTEM

by

G. Lachenmeier

Gulton Industries, Incorporated
Engineered Magnetics Division
13041 Cerise Avenue
Hawthorne, California
Under Subcontract with Pesco Products
Division of Borg-Warner Corporation

Prepared For
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

December 3, 1969
CONTRACT NAS3-10935

NASA Lewis Research Center
Cleveland, Ohio
Guy H. Ribble, Jr., Project Manager
Space Power Systems Division

FOREWORD

The work described in this report was performed at Gulton Industries, Inc., Engineered Magnetics Division, for the Borg-Warner Corporation, Pesco Products Division, as authorized by NASA Contract NAS3-10935. The Project Manager for Pesco Products Division was Mr. L. E. Gebacz. Mr. G. H. Ribble of the Space Power Systems Division, NASA-Lewis Research Center, was the NASA Project Manager with technical assistance from Mr. J. H. Shank.

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ABSTRACT

The Static Inverter converts and conditions available DC power to 400 Hz quasi-square wave power to drive the pump motor assembly in the coolant loop of the Brayton Power Conversion System. The Static Inverter has a tested efficiency of 94% and a calculated Mean Time Between Failure of 88511 hours.

The report contains a text of the theory of operation, electrical and mechanical design drawings, reliability calculations, parts selection, stress analysis, thermal calculations, and typical test results.

SUMMARY

The NASA Lewis Research Center is currently engaged in a Brayton space power technology program. The Brayton Power Conversion System (PCS) has applicability for solar, radioisotopes, and nuclear space power systems. The initial demonstration system has a net output power range of 2.25 to 10.5 kW at 1200 Hertz. The Brayton PCS is designed to operate unattended in space for five (5) years.

The Static Inverter Program was conducted at Gulton Industries, Inc., Engineered Magnetics Division, under a sub-contract for the Borg-Warner Corporation, Pesco Products Division. This program included the design, development, fabrication, testing, and delivery of seven Static Inverters.

A portion of the 1200 Hertz Brayton PCS electrical output is converted to DC power. The Static Inverter inverts and conditions this available DC power (50 to 60 VDC) to 400 Hertz quasi-square wave power to drive the pump motor assembly in the coolant loop of the Brayton PCS.

Judicious circuit design, including the Gulton patented "RIPPLE REGULATOR" enabled the Static Inverter to attain an efficiency of 94%. With the use of Ultra-High Reliability components, the calculated Mean Time Between Failure of the Static Inverter is 88511 hours.

This report contains a text of the theory of operation, electrical and mechanical design drawings, reliability calculations, parts selection, stress analysis, thermal calculations, and typical test results.

This program was conducted with a minimum of design, fabrication, and testing problems. The Static Inverter meets or exceeds all requirements of the Static Inverter Specification.

INTRODUCTION

The EMIU104D Static Inverter converts and conditions available DC power (50 to 60 VDC) to the specific requirements of the pump motor assembly for use in a Brayton Power Conversion System. There were no major problems encountered during the design, development, or fabrication phases of the program. Problems that did occur were overcome by accomplishing electrical or mechanical design changes to the unit.

During the preliminary design phase of the program, design and assembly details defining operating parameters and design envelope for Engineered Magnetics Model EMIU104D Static Inverter were accomplished, a satisfactory baseline was established, and preliminary schematic drawings of the Static Inverter were obtained. Engineered Magnetics Quality Program Plan and Reliability Program Plan for Static Inverter EMIU104D were written and submitted to Pesco Products.

The mechanical design of the Static Inverter was defined and sufficient work was accomplished to determine that no major problems existed in the areas of heat transfer, mounting position, or packaging of the Inverter. A preliminary reliability estimate was calculated for the component parts of the Static Inverter. The reliability estimate was revised and updated after finalization of the Inverter design was accomplished.

The Inverter mounting base is designed to interface with a separate coldplate. Inverter cooling is accomplished by heat conduction to the coldplate. The unit is conformal coated and the case is gasket sealed.

The final electrical design, list of materials, and mechanical configuration of the EMIU104D Static Inverter are presented in Appendix I.

Waveform photographs obtained during the performance tests conducted on the breadboard model of the Static Inverter and Acceptance Test Record Forms are presented in Appendix II.

FINAL DESIGN

The schematic, outline, and final assembly drawings of Engineered Magnetics Model EMIU104D Static Inverter are presented in Appendix I.

A. Electrical Design.

The Static Inverter operates with an input voltage of 50 to 60 VDC (56 VDC rated) and maintains a quasi-square wave, 400 Hz AC peak output voltage at a level two volts lower than the DC input voltage. The inverter circuits shown on Schematic Drawing 513634 consist of the following basic sections.

1. RFI Filter.

Capacitors C26 and C27, and chokes L1 and L3 are connected to form a low-pass filter in each DC input line. The common point of the capacitors is connected to system neutral to provide low RF impedance to system neutral.

2. Audio Filter.

The balanced low-pass audio filter circuit consists of coils A and B of choke L2, and capacitors C10A and C10B. The audio filter has a cut-off frequency of approximately 150 Hz and functions to reduce inverter induced noise on the DC bus and to reduce any ripples or modulations that may appear on the DC bus.

3. Low Level Series Regulator.

The voltage supplied to the oscillator is regulated by the low level series regulator which also functions as an overcurrent protection device.

The voltage regulation circuit consists of diodes CR6 and CR7, transistors Q10 through Q12, capacitors C9A

through C9D, and resistors R32 through R37 and R94. The regulation circuit functions as follows: Q11, the control or pass element, and Q10 are connected as a high gain Darlington amplifier. CR6 is a voltage reference diode to which current is supplied from the regulator output through R33, to form a very stable reference. Resistors R35 through R37 are connected as a resistance divider for sensing the regulator output voltage. Any error signal is applied to correction amplifier Q12 and compared to the voltage reference. The difference in the signals is amplified by Q12 and supplied to Q10. Output filter capacitors C9A through C9D are connected in a series-parallel combination for purposes of redundancy. Diode CR7 functions for overall temperature correction of the regulator. Resistors R89, R90, and R96 form a path for transistor leakage current. Drive power for Q11 is supplied through resistor R94. The Darlington circuit transistors Q10 and Q11 are protected from being overdriven by R32 which functions as a current limiting resistor.

The pulse turn on and turn off circuits are made up of transistors Q8 and Q9, transformers T1 and T2, diodes CR32 and CR33, resistors R23, R27, R28, R88, R90, R91 and R92, and capacitors C2, C3, C6, and C7. Initial conditions of applying the DC bus with no turn on pulse are as follows: Q9 is turned on through the R27 and C7 time constant. (R27 and C7 are faster operating than R28 and C6). With Q9 saturated or turned on, the common point of R28 and R91 is almost at ground thereby holding Q8 off and the voltage regulator off. When Q8 is off, a DC signal is applied to the ripple regulator through R97, holding this circuit off also.

When a turn on pulse is applied to the input winding

of transformer T2 (terminals 1 and 2) through DC blocking capacitor C3, the pulse is transformed to output winding terminals 3 and 4, rectified by CR33 and applied across R92. This voltage drives the emitter of Q9 more positive than its base, therefore turning Q9 off. As Q9 is going off, the common point of R28 and R91 is changing from ground to positive, turning on Q8 and the voltage regulator circuits. Q8 is now ready for the turn off pulse that is applied to winding 1 and 2 of T1, which reverses the turn on procedure.

If the AC output current increases to a level above a preset point (approximately 19 amperes RMS) for a period exceeding five seconds, a signal is applied through CR31 from the overcurrent circuit to R88 which turns off the regulator in the same manner that a signal to the input terminals of T1 turns off the regulator.

4. Ripple Regulator. (U.S. Pat. No. 3,368,139 assigned to Gulton Industries)

The ripple regulator is divided into four sub-circuits:

Pass element and drive circuits.

Filter section.

Voltage sense, reference and comparison.

Load current demand circuits.

The pass elements and drive circuits of the ripple regulator consists of Q1 through Q5, R1 through R4, R8, R9, R93, and R98. Q1 through Q3 form a compound Darlington amplifier with a forward bias supply from ϕA driver supplying +2.5 VDC between points Z and Z'. Q4 and Q5 form a Schmitt trigger. As the regulator output voltage increases above a preset point, Q5 is turned on thereby turning off transistors Q1 through Q4. As the output voltage decreases past the preset point, Q5 switches off allowing Q1 through Q4 to switch on. This regulator operates in a switching mode and by

careful selection of component parts high efficiency is obtained.

The filter section consists of L4, C8A, C8B, and CR1. When the voltage is low, Q1 is on passing current to charge L4. When the output voltage exceeds the preset point, Q1 switches off. L4 discharges its energy through the path of the load and CR1. When the voltage is reduced below the preset point, Q1 switches on therefore restarting the charge-discharge cycle.

The output voltage sense circuit consists of Q7, Q52 CR5, R22, R24 through R26, and R29 through R31. This circuit forms a differential amplifier. Q7, CR5, R22, and R25 form an emitter follower that holds a constant voltage across R25. This voltage is equal to Zener diode CR5 voltage less V_{BE} of Q7. R29A, R29B, R30 form a resistance divider that senses the output voltage. As this voltage increases past R25 voltage, Q52 is driven further into saturation thereby supplying drive to turn Q5 on and Q1 through Q4 off. When the input voltage is reduced below R25 voltage, Q52 is driven further out of saturation and reverses the mode of operation. R24 and R25 are current limiting resistors. R31 is a set-in-test resistor and used for initial factory calibration of the regulator.

The load current demand circuit is made up of the following components: Q6, Q51, CR3, CR4, C4, C5, C32, R7, and R12 through R21. Q6 and Q51 form a differential amplifier. As the load current that passes through R7 increases, there is also a voltage increase across R7. This voltage is applied to the base of Q51 through the parallel combination of R15 and R16. (R16 is a set-in-test resistor that is set only during initial calibration). This voltage signal then biases Q51 off thereby reducing

the voltage across the common emitter resistor R19 as the base of Q6 is held at a fixed point by Zener diode CR4 and voltage divider R13 and R20. This reduction in emitter voltage biases Q6 further on and results in more collector current flow, which in turn increases the voltage drop across R18 and R21. R21 is connected in series with Zener diode reference CR5 in the voltage sense and control circuit. The increased voltage drop forces the voltage regulator to regulate at a higher output voltage...normally 40 volts at running load to 45 volts at starting load. The increased regulator voltage goes to the driver stages where it is supplied as higher base drive power for the output stages during the period that high output current is required. CR3 is used for temperature compensation. R12 and R17 are current limiting resistors. C4, C5, and C32 function as AC bypass capacitors.

5. Oscillator.

The oscillator section consists of the ØA, ØB, and ØC stages. The basic generation of the 400 Hz frequency is accomplished in the ØA oscillator. The ØA oscillator stage is made up of T3, Q13, Q14, C12 through C14, CR8, CR9, R38, R40, and L5.

L5 is a precision inductor and is combined with C14, a stable polycarbonate capacitor, to form a series resonant circuit. The oscillations started at turn-on by R38, C13, R40 and C12, are amplified by transistors Q13 and Q14, and sustained by regenerative feedback through windings 4 and 5 of transformer T3.

Diodes CR8 and CR9 provide reverse bias to hold the non-conducting transistor off while the other transistor is on during the half cycle. As an example, assume that transistor Q13 is turned on. Current flowing in the

series resonant circuit provides base drive through Q13 emitter-base diode and through CR9 in a forward direction. The voltage drop across CR9 is approximately 0.7 volt and is of such a polarity as to hold Q14 off. The diode voltage drop will maintain Q14 at the off condition until the resonant circuit current reverses direction. At this time, Q14 will start to conduct and the polarity across CR8 will hold Q13 in the nonconducting state. T3 windings 6-7 and 8-9 supply base drive for the ØA driver stage. Winding 10-11 supplies a synchronizing signal to ØC oscillator stage. Windings 12-13-14 and diodes CR10, CR11, and C16 form a full wave DC rectifier circuit which supplies a bias voltage to the overcurrent time protection circuit. Winding 15 and 16 supplies the 400 Hz squarewave AC instrumentation frequency signal.

Since the circuits for ØB and ØC oscillators are identical, only one will be described. ØC is synchronized to ØA; ØB is synchronized to ØC.

The ØC oscillator is a free-running, magnetic multivibrator that is synchronized to the ØA oscillator.

Transformer T5 windings 1-2-3 are the primary for ØC. Windings 1 and 3 are connected to individual transistor collectors. The regulated DC power is supplied between winding 2 and the common transistor emitters. Initial oscillation is started by a bias resistor (R50) connected from transistor Q21 collector to the base of transistor Q22. Once oscillation is started it is self-driven or regenerative by transformer windings 4-5-6. In the basic multivibrator, the transformer core must be saturated in order to switch conduction to the second transistor. The ØC oscillator uses the synchronizing winding, T3-10 and 11, and saturable reactor L6 to switch conduction prior to saturation of the

core, thus controlling the oscillator frequency. The saturable reactor reaches saturation after a time equivalent to 120° of the 400 Hz signal. The applied voltage then appears across the base drive resistors in the proper polarity to switch conduction to the second transistor. On the second half of the 400 Hz signal from the synchronizing winding, the saturable reactor is forced to the other side of its hysteresis curve towards saturation in the reverse direction. After a time equivalent to 120° the reactor reaches saturation and the signal across the base drive resistors switches conduction from the second transistor back to the first transistor. In this manner, ϕ_C oscillator is slaved to the ϕ_A oscillator and delayed 240° with respect to it.

6. Driver Section.

Since all three phases of the driver section are identical, only one phase will be described. The ϕ_A driver consists of T6, Q15, Q16, R41, and R42. These components are connected to form a push-pull power amplifier. The regulated DC voltage is supplied between T6-2 and the common emitter point. With no drive signal from ϕ_A oscillator, Q15 or Q16 will not switch and no voltage can be transformed to the T6 secondary windings 4 through 19.

When windings T3-6 and 8 are positive to T3-7 and 9, Q15 will conduct. Base drive current is limited by R41 for Q15 and by R42 for Q16. During the half cycle that Q15 is conducting, Q16 is biased off and power is transformed to all secondary windings. The next half cycle, when the T3 winding has reversed polarity, Q15 is driven off and Q16 is on.

7. Output Power Section.

The output power stage is a three-phase full wave bridge connection. For ease of describing this circuit, the parallel components will not be considered. Since the individual phase stages are identical, only the ØA will be described.

The output power section is made up of transistors Q28 and Q29, base drive resistors R55 and R56, reverse current diodes CR12 through CR15, choke L11A and diodes CR36 and CR37. Power transistors Q28 and Q29 obtain base drive from windings T6-8 and 9, and T6-13 and 12 respectively on the drive transformers. The polarities applied to the base-to-emitter junctions drive one transistor into conduction while its series mate is driven into cut-off during one half cycle and then the polarities switch the transistors into a reverse condition during the other half cycle. Therefore, the ØA lead is alternately connected to positive and negative input leads through a power transistor. The reverse current diodes are connected across the collector-to-emitter of each power transistor. These diodes provide a path for the kickback current from the motor load. Choke L11A is connected in series with the DC bus and appears for approximately 10 microseconds as a high impedance to the DC current. This time duration allows for the worst case switching times of the power transistors (the differences in turn on vs turn off times). Diodes CR36 and CR37 form a redundant discharge path for L11A during the time period that it is not at high impedance.

The individual transistor emitter-collector voltage waveforms are squarewave, but the voltage across any two phases combine to form a quasi-square waveform as required by the Pesco Products Specification.

8. Voltage Sense Signal.

For instrumentation requirements there are two DC signals that are proportional to the rms output voltages for phases AB and CA. The ϕ AB circuit consists of T9, CR24, CR25, L9, C18, R76 and R77. Components for ϕ CA are T11, CR29, CR30, L10, C22, R86 and R87.

Transformer T9 provides isolation and voltage step-down. Diodes CR24 and CR25 with T9 windings 3-4-5 form a full wave, center tap rectifier circuit. L9 and C18 form a low pass filter section that supplies a well filtered DC voltage to the instrumentation output. R76 and R77 are factory calibration resistors.

9. Overcurrent Time Protection.

This circuit performs the function which turns off the inverter in the event of a locked motor rotor, if such condition lasts five seconds or longer. By reapplying the turn on pulse, the inverter will come back on, but will again turn itself off if the locked rotor condition still exists.

The overcurrent time protection circuit for ϕ A contains the following components with supply bias voltage from the ϕ A oscillator: Q49, Q50, CR26 through CR28, CR31, R78 through R85, C20 and C21.

The ϕ B current sensing circuit and ϕ A current sensing circuit are identical, therefore the ϕ B sensing circuit will not be discussed separately. Q49 is a unijunction transistor, R78 is a current limiting resistor, R79 through R81 and C20 form a pulse timer circuit. The RC time constant is formed by resistors R79 through R81 and capacitor C20. (The resistors are for factory calibration purposes). As C20 charges through the R at 5 ± 1 seconds, the voltage across this capacitor will reach the unijunction trigger voltage.

At this trigger voltage point a positive pulse is applied through CR31 to the low level series regulator which starts the inverter turn off conditions. To have this function based on a condition of overcurrent, the following circuit was used...Q50, R82, and R83. Q50 is connected emitter-collector across C20. R82 and R83 are connected as a voltage divider across the bias voltage and are of such values that cause Q50 to be full on or saturated, shorting out C20. T10A windings 4 and 5 sense the ϕ A output current. This signal is amplified by the turns ratio of T10 secondary winding 1-2-3 and then applied to the full wave rectifier circuit CR27 and CR28. The resulting DC signal is filtered by C21 and loaded by factory calibrated resistors R84 and R85. Below the overcurrent trip point of approximately 19 amperes rms, the DC voltage is less than the Zener voltage of CR26 and thereby is blocked from turning Q50 off and does not allow C20 to start its five second timing. At 19 amperes or greater, the DC signal has sufficient amplitude to exceed the Zener voltage of CR26 and is applied directly to the base of Q50 with the polarity required to turn off Q50 and thereby start the five second count before turn off.

B. Mechanical Design.

Packaging of the EMIU104D Static Inverter is shown on the drawings in Appendix I. The inverter design is based on conventional techniques which have been used successfully on many other space programs. Special design considerations were necessary in the areas affected by long term orbital mission requirements of the Brayton Power Conversion System.

Efficient heat transfer methods were necessary to assure moderate temperatures, long life, and reliable operation of the internal electrical components. This

objective was achieved by designing an internal configuration that provides direct heat conduction paths to the inverter baseplate. The baseplate bolt pattern as shown on Figure 1, is closely spaced and the smooth machined surfaces of the baseplate assure intimate contact with the systems coldplate.

Features of structural rigidity and the ability to withstand dynamic loads were also obtained as a result of the thermal design consideration. Large cross-sectional areas which function to minimize thermal resistances resulted in overdesign from a strength standpoint.

The non-metallic materials for electrical insulation, potting and coating were selected on the basis of physical stability and prolonged life in a hard vacuum for extended periods.

Protection from earth associated contaminants such as moisture or sand and dust is provided by gasket-sealing the cover to the unit.

C. Thermal Analysis.

The thermal map of the Static Inverter was obtained as follows:

Assume that the thermal network of the Inverter is as shown on Figure 2. Also assume that all boundary temperatures (t_o) are equal, where o is the isothermal coldplate temperature. With these assumptions established the thermal resistance calculations are performed as follows:

$$R_{1b,o} = \frac{1}{hA} = -\frac{1}{(100)(4)} \cdot x (3.41)(144) \left(\frac{5}{9}\right) = .68^{\circ}\text{C/WATT}$$

$$R_{1a,o} = R_{1b,o} = .68^{\circ}\text{C/W}$$

$$R_{1,o} = \frac{4}{24} \cdot x .68 = .113^{\circ}\text{C/W}$$

$$R_{3,o} = \frac{4}{33} \cdot x .68 = .082^{\circ}\text{C/W}$$

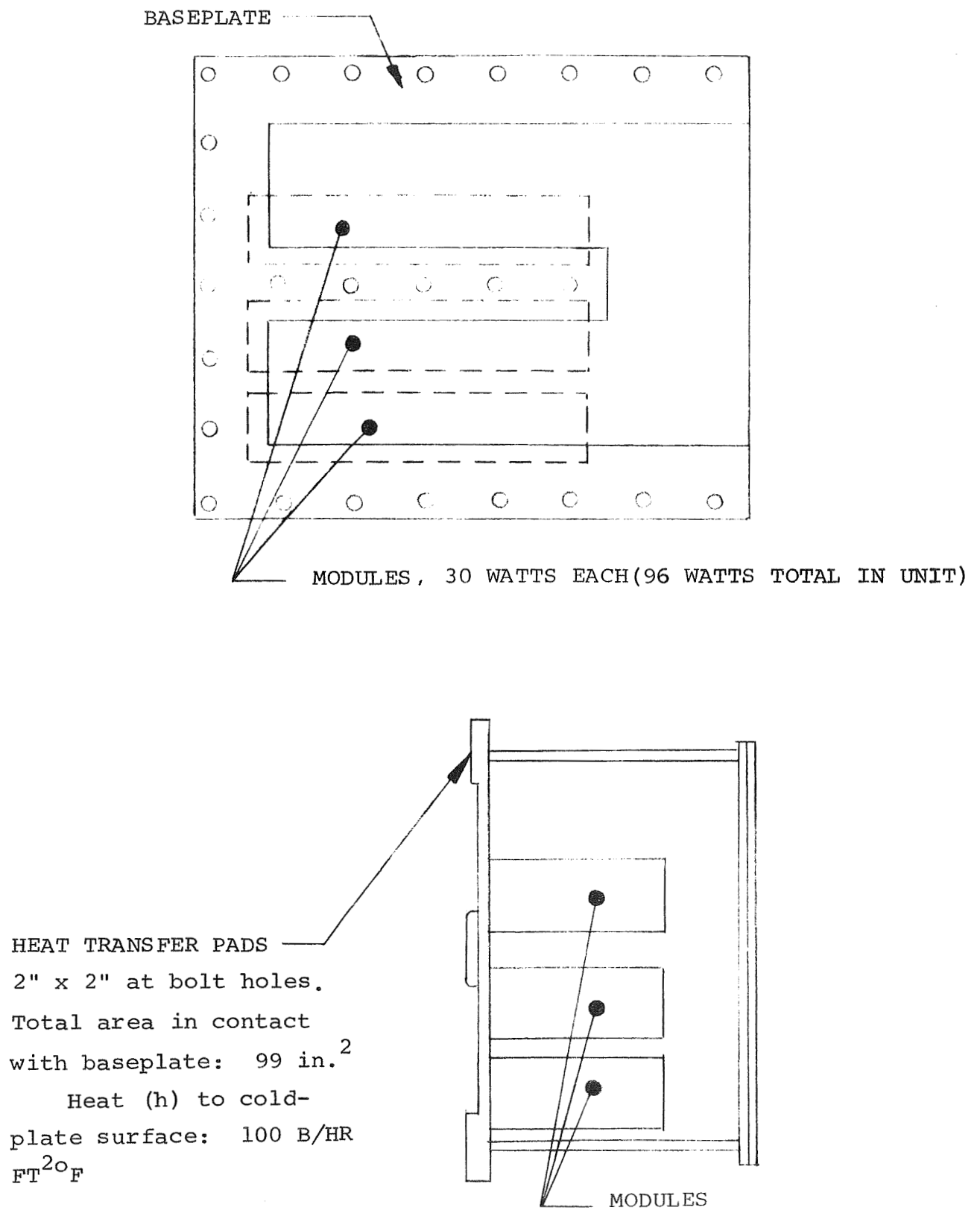


FIGURE 1. EMIU104D BASEPLATE CONFIGURATION

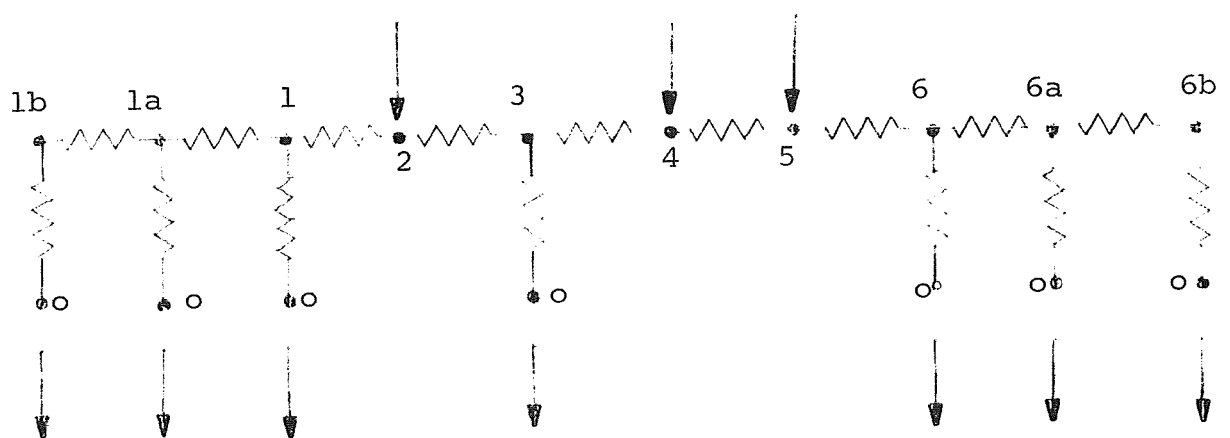
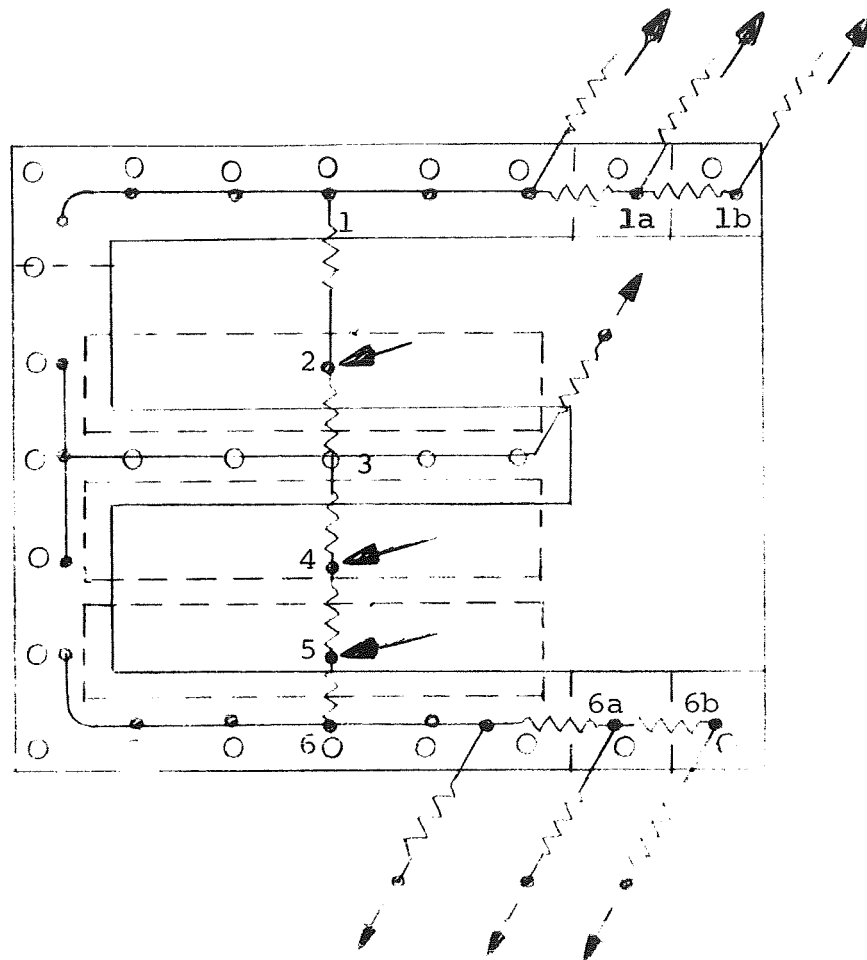


FIGURE 2. ASSUMED THERMAL NETWORK.

$$R_{6,o} = \frac{4}{26} \times .68 = .105^{\circ}\text{C/W}$$

$$R_{1b,1a} = \frac{1}{kA} = \frac{2}{(4.3)(2 \times .25)} = .93^{\circ}\text{C/W}$$

$$R_{1,1a} = R_{6,6a} = R_{6a,6b} = R_{1b,1a} = .93^{\circ}\text{C/W}$$

$$R_{1,2} = \frac{2.625}{(4.3)(9.5 \times .2)} + \frac{1}{(4.3)(9.5 \times .25)} = .419^{\circ}\text{C/W}$$

$$R_{2,3} = \frac{.875}{(4.3)(9.5 \times .2)} = \frac{1}{(4.3)(9.5 \times .25)} = .205^{\circ}\text{C/W}$$

$$R_{3,4} = R_{2,3} = .205^{\circ}\text{C/W}$$

$$R_{4,5} = \frac{2.188}{(4.3)(9.5 \times .2)} = .268^{\circ}\text{C/W}$$

$$R_{5,6} = \frac{.438}{(4.3)(9.5 \times .2)} + \frac{1}{(4.3)(9.5 \times .25)} = .152^{\circ}\text{C/W}$$

To obtain the equivalent resistance of $R_{1a,1}$; $R_{1,o}$;

$R_{1a,o}$; $R_{1b,1a}$; and $R_{1b,o}$ the following procedure is used.

$$R \{1a,o + 1b,1a + 1b,o\} = \frac{(R_{1a,1b} + R_{1b,o})(R_{1a,o})}{R_{1a,1b} + R_{1b,o} + R_{1a,o}}$$

$$= \frac{(.93 + .68)(.68)}{.93 + .68 + .68} = .478^{\circ}\text{C/W}$$

$$R \{1,1a + 1,o + .478\} = \frac{(.93 + .478)(.113)}{.93 + .478 + .113} = .104^{\circ}\text{C/W}$$

$$\text{Equivalent } R_{2,1,o} = .419 + .104 = .523^{\circ}\text{C/W}$$

The equivalent resistance of $R_{6,6a}$; $R_{6a,6b}$; $R_{6,o}$; $R_{6a,o}$;

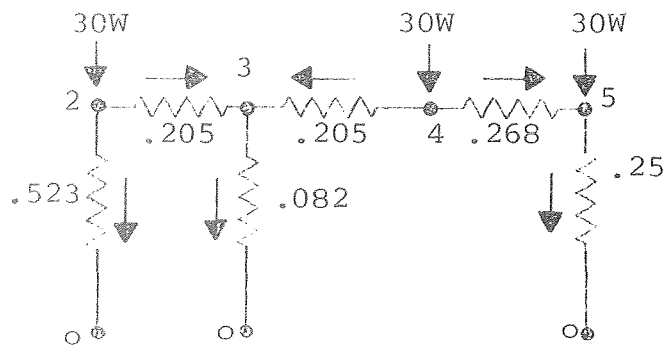
and $R_{6b,o}$ is

$$R \{6b,o + 6a,6b,6a,o\} = \frac{(.93 + .68)(.68)}{.93 + .68 + .68} = .478^{\circ}\text{C/W}$$

$$R \{6,6a + 6,o + .478\} = \frac{(.93 + .478)(.105)}{.93 + .478 + .105} = .098^{\circ}\text{C/W}$$

$$\text{Equivalent } R_{5,6,o} = .152 + .098 = .25^{\circ} \text{ C/W}$$

The equivalent network is



(q = heat load
from inverter;
BTU/HR)

$$1) \quad .523q_{2,o} = .205q_{2,3} + .082q_{3,o}$$

$$2) \quad .205q_{4,3} + .082q_{3,o} = .268q_{4,5} + .25q_{5,o}$$

$$3) \quad q_{2,o} + q_{2,3} = 30$$

$$4) \quad q_{3,o} = q_{2,3} + q_{4,3}$$

$$5) \quad q_{4,3} + q_{4,5} = 30$$

$$6) \quad q_{5,o} = 30 + q_{4,5}$$

$$7) \quad q_{2,o} + q_{3,o} + q_{5,o} = 90$$

$$1) \text{ and } 3) \quad .523q_{2,o} = .205(30 - q_{2,o}) + .082q_{3,o}$$

$$.523q_{2,o} = 6.15 - .205q_{2,o} + .082q_{3,o}$$

$$.728q_{2,o} = 6.15 + .082q_{3,o}$$

$$2) \text{ and } 5) \quad .205(30 - q_{4,5}) + .082q_{3,o} = .268q_{4,5} + .25q_{5,o}$$

$$6.15 - .205q_{4,5} + .082q_{3,o} = .268q_{4,5} + .25q_{5,o}$$

$$6.15 - .743q_{4,5} + .082q_{3,o} = .25q_{5,o}$$

$$2), 5) \text{ and } 6) \quad 6.15 - .473 (q_{5,o} - 30) + .082q_{3,o} = .25q_{5,o}$$

$$6.15 - .473q_{5,o} + 14.19 + .082q_{3,o} = .25q_{5,o}$$

$$.082q_{3,o} + 20.34 = .723q_{5,o}$$

$$1), 3) \text{ and } 7) \quad .728 (90 - q_{3,o} - q_{5,o}) = 6.15 + .082q_{3,o}$$

$$65.52 - .728q_{3,o} - .728q_{5,o} = 6.15 + .082q_{3,o}$$

$$59.37 - .81q_{3,o} = .728q_{5,o}$$

$$q_{5,o} = 81.5 - 1.11q_{3,o}$$

$$2), 5), 6) \text{ and } 1), 3), 7) \quad .082q_{3,o} + 20.34 = .723 (81.5 - 1.11q_{3,o})$$

$$.082q_{3,o} + 20.34 = 59 - .805q_{3,o}$$

$$q_{3,o} = \frac{59 - 20.34}{.082 + .805} = 43.6 \text{ WATTS}$$

$$q_{5,o} = 81.5 - 1.11(43.6) = 33 \text{ WATTS}$$

$$q_{2,o} = 90 - 43.6 - 33 = 13.4 \text{ WATTS}$$

$$\text{Set } t_o = 0$$

$$t_2 = R_{2,o} q_{2,o} = (.523)(13.4) = 7^{\circ}\text{C}$$

$$t_3 = R_{3,o} q_{3,o} = (.082)(43.6) = 3.58^{\circ}\text{C}$$

$$t_4 = t_3 + q_{4,3} R_{4,3} = 3.58 + (27)(.205) = 9.13^{\circ}\text{C}$$

$$t_5 = R_{5,o} q_{5,o} = (.25)(33) = 8.25^{\circ}\text{C}$$

Referring back to the assumed thermal network diagram

$$t_1 = t_2 - R_{2,1} q_{2,1} = 7 - (.419)(13.4) = 1.4^{\circ}\text{C}$$

$$q_{1,o} = \frac{t_1}{R_{1,o}} = \frac{1.4}{.113} = 12.4 \text{ WATTS}$$

$$q_{1,1a} = 13.4 - 12.4 = 1 \text{ WATT}$$

$$t_{1a} = t_1 - R_{1,1a} q_{1,1a} = 1.4 - (.93)(1) = .47^{\circ}\text{C}$$

$$q_{1a,o} = \frac{t_{1a}}{R_{1a,o}} = \frac{.47}{.68} = .69 \text{ WATTS}$$

$$q_{1a,1b} = 1 - .69 = .31 \text{ WATTS}$$

$$t_{1b} = t_{1a} - R_{1a,1b} q_{1a,1b} = .47 - (.93)(.31) = .18^{\circ}\text{C}$$

$$t_6 = t_5 - R_{5,6} q_{5,6} = 8.25 - (.152)(33) = 3.23^{\circ}\text{C}$$

$$q_{6,o} = \frac{t_6}{R_{6,o}} = \frac{3.23}{.105} = 30.8 \text{ WATTS}$$

$$q_{6,6a} = 33 - 30.8 = 2.2 \text{ WATTS}$$

$$t_{6a} = t_6 - R_{6,6a} q_{6,6a} = 3.23 - (.93)(2.2) = 1.18^{\circ}\text{C}$$

$$q_{6a,o} = \frac{t_{6a}}{R_{6a,o}} = \frac{1.18}{.68} = 1.74 \text{ WATTS}$$

$$q_{6a,6b} = 2.2 - 1.75 = .46 \text{ WATTS}$$

$$t_{6b} = t_{6a} - R_{6a,6b} q_{6a,6b} = 1.18 - (.93)(.46) = .75^{\circ}\text{C}$$

Worst case t_o :

$$t_o = t_c + \frac{q}{hA}$$

Where:

t_o = Coldplate surface temperature ($^{\circ}\text{F}$)

t_c = Maximum coolant temperature ($^{\circ}\text{F}$)

q = Heat load from inverter (BTU/HR)

h = Conductance, coolant to coldplate
surface (BTU/HR FT^2 $^{\circ}\text{F}$)

A = Coldplate surface area (FT^2)

(assume coolant heat transfer

only in baseplate contact area)

$$t_o = 150 + \frac{(96)(3.41)(144)}{(300)(99)}$$

$$= 150 + 16$$

$$= 151.6^{\circ}\text{F}$$

$$= 66.5^{\circ}\text{C}$$

Worst case baseplate temperatures:

$$t_1 = 66.5 + 1.4 = 67.9^{\circ}\text{C}$$

$$t_{1a} = 66.5 + .5 = 67^{\circ}\text{C}$$

$$t_{1b} = 66.5 + .2 = 66.7^{\circ}\text{C}$$

$$t_2 = 66.5 + 7 = 73.5^{\circ}\text{C}$$

$$t_3 = 66.5 + 3.6 = 70.1^{\circ}\text{C}$$

$$t_4 = 66.5 + 9.1 = 75.6^{\circ}\text{C}$$

$$t_5 = 66.5 + 8.2 = 74.7^{\circ}\text{C}$$

$$t_6 = 66.5 + 3.2 = 69.7^{\circ}\text{C}$$

$$t_{6a} = 66.5 + 1.2 = 67.7^{\circ}\text{C}$$

$$t_{6b} = 66.5 + .8 = 67.3^{\circ}\text{C}$$

The Static Inverter component part temperatures were

calculated based on the following power dissipations (watts):

WATTS

Power transistors : 1.79W each x 8 = 14.3

Base drive resistors: 1.125W each x 8 = 9

Choke reset diodes: 1W each x 2 = 2

Reverse current diodes: .5W each x 2 = 1

Transformer: 1W x 1 = 1

TOTAL Power Dissipation Per Module 27.3W

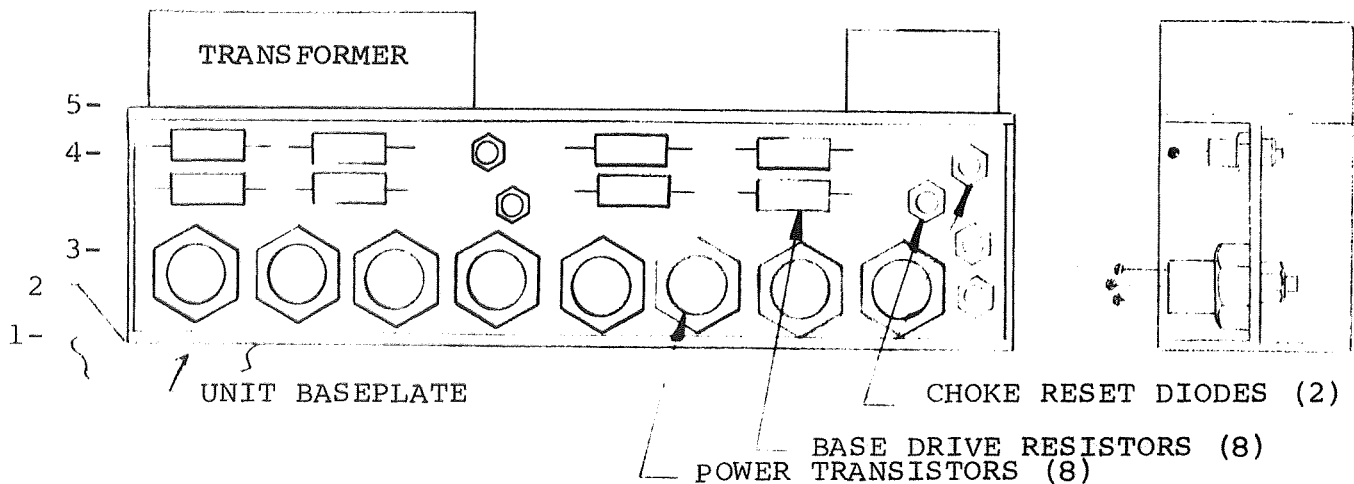
3 modules at 27.3W each = 82W

Miscellaneous losses = 8W

TOTAL POWER DISSIPATION = 90W

The above calculation is based on laboratory measurements of total power and calculated allocations for individual power dissipations. The baseplate thermal map calculations were based on previously obtained data which indicated a total load of 96 watts with 30 watts per module. The effect of this difference is negligible.

MODULAR CONFIGURATION



$$t_1 = 75.6^{\circ}\text{C} \text{ (From baseplate thermal map for Phase B. Module.)}$$

$$t_2 = t_1 + \frac{q}{hA} \text{ (Temperature at bottom of module.)}$$

$$q = 27.3 \text{ watts, total module dissipation}$$

$$h = 50 \text{ BTU/HR FT}^2\text{ }^{\circ}\text{F, assumed joint conductance between module and baseplate}$$

$$A = \frac{9.25 \times 2}{144} = .1285 \text{ FT}^2$$

$$t_2 = 75.6 + \frac{(27.3)(3.41)}{(50)(.1285)} \left(\frac{5}{9} \right)$$

$$= 75.6 + 8.05$$

$$= 83.65^{\circ}\text{C}$$

$$t_3 = t_2 + \frac{q}{kA} \quad (\text{Temperature at transistor location})$$

$$q = 27.3 \text{ WATTS}$$

$$L = .75 \text{ INCH}$$

$$k = 4.3 \text{ WATTS}/^{\circ}\text{C}$$

$$A = 9.25 \times 125 = 1.158 \text{ IN}^2$$

$$t_3 = 83.65 + \frac{(27.3)(.75)}{(4.3)(1.158)}$$

$$= 83.65 + 4.11$$

$$= 87.76^{\circ}\text{C}$$

Transistor Case Temperature (t_c):

$$t_c = t_3 + qR$$

$$q = 1.79 \text{ WATTS}$$

$$R = 2^{\circ}\text{C/W} \quad (\text{Assumed value for dry mica insulator})$$

$$t_c = 87.76 + (1.79)(2)$$

$$= 87.76 + 3.58$$

$$= 91.34^{\circ}\text{C}$$

(Manufacturer's recommended case temperature limit:

$$175^{\circ}\text{C} - (.5^{\circ}\text{C/W})(1.79\text{W}) \approx 174^{\circ}\text{C})$$

91.34 $^{\circ}\text{C}$ case temperature is acceptable

$$t_4 = t_3 + \frac{q\ell}{kA} \text{ (Temperature at location of base drive resistors and choke reset diodes)}$$

$$q = 27.3 - 14.3 = 13 \text{ WATTS}$$

$$\ell = 1 \text{ INCH}$$

$$k = 4.3 \text{ WATTS/IN}^{\circ}\text{C}$$

$$A = 9.25 \times 1.25 = 1.158 \text{ IN}^2$$

$$t_4 = 87.76 + \frac{(13)(1)}{(4.3)(1.158)}$$

$$= 87.76 + 2.61$$

$$= 90.37^{\circ}\text{C}$$

Diode Case Temperature (t_d):

$$t_d = t_4 + qR$$

$$q = 1 \text{ WATT}$$

$$R = 3^{\circ}\text{C/W} \quad \text{(Assumed value for dry mica insulator)}$$

$$t_d = 90.37 + (1)(3)$$

$$= 93.37^{\circ}\text{C}$$

(Manufacturer's recommended case temperature limit:

$$200^{\circ}\text{C} - (2^{\circ}\text{C/W})(1\text{W}) = 198^{\circ}\text{C})$$

93.37 $^{\circ}\text{C}$ case temperature is acceptable.

Base Drive Resistor Temperature (t_R):

$$t_R = t_4 + qR$$

$$q = 1.125 \text{ WATTS}$$

$$R = \frac{(6^{\circ}\text{CIN}^2/\text{W})}{(.75\text{IN}^2)} + \frac{(.08\text{IN})}{(.00528\text{W/IN}^{\circ}\text{C})(.3\text{IN}^2)} = 8 + 50 = 58^{\circ}\text{C/W}$$



Interface,
module to
terminal board



Conduction thru epoxy terminal board
epoxy fillet to resistor

$$t_R = 90.37 + (1.125)(58)$$

$$= 90.37 + 65.25$$

$$= 155.62^{\circ}\text{C}$$

(Manufacturer's recommended case temperature limit = 275 $^{\circ}\text{C}$)

155.62 $^{\circ}\text{C}$ is acceptable.

$$t_5 = t_4 + \frac{ql}{kA} \quad (\text{Temperature at top surface of module})$$

$$q = 1 \text{ WATT}$$

$$l = .75 \text{ INCH}$$

$$k = 4.3 \text{ WATTS/IN}^{\circ}\text{C}$$

$$A = 9.25 \times 125 = 1.158 \text{ IN}^2$$

$$\begin{aligned}
 t_5 &= 90.37 + \frac{(1)(.75)}{(4.3)(1.158)} \\
 &= 90.37 + .15 \\
 &= 90.52^{\circ}\text{C}
 \end{aligned}$$

Transformer Temperature (t_r)

$$t_r = t_5 + qR$$

$$q = 1 \text{ WATT}$$

$$R = \frac{(6^{\circ}\text{CIN}^2/\text{W})}{(6\text{IN}^2)} + \frac{(.1\text{IN})}{(.00528\text{W/IN}^2\text{C})(6\text{IN}^2)}$$

Interface:

module to
transformer cup

Conduction thru epoxy
cup and potting mat'l

$$= 1^{\circ}\text{C/W} + 3.15^{\circ}\text{C/W} = 4.15^{\circ}\text{C/W}$$

$$t_r = 90.52 + (1)(4.15)$$

$$= 94.67^{\circ}\text{C}$$

Transformer temperature limit 105°C continuous

94.67°C short term (2 hours max) is acceptable.

SUMMARY OF THERMAL ANALYSIS

COMPONENT	ACTUAL TEMPERATURE (°C)	RATED TEMPERATURE (°C)
POWER TRANSISTOR	91.34	174
BASE DRIVE RESISTOR	155.62	275
CHOKES RESET DIODES	93.37	198
TRANSFORMER	94.67	105

NOTE: The above calculated temperatures are based on worst case coolant temperature of 150°F. Since this condition will exist only intermittently for two hour periods, actual steady state temperatures will be lower.

D. Reliability

1. Reliability Estimate

This reliability estimate is based on the total electrical component parts count and utilizes component part failure rates and other estimating techniques as outlined in the Engineered Magnetics Reliability Handbook and MIL-HDBK-217A. This reliability estimates consists of two parts:

Part a: Based on H-version (high reliability)parts.

Part b: Based on U-version (ultra high reliability)parts.

Certain basic assumptions were used in the preparation of this reliability estimate and are defined as follows:

- a. No workmanship errors exist which can contribute to a system failure (special controls and procedures have been devised to eliminate this failure mode).
- b. Failure of any part used in the calculations will constitute a system failure.
- c. Ambient temperature is less than 40°C.
- d. Redundant parts, as such, are not used in the system.
- e. All component parts are used with proper deratings as per Engineered Magnetics' derating policy and Pesco Products derating policy.
- f. Transformers will be considered as separate windings.

The MTBF (Mean Time Before Failure) can be calculated by summing the individual component part failure rates and then taking the reciprocal of this sum, i.e.,

$$MTBF = \frac{1}{\sum \lambda_i}$$

where λ_i = individual component part failure rate, which will be expressed in 10^{-8} failures/hour (bits).

Part a) For the H-version parts,

$$MTBF = \frac{1}{\sum \lambda_{i_H}} = \frac{1}{4314.8 \times 10^{-8}} = 23,176 \text{ hours.}$$

Part b) For the U-version parts,

$$MTBF = \frac{1}{\sum \lambda_{i_U}} = \frac{1}{1129.8 \times 10^{-8}} = 88,511 \text{ hours.}$$

Table I lists the H-version parts and their bit count,
Table II similarly lists the U-version parts bit count.

PART NUMBER	QTY	FR	NFR	SYMBOL
<u>CAPACITORS</u>				
CSR13 (solid ta)	13	33.00	429.00	C1-5, C15,16,18, C20-22, C26-27
625B	3	9.00	27.00	C6,7,24
118P	6	1.60	9.60	C11,13,17,19,23
GI75576 (ta foil)	4	10.00	40.00	C8A, 10A, 10B, 8B
EM79474 (ta foil)	4	1.00	4.00	C9A, 9B, 9C, 9D
EM78381 (polycarb.)	1	6.80	6.80	C14
<u>DIODES</u>				
JAN 1N645	18	19.50	351.00	CR2, 3,7-11, 24,25, CR27-33, CR36, 37
JAN 1N645	18	28.00	504.00	CR12-23, CR38-43
GI79430H (6.6V Zener)	4	40.00	160.00	CR4, 5,6,26
EM74808H-1	1	28.00	38.00	CR1
EM76014-1H	2	30.00	60.00	CR34,35
<u>TRANSISTORS AND UNIJUNCTIONS</u>				
GI711347H	1	28.00	28.00	Q1
GI78324H	1	28.00	28.00	Q2
GI711477H	5	30.00	150.00	Q3,7,10,11,52
GI73531H-2	7	30.00	210.00	Q4-6,8,9,12,51

TABLE I. H-VERSION PARTS ESTIMATE

PART NUMBER	QTY	FR	NFR	SYMBOL
<u>TRANSISTORS AND UNIJUNCTIONS</u>		(CONT'D)		
GI73531-120H	6	30.00	180.00	Q13,14,17,18,21,22
EM710438H-1	6	28.00	168.00	Q15,16,19,20,23,24
EM79807	24	28.00	672.00	Q25-48
GI74706H	1	14.00	14.00	Q50
EM74762H	1	30.00	30.00	Q49
<u>RESISTORS</u>				
RN55C	49	14.00	742.00	R3-6,8-11,13-20 R23-32,35-38,40 R45,50,78-85 R88-97, R84A-85A
RN60C	1	14.00	14.00	R34
RS2B	45	4.00	180.00	R1,2,12,21,22,39 R41-44,46-49,53-75, R76,77,86,87,94
WIRE (Resistance)	1	4.00	4.00	R7
<u>MAGNETICS</u>				
<u>Chokes</u>				
EM3XXXX (1 winding)	10	1.00	10.00	L1,3,4,5,8,9,10,11A, B,C
EM3XXXX (2 windings)	1	2.00	2.00	L2

TABLE I. H-VERSION PARTS ESTIMATE (CONT'D)

PART NUMBER	QTY	FR	NFR	SYMBOL
<u>MAGNETICS</u> (CONT'D				
<u>Saturable Reactors</u>	2	2.00	4.00	L1, L2
<u>Transformers</u>				
2 windings	2	2/wnd (4)	8.00	T1, T2
3 windings	4	2/wnd (6)	24.00	T9,10,11,10B
6 windings	1	2/wnd (12)	12.00	T3
7 windings	1	2/wnd (14)	14.00	T5
9 windings	1	2/wnd (18)	18.00	T4
10 windings	2	2/wnd (20)	40.00	T7,T8
12 windings	1	2/wnd (24)	24.00	T6
<u>MISCELLANEOUS</u>				
Connectors	3	6.0	18.00	J1,2,3
Connections	1000	.1	100.00	-----
$\sum \lambda_{i_H} = \text{Total FR} = 4314.80$				

TABLE I. H-VERSION PARTS ESTIMATE (CONT'D)

PART NUMBER	QTY	FR	NFR	SYMBOL
<u>CAPACITORS</u>				
CSR13	13	.30	3.9	C1-5,15,16,18, C20-22, C26-27
CYK (per 711411)	2	2.00	6.00	C6,7
CYFR (per 711468)	3	.60	1.80	C11,12,13
GI75576	4	10.00	40.00	C10,10A,8A,8B
EM79474	4	1.00	4.00	C9A,B,C,D
EM78381	5	5.00	25.00	C14,17,19,23,24
<u>DIODES</u>				
GI710456U	18	.20	3.60	CR2,3,7-11,24,25 CR27-33,CR36-37
JAN TX1N1202	18	3.00	54.00	CR12-23,CR38-43
GI79430U-1	4	4.00	16.00	CR4-6,26
EM74808U-1	1	3.00	3.00	CR1
EM76014-1U	2	4.00	8.00	CR34,35
<u>TRANSISTORS AND UNIJUNCTIONS</u>				
GI711347U	1	5.00	5.00	Q1
GI78324U	1	10.00	10.00	Q2
GI711477U	5	5.00	25.00	Q3,7,10,11,52
GI73531U-2	7	5.00	35.00	Q4-6,8,9,12,51
GI73531-120U	6	5.00	30.00	Q13,14,17,18,21,22

TABLE II. U-VERSION PARTS ESTIMATE

PART NUMBER	QTY	FR	NFR	SYMBOL
<u>TRANSISTORS AND UNIUNCTIONS</u>		(CONT'D)		
EM710438U-1	6	5.00	30.00	Q15,16,19,20, 23, 24
EM77684U	24	20.00	480.00	Q25-48
GI74706U	1	4.00	4.00	Q50
EM74762U	1	4.00	4.00	Q49
<u>RESISTORS</u>				
RNC55H	53	1.00	53.00	R3-6,8-11,13-20, R23-32,35-38,40, R45,50,78-85, 88-97,84A, 85A
RN60C	1	1.30	1.30	R34
AGS	40	.12	4.80	R1,2,21,39, 41-44, 46-49, 53-75,76, 86
ARS	4	.12	.48	R12,22,77,87
RS2B (20 K Ω)	1	4.00	4.00	R33
WIRE (Resistance)	1	2.00	2.00	R7
<u>MAGNETICS</u>				
<u>Chokes</u>				
EM3XXXX (1 winding)	10	1.00	10.00	L1,3-5,8,9
EM3XXXX (2 windings)	1	2.00	2.00	L2

TABLE II. U-VERSION PARTS ESTIMATE (CONT'D)

PART NUMBER	QTY	FR	NFR	SYMBOL
<u>MAGNETICS (CONT'D)</u>				
<u>Saturable Reactors</u>				
EM3XXXX	2	2.00	4.00	L6, L7
<u>Transformers</u>				
EMXXXXX				
2 windings	2	4.00	8.00	T1, 2
3 windings	4	6.00	24.00	T9, 10, 11, 10B
6 windings	1	12.00	12.00	T3
7 windings	1	14.00	14.00	T5
9 windings	1	18.00	18.00	T4
10 windings	2	20.00	40.00	T7, 8
12 windings	1	24.00	24.00	T6
<u>MISCELLANEOUS</u>				
Connectors	3	6.00	18.00	J1, 2, 3
Connections	1000	.1	100.00	-----
$\sum \lambda_{i_U} = \text{Total FR} = 1129.48$				

TABLE II. U-VERSION PARTS ESTIMATE (CONT'D)

2. Failure Mode and Failure Effect Analysis

Failure Effect Analysis is a method of systematically examining the principal manner in which an article of equipment may fail. Engineered Magnetics has prepared a form for this purpose and lists the most conceivable failures together with their effect on the equipment and consequences to the performance of the equipment.

Under the column headed "System Failure" an explanation is given as to the system failure resulting from an assumed failure. "Degrading Failure" means the primary mission of the equipment is not effected by the assumed failure except for some degradation to the performance of the unit. "Catastrophic Failure" means the primary mission of the equipment will not be met by the assumed failure.

The Probability of Failure of each mode is entered in accordance with the following code:

20%	=	1 failure out of 5 possible failures.
10%	=	1 failure out of 10 possible failures.
5%	=	1 failure out of 20 possible failures.
1%	=	1 failure out of 100 possible failures.
.1%	=	1 failure out of 1,000 possible failures.
.01%	=	1 failure out of 10,000 possible failures.

These probabilities reference the likelihood of failures to the known failures of existing units of similar type(s) and are an estimate. For any one assumed failure the probability indicates the likelihood that the part being considered would fail. The highest probability is reserved for the power handling devices. Each row lists the effect of one part even though several parts, which have duplicate functions, are listed.

Since the predominant catastrophic mode of failure in a resistor is "open", the Failure Effect Analysis has not considered shorted resistors.

CUSTOMER NO. _____
 EM MODEL NO. EMIU104D

GULTON INDUSTRIES, INC.
 Engineered Magnetics Division

FAILURE MODE AND FAILURE EFFECT ANALYSIS

ITEM	FAILURE MODE	SYSTEM EFFECT	SYMPTOMS AND LOCAL EFFECT INCLUDING DEPENDENT FAILURE	DETAIL EFFECT	AUDIO FILTER	
					PROBABILITY OF FAILURE/10 ⁶ HOURS	REMARKS
L2A or L2B	open	C.F.	No input power to the inverter	Inverter will stay off	.2	
L2A or L2B	short	D.F.	Inverter will be more susceptible to input ripple (audio)	Increased induced ripple into DC buss line	.05	
C10A or C10B	open	D.F.	same as above	same as above	.1	

CUSTOMER NO.

EM MODEL NO. EMIU104DGULTON INDUSTRIES, INC.
Engineered Magnetics Division

FAILURE MODE AND FAILURE EFFECT ANALYSIS

RFI FILTER SECTION

ITEM	FAILURE MODE	SYSTEM EFFECT	SYMPTOMS AND LOCAL EFFECT INCLUDING DEPENDENT FAILURE	DETAIL EFFECT	PROBABILITY OF FAILURE/10 ⁶ HOURS	REMARKS
L1	open	C.F.	No input power to the ripple regulator and low level series regulator	Since oscillators + power amplifier will not receive any pwr. inverter will stay off	.02	
L1	short	D.F.	Inverter will produce more RFI noise into the DC buss	Ripple reflected back into the input line will increase	.1	
L3	open	C.F.	No input power to the ripple regulator and low level series regulator	Since oscillators + power amplifier will not receive any pwr. inverter will stay off	.02	
L3	short	D.F.	Inverter will produce more RFI noise into the DC buss	Ripple reflected back into the input line will increase	.1	
C26	open	D.F.	same as above	same as above	.05	
C26	short	D.F.	+50 VDC line will clear the shorted component	No output	.01	
C27	open	D.F.	Inverter will produce more RFI noise into the DC buss	Ripple reflected back into the input line will increase	.05	
C27	short	D.F.	same as above	same as above	.01	

CUSTOMER NO.

EM MODEL NO. EMIU104DGULTON INDUSTRIES, INC.
Engineered Magnetics Division

FAILURE MODE AND FAILURE EFFECT ANALYSIS

TURN ON AND TURN OFF
CIRCUIT SERIES REGULATOR

ITEM	FAILURE MODE	SYSTEM EFFECT	SYMPTOMS AND LOCAL EFFECT INCLUDING DEPENDENT FAILURE	DETAIL EFFECT	PROBABILITY OF FAILURE/10 ⁶ HOURS	REMARKS
R27	open	C.F. or D.F. depending on system	Q8 will turn on, turning on the ripple regulator + series voltage regulator	Turn off pulses have no effect on the inverter	.05	
R28	open	C.F.	Q9 will turn on, turning off the ripple regulator + and series voltage regulator	Turn on pulses have no effect on the inverter	.05	
R23	open	C.F.	Q8 will have no supply voltage, R97 will act as if open. Ripple regul. will be on but series regulator will be off	No output from the inverter	.05	
R91	open	C.F.	Q9 will have no supply voltage, Q8 and thereby ripple regulator will be off, series regul. will be on	No output from the inverter	.05	
R90	open	C.F.	Series regul. will be on, but Q8 and thereby ripple regulator will be off; turn on and turn off circuit will have no effect	No output from the inverter	.05	

CUSTOMER NO.

GULTON INDUSTRIES, INC.
Engineered Magnetics Division

EM MODEL NO. EMIU104D

FAILURE MODE AND FAILURE EFFECT ANALYSIS

TURN ON AND TURN OFF
CIRCUIT SERIES REGULATOR

ITEM	FAILURE MODE	SYSTEM EFFECT	SYMPTOMS AND LOCAL EFFECT INCLUDING DEPENDENT FAILURE	DETAIL EFFECT	PROBABILITY OF FAILURE/10 ⁶ HOURS	REMARKS
R89	open	C.F.	Q10 will always be off; by applying turn off pulse, ripple regulator will turn off but series regulator will stay on	Output of the inverter will be normal except during off state will drain more than normal (leakage) current	.05	
R96	open	C.F.	Q11 will always be off; by applying turn on pulse, ripple regulator will turn on but series regulator will stay off	No output from the inverter	.05	
R32	open	D.F.	Series regulator will not be able to regulate	Shift will change, but will have a tendency to be held by the motor		
R34	open	D.F.	same as above	same as above	.05	
R36 or R35 or R37	open	C.F.	Series voltage reg. will not be able to sense output voltage	same as above	.15	

CUSTOMER NO.

GULTON INDUSTRIES, INC.
Engineered Magnetics Division

EM MODEL NO. EMIU104D

TURN ON AND TURN OFF
CIRCUIT SERIES REGULATOR

FAILURE MODE AND FAILURE EFFECT ANALYSIS

ITEM	FAILURE MODE	SYSTEM EFFECT	SYMPTOMS AND LOCAL EFFECT INCLUDING DEPENDENT FAILURE	DETAIL EFFECT	PROBABILITY OF FAILURE/10 ⁶ HOURS	REMARKS
C6	open	depends on system	Q8 will turn on before Q9 turning on ripple regulat. and series voltage regulator	Turn on and turn off pulse will have no effect; inverter will start when DC bus voltage is applied	.05	
C6	short	C.F.	Base of Q8 will be grounded keeping it off at all times	Inverter will have no output since series regulator and ripple regulator will stay off	.02	
C7	open	C.F.	Q9 will turn on before Q8, keeping series and ripple regulator off	The inverter will have no output	.02	
C7	short	depends on system	Q9 will always stay off, it will turn on ripple + series regulator before applying turn on pulse	Turn on pulse will have no effect on the inverter; turn off pulse will turn off the invert. but will turn back on after pulse is removed	.05	
C9A or C9B or C9C or C9D	open	D.F.	Increase ripple at the output of series regulator	Since output capacit. of the series regul. have built in redundancy there will be no effect on the regul.	.4	

CUSTOMER NO.

EM MODEL NO. EMIU104DGULTON INDUSTRIES, INC.
Engineered Magnetics DivisionTURN ON AND TURN OFF
CIRCUIT SERIES REGULATOR

FAILURE MODE AND FAILURE EFFECT ANALYSIS

ITEM	FAILURE MODE	SYSTEM EFFECT	SYMPTOMS AND LOCAL EFFECT INCLUDING DEPENDENT FAILURE	DETAIL EFFECT	PROBABILITY OF FAILURE/10 ⁶ HOURS	REMARKS
CR32	open	depending on system D.F.	Turn off pulse will be missing to the series regulator	Turn off pulse will not turn off the inverter	.02	
CR32	short	C.F.	Secondary of T1 will saturate	same as above	.05	
CR33	open	C.F.	Turn on pulse will be missing to the series regulator	Turn on pulse will not turn on the inverter	.02	
CR33	short	C.F.	Secondary of T2 will saturate	same as above	.05	
CR31	open	D.F.	Pulse from the overcurrent time protection circuit to the series regulator will be missing	Overcurrent time protection circuit will not turn off the inverter even after the trip point is reached at phase B or C	.02	
CR31	short	C.F.	Time protection erratic	Time protection erratic	.05	
CR7	open	depending on system	Series regulator will not be able to regulate	Shift in the output phase	.02	
CR7	short	D.F.	Change in the regulation voltage of the series regulator.	Shift in the output phase	.05	

CUSTOMER NO. _____
 EM MODEL NO. EMIU104D

GULTON INDUSTRIES, INC.
 Engineered Magnetics Division

FAILURE MODE AND FAILURE EFFECT ANALYSIS

TURN ON AND TURN OFF
 CIRCUIT SERIES REGULATOR

ITEM	FAILURE MODE	SYSTEM EFFECT	SYMPTOMS AND LOCAL EFFECT INCLUDING DEPENDENT FAILURE	DETAIL EFFECT	PROBABILITY OF FAILURE/10 ⁶ HOURS	REMARKS
C9A or C9B or C9C or C9D	short	D.F.	Decreased ripple	Since outout cap. of the series reg. have built in redundancy, there will be no effect on the regulator	.1	
C2	open	depending on system	Turn off pulse will have no effect on the series regul.	Turn off pulse will be unable to turn off the inverter since turn off pulse will be missing to the series regulator		
C2	short	C.F.	Turn off pulse will saturate the primary of T1	same as above	.002	
C3	open	C.F.	Turn on pulse will have no effect on the series regulat.	Turn on pulse will be unable to turn on the inverter since turn on pulse will be missing to the series regulator	.1	
C3	short	C.F.	Turn on pulse will saturate the primary of T2	same as above	.02	

CUSTOMER NO.

GULTON INDUSTRIES, INC.
Engineered Magnetics Division

EM MODEL NO. EMIU104D

FAILURE MODE AND FAILURE EFFECT ANALYSIS

TURN ON AND TURN OFF
CIRCUIT SERIES REGULATOR

ITEM	FAILURE MODE	SYSTEM EFFECT	SYMPTOMS AND LOCAL EFFECT INCLUDING DEPENDENT FAILURE	DETAIL EFFECT	PROBABILITY OF FAILURE/10 ⁶ HOURS	REMARKS
Q8	short	depending on system D.F.	Ripple regulator will always stay on	Turn off or turn on pulse will have no effect on the inverter	.1	
Q8	open	C.F.	Ripple regulator will always stay off	No output from the inverter	.1	
Q9	short	C.F.	same as above	same as above	.1	
Q9	open	depending on system D.F.	Ripple regulator + series regulator will always stay on	Turn on or turn off pulse will have no effect on the inverter	.1	
Q10	short	C.F.	Series regulator will not work	No output from the inverter	.5	
Q10	open	depending on system	Series regulator will turn on before applying turn on pulse	Inverter will draw more than normal (leakage) current in the off state, change in the phase of the output	.5	
Q11	short	depending on system	Series regulator will not regulate, series regulator will not be able to turn off	Change in the output phase of the inverter	6	
Q11	open	depending	No regulated output from the series regulator	Change in the output phase, no other effect	2	

CUSTOMER NO.

MODEL NO.

EMIU104D

GULTON INDUSTRIES, INC.
Engineered Magnetics Division

FAILURE MODE AND FAILURE EFFECT ANALYSIS

TURN ON AND TURN OFF
CIRCUIT SERIES REGULATOR

ITEM	FAILURE MODE	SYSTEM EFFECT	SYMPTOMS AND LOCAL EFFECT INCLUDING DEPENDENT FAILURE	DETAIL EFFECT	PROBABILITY OF FAILURE/ 10^6 HOURS	REMARKS
Q12	open or short	depending on system	Series regulator will not be able to regulate	Change in the output phase inverter	.1	

CUSTOMER NO. _____
 EM MODEL NO. EMIU104D

GULTON INDUSTRIES, INC.
 Engineered Magnetics Division

FAILURE MODE AND FAILURE EFFECT ANALYSIS

DRIVE STAGE

ITEM	FAILURE MODE	SYSTEM EFFECT	SYMPTOMS AND LOCAL EFFECT INCLUDING DEPENDENT FAILURE	DETAIL EFFECT	PROBABILITY OF FAILURE/10 ⁶ HOURS	REMARKS
Q15 or 16 or 19 or 20 or 23 or 24	short	C.F.	+ 50 V shorted through transistor	Probably open up the winding of T6, T7, or T8, or open up the transistor. The remaining two phases will be operational, one of the voltage senses will not work	3.0	
Q15 or 16 or 19 or 20 or 23 or 24	open	C.F.	Phase A, B or C will not work	Two phases will be operational, one of the voltage senses will not work	12.0	
R41 or 42 or 46 or 47 or 51 or 52	open	C.F.	same as above	same as above	.3	
Secondary of T3 (6,7) or T3 (9,8) or T4 (7,8)	open	C.F.	One of the phases of A, B, or C will not work	Two phases of the inverter will be operational; one of the voltage senses will not work	.6	
Secondary of T3 (6,7) or T3 (9,8) or T4 (7,8)	short	C.F.	Oscillators will not work	No output at any of the phases	.4	

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EM MODEL NO. EMIU104D

FAILURE MODE AND FAILURE EFFECT ANALYSIS DRIVE STAGE

ITEM	FAILURE MODE	SYSTEM EFFECT	SYMPTOMS AND LOCAL EFFECT INCLUDING DEPENDENT FAILURE	DETAIL EFFECT	PROBABILITY OF FAILURE/10 ⁶ HOURS	REMARKS
Primary of T6(1,2) or T6(2,3) or T7(1,2) or T7(2,3) or T8(1,2) or T8(2,3)	open	C.F.	One of the phases of A, B, or C will not work	Two phases of the inverter will be operational; one of the voltage senses will not work	.6	
Primary of T6(1,2) or T6(2,3) or T7(1,2) or T7(2,3) or T8(1,2) or T8(2,3)	short	C.F.	Drive stage will draw excessive current and probably open up the winding or transistor	same as above	.4	

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 EM MODEL NO. EMIU104D

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FAILURE MODE AND FAILURE EFFECT ANALYSIS

FREQUENCY SENSE

ITEM	FAILURE MODE	SYSTEM EFFECT	SYMPTOMS AND LOCAL EFFECT INCLUDING DEPENDENT FAILURE	DETAIL EFFECT	PROBABILITY OF FAILURE/10 ⁶ HOURS	REMARKS
R39	open	C.F.	Instrumentation failure	No output at the frequency sense points; no other effect	.05	
C11	open	D.F.	same as above	Frequency sense output will increase in amplitude	.05	
C11	short	C.F.	same as above	No output at the frequency sense points; no other effect		
T3 (15,16)	Short	C.F.	Master oscillator will not work	No output from the inverter	.05	
T3 (15,16)	Open	D.F.	Instrumentation failure	No output at the frequency sense points, no other effect	.1	

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EM MODEL NO. EMIU104D

MASTER OSCILLATOR

PHASE A, B, AND C

FAILURE MODE AND FAILURE EFFECT ANALYSIS

ITEM	FAILURE MODE	SYSTEM EFFECT	Symptoms and Local Effect Including Dependent Failure	DETAIL EFFECT	PROBABILITY OF FAILURE/10 ⁶ HOURS	REMARKS
R38 or 40	open	D.F.	Master oscillator switching effected	No effect on the inverter	.1	
C12 or 13	open	D.F.	same as above	same as above	.1	
C12 or 13	short	D.F.	same as above	same as above	.08	
C13 or 14	open	D.F.	Loss of master oscillator	No inverter output	.2	
Q13 or 14	short	D.F.	same as above	No inverter output	.1	
L5	open	C.F.	same as above	The inverter will stay off	.1	
L5	short	C.F.	same as above	same as above	.05	
C14	open	C.F.	same as above	same as above	.05	
T3(1,2) or T3(2,3)	open	C.F.	same as above	same as above	.2	
T3(1,2) or T3(2,3)	short	C.F.	same as above	same as above	.1	

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GULTON INDUSTRIES, INC.
Engineered Magnetics Division

M MODEL NO.

EMIUL04D

FAILURE MODE AND FAILURE EFFECT ANALYSIS

ITEM	FAILURE MODE	SYSTEM EFFECT	SYMPTOMS AND LOCAL EFFECT INCLUDING DEPENDENT FAILURE	DETAIL EFFECT	PROBABILITY OF FAILURE/10 ⁶ HOURS	REMARKS
R43, 44, 48 or 49	open	C.F.	Phase B or C oscil. will not work	Loss of B or C output phase	0.2	
R45 or R50	open	C.F.	Oscillator will not start	Loss of inverter	0.1	
L6 or L7	open	C.F.	Oscillator freq. will change as switching of the oscillator is done by saturable reactor prior to saturation of the transformer T3 or T4, phase angle + freq. will change	Loss of phase and freq. control on inverter output	0.2	
L6 or L7	short	C.F.	same as above	same as above	0.1	
Q17, 18, 21 or 22	open	C.F.	Loss of one of the two oscillators	Loss of one output phase and change in the freq. of the other	4.0	
T4 (1, 2) or T4 (2, 3) or T5 (1, 2) or T5 (2, 3)	open	C.F.	same as above	same as above	0.4	
	short	C.F.	same as above	same as above		

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GULTON INDUSTRIES, INC.
Engineered Magnetics Division

MODEL NO. EMIU104D

FAILURE MODE AND FAILURE EFFECT ANALYSIS

ITEM	FAILURE MODE	SYSTEM EFFECT	SYMPTOMS AND LOCAL EFFECT INCLUDING DEPENDENT FAILURE	DETAIL EFFECT	PROBABILITY OF FAILURE/10 ⁶ HOURS	REMARKS
T4 (4,5) or T4 (5,6) or T5 (4,5) or T5 (5,6)	open	C.F.	Loss of one of the two oscillators	Loss of one output phase	.4	
	short	C.F.	same as above	same as above	.2	
T3 (10,11) or T5 (11,12)	open	C.F.	Loss of two oscillators	Loss of output	.2	
T3 (10,11) or T5 (11,12)	short	C.F.	same as above	same as above	.2	

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 EM MODEL NO. EMIU104D

GULTON INDUSTRIES, INC.
 Engineered Magnetics Division

VOLTAGE SENSE

V_{AB}

FAILURE MODE AND FAILURE EFFECT ANALYSIS

ITEM	FAILURE MODE	SYSTEM EFFECT	SYMPTOMS AND LOCAL EFFECT INCLUDING DEPENDENT FAILURE	DETAIL EFFECT	PROBABILITY OF FAILURE/ 10^6 HOURS	REMARKS
R86, 87, 76, or 77	open	D.F.	Output of the voltage sense circuit will increase	Will have no effect on the inverter; output voltage and impedance of the voltage sense circuit will increase	0.8	
C22, C18	open	D.F.	Ripple at the output of the voltage sense circuit will increase	Will have no effect on the inverter	0.1	
L10, L9	short	D.F.	same as above	same as above	0.2	
L10, L9	open	D.F.	Output of the volt. sense V_{AC} will be 0	same as above	0.2	
CR30 or 29 CR24 or 25	open	D.F.	Peak current through the diode will increase	Output of the volt. sense V_{AC} will have increased ripple	0.1	
CR30 or 29 CR24 or 25	short	C.F.	Fuse will clear the inverter	Inverter will not function	0.2	
C22 or 18	short	C.F.	same as above	same as above	0.1	

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 MODEL NO. EMIU104D

GULTON INDUSTRIES, INC.
 Engineered Magnetics Division

FAILURE MODE AND FAILURE EFFECT ANALYSIS

OVERCURRENT TIME
 PROTECTION

ITEM	FAILURE MODE	SYSTEM EFFECT	SYMPTOMS AND LOCAL EFFECT INCLUDING DEPENDENT FAILURE	DETAIL EFFECT	PROBABILITY OF FAILURE/10 ⁶ HOURS	REMARKS
R80	open	D.F.	The overload protection timing will change from 5 ±.5 SEC to 7.5 ±.5 SEC	Will have no signif. effect on the inverter or pump motor assembly	.02	
R79	open	D.F.	The overload protection timing will change from 5 ±.5 SEC to 6.5 ±.5 SEC	same as above	.02	
R81 or 78	open	C.F.	The overload protection timing circuit will not work	In case of locked motor rotor, pump assembly may be damaged	.05	Double failure, motor and resistor
R82	open	C.F.	The overload time protection circuit will turn off the inverter without having experienced overload	By applying the turn on pulse, the invert. will come back on, but will again turn itself off after 5SEC as if locked motor condition existed	.05	
R84 or 84A	open	C.F.	CR26 or CR26A will turn on at much lower current than before, e.g. if R84 opens up, zener will turn on at approx. 7 A.	The overcurrent time protection circuit will turn off the inverter much sooner than 30A, e.g. 8A	.2	Will not start motor but will allow running operation

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GULTON INDUSTRIES, INC.
 Engineered Magnetics Division

OVERCURRENT TIME
 PROTECTION

FAILURE MODE AND FAILURE EFFECT ANALYSIS

ITEM	FAILURE MODE	SYSTEM EFFECT	SYMPTOMS AND LOCAL EFFECT INCLUDING DEPENDENT FAILURE	DETAIL EFFECT	PROBABILITY OF FAILURE/10 ⁶ HOURS	REMARKS
C20	open or short	C.F.	The overload protection will not work	In case of locked motor rotor, pump assembly may be damaged	0.1	Double failure.
CR26	open	D.F.	Phase B or C overcurrent time protection will not work	Will have no effect on the inverter except one of the two overcurrent protections will not work	0.1	
CR26	short	C.F.	Overcurrent protection will work at a lower value of I _{line}	Turn off at running condition	0.5	
Q50	open	C.F.	Unijunction will free run, inverter will turn itself off after 5 MS	After applying turn on pulse, inverter will turn on for 5MS and will turn itself off	0.08	
Q50	short	D.F.	Capacitor C20 will be shorted so unijunction will never turn on	Inverter will never be able to sense locked motor rotor, pump motor assembly could be damaged	0.1	
CR27 or 28 CR36 or 37	open	D.F.	Diode will draw more peak current but will not be damaged	Overcurrent trip point will be changed higher than nominal set	0.15	

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EM MODEL NO. EMIU104DGULTON INDUSTRIES, INC.
Engineered Magnetics Division

FAILURE MODE AND FAILURE EFFECT ANALYSIS

OVERCURRENT TIME
PROTECTION

ITEM	FAILURE MODE	SYSTEM EFFECT	SYMPTOMS AND LOCAL EFFECT INCLUDING DEPENDENT FAILURE	DETAIL EFFECT	PROBABILITY OF FAILURE/10 ⁶ HOURS	REMARKS
CR27-28	short	D.F.	AC applied across C21A, running load should be ok	Overcurrent trip point will be changed higher than nominal set	0.2	
T10(4,5) T10B(4,5)	open or short	C.F.	Phase B or C over- current time pro- tection will not work	Loss of output from the inverter	0.2	
T10A(1,2) or T10A(2,3) or T10B(1,2) or T10B(2,3)	open	D.F.	Full wave C.T., diode will draw more peak current but will not be damaged	overcurrent trip point will be changed than nominal set valve	0.4	
	short	D.F.	Phase B or C over- current time pro- tection will not work	No effect on the in- verter	0.2	

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 EM MODEL NO. EMIU104D

GULTON INDUSTRIES, INC.
 Engineered Magnetics Division

FAILURE MODE AND FAILURE EFFECT ANALYSIS

POWER AMPLIFIER

ITEM	FAILURE MODE	SYSTEM EFFECT	SYMPTOMS AND LOCAL EFFECT INCLUDING DEPENDENT FAILURE	DETAIL EFFECT	PROBABILITY OF FAILURE/10 ⁶ HOURS	REMARKS
Q25-48	open	D.F.	If any one of the transistors opened up, the rest of the transistor will be able to carry the load	There will be no significant effect on the inverter	4.0	
Q25-48	short	C.F.	Fuse will clear before any damage	No output from the inverter	20.0	
R53-75	open	D.F.	One of the transistor will be open rest of the trans. will be able to carry the load	No effect on the inverter	2.4	
T6(4,5) T6(10,11) T6(6,7) T6(8,9) T6(13,12) T6(15,14) T6(17,16) T6(19,18)	open	D.F.	The rest of the amplifiers will be able to carry the load	No effect on the inverter	0.8	
T7(4,5) T7(10,11) T7(6,7) T7(8,9) T7(13,12) T7(15,14) T7(17,16) T7(19,18)	open	D.F.	same as above	same as above	0.8	

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GULTON INDUSTRIES, INC.
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M MODEL NO.

EMIUL04D

POWER
AMPLIFIER

FAILURE MODE AND FAILURE EFFECT ANALYSIS

ITEM	FAILURE MODE	SYSTEM EFFECT	SYMPTOMS AND LOCAL EFFECT INCLUDING DEPENDENT FAILURE	DETAIL EFFECT	PROBABILITY OF FAILURE/10 ⁶ HOURS	REMARKS
T7(4,5) T7(10,11) T7(6,7) T7(8,9) T7(13,12) T7(15,14) T7(17,16) T7(19,18)	open	D.F.	The rest of the amplifiers will be able to carry the load	No effect on the inverter	0.8	
T8(4,5) T8(10,11) T8(6,7) T8(8,9) T8(13,12) T8(15,14) T8(17,16) T8(19,18)	open	D.F.	same as above	same as above	0.8	
T6(4,5) T6(10,11) T6(6,7) T6(8,9) T6(13,12) T6(15,14) T6(17,16) T6(19,18)	short	C.F.	Fuse will clear before any damage	No out from the inverter	0.6	
T7(4,5) T7(10,11) T7(6,7) T7(8,9) T7(13,12) T7(15,14) T7(17,16) T7(19,18)	short	C.F.	same as above	same as above	0.6	

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FAILURE MODE AND FAILURE EFFECT ANALYSIS

POWER
AMPLIFIER

ITEM	FAILURE MODE	SYSTEM EFFECT	SYMPTOMS AND LOCAL EFFECT INCLUDING DEPENDENT FAILURE	DETAIL EFFECT	PROBABILITY OF FAILURE/10 ⁶ HOURS	REMARKS
T8(4,5) T8(10,11) T8(6,7) T8(8,9) T8(13,12) T8(15,14) T8(17,16) T8(19,18)	short	C.F.	Fuse will clear before any damage	No out from the inverter	0.6	
CR12-23	short	C.F.	same as above	same as above	0.8	
CR12-23	open	D.F.	The other parallel diode will be able to carry the load	No effect on the output	1.2	

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Engineered Magnetics Division

EMTU104D

FAILURE MODE AND FAILURE EFFECT ANALYSIS

RIPPLE

REGULATOR

ITEM	FAILURE MODE	SYSTEM EFFECT	SYMPTOMS AND LOCAL EFFECT INCLUDING DEPENDENT FAILURE	DETAIL EFFECT	PROBABILITY OF FAILURE/10 ⁶ HOURS	REMARKS
R2	open	C.F.	Forward bias to transistor Q3 will be missing, keeping pass transistors off	Ripple regulator will stay off, no output from the inverter	.02	
R1	open	C.F.	Transistor Q1 will be missing, the drive required since Q1 will stay off	same as above	.02	
R9B or R4	open	C.F.	Transistor Q4 will always stay off thereby keeping Q1, Q2, and Q3 off	Ripple regulator will stay off, no output from the inverter	.02	
R29B or	open	D.F.	Output sense volt. will change, i.e. pass transistors will turn on before the preset value	Output of the ripple regulator will go down changing bias to the power amplifier; power output of the inverter will be slightly lower in amplitude		
R30	open	D.F.	Output voltage sense will be missing	Ripple regulator will stay on; output from the inverter not affected	.02	
R29A	open	C.F.	Q52 will always be on	Ripple regulator will always stay off, no output from inverter	0.2	

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EMIUL04D

FAILURE MODE AND FAILURE EFFECT ANALYSIS

RIPPLE
REGULATOR

ITEM	FAILURE MODE	SYSTEM EFFECT	SYMPTOMS AND LOCAL EFFECT INCLUDING DEPENDENT FAILURE	DETAIL EFFECT	PROBABILITY OF FAILURE/10 ⁶ HOURS	REMARKS
R26	open	C.F.	Ripple regulator will loose its sense and comparison circuitry; pass transistor will always stay on	Efficiency of the inverter will go down and Q1 will dissipate more power than normal	.02	
R21 or R22	open	C.F.	Ripple regulator will loose its reference	Output of the ripple regulator will change and load current demand circuitry will not work; this will cause the driver stage to starve for current and shut off the inverter	.04	
R25	open	C.F.	Q52 will always be on	Inverter will stay off	.02	
R15 or R16	open	D.F.	Load current demand circuitry will regulate ripple regulator at lower voltage for higher current, which starves the driver for current	Inverter may shut off during starting	.04	
R17 or R12 or R14	open	D.F.	Load current demand circuitry will not function	same as above	.08	

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REGULATOR

FAILURE MODE AND FAILURE EFFECT ANALYSIS

ITEM	FAILURE MODE	SYSTEM EFFECT	SYMPTOMS AND LOCAL EFFECT INCLUDING DEPENDENT FAILURE	DETAIL EFFECT	PROBABILITY OF FAILURE/10 ⁶ HOURS	REMARKS
R7	open	C.F.	-DC bus will be open	no output from the inverter	.05	
CR5	open	C.F.	Ripple regulator will loose ref.	Regulator will stay off	1.0	
CR5	short	C.F.	Ripple regulator will change its reference voltage	same as above	3.0	
CR4	open	D.F.	Q6 will draw more current than present	Output of the volt. regulator will go up	1.0	
CR4	short	C.F.	Q6 will draw less current than preset	There will be no effect on the regu- lator	3.0	
Q1	open	C.F.	Ripple regulator will not work	No output from the inverter	2.0	
Q1	short	D.F.	Output of the ripple regulator is the same as input	Efficiency will go down, no current limiting	6.0	
Q2 or Q3	open	C.F.	Ripple regulator will not work	No output from the inverter	.16	
Q2 or Q3	short	D.F.	Q1 will be saturat- ed all the time	Efficiency will go down and there will be no current limit- ing	.2	

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EMIU104DGULTON INDUSTRIES, INC.
Engineered Magnetics Division

RIPPLE

REGULATOR

FAILURE MODE AND FAILURE EFFECT ANALYSIS

ITEM	FAILURE MODE	SYSTEM EFFECT	SYMPTOMS AND LOCAL EFFECT INCLUDING DEPENDENT FAILURE	DETAIL EFFECT	PROBABILITY OF FAILURE/10 ⁶ HOURS	REMARKS
Q4	open	C.F.	Ripple regulator will not work	No output from the inverter	.08	
Q4	short	D.F.	Q1, Q2, and Q3 will always stay on	Efficiency will go down and there will be no current limiting	.1	
Q5	open	D.F.	Q4, Q1, Q2 and Q3 will always stay on	Efficiency will go down, no current limiting	.08	
Q5	short	C.F.	Ripple regulator will always be off	No output from the inverter	.1	
Q52	short	C.F.	same as above	same as above	.05	
Q52	open	D.F.	Pass transistor will always be on	Efficiency will go down and no current limiting	.02	
Q7	open	C.F.	Q1, Q2, Q3 and Q4 always off	No output from the inverter	.08	
Q7	short	C.F.	Ripple regulator will loose its ref.	same as above	.1	

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EM MODEL NO.

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RIPPLE

REGULATOR

FAILURE MODE AND FAILURE EFFECT ANALYSIS

ITEM	FAILURE MODE	SYSTEM EFFECT	SYMPTOMS AND LOCAL EFFECT INCLUDING DEPENDENT FAILURE	DETAIL EFFECT	PROBABILITY OF FAILURE/10 ⁶ HOURS	REMARKS
Q6	open	D.F.	Current sense will	no effect on reg.	.02	
Q6	short	D.F.	Output of the volt. reg. will go up	lower efficiency of the inverter	.05	
Q51	open	C.F.	same as above	same as above	.02	
Q51	short	D.F.	Current sense will not work	No effect on reg.	.05	

3. Reliability Stress Analysis.

Engineered Magnetics Stress Analysis of the individual component parts of the EMIU104D Static Inverter is presented on pages 66 through 77.

Gulton Industries Inc.
18000 Harwin Drive
Houston, Texas 77033

CONTRACTOR PESCO

RATING AND STRESS DATA
CAPACITORS

RATING AND STRESS DATA CAPACITORS					RATED VALUES										APPLIED VALUES						RELIABILITY RECOMMENDATIONS	REV
CIRCUIT SYMBOL	G.I. PART NO.	MFR.	MFR OR MIL TYPE	DIELECTRIC *	CAPACITANCE	TOLERANCE (%)	WVDC AT 85°C (VOLTS)	WVDC AT 125°C (VOLTS)	V _{RMS OR} (VOLTS)	V _{DC} (VOLTS)	V _{RMS OR} (VOLTS)	TOTAL VOLTAGE (VOLTS)	FREQUENCY (HZ)	DUTY CYCLE (%)	STRESS RATIO V _{tot} /V _{RTD}	FAILURE RATE IN BITS(10-8)						
C1		SPRAGUE KEMET	CSR13F685KPU	Ta ₂ O ₅	6.8	+10	35	23		3.2			3.2			.091						
C2,3		"	CSR13E156KPU	Ta ₂ O ₅	15.0	+10	20	13								NIL						
C7		ELECTRO CUBE	625B1B472J	Metal. Polycarb.	0.0047	+5	100	50		2			2			.02						
C6		"	625B1B682J	"	0.0068	+5	100	50		1.4			1.4			.014						
C8A,8B	GI75576-4	GE	29F	Ta Foil	280	-15	75	50		41.0	0.1	41.1	6x10 ³	50	.54							
C9	EM79474-6	GE	16K	Ta Foil	30	015	75	50		46.7			46.7	50	.62							
C10B	GI75576-34	GE	29F	Ta Foil	660	-15	75	50		60	0.2	60.2	400	50	.80							
C10A	GI75576-34	GE	29F	Ta Foil	660	-15	75	50		59.5	1.0	60.5	1200	50	.81							
C11		SPRAGUE	118P33392S2	Metal,paper & Polyester	0.033	+10	200	200			3.55	3.55	400	50	.018							
C12,13		"	118P22302S1	"	0.022	+20	200	200			35	35	400	50	.18							
C14	EM78381-12	SPRAGUE DEAR.DIV.	1P8A1	Polycarbonate	0.5	+5	200	200			21.8	21.8	400	50	.11							
C15		SPRAGUE KEMET	CSR13C396KPU	Ta ₂ O ₅	39	+10	10	7		2.25	0.15	2.4	6x10 ³	50	.24							
C16		"	CSR13F226KPU	Ta ₂ O ₅	22	+10	35	23		14.0			14.0			.40						
C23, C17,19		SPRAGUE	118P47402S2	Metal,paper & Polyester	0.47	+20	200	200			27		400	50	.14							
C18,22		SPRAGUE KEMET	CSR13C127KPU	Ta ₂ O ₅	120	+10	10	7		4.95			4.95			.495						
C24		ELECTRO CUBE	625B1B224J	Metal. Polycarb.	0.22	+5	100	50		40			40			.40						
C25		SPRAGUE KEMET	CSR13E225KPU	Ta ₂ O ₅	2.2	+10	20	13		2.5			2.5			.10						
C26,27	EM77308-4	GULFON GLEN. DIV.		Ceramic	2	+20	100	50		30			30			.30						
C28		ELECTRO CUBE	625B1B223J	Metal. Polycarb.	0.022	+5	100	50			0.5	0.5	6x10 ³	50	.005							
C29		"	625B1B332J	"	0.0033	+5	100	50			0.5	0.5	6x10 ³	50	.005							
C30		"	625B1B332J	"	0.0033	+5	100	50		27			27			.27						

SPEC NO. _____ EMI7104D

EMD MODEL NO. _____

* P-PULSE, AC-ALTERNATING F-FILTER, DC-DIRECT CURRENT

CONTRACTOR PESCO

SPEC NO. _____

EMD MODEL NO. EM1UI04D

ZENER DIODES

[illegible]

RATING AND STRESS DATA
INDUCTORS

CONTRACTOR PESCO
SPEC NO. _____
EMD MODEL NO. EMIU104D

CIRCUIT SYMBOL G.I. PART NO.	INSUL. CLASS TEMP.	WINDING	WIRE RATING				INSULATION VOLTAGE RATING BETWEEN WINDING (s) OR CORE (VOLTS)	CORE VOLTAGE*		FREQUENCY (HZ)	DC RESISTANCE (OHMS)	INDUCTANCE (MH)	TEMP. RISE (ΔT) (°C)	REMARKS
			BREAKDOWN Δ VOLTAGE,TURN TO TURN (VOLTS)		CURRENT			SUPPORT (VOLTS)	APPLIED (VOLTS)					
					APPLIED CURRENT (AMPS)	DUTY CYCLE								
APPLIED	RATED													
L2A, L2B	R	1 - 2	< 1	62	5	100%	500		.04	1200	< 0.01		< 5°C	} INPUT FILTER CHOKES
L1	R		< 1	62	5	100%	500		.03	1200	< 0.01		< 5°C	
L3	R		< 1	62	5	100%	500		.03	1200	< 0.01		< 5°C	
L4	R		2	23	1.2	80%	500		0.1	10K			< 5°C	20V TOTAL
L5	R		1	23	0.4	100%	500		24	400			< 5°C	FREQUENCY DETER- MINING ELEMENT.
L8	R		1	23	.00025	100%	500		0.2	10K			< 5°C	
L9, L10	R		1	14	.003	100%	500	10	4.2	800	100	0.5	< 5°C	
L11A,B,C	R		1	62	2.5 AP 1.2	100%	500		29	400			< 5°C	

Δ THE HIGHEST VOLTAGE USUALLY OCCURS AT THE INSTANT THE TOTAL VOLTAGE IS APPLIED TO THE CIRCUIT.

* $E = 4A_C E_{B_M} NS \times 10^{-8} (V)$ FOR Π , $E = 4.44A_C F B_M NS \times 10^{-8} (V)$ FOR $\sim$ -FOR AC ONLY.

**RATING AND STRESS DATA
 SATURABLE REACTORS**

CONTRACTOR PESCO
 SPEC NO. _____
 EMD MODEL NO. EMIUI04D

CIRCUIT SYMBOL G.I. PART NO.	INSUL CLASS TEMP.	WINDING	WIRE RATING				INSULATION VOLTAGE RATING BETWEEN WINDING (s) OR CORE (VOLTS)	CONTROL WINDING *		FREQUENCY (HZ)	WINDING RESISTANCE (OHMS)	COPPER LOSS (WATTS)	REMARKS
			BREAKDOWN VOLTAGE,TURN TO TURN (VOLTS)		CURRENT			SUPPORT (VOLTS)	APPLIED (VOLTS)				
			APPLIED	RATED	APPLIED CURRENT (AMP)	DUTY CYCLE							
L6	R		<1	23	0.5	10%	500			400			} PROVIDES SMALL DELAY FOR PHASE CONTROL.
L7	R		<1	23	0.5	10%	500			400			

* $E = 4 A_C F B_M NS \times 10^{-8}$ (V) FOR Π , $E = 4.44 A_C F B_M NS \times 10^{-8}$ (V) FOR $\sim$ - FOR DRIVE WINDING ONLY.

RATING AND STRESS DATA
TRANSISTORS

CONTRACTOR PESCO

SPEC NO. _____

EMD MODEL NO. EMI101D

CIRCUIT SYMBOL	G.I. PART NO.	MFG.	TYPE	V _{CE} NORMAL OFF VOLTAGE	V _{CE} VOLTS (PEAK)	V _{EB} (VOLTS)	I _C MILLIAMPS PEAK	I _C MILLIAMPS AVERAGE	DUTY CYCLE	P _{TOTAL} (AVERAGE) WATTS	P _{PEAK} (WATTS)	FAILURE RATE IN BITS (10 ⁻⁸)	RELIABILITY COMMENTS	REV
				APPLIED	APPLIED	APPLIED	APPLIED	APPLIED	T _{ON}	APPLIED	APPLIED			
				RATED	RATED	RATED	RATED	RATED	T _{OFF}	RATED	RATED			
Q1	GI711347H	TI	NPN-POWER 857M-4	60	66	0.8	2.6x10 ⁻³	1.2x10 ³	60	0.5	200/.2μS			
				100	120	.7	30x10 ³	20x10 ³	40	.67	1000/500μS			
				62	62	0.8	0.634x10 ³	0.32x10 ³	60	0.08	12.5/.2μS			
Q2	GI78324H	SOLITRON	2N2658	80	80	.8	7.5x10 ⁻³	5x10 ³	40	1.25	450/1μS			
				64	64	0.7	.80	.40	60	0.06	26.6/.3μS			
				140	140	.5	1000	1000	40	1				
Q3	GI711477H	MOT	2N3635	60	60	0.8	3.42	1.1	50	0.01	0.03			
				80	80	.7	1000	1000	50	1	1			
				0.8	0.8	0.6	1.0	0.5	50	.8x10 ⁻³				
Q4	GI73531H-2	RAY RCA	2N2102	80	80	.7	1000	1000	50	1				
				38	38	0.7	0.46	0.46	100	0.0175	0.0175			
				80	80	.7	1000	1000	0	1	1			
Q5	GI73531H-2	"	2N2102	24	26	0.7	0.37	0.3	100	0.0072	0.0072			
				140	140	.5	1000	1000	0	1				
				22	23	0.7	3.0	3.0	100	0.0066	0.0066			
Q6	GI73531H-2	"	2N2102	80	80	.7	1000	1000	0	1	1			
				18	28	0.7	0.34	0.2	50	2.2x10 ⁻³	4.5x10 ⁻³			
				140	140	.5	1000	1000	50	1	1			
Q7	GI711477H	MOT	2N3635	0.2	0.2	0.65	1.0	1.0	100	0.2x10 ⁻³	0.2x10 ⁻³			
				80	80	.7	1000	1000	0	1	1			
				45	45	0	0	0	0	NIL				
Q8	GI73531H-2	RAY RCA	2N2102	80	80	.7	1000	1000	100	1	1			
				0.7	0.7	0.75	14	14	100	9.8x10 ⁻⁵	9.8x10 ⁻⁵			
				140	140	.5	1000	1000	0	1	1			
Q9	GI711477H	MOT	2N3635	13.6	13.6	0.7	55	55	100	0.75	0.75			
				80	80	.5	2000	2000	0	30	30			
				55	56	0.7	0.22	0.22	100	12.3x10 ⁻³	12.3x10 ⁻³			
Q10	GI73531H-2	RAY RCA	2N2102	80	80	.7	1000	1000	0	1	1			
				96	98	1.0	23	11.5	50	1.8x10 ⁻³	45			
				120	120	.7	1000	1000	50	1	1			
Q11, 14	GI73531-120H	"	2N2102	87	87	3.6	510	255	50	0.13	0.26			
				120	120	.8	10x10 ³	7.5x10 ³	50	40	550/100μS			
				96	110	2.0	18	9	50	20x10 ⁻³	100/.2μS			
Q12	GI73531H-2	RAY RCA	2N2102	120	120	.7	1000	1000	50	1				
				60	60	2.3	2.5x10 ³	1.2x10 ³	50	1.65	480/2μS			
				100	100	1.0	40x10 ³	40x10 ³	50	200	3000/50μS			
Q13, 16, 19, 20, 23, 24	EM710438H1	WESTING- HOUSE	2N3431	15	15	0.3	1.5	1.5	100	22.4x10 ⁻³	22.4x10 ⁻³			
				60	60	.20	70	70	0	450x10 ⁻³	450x10 ⁻³			
				0.3	0.3	0.4	0.087	0.087	100	0.26x10 ⁻³	0.26x10 ⁻³			
Q17, 18, 21, 22	GI73531-120H	RAY RCA	2N2102	40	40	.5	500	500	0	500x10 ⁻³	500x10 ⁻³			
Q25-48	EM79807	WESTING- HOUSE	2N2771											
Q49	EM74762H	GE	UNIJUNCTION 2N2420A											
Q50	GI74706H	MOT RAY	2N2222											

CONTRACTOR PESCO

RATING AND STRESS DATA
 RESISTORS

RATING AND STRESS DATA RESISTORS					RATED VALUES				APPLIED VALUES							SPEC NO. _____ EMD MODEL NO. EMI01.04D		
CIRCUIT SYMBOL	G.I. PART NO.	MFR.	MFR'S PART NO.	MIL TYPE	RESISTANCE (OHMS)	RESISTANCE TOLERANCE (%)	POWER (MW) AND VOLTAGE DC	MAX TEMP FOR MAX POWER (°C)	TEMP ZERO POWER (°C)	I _{DC} (MA)	V _{DC} (VOLTS)	V _{RMS} (VOLTS)	DUTY CYCLE	POWER (MW)	STRESS RATIO	FAILURE RATE IN BITS (10 ⁻⁹)	RELIABILITY COMMENTS	REV
R29A		DALE	WNA-13-18	MIL-R-39005 MIL-R-93	1.5K	+1	125 50	125	145	0.4	0.6		.24	.0019				
R53-75		DALE	RS-5-.75Ω		0.75	+1	5000 330	25	275	1.17K 10.3		0.7	819	.164				
R76, 86		CORNING	RN55C1471F	MIL-R-10509	1.47K	+1	100 200	125	175	3.2	5.0		16.0	.16				
R77, 87		"	RN55C3001F	"	3K	+1	100 200	125	175	1.66	5.0		8.30	.083				
R78		"	RN55C4640F	"	464	+1	100 200	125	175	1.5	0.7		1.05	.0105				
R79		"	RN55C1963F	"	196K	+1	100 200	125	175	0.012	2.0		.024	<.001				
R80		"	RN55C2872F	"	28.7K	+1	100 200	125	175	0.071	2.0		.142	.0014				
R81		"	RN55C1403F	"	140K	+1	100 200	125	175	0.089	12.5		.111	.0011				
R82		"	RN55C3012F	"	30.1K	+1	100 200	125	175	0.467	14.0		6.54	.065				
R83		"	RN55C3831F	"	3.83K	+1	100 200	125	175	0.083	0.32		.0266	<.001				
R84, 84A		"	RN55C3000F	"	300	+1	100 200	125	175	1.66	5.0		8.3	.083				
R85, 85A		"	RN55C1001F	"	1K	+1	100 200	125	175	5	5.0		25.0	.25				
R88, 92		CORNING	RN55C3000F	MIL-R-10509	300	+1	100 200	125	175	3.32	1.0		3.32	.033				
R89		DALE	WNA-13-18	"	5K	+1	125 50	125	145	0.06	0.3		.018	<.001				
R90		CORNING	RN55C9091F	MIL-R-10509	9.09K	+1	100 200	125	175	0.132	1.2		.158	.0016				
R91		"	RN55C4642F	"	46.4K	+1	100 200	125	175	0.258	12		3.096	.031				
R93		CORNING	RN55C2151F	MIL-R-10509	2.15K	+1	100 200	125	175	0.232	0.5		.116	.0012				
R94		DALE	RS2B-4K		4K	+1	3000 135	25	275	14.7	59		867.3	.289				
R95		CORNING	RN55C8660F	MIL-R-10509	866	+1	100 200	125	175	0.23			.046	<.001				
R97		CORNING	RN55C1963F	MIL-R-10509	196K	+1	100 200	125	175									
R96		"	RN55C3011F	"	3.01K	+1	100 200	125	175	0.166	0.5		.083	<.001				

RATING AND STRESS DATA
TRANSFORMER

CONTRACTOR PESCO
SPEC NO. _____
EMD MODEL NO. EMIU104D

CIRCUIT SYMBOL G.I. PART NO.	INSUL. CLASS TEMP.	WINDING	WIRE RATING						CORE VOLTAGE*		CORE LOSS Δ (WATTS)	WINDING RESISTANCE R _{dc} (OHMS)	COPPER LOSS ~~(WATTS)~~ (mW)	TOTAL POWER LOSS ∇ (WATTS)	∇ T TEMP RISE ABOVE AMBIENT (°C)	REMARKS
			VOLTAGE .TURN TO TURN (VOLTS)		APPLIED CURRENT (AMP)	DUTY CYCLE	VOLTAGE BETWEEN WINDING (s) OR CORE (VOLTS)	SUPPORT (VOLTS)	APPLIED (VOLTS) RMS							
			APPLIED	RATED						APPLIED						
T3	R	1 - 2 & 2 - 3	<1 (50V Total)	23	12x10 ⁻³	50%	< 50	1000	54	47.0	34x10 ⁻³	74.0	10.7	94.4mW		
T3	"	4 - 5	< 1	23	50x10 ⁻³			"	4.65	4.0		7.4	18.5			
T3	"	6 - 7 & 8 - 9	< 1	62	67.5x 10x ⁻³			"	4.08	2.1		2.5	9.55			
T3	"	10 - 11	< 1	62	25x10 ⁻³			"	5.14	4.4		1.51	.945			
T3	"	12 - 13 & 13 - 14	< 1	23	2x10 ⁻³			"	17.8	15.0		31.8	.128			
T3	"	15 - 16	< 1	23	0.38x 10 ⁻³			"	4.85	4.1		9.37	1.4μW			
T4 & T5	"	1 - 2 & 2 - 3	< 1	23	10x10 ⁻³			"	54	47	34x10 ⁻³	74.0	7.4	73.1mW		
"	"	4 - 5 & 5 - 6	< 1	23	25x10 ⁻³			"	4.16	2.0		3.68	2.3			
T4 & T5	"	7 - 8 & 9 - 10	< 1	62	67.5x 10 ⁻³			"	4.16	2.1		2.5	9.55			
T6	"	1 - 2 & 2 - 3	<1 (50V Total)	85	0.255			"	52.2	40.0	158.5x 10 ⁻³	3.24	213	1.069W		
"	"	4-5, 6-7, 8-9,	<.01 (3V Total)	144	1.0			"	3.35	2.25		0.060	60			
		10-11, 12-13, 14-15, 16-17, 18-19.														
T6	"	20-21 & 21-22	<.01 (7V Total)	23	0.25			"	4.6	3.5		0.12	7.5			
T7 & T8	"	1 - 2 & 2 - 3	< 1	85	0.255			"	52.2	40.0	158.5x 10 ⁻³	3.24	2.3	1.054W		
T7 & T8	"	4-5, 6-7, 8-9,	< 1	144	1.0	50%		"	3.35	2.25		0.06	60			
		10-11, 12-13.					< 50									

Δ AT FREQUENCY OF OPERATION FOR DRIVE WINDING ONLY

* $E = 4A_C F B_M NS \times 10^{-8}$ (V) FOR Π , $E = 4.44A_C F B_M NS \times 10^{-8}$ (V) FOR Δ -FOR DRIVE WINDINGS ONLY

∇ TOTAL POWER LOSS = CORE LOSS + $\sum_{n=1}^n R_{dc} \times I_{rms}^2$, WHERE I_{rms} IS DETERMINED FOR EACH WINDING

[illegible]

Δ AT FREQUENCY OF OPERATION FOR DRIVE WINDING ONLY

*E=4A_CF B_M NS X 10⁻⁸(V) FOR Π, E=4.44A_CF B_M NS X 10⁻⁸(V) FOR ∇ -FOR DRIVE WINDINGS ONLY

$$\nabla \text{ TOTAL POWER LOSS} = \text{CORE LOSS} + \sum_{n=1}^n R_{dc} \times I_{rms}^2, \text{ WHERE } I_{rms} \text{ IS DETERMINED FOR EACH WINDING}$$

E. Electrical Performance Tests

Waveform photographs obtained during tests performed on the breadboard model are presented in Appendix II.

Each Static Inverter was subjected to and passed, an Acceptance Test in accordance with Engineered Magnetics Acceptance Test Procedure 712954, prior to shipment to Pesco Products. A complete set of Acceptance Test Record Forms showing the Acceptance Test results of EMIU104D Static Inverter Serial No. 25501 are presented in Appendix II.

Specific input and output data obtained during the Acceptance Tests performed on each of the seven Static Inverters are presented on the following table. (Specified requirements are in parentheses).

		EMIU104D UNIT SERIAL NUMBER						
		25505	25506	25507	25508	25509	25510	25511
INPUT: 56VDC								
CURRENT (A)		9.6	9.8	9.8	10.0	10.0	9.8	9.9
POWER (W)		537.6	548	548	560	560	548	554
OUTPUT	ØA	26.0	26.47	26.56	26.32	26.43	26.11	26.43
VOLTAGE RMS	ØB	25.9	26.34	26.46	26.12	26.25	25.97	26.21
LINE TO NEUTRAL	ØC	26.0	26.50	26.66	26.38	26.38	26.30	26.34
FREQ (Hz)								
(396-404)		400	399	399	398	399	399	399
PHASE DISPLACE-	ØA-B	120.19	119.7	119.8	119.5	118.6	119.8	119.1
MENT (°) (120°±5°)	ØA-C	119.55	120.1	120.5	120.0	119.6	119.6	120.6
(AT RUNNING LOAD)	ØC-A	120.23	120.2	119.8	120.6	120.2	120.6	120.5
EFFICIENCY (%)								
(85% MIN.)		94.5	95.2	97.0	97.8	92.5	95.6	94.2
OVERLOAD	ØA	28.5	29.5	29.5	29.0	29.0	28	28
OUTPUT	ØB	29.2	30.0	30.0	29.0	29.5	29	28
CURRENT	ØC	28.8	29.5	29.5	29.0	29.5	29	28.5

CONCLUSIONS AND RECOMMENDATIONS

The electrical and mechanical design of Engineered Magnetics Model EMIU104D Static Inverter complies with, or exceeds, the specified design requirements. Redesign of the low level regulator may be required at a later date. During testing, Pesco Products observed that if the DC bus voltage is not applied as a step function, the inverter can turn on without the application of the turn on pulse. The source of this is located in the exponential time curve of the two internal time constant circuits (R27 and C7, and R28 and C6). These circuits are affected when subjected to a slow rise of input voltage. Under this condition, the leakage currents of Q8 and Q9 effect inverter operation to a greater extent than do the RC time constants.

The pulse turn on and/or turn off circuits can be reduced through the use of latching relays. This change will effect the inverter MTBF reliability calculation.

After completion of the test program at Pesco Products and NASA Lewis, more realistic system requirements will be known and a reduction in size, weight, and component part count can then be initiated.

APPENDIX I

DETAIL DESIGN, EMIU104D STATIC INVERTER

Electrical Schematic, Drawing No. 513634C

Outline and Specification, Drawing No. 413519A

Final Assembly, Drawing No. 514100B

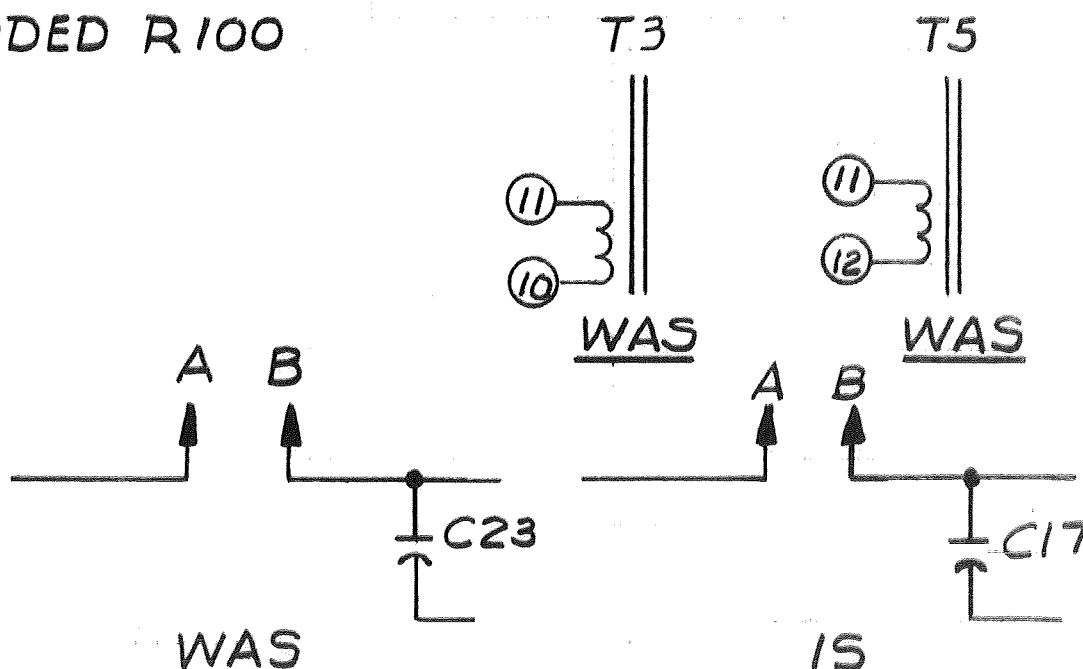
List of Materials, Drawing No. LM514100B

GULTON INDUSTRIES, INC. HAWTHORNE, CALIFORNIA		CODE IDENT NO. 06509	EO NO. 24689 ENGINEERING ORDER	
19/ LM NO. LM514100		DWG TITLE SCHEMATIC EMIUIO4D		DWG NO. 513634 C
MODEL NO. EMIUIO4D		DATE 19 AUG. 1968		INCORPORABLE: YES ☒ NO
REQD BY R. SIMONSON		OTHER DWGS AFFECTED _____		DEPT. AFFECTED
DR P. MANA		PROTO: ☒ PROD: ☒		SPL PROD: WHT RM:
CHK Berriman 8-22-68.		REASON: UPDATE DWG.		
ENG		EFFECTIVITY (LIST JOB & SERIAL NO.): JOB NO. 6502 & FUTURE		
MECH ENG		DISPOSITION OF MATL / PARTS: _____		
REL ENG				
Q.C.				
PROJ ENG Lo J				
PROD MGR				
APPD B. McComb				
CUSTOMER APPD				

REVISION

CHANGE NOTICE

ADDED R100



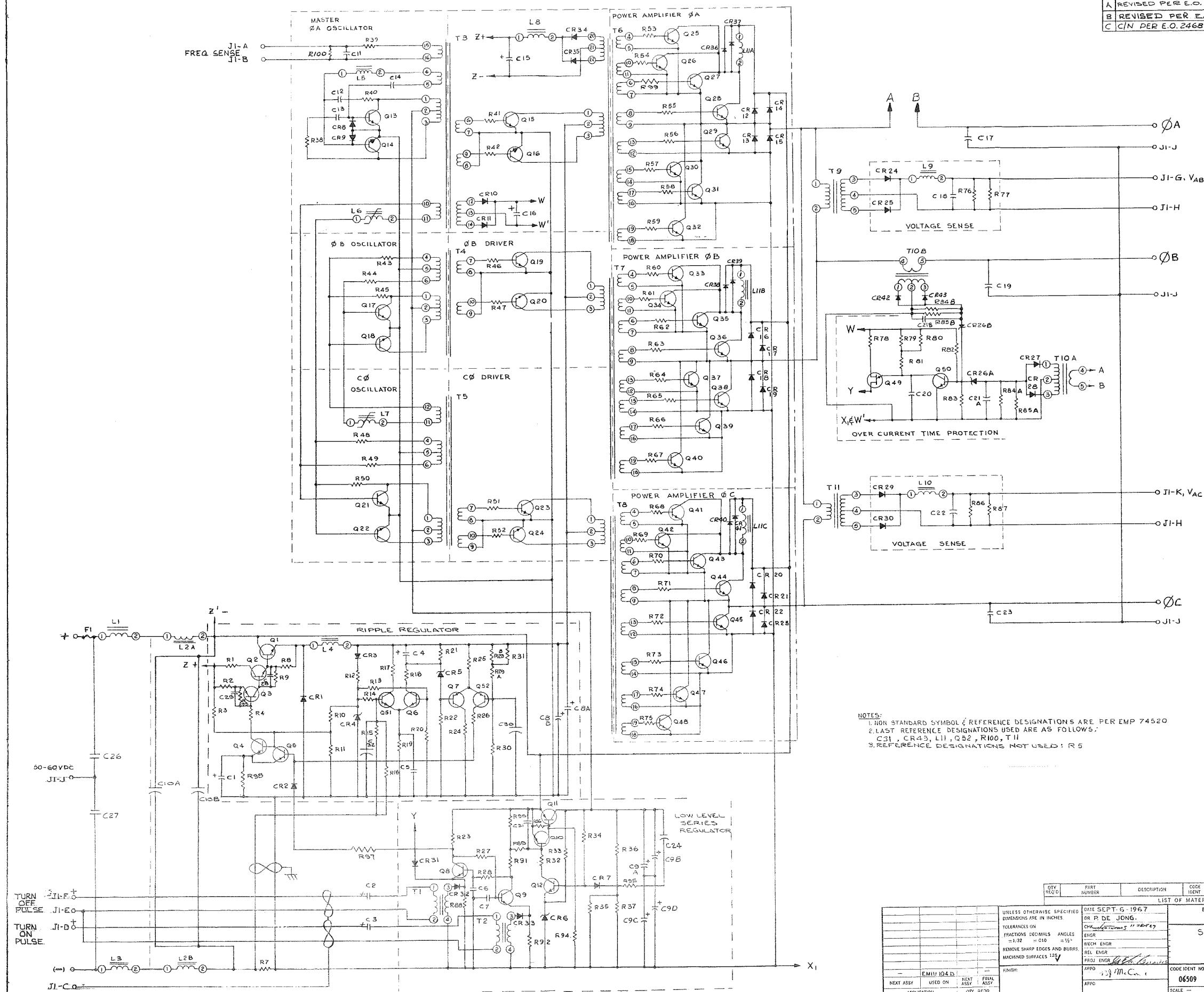
WAS DIODE DESIGNATION F/D AT T10B IS CR42 WAS CR36
CR43 WAS CR37

NOTE 2. LAST REF DESIGNATION WAS CR37 & R97

INCORPORATED	DATE 19 AUG 68	DR P. Manana	CHK E.J. BERRIMAN.
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DWG NO. 513634 C

REVISIONS			
SYN	DESCRIPTION	DATE	APPROVED
A	REVISED PER E.O. 22907	8/27/67	
B	REVISED PER E.O. 11986	11/15/68	
C	C/N PER E.O. 24689	11/15/68	



NOTES:
 1. NON STANDARD SYMBOL & REFERENCE DESIGNATIONS ARE PER EMP 74520
 2. LAST REFERENCE DESIGNATIONS USED ARE AS FOLLOWS:
 C31, CR43, L11, Q52, R100, T11
 3. REFERENCE DESIGNATIONS NOT USED: R5

513634 C

QTY REQ'D	PART NUMBER	DESCRIPTION	CODE IDENT	SPECIFICATION	MATERIAL	ITEM NO.
LIST OF MATERIAL						
UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS DECIMALS ANGLES = .010 = .010 = 15° REMOVE SHARP EDGES AND BURRS MACHINED SURFACES 125°						
DATE SEPT. 6 - 1967 DR. P. DE JONG. CHK. 11/15/68 ENGR. MECH. ENGR. REL. ENGR. PROD. ENGR.						
ENGINEERED MAGNETICS DIVISION OF GULF INDUSTRIES, INC. HAWTHORNE, CALIFORNIA						
SCHEMATIC DIAGRAM - STATIC INVERTER, EMU 104 D						
CODE IDENT NO. 06509 SIZE E 513634						
SCALE - SHEET 1 OF 1						

GULTON INDUSTRIES, INC. HAWTHORNE, CALIFORNIA		CODE IDENT NO. 06509	EO NO. N ^o 25117 ENGINEERING ORDER	
✓M 514100		DWG TITLE	DWG NO.	REV
MODEL EMIU104D		FINAL ASSY.	514100	B
REQD BY H. TAMANAKA		OTHER DWGS AFFECTED LM.	INCORPORABLE: YES ☒ NO ☐	
DR E. J. BERRIMAN.			DEPT. AFFECTED	
CHK <i>H. T.</i> 31 DEC 68			PROTO: ☒	PROD: ☒
MECH <i>H. T.</i>			SPL PROD:	WHT RM:
DES ENG		REASON:		
REL		UPDATE DWG.		
PROG MGR		EFFECTIVITY (LIST JOB & SERIAL NO.):		
ENG MGR <i>E. J.</i>		JOB NO. 6502 & FUTURE		
QC		DISPOSITION OF MATL / PARTS:		
APPD <i>B. J. McConel</i>		UNIT MUST CONFORM		
CUSTOMER APPD				

REVISION

CHANGE NOTICE.

- ON F/D ADDED ITEM: 55 & ON R.H. VIEW ADDED LUG WITH HARDWARE ITEMS 21, 26, 31, 38, 56, 57 & 58
- CAPACITORS WERE SHOWN C10B, L2B, R.H & C10A, L2A, L.H.
- ON LM ITEM: 21 WAS 6 REQ'D

	26		38	
	31		6 REQ'D	

ITEM: 38 WAS MS 51957-29, #6-32 X 7/16, 24 REQ'D
ITEM: 53 WAS MS 35230-83, #1/4-28 X 1"
ITEMS 55-58 ADDED

DWG NO. 514100 B

INCORPORATED	DATE 12-30-68.	DR E. J. BERRIMAN.	CHK <i>H. T.</i>
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GULTON INDUSTRIES, INC. HAWTHORNE, CALIFORNIA		CODE IDENT NO. 06509	EO NO. N° 26196 ENGINEERING ORDER	
L/M LM514100	DWG TITLE		SHEET 1 OF 1	REV
MODEL 1U104D	LIST OF MATERIALS		DWG LM514100	B
REQD BY H. TAMANAKA	COMPONENT ASSY		NO. 314109	A
DR K. JACOBS	OTHER DWGS AFFECTED		INCORPORABLE: YES ☒ NO ☐	
CHK <i>[Signature]</i>	NONE		DEPT. AFFECTED	
MECH			PROTO:	PROD: ☒
DES ENG <i>[Signature]</i>	REASON:		SPL PROD:	WHT RM:
REL	DRAFTING ERROR - 2 R99 EXIST			
PROG MGR <i>[Signature]</i>	EFFECTIVITY (LIST JOB & SERIAL NO.):			
ENG MGR	JOB 6502 & FUTURE			
QC				
APPD <i>[Signature]</i>	DISPOSITION OF MATL / PARTS:			
CUSTOMER APPD	NOT AFFECTED			

REVISION

LM514100

1. ITEM 531 - CHG REF DESIG FROM R99 TO R100

314109

2. ITEM 17 & ON ASSY VIEW - CHANGE
REF DESIG FROM R99 TO R100.

INCORPORATED	DATE	DR	CHK
--------------	------	----	-----

DWG NO. LM514100
314109
B

GULTON INDUSTRIES, INC. HAWTHORNE, CALIFORNIA		CODE IDENT NO. 06509	EO NO. N ^o 25118 ENGINEERING ORDER	
L/M 514100		DWG TITLE		SHEET 1 OF 1
MODEL EMIU104D		LIST OF MATERIALS		DWG NO. LM514100 B
REQD BY H. TAMANAKA		OTHER DWGS AFFECTED 514100		INCORPORABLE: YES ☒ NO ☐
DR E.J. BERRIMAN.				DEPT. AFFECTED
CHK <i>[Signature]</i> PROD. 1.02				PROTO: ☒ PROD: ☒
MECH <i>[Signature]</i>				SPL PROD: WHT RM:
DES ENG		REASON: UPDATE LM.		
REL				
PROG MGR				
ENG MGR <i>[Signature]</i>				
QC		EFFECTIVITY (LIST JOB & SERIAL NO.): JOB NO. 6502 & FUTURE		
APPD <i>[Signature]</i>		DISPOSITION OF MATL / PARTS: UNIT MUST CONFORM		
CUSTOMER APPD				

REVISION

CHANGE NOTICE.

1. ITEM: 51 WAS 6 REQ'D
2. | 58 | 38 |
3. | 66 | 6 REQ'D
4. | 79 | MS 51357-29, #6-32 x 7/16, 24 REQ'D
5. ITEM: 100 WAS MS 35230-83, 1/4-28 x 1"
6. ADDED ITEMS 102 - 105

DWG NO. LM514100 B

INCORPORATED	DATE 12-30-68.	DR E.J. BERRIMAN	CHK <i>[Signature]</i>
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REVISIONS			
SYM	DESCRIPTION	DATE	APPROVED
A	C/N PER E.O. 24691 <i>A2</i>	20 AUG. 68	<i>[Signature]</i>
B	C/N PER E.O. 25118 E.J.B.	12-30- 68.	<i>[Signature]</i>

DATE 8 APRIL 68	Gulton Industries, Inc. HAWTHORNE, CALIFORNIA			
DR <i>John M. O'Brien</i>				
CHK <i>[Signature]</i> 6-4-68.	LIST OF MATERIALS EMIUI04D			
ENGR				
MECH ENGR <i>[Signature]</i>				
REL ENGR				
PROJ ENGR <i>[Signature]</i>				
APPD <i>Bj McComb</i>	CODE IDENT NO.	SIZE		
	06509	A	LM514100	B
APPD	SCALE		SHEET 1 OF 22	

ITEM	PART NUMBER	ASSY LEVEL						DESCRIPTION SYM, SPEC, CODE IDENT NO.	QTY REQ
		1	2	3	4	5	6		
1	413519							OUTLINE & SPEC DWG	
2									
3	513634							SCHEMATIC	
4									
5	710410							RIVET INSTALLATION	
6	72378							WELDING MANUAL	
7	EMP74444							IDENT & MARKING PARTS & ASSEMBLIES	
8	EMP77430							PROCESS SPEC COATING & ADHESIVES	
9	EMP77431							PROCESS SPEC EPOCAST 202	
10	EMP74960							MFR OF WINDINGS	
11	EMP77433							MFG PROCESS & PROCEDURE	
12								"C" CORE WINDINGS	
13	77918							PROC SPEC MATL LEAD	
14								COMPONENT PARTS	
15	79400							WORKMANSHIP STDS	
16	79492							HAND SOLDERING ELECT	
17								CONNECTIONS	
18									
19	EMP74447							METHODS OF MTG.	
20								SEMICONDUCTORS	
21	T413059							WELDING FIXTURE	
22	EMP711304							MTG SEMICONDUCTORS	
23								(FLATPACKS)	
24									
25	EMP712744							POTTING SPEC, SILICONE RUBBER	
26									
27	EMP11019							POTTING SPEC, FLEXIBLE EPOXY RESIN	
28									
29	EMP74448							PROCESS SPEC, IDENT PLATES	
30									
31	711488							CORES, PERMALLOY TYPE POWDER	
32	75908							PROC SPEC RES	
33	75574							PROC SPEC TOROIDAL CORES	
34	711476							SPEC CONTROL DWG, CAP	
35	710465							SPEC CONTROL DWG, RES	
		SIZE		CODE IDENT NO					
		A		06509				LM 514100	
		SCALE				REV B			SHEET 2

ITEM	PART NUMBER	ASSY LEVEL						DESCRIPTION SYM, SPEC, CODE IDENT NO.	QTY REQ
		1	2	3	4	5	6		
36	514100							FINAL ASSY	1
37	A313561							SILKSCREEN, NAMEPLATE	1
38	314177							INSULATOR BKT	1
39	414102							COVER PLATE &	1
40								GASKET ASSY	
41									
42									
43	MS3116E-12-10P							PLUG MIL-C-26482	2
44	MS3112E-12-10S							CONNECTOR J1, MIL-C-26482	1
45	2N5001							TSTR Q11 FAIRCHILD	1
46	14101-5C12							SPACER	4
47									
48									
49									
50									
51	MS35649-64							NUT, HEX #6-32	7
52									
53	MS35649-84							, HEX #8-32	1
54	AN345B416							NUT, HEX 1/4-28 BRASS	10
55									
56									
57	MS15795-803							WASHER, FLT #4	4
58	-805							, FLT #6	39
59	MS15795-807							WASHER, FLT #8	3
60									
61	AN961-416							WASHER, FLT 1/4 BRASS	10
62									
63									
64									
65	MS35338-78							WASHER, LOCK #4	1
66	-79							, LOCK #6	7
67									
68	MS35338-80							, LOCK #8	1
69	AN935B416							WASHER, LOCK 1/4 BRONZE	10
70									
		SIZE CODE IDENT NO							
		A 06509						LM 514100	
		SCALE ———						REV B SHEET 3	

ITEM	PART NUMBER	ASSY LEVEL						DESCRIPTION SYM, SPEC, CODE IDENT NO.	QTY REQ
		1	2	3	4	5	6		
71	313559	\						IDENTIFICATION PLATE	1
72	A313560	\						SILKSCREEN	1
73									
74	1747-2	\						WASHER, MICA #8	1
75	14092-4	\						WASHER, EPOXY #8	1
76									
77	MS51957-31	\						SCREW, PAN HD #6-32X5/8	4
78	MS51957-15	\						SCREW, PAN HD #4-40X3/8	4
79	MS51957-30	\						SCREW, PAN HD #6-32X1/2	25
80	MS51957-49	\						SCREW, PAN HD #8-32X1	2
81	MS51957-27	\						SCREW, PAN HD #6-32X5/16	2
82	MS35233-33	\						SCREW, PAN HD #6-32X7/8	2
83	MS24693C-29	\						SCREW, C'SK #6-32X5/8	4
84									
85		-42	\					, C'SK #6-32X2 1/2	2
86									
87		-28	\					, C'SK #6-32X1/2	12
88		-40	\					, C'SK #6-32X2	4
89	MS24693C-274	\						SCREW C'SK #10-32X3/4	30
90									
91									
92									
93	25429-3-3	\						INSERT #8	1
94									
95									
96	MS35489-4	\						GROMMET	2
97									
98	208-.250	\						LUG ZIERICK	5
99	127-.281	\						LUG ZIERICK	1
100	MS35230-84	\						SCREW, PAN HD. 1/4-28X1/4 BRASS	1
101									
102	3/8 O.D.X.28 I.D.X.125	\						TUBE EPOXY GL. LAM. NEMA GIO	1
103	110X.144	\						LUG ZIERICK	1
104	25429-2	\						INSERT, INS	1
105	14092-3	\						WASHER, FLT. INS	2
		SIZE		CODE IDENT NO				LM 514100	
		A		06509					
		SCALE				REV B			SHEET 4

ITEM	PART NUMBER	ASSY LEVEL						DESCRIPTION, SYM, SPEC, CODE IDENT NO.	QTY REQ
		1	2	3	4	5	6		
106									
107									
108									
109									
110									
111									
112	314161							HEAT SINK ASSY, TB7	1
113	314152							TERM BD ASSY TB7	1
114	4535-A							TERMINAL LERCO	3
115	314138							CHOKE L4	1
116	214618							POTTING CLIP	1
117	33449BC13-0							CLIP	1
118	5026-A							TERMINAL LERCO	2
119	55930-W4							CORE MAG. INC.	1
120	74808H							DIODE CRI	1
121	711347H							TRANSISTOR Q1	1
122	MS35233-15							SCREW, P.H.#4-40	2
123	27999C0421							SCREW, P.H.#4-40	1
124	MS35649-104							NUT, HEX#10-32	1
125	MS35649-44							NUT, HEX#4-40	3
126	NAS620-A4L							WASHER, FLT #4	6
127	MS15795-808							WASHER, FLT #10	1
128	MS35337-78							WASHER, LOCK #4	3
129	MS35337-81							WASHER, LOCK #10	1
130									
131	25429-4-7							INSERT	1
132	314153							HEAT SINK	1
133	MK2331-06							NUT ANCHOR#6-32 KAYLOCK	1
134	MF1001-06							NUT ANCHOR#6-32 KAYLOCK	3
135	MS20426AD2							RIVET	2
136	MS20426AD3							RIVET	6
137	BBD-625-063							HEAT SINK, INS NAT. BERYLLIA CO.	1
138									
139	TYPE E							WIRE FLEX MIL-W-16878 TEFLON	A/R
140									
		SIZE		CODE IDENT NO					
		A		06509		LM 514100			
		SCALE		REV		B		SHEET	
								5	

ITEM	PART NUMBER	ASSY LEVEL						DESCRIPTION SYM, SPEC, CODE IDENT NO.	QTY REQ
		1	2	3	4	5	6		
141	514101							CASE ASSY	1
142	MT2S632K							NUTPLATE BOOTS AIRCRAFT	4
143	KNHLO632							INSERT KEENSERT	24
144	MS20426AD2							RIVET	16
145	MS20426AD3							RIVET	8
146	MF1001-08							NUTPLATE KAYNAR	2
147	MF1301-04							NUTPLATE KAYNAR	4
148	MK2001-06							NUTPLATE KAYNAR	2
149									
150									
151									
152	314164							CAPACITOR MOUNT - A7 ASSY	1
153	214165							CUP ASSY	1
154	3010B							TERMINAL LERCO	2
155	MF6001-06							NUTPLATE KAYNAR	2
156	MS20426AD3							RIVET	4
157	75576-4							CAPACITOR C8A & B	2
158	771							CLAMP HERMAN H. SMITH	2
159									
160									
161									
162	314155							COMPONENT ASSY, A6	1
163	214151							TERMINAL BD, TB9	1
164	3050-B							TERMINAL LERCO	6
165	214154							MODULE, POTTED A6	1
166	314150							CUP ASSY	1
167	3050-B							TERMINAL LERCO	11
168	214157							MODULE	1
169	314123							TRANS. T1, T2	1
170	A13A1							CORE EM75574	1
171	414156							MODULE ASSY, LOW LEVEL A6	1
172	A414156-2							POSITIONER (ARTWORK)	1
173	A414156-3							POSITIONER (ARTWORK)	1
174									
175									
		SIZE CODE IDENT NO							
		A 06509						LM 514100	
		SCALE —						REV B SHEET 6	

ITEM	PART NUMBER	ASSY LEVEL						DESCRIPTION, SYM, SPEC, CODE IDENT NO.	QTY REQ
		1	2	3	4	5	6		
176									
177	M39003/DI-2049							CAP C2, C3 15 μ F 20 VDC	2
178								MIL-C-39003	
179	CYKOIBT682K							CAP C6 .0068 μ f @ 50 VDC	1
180								PER 711476	
181	CYKOIBT472K							CAP C7 .0047 μ f @ 50 VDC	1
182								PER 711476	
183	LP8AIB224K							CAP C24 0.22 μ F @ 100 VDC	1
184								DEARBORN	
185	CYKOIBV223K							CAP C31 0.022 μ F PER 711476	1
186	AFIN645							DIODE CR7, 31A, 32, 33 MIL-E-1 / 1143	4
187	79430H							DIODE CR6A	1
188	RN55C5112F							RES R23 51.1K 710465	1
189	RN60C2493F							R27 249K 75908	1
190	RN60C3013F							R28 301K 75908	1
191	RN55C4221F							R32 4.22K 710465	1
192	RS-2 - 20K Ω							R33 20K Ω DALE	1
193	RN60C1003F							R34 100K 75908	1
194	RN60C3012F							R36 30.1K 75908	1
195	RN55C5361F							R37 5.36K 710465	1
196	RN55C3000F							R88, 92 300 Ω 710465	2
197	WWA-13-18-5K							R89 5K BALCO	1
198	RN55C4421F							R90 4.42 K 710465	1
199	RN55C4642F							R91 46.4K 710465	1
200	RW79U4001F							R94 4K MIL-R-26	1
201	RN55C8660F							R95 866 Ω 710465	1
202	RN55C3011F							R96 3.01K Ω 710465	1
203	RN60C1963F							RES R97 196K 75908	1
204	73531H							TSTR Q8, 9, 12	3
205	711477H							TSTR Q10	1
206	77977							RIBBON, NICKEL .030 X .010	A/R
207	77976							WIRE, NICKEL .020 DIA	A/R
208	TYPE E							WIRE FLEX MIL-W-16878 TEFLON	A/R
209									
210									
		SIZE		CODE IDENT NO					
		A		06509		LM 514100			
		SCALE		REV B		SHEET 7			

ITEM	PART NUMBER	ASSY LEVEL						DESCRIPTION, SYM, SPEC, CODE IDENT NO.	QTY REQ
		1	2	3	4	5	6		
211									
	EM79474-6							CAP C9A,B,C,D 30 μ F, 75VDC G.E.	4
	RN55C...F*							RES. R35*SET IN TEST 710465	1
215	TYPE E							WIRE, FLEX MIL-W-16878 TEFLON	A/R
	TYPE S							WIRE, BUSS QQ-W-343	A/R
								SOFT COAT	
220									
225									
	314182							MODULE ASSY A8	1
	314168							CUP ASSY, A8	1
	3050-B							TERMINAL LERCO	10
230	MF6001-06							NUTPLATE KAYNAR	4
	MS20426AD3							RIVET	8
	414184							MODULE COMPONENT ASSY	1
	A414184-2							POSITIONER (ARTWORK)	1
	A414184-3							POSITIONER (ARTWORK)	1
235	M39003/01-2064							CAP C1,4,5 6.8 μ F @ 35VDC MIL-C-39003	3
	CYK01BT332K							CAP C29,30 0.0033 μ F 711476	2
	CYK01BV223K							CAP C28 0.022 μ F 711476	1
	39003/01-2043							CAP C32, 2.2 μ F, 20VDC MIL-C-39003	1
	AFIN645							DIODE CR2, CR3 MIL-E-1/1143	2
240	79430H							DIODE CR4, CR5	2
	RW79U3R01F							RES R1 3 Ω MIL-R-26	1
	RW79U12R4F							R2 12.5 Ω MIL-R-26	1
	RN55C7152F							R3 71.5K Ω 710465	1
	RN55C1782F							R4 17.8K Ω 710465	1
245	RN55C1000F							RES R8 100 Ω 710465	1
		SIZE		CODE IDENT NO					
		A		06509				LM 514100	
		SCALE		REV B				SHEET 8	

ITEM	PART NUMBER	ASSY LEVEL						DESCRIPTION SYM, SPEC, CODE IDENT NO.	QTY REQ
		1	2	3	4	5	6		
246	RN55C5110F							RES R9 511Ω 710465	1
	RN55C2151F							R10 2.15KΩ 710465	1
	RN55C3651F							R11 3.65KΩ 710465	1
	RW74U4991F							R12 5KΩ MIL-R-26	1
250	RN55C2871F							R13 2.87KΩ 710465	1
	2151F							R14 2.15KΩ 710465	1
	2051F							R15 2.05KΩ 710465	1
	5621F							R17 5.62KΩ 710465	1
	2151F							R18 2.15KΩ 710465	1
255	5360F							R19 536Ω 710465	1
	RN55C1781F							R20 1.78KΩ 710465	1
	RW79U8500F							R21 850Ω MIL-R-26	1
	RW74U6491F							R22 6.5KΩ MIL-R-26	1
	RN55C2492F							R24 24.9KΩ 710465	1
260	2742F							R25 27.4KΩ 710465	1
	6192F							R26 61.9KΩ 710465	1
	3652F							R29B 36.5KΩ 710465	1
	8252F							R30 82.5KΩ 710465	1
	RN55C2151F							R93 2.15K 710465	1
265	RN55C1211F							RES R98 1.21K 710465	1
	711477H							TSTR Q3, 7.52 2N3635	3
	WWA-13-18-1.5K							RES R29A BALCO	1
	73531H							TSTR Q4-6, 51 2N2102	4
270	78324H							TSTR Q2 2N2658	1
	RN55C---F*							RES R31, R16* S.I.T. 710465	2
275									
280									
		SIZE		CODE IDENT NO					
		A		06509				LM 514100	
		SCALE		—				REV B SHEET 9	

ITEM	PART NUMBER	ASSY LEVEL						DESCRIPTION, SYM, SPEC, CODE IDENT NO.	QTY REQ
		1	2	3	4	5	6		
281	414114							PHASE B ASSY	1
285	313557							TRANSFORMER TIOB	1
	AFIN645							DIODE CR42,43	2
	313555-1							POTTING CUP ASSY	1
	313555-2							CUP	1
290	5026-A							TERMINAL LERCO	4
	14101-4A28							TUBE	1
	314133							XMFR TIOB	1
	A22A1							CORE EM75574	1
295	#2538							TAPE 3M	A/R
	414104							HEAT SINK, TSTR MT	1
	10140-2402							H-BEAM TIERNEY METALS	1
	MF1001-3							NUT PLATE #10-32 KAYNAR	10
300	MF1001-06							NUT PLATE #6-32 KAYNAR	2
	MS20426AD3							RIVET	36
	NCN-4-6-2							CAPTIVE NUT #4-40 NATIONAL RADIO CO.	2
	MF1001-08							NUT PLATE #8-32 KAYNAR	2
	MK2001-06							NUT, ANCHOR #6-32 KAYNAR	2
305	MK2001-08							NUT, ANCHOR #8-32 KAYNAR	2
	314175							COMP BD ASSY, TB2	1
	314173							TERM. BD ASSY TB2	1
	3025A							TERMINAL LERCO	17
	RW-79U34R8F							RES R43,44 34.8 Ω MIL-R-26	2
310	RW-79U20ROF							R46,47 20 Ω	2
	RW-79U1501F							R76 1500 Ω	1
	RW-79U-----F*							RES R77*S.I.T. MIL-R-26	1
	M39003/01-2023							CAP C18 120 μ F @ 10VDC MIL-C-39003	1
	73531H-120							TSTR Q17,18	2
315	10038							TRANSIPAD MILTON ROSS	2
		SIZE		CODE IDENT NO					
		A		06509		LM 514100			
		SCALE —		REV B		SHEET 10			

ITEM	PART NUMBER	ASSY LEVEL						DESCRIPTION, SYM, SPEC, CODE IDENT NO.	QTY REQ
		1	2	3	4	5	6		
316	RN55C5112F							RES R45 51.1K Ω 710465	1
	3009-A							TERMINAL LERCO	1
	314113							CUP ASSY A2	1
	314172							POTTING CUP	1
320	3520-B							TERMINAL LERCO	2
	5026-B							TERMINAL LERCO	26
	314126							TRANSFORMER T4	1
	A20A1							CORE EM75574	1
	314129							TRANSFORMER T7	1
325	5203B-2A							CORE MAG INC	1
	1747-1							WASHER, MICA	2
	25429-4-3							INSERT, INS	1
	NAS671-C10							NUT #10-32	6
330									
	214149							TERM BD TB5A & 5B	2
	3010A							TERMINAL LERCO	8
335									
	RW74UR750F							RES. R60-67 MIL-R-26	8
	JANIN1202							DIODE, CR16-19, 38, 39 MIL-S-19500/260	6
	79807H							TSTR Q33-40	8
	MS35691-530							NUT, HEX 5/16-24	8
340	MS35691-430							NUT, HEX 1/4-28	2
	AN345B10							NUT, HEX BRASS	1
	1747-2							WASHER, MICA #10	6
	MS15795-812							WASHER, FLT 5/16	8
	MS15795-810							, FLT 1/4	2
345	MS15795-808							, FLT #10	6
	MS15795-807							, FLT #8	4
	MS15795-805							, FLT #6	4
	MS15795-803							, FLT #4	2
	MS35337-83							, LOCK 5/16	8
350	MS35337-82							WASHER, LOCK 1/4	2
		SIZE		CODE IDENT NO					
		A		06509		LM 514100			
		SCALE		—		REV		B	
						SHEET		11	

ITEM	PART NUMBER	ASSY LEVEL						DESCRIPTION, SYM, SPEC, CODE IDENT NO.	QTY REQ
		1	2	3	4	5	6		
351	MS35337-81							WASHER, LOCK #10	6
	14092-6							, EPOXY 1/4	2
	14092-7							, EPOXY 5/16	8
	14092-5							, EPOXY #10	7
355	MW-880-320							WASHER, MICA 5/16 DELBERT BLINN	8
	MS35230-68							SCREW, P.H. #10-32X1 1/4 BRASS	1
	MS51957-52							, P.H. #8-32X1 3/4	4
	MS51957-36							, P.H. #6-32X1 1/2	4
	MS51957-22							SCREW, P.H. #4-40X1 1/4	2
360	115-.196							LUG ZIERICK	2
	112-.196							LUG ZIERICK	6
	25429-5-7							INSERT, INS	2
	25429-6-7							INSERT, INS	8
	25429-4-7							INSERT, INS	6
365	MS20426AD3							RIVET	6
	710438H-1							TSTR Q19, 20	2
	214186							CHOKE ASSY LIIB	1
	214163							CUP ASSY	1
	314145							CHOKE LIIB	1
370	CL-3							CORE CARSTEDT	1
	14597-1							BOBBIN WESTINGHOUSE	1
	3/16 x 3/16							BAND SEAL	1
	3/16 x .006							BAND BRONZE	A/R
375	314615							CUP ASSY A4	1
	314176							CUP	1
	5026-B							TERMINAL LERCO	7
	314134							TRANSFORMER T9	1
	A22A1							CORE EM75574	1
380	*2538							TAPE 3M	A/R
	314143							CHOKE L9, L10	2
	55046-A2							CORE MAG INC.	2
	AFIN645							DIODE CR24, 25 MIL-E-11143	2
	AN961-10							WASHER, FLT #10 BRASS	3
385	AN935B10							WASHER, LOCK #10 BRONZE	1
		SIZE		CODE IDENT NO					
		A		06509				LM 514100	
		SCALE		REV B				SHEET 12	

ITEM	PART NUMBER	ASSY LEVEL						DESCRIPTION, SYM, SPEC, CODE IDENT NO.	QTY REQ
		1	2	3	4	5	6		
386	414118							PHASE C ASSY	1
	414104							HEAT SINK TSTR MT.	1
	10140-2402							H-BEAM TIERNEY METALS	1
	MF1001-3							NUT PLATE #10-32 KAYNAR	10
390	MF1001-06							NUT PLATE #6-32 KAYNAR	2
	MS20426AD3							RIVET	36
	NCN-4-6-2							CAPTIVE NUT #4-40 NATIONAL RADIO CO	2
	MF1001-08							NUT PLATE #8-32 KAYNAR	2
	MK2001-06							NUT, ANCHOR #6-32 KAYNAR	2
395	MK2001-08							NUT, ANCHOR #8-32 KAYNAR	2
	314174							COMP BD ASSY TB3	1
	314173							TERM BD ASSY TB3	1
	3025A							TERMINAL LERCO	17
	RW-79U34R8F							RES R48,49 34.8 Ω MIL-R-26	2
400	RW-79U20ROF							R51,52 20 Ω	2
	RW-79U150IF							R86 1500 Ω	1
	RW-79U----F*							RES R87 *S.I.T. MIL-R-26	1
	M39003/01-2023							CAP C22 120 WFD @ 10VDC MIL-C-39003	1
	73531H-120							TSTR Q21,22	2
405	1003B							TRANSIPAD MILTON ROSS	2
	RN55C5112F							RES R50 51.1K Ω 710465	1
	314117							CUP ASSY A3	1
	314172							CUP	1
	3520-B							TERMINAL LERCO	2
410	5026-B							TERMINAL LERCO	26
	314129							TRANSFORMER T8	1
	52038-2A							CORE MAG INC	1
	3009-A							TERMINAL LERCO	1
415	314127							TRANSFORMER T5	1
	A20A1							CORE EM75574	1
	314140							SATURABLE REACTOR L7	1
	A13A1							CORE EM75574	1
420									
		SIZE		CODE IDENT NO					
		A		06509		LM 514100			
		SCALE		REV		B		SHEET 13	

ITEM	PART NUMBER	ASSY LEVEL						DESCRIPTION, SYM, SPEC, CODE IDENT NO.	QTY REQ
		1	2	3	4	5	6		
421									
	214149							TERM BD TB6A, B	2
425	3010A							TERMINAL LERCO	8
	RW74UR750F							RES R68-75 0.75Ω MIL-R-26	8
	JANINI202							DIODE CR20-23,40,41 MIL-S-19500/260	6
	79807H							TSTR Q41,48	8
	MS35691-530							NUT, HEX 5/16-24	8
430	MS35691-430							NUT, HEX 1/4-28	2
	NAS671-C10							NUT, HEX #10-32	6
	1747-2							WASHER, MICA #10	6
	MW-880-320							, MICA 5/16 DELBERT BLINN	8
	MS15795-812							, FLT 5/16	8
435	-810							, FLT 1/4	2
	-808							, FLT #10	6
	-807							, FLT #8	4
	-805							, FLT #6	4
	MS15795-803							, FLT #4	2
440	MS35337-83							, LOCK 5/16	8
	MS35337-82							, LOCK 1/4	2
	MS35337-81							, LOCK #10	6
	14092-6							, EPOXY 1/4	2
	14092-7							, EPOXY 5/16	8
445	14092-5							WASHER, EPOXY #10	6
	MS51957-52							SCREW, PAN HD #8-32X 1 3/4	4
	MS51957-36							SCREW, PAN HD #6-32X 1 1/2	4
	MS51957-22							SCREW, PAN HD #4-40X 1 1/4	2
	112-196							LUG ZIERICK	6
450	25429-5-7							INSERT, INS 1/4	2
	25429-6-7							INSERT, INS 5/16	8
	25429-4-7							INSERT, INS #10	6
	MS20426AD3							RIVET	6
	710438H-1							TSTR Q23,24	2
455	1747-1							WASHER, MICA	2
		SIZE		CODE IDENT NO					
		A		06509		LM 514100			
		SCALE		REV		B		SHEET 14	

ITEM	PART NUMBER	ASSY LEVEL						DESCRIPTION, SYM, SPEC, CODE IDENT NO.	QTY REQ
		1	2	3	4	5	6		
456									
	314616							CUP ASSY A5	1
460	314176							POTTING CUP	1
	5026-B							TERMINAL LERCO	7
	314134							TRANSFORMER T11	1
	A22A1							CORE EM75574	1
465	*2538							TAPE 3M	A/R
	AFIN645							DIODE CR29,30 MIL-E-11143	2
470									
	214186							CHOKE ASSY LIIC	1
	214163							CUP ASSY	1
475	314145							CHOKE LIIC	1
	CL-3							CORE CARSTEDT	1
	14597-1							BOBBIN WESTINGHOUSE	1
	3/16 X 3/16							BAND SEAL	1
	3/16 X .006							BAND BRONZE	A/R
480									
485									
490									
		SIZE		CODE IDENT NO					
		A		06509		LM 514100			
		SCALE		REV B		SHEET 15			

ITEM	PART NUMBER	ASSY LEVEL						DESCRIPTION SYM, SPEC, CODE IDENT NO.	QTY REQ
		1	2	3	4	5	6		
491									
495									
500	414111							PHASE A ASSEMBLY	1
	414105							HEAT SINK TSTR MOUNT	1
	10140-2402							H-BEAM TIERNEY METALS	1
								6061-T6-511	
	MF1001-3							NUT PLATE #10-32 KAYNAR	10
505	NCN-4-6-2							CAPTIVE NUT #4-40	2
								NATIONAL RADIO CO	
	MS20426AD3							RIVET	32
	MF1001-08							NUTPLATE #8-32 KAYNAR	2
	MK2001-06							NUT, ANCHOR #6-32 KAYNAR	2
510	MK2001-08							NUT, ANCHOR #8-32 KAYNAR	2
	314109							COMP BD ASSY TBI	1
	314108							TERMINAL BD ASSY	1
	3025A							TERMINAL LERCO	24
515	RN55C1272F							RES R38 710465 12.7KΩ	1
	3009-A							TERMINAL LERCO	3
	RW-79U1001F							RES R39 MIL-R-26	1
	RN55C1272F							R40 710465 12.7KΩ	1
	RW-79U20ROF							RES R41,42 MIL-R-26	2
520	CYK01BV333K							CAP C11 PER 711476 0.033μF @	1
								200VDC	
	LP8A1C224K							C12,13 DEARBORN	2
								0.022μF @ 200VDC	
	LP8A1C474K							CAP C14 0.47μF @ 200VDC	1
525								DEARBORN	
		SIZE		CODE IDENT NO					
		A		06509		LM 514100			
		SCALE		REV B		SHEET 16			

ITEM	PART NUMBER	ASSY LEVEL						DESCRIPTION SYM, SPEC, CODE IDENT NO.	QTY REQ
		1	2	3	4	5	6		
526	M39003/01-2019							CAP C15 MIL-C-39003 39 uf @ 10VDC	1
	M39003/01-2066							CAP C16 MIL-C-39003 22 uf @ 35VDC	1
530	73531H-120							TSTR Q13,14	2
	RN55C----F*							RES R99* S.I.T. APPROX. 10K 710465	1
	AFIN645							DIODE CRB,9 MIL-E-1/1143	2
	314139							CHOKE L5	1
	33449BF10F02-0							POTTING CUP	1
535	10W5Z							CORE 711488	1
	10038							TRANSIPAD MILTON ROSS	2
540									
	314120							CUP ASSY A1	1
	314119							POTTING CUP	1
	3520-B							TERMINAL LERCO	2
	5026-B							TERMINAL LERCO	36
545									
	314128							TRANSFORMER T6	1
	52038-2A							CORE MAG INC	1
550	314143							TRANSFORMER T3	1
	A20A1							CORE EM75574	1
	314140							SATURABLE REACTOR L6	1
	A13A1							CORE EM75574	1
555									
	314141							CHOKE L8	1
	55310-2A							CORE MAG INC.	1
	AFIN645							DIODE CR10,11 MIL-E-1/1143	2
560	76014H							DIODE CR34,35 GE	2
		SIZE		CODE IDENT NO					
		A		06509		LM 514100			
		SCALE		REV B		SHEET 17			

ITEM	PART NUMBER	ASSY LEVEL						DESCRIPTION, SYM, SPEC, CODE IDENT NO.	QTY REQ
		1	2	3	4	5	6		
561	313556							TRANSFORMER T10A	1
	AFIN645							DIODE CR27,28	2
	313555-1							POTTING CUP ASSY	1
565	313555-2							CUP	1
	5026-A							TERMINAL LERCO	4
	14101-4A28							TUBE	1
570									
	314133							XMFR T10A	1
	A22A1							CORE EM75574	1
	#2538							TAPE 3M	A/R
575									
580	314189							MODULE ASSY A9	1
	314185							POTTING CUP	1
	3025-A							TERMINAL LERCO	10
	314187							WELDED MODULE ASSY	1
	A314187-2							POSITIONER (ARTWORK)	1
585	A314187-3							POSITIONER (ARTWORK)	1
	RN60C1403F							RES R81 140K Ω 75908	1
	RN55C3012F							R82 30.1K Ω 710465	1
	C3831F							R83 3.83K Ω 710465	1
	RN55C5361F							R78 5.36K 710465	1
590	RN55C---*F							R84A* 5.1T $\approx$ 200K Ω 710465	1
	RN55C---*F							R84B* S.I.T. $\approx$ 800K Ω 710465	1
	RN55C1001F							RES R85AR85B 710465	2
								1.0K Ω	
	M39003/01-2066							CAP C20 MIL-C-39003	1
595								22 μ F @ 35VDC	
		SIZE		CODE IDENT NO					
		A		06509		LM 514100			
		SCALE		—		REV B		SHEET 18	

ITEM	PART NUMBER	ASSY LEVEL						DESCRIPTION, SYM, SPEC, CODE IDENT NO.	QTY REQ
		1	2	3	4	5	6		
596	M39003/01-2055							CAP C21B MIL-C-39003 47µF @ 20VDC	1
	79430H							DIODE CR26A, CR26B PS12034A/B	2
600	74762H							TSTR Q49	1
	74706H							TSTR Q50	1
	M39003/01-2055							CAP C21A 47µF @ 20VDC MIL-C-39003	1
	RN55C --- F*							RES R805.1.T.=100KΩ 710465	1
	RN55C --- F*							RES R845.1.T.=200KΩ 710465	1
605	214149							TERM BD TB4A & TB4B	2
	3010A							TERMINAL LERCO	8
	AN961-10							WASHER, FLT #10 BRASS	3
610	AN935B10							WASHER, LOCK #10 BRONZE	1
	RW74UR750F							RES R53-R59, R99 MIL-R-26	8
	JANIN1202							DIODE CR12-15, 36, 37 MIL-S-19500/260	6
	79807H							TSTR Q25-32	8
	MS35691-530							NUT, HEX 5/16-24	8
615	MS35691-430							NUT, HEX 1/4-28	2
	AN345B10							NUT, HEX #10-32 BRASS	1
	1747-2							WASHER, MICA #10	6
	MS15795-812							WASHER, FLT 5/16	8
620	-810							, FLT 1/4	2
	-808							, FLT #10	6
	-807							, FLT #8	4
	-805							, FLT #6	2
	MS15795-803							, FLT #4	2
625	MS35337-83							, LOCK 5/16	8
	MS35337-82							, LOCK 1/4	2
	MS35337-81							, LOCK #10	6
	14092-6							, EPOXY 1/4	2
	14092-7							, EPOXY 5/16	8
630	14092-5							WASHER, EPOXY #10	7
		SIZE		CODE IDENT NO					
		A		06509		LM 514100			
		SCALE		REV B		SHEET 19			

ITEM	PART NUMBER	ASSY LEVEL						DESCRIPTION, SYM, SPEC, CODE IDENT NO.	QTY REQ
		1	2	3	4	5	6		
631	MW-880-320							WASHER, MICA 5/16 DELBERT BLINN	8
	MS35230-68							SCREW, PAN HD #10-32 X 1/4 BRASS	1
	MS51957-52							, PAN HD #8-32 X 1 3/4	4
	MS51957-37							, PAN HD #6-32 X 1 3/4	2
635	MS51957-22							SCREW PAN HD #4-40 X 1 1/4	2
	115-196							LUG ZIERICK	2
	112-196							LUG ZIERICK	6
	25429-5-7							INSERT, INSULATOR	2
	25429-6-7							INSERT, INSULATOR	8
640	25429-4-7							INSERT, INSULATOR	6
	MS20426AD3							RIVET	6
	710438H-1							TSTR Q15, 16	2
	214186							CHOKE ASSY L11A	1
	214163							CLIP ASSY	1
645	314145							CHOKE L11A	1
	CL-3							CORE CARSTEDT	1
	14597-1							BOBBIN WESTINGHOUSE	1
	3/16 X 3/16							BAND SEAL	1
	3/16 X .006							BAND, BRONZE	A/R
650									
	1747-1							WASHER, MICA	2
	25429-4-3							INSERT, INSULATOR	1
	NAS671-C10							NUT	6
	314148							RFI ASSEMBLY	1
655	314181							RFI SHIELD	1
	LHA27M2860-62							NUTPLATE ESNA	4
	MS20426AD2							RIVET	8
	314167							COMP BD ASSY	1
	314166							TERM BD ASSY	1
660	3010-A							TERMINAL LERCO	9
	4030-B							TERMINAL LERCO	1
	314135							CHOKE L1, L3	2
	33449AG9F02-O							POTTING CUP	1
								CORE MAG INC	1
665	T7308-4							CAP C26, 27	2
		SIZE		CODE IDENT NO					
		A		06509		LM 514100			
		SCALE		REV		B		SHEET 20	

[illegible]

ITEM	PART NUMBER	ASSY LEVEL						DESCRIPTION, SYM, SPEC, CODE IDENT NO.	QTY REQ
		1	2	3	4	5	6		
701	413510-1							BRACKET	1
	413510-2							BRACKET	1
	MF1301-06							NUT-ANCHOR KAYNAR	6
	K7001-06-6							CLINCH NUT KAYNAR	6
705	MS20426-AD2							RIVET	12
	314122							TERM BD TB11	1
	MS35233-28							SCREW	2
	NAS620A6L							WASHER, FLAT	2
	75576-34							CAP C10A, C10B 660 wtd	2
710								Q 75VDC GE 29F SERIES	
	SST-2B							CABLE-TIE MS17821-1-9	4
								PANDUIT	
715									
	627 X.169							LUG ZIERICK	9
	MS24693-C26							SCREW	4
	MS35230-45							SCREW	4
720	AN935B8							WASHER, LOCK	4
	AN961-B							WASHER, FLAT	8
	MS35650-85							NUT	4
	26756-32X16							INSUL BD	4
725									
	313497							COMP BD ASSY TB10	1
	213558							RES R7	1
	MS24693-C26							SCREW	2
730	573-.156							LUG ZIERICK	3
	MS15795-805							WASHER, FLAT	2
	MS35337-79							WASHER, LOCK	2
	MS35649-64							NUT, HEX	2
735									
		SIZE		CODE IDENT NO					
		A		06509		LM 514100			
		SCALE		REV B		SHEET 22			

APPENDIX II

WAVEFORM PHOTOGRAPHS (BREADBOARD)

AND

ACCEPTANCE TEST RECORD FORMS

(UNIT SERIAL NUMBER 25506)

WAVEFORM PHOTOGRAPHS

1. Figures 1 and 2 show initial inrush current when the inverter is not operating. This current is charging the audio filter capacitors. The peak current is approximately 260 amperes.
2. Figures 3 through 6 show inrush currents on both running and starting loads at 50 and 60 volts DC input.
3. Figures 7 through 10 cover the induced ripple kicked back into the DC power source during running and starting loads at both 50 and 60 volts DC. The maximum inverter ripple is 2.8 amperes peak-to-peak at 2400 Hz. The 3.3 amps peak-to-peak is a result of modulation or ripple from the DC power source. This ripple has a 320 Hz rep rate.
4. Figure 11 shows the AC Instrumentation output. This signal does not meet the specification requirements as far as peak-to-peak amplitude. This will be corrected on the production units by changing the transformer turns ratio.
5. Figures 12 and 13 show Q_{11} , V_{CE} Vs. I_C , at running load and 50 to 60 volts DC input. Q_1 is the pass or control element in the pulse width regulator that supplies regulated DC power to the driver stages.
6. Figures 14 and 15 show Q_1 , V_{CE} Vs. I_C , at starting load under both 50 and 60 volts DC input. There is a low frequency modulation appearing on both the V_{CE} and I_C waveforms. This is a result of the induced ripple

from the inverter passing load current through the sense resistor, R7. There is a difference of approximately one ampere peak between Figures 13 and 15. This is a result of the increased drive power supplied during starting load.

7. Figures 16 and 17 show V_{CE} Vs. I_C for Q11. Q11 is the series control element in the low level series regulator that supplies power to the oscillator stages.
8. Figures 18 through 21 show V_{CE} and I_C waveforms for Q13, an AØ oscillator transistor, at both loads and 60 volts DC input. Figures 26 through 29 cover the same points for Q17, a BØ oscillator transistor, for comparison with Q13
9. Figures 22 through 25 show V_{CE} and I_C waveforms for Q15, an AØ driver transistor, at both loads and 60 volts DC input. Figures 30 through 33 cover the same points for Q19, a BØ oscillator transistor, for comparison with Q15. The difference between the current waveforms, figures 23 and 25, is a result of the reactive energy difference between running and starting loads. There is more energy kicked back into the inverter output stage. This current passes through the output transistor emitter-base diode placing an additional load on the driver stage.
10. Figures 34 and 35 show the V_{CE} waveform of Q25, an output transistor during running load at 50 and 60 volts DC. Figures 38 and 39 cover the same points but at starting load.

11. Figures 36 and 37 show the I_C waveform for Q25. During running load and input voltages of 50 and 60 volts DC. the negative current is a result of reactive loading. Figures 40 and 41 show the same conditions but at starting load.
12. Figures 42 and 43 show the forward current that passes through CR12 and CR14 during running load and at 50 and 60 volts DC input. As the load P.F. is approximately 0.8 lagging at these conditions, there is very little reactive current.
13. Figures 44 and 45 show the forward current that passes through CR12 and CR14 during starting load and at 50 and 60 volts DC input. The load P.F. is approximately 0.3 lagging at this condition. The peak forward current is 50 amperes for less than 1/6 of a cycle.
14. Figures 46 through 49 show V_{CE} Vs. I_{line} for running and starting loads at 50 and 60 volts DC input.
15. Figures 50 through 53 show V_{A-B} Vs. I_{line} for running and starting loads at 50 and 60 volts DC.

INRUSH CURRENT

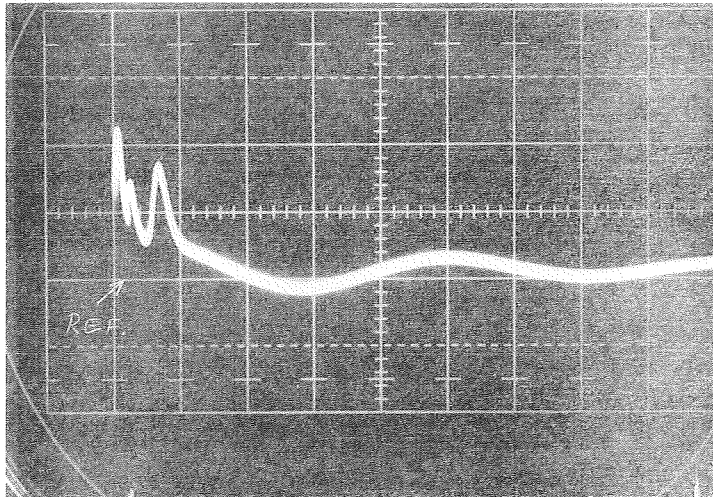


FIGURE 1

Vert. = 100 Amp/Cm

Horiz. = 1 MS/Cm

Input = 50 Volts DC

Load = No Load

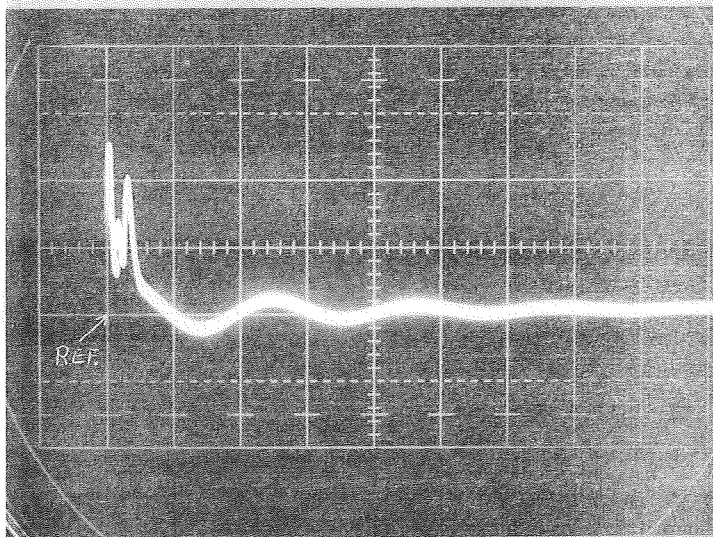


FIGURE 2

Vert. = 100 Amp/Cm

Horiz. = 2 MS/Cm

Input = 60 Volts DC

Load = No Load

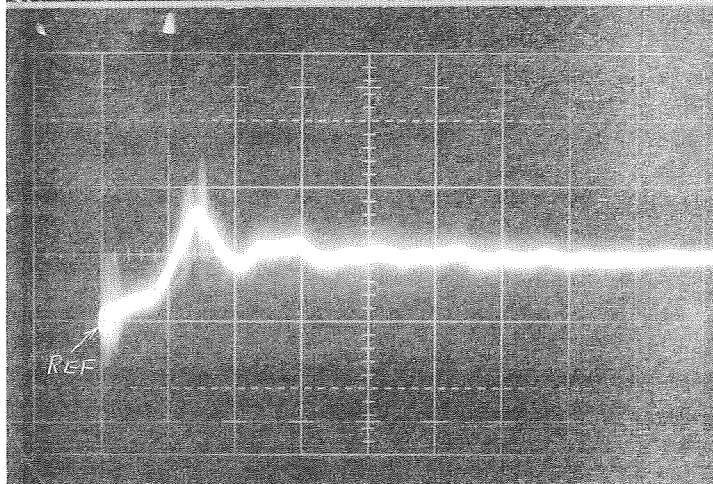


FIGURE 3

Vert. = 20 Amp/Cm

Horiz. = 2 MS/Cm

Input = 50 Volts DC

Load = Running

CODE IDENT NO.

06509

SIZE

A

SCALE

SHEET

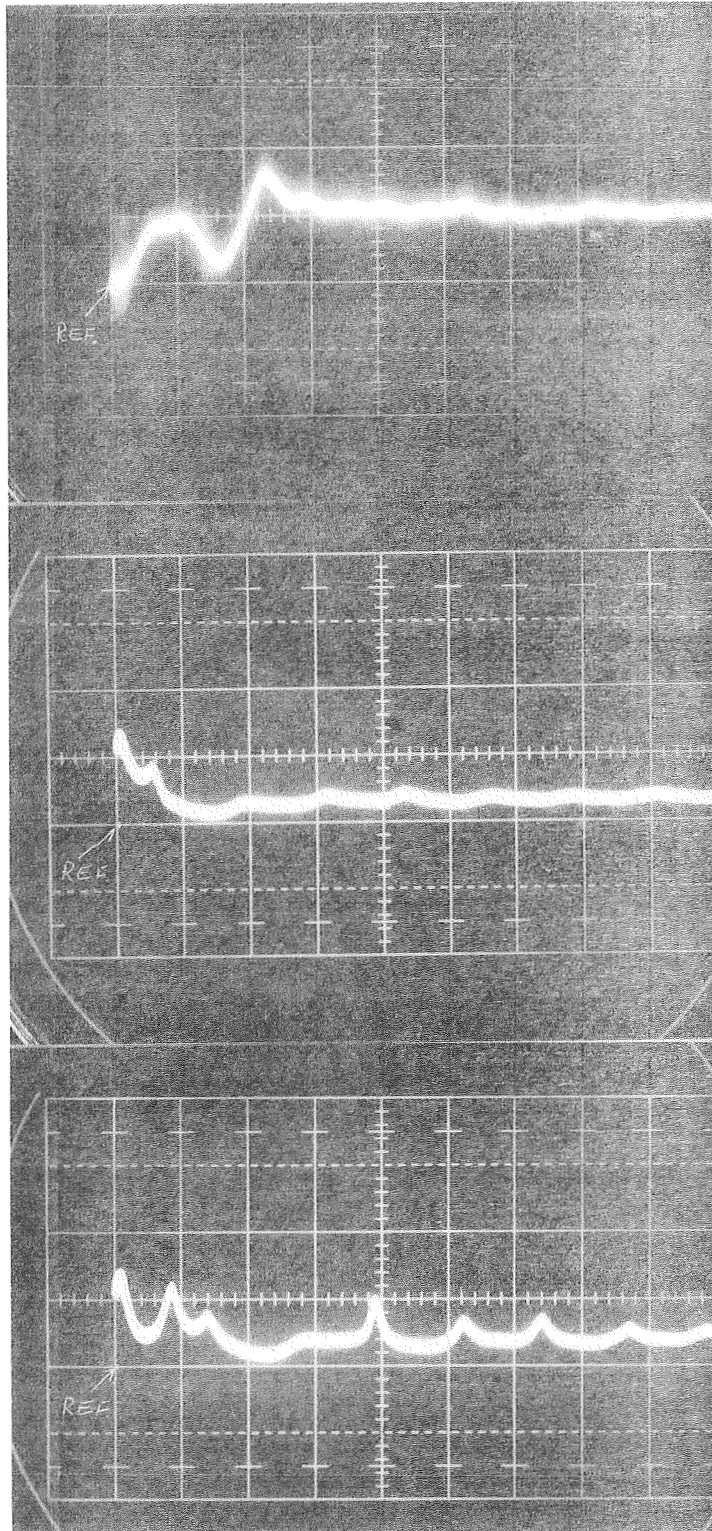


FIGURE 4

Vert. = 20 Amp/Cm

Horiz. = 2 MS/Cm

Input = 60 Volts DC

Load = Running

FIGURE 5

Vert. = 100 Amp/Cm

Horiz = 1 MS/Cm

Input = 50 Volts DC

Load = Starting

FIGURE 6

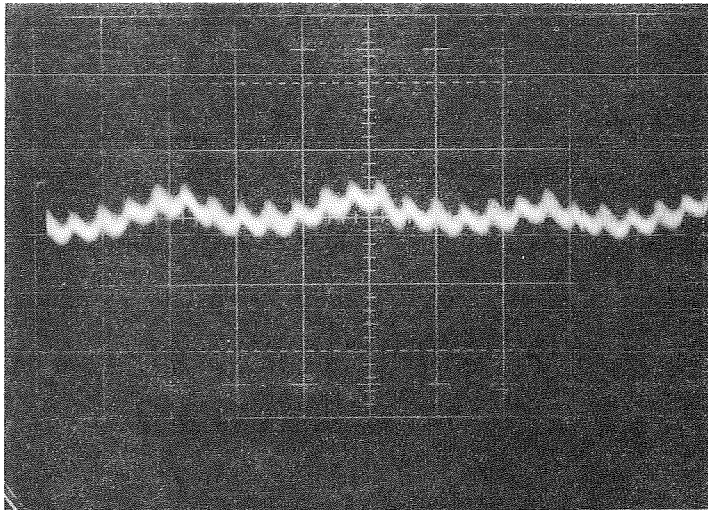
Vert. = 100 Amp/Cm

Horiz = 1 MS/Cm

Input = 60 Volts DC

Load = Starting

CODE IDENT NO.	SIZE	
06509	A	
SCALE		SHEET



INDUCED RIPPLE

FIGURE 7

Vert. = 1 Amp/Cm

Horiz. = 1 MS/Cm

Input = 50 Volts DC

Load = Running

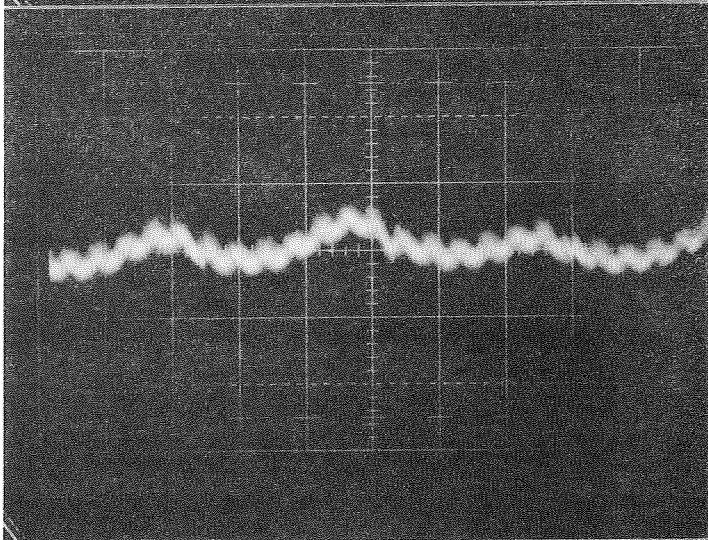


FIGURE 8

Vert. = 1 Amp/Cm

Horiz. = 1 MS/Cm

Input = 60 Volts DC

Load = Running

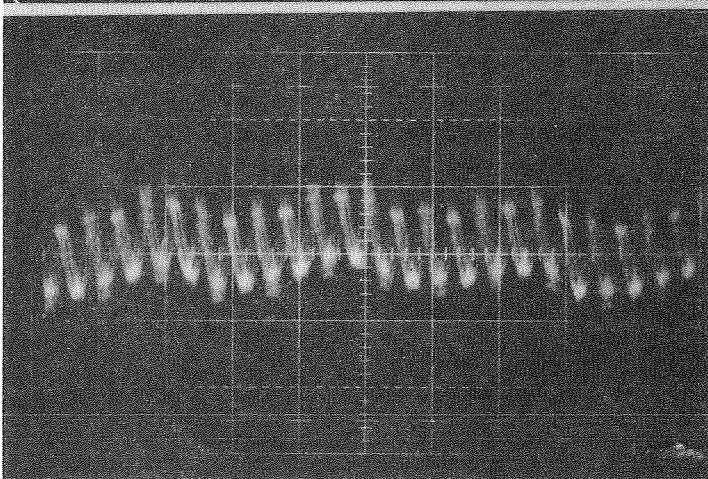


FIGURE 9

Vert. = 1 Amp/Cm

Horiz. = 1 MS/Cm

Input = 50 Volts DC

Load = Starting

CODE IDENT NO.

06509

SIZE

A

SCALE

SHEET

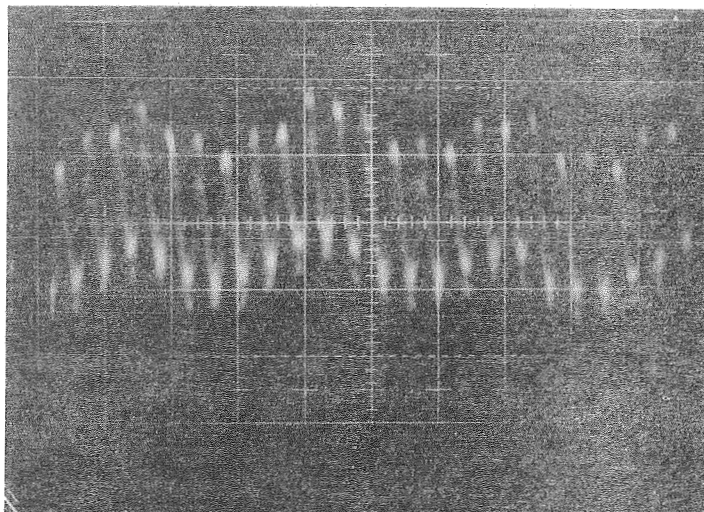


FIGURE 10

Vert. = 1 Amp/Cm

Horiz. = 1 MS/Cm

Input = 60 Volts DC

Load = Starting

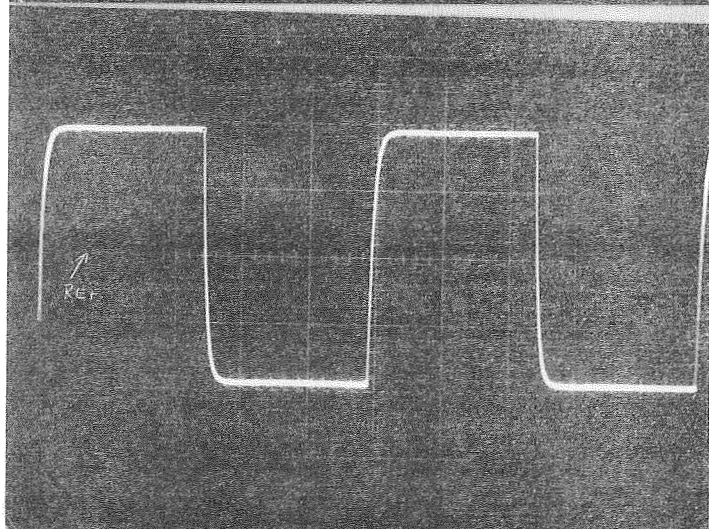
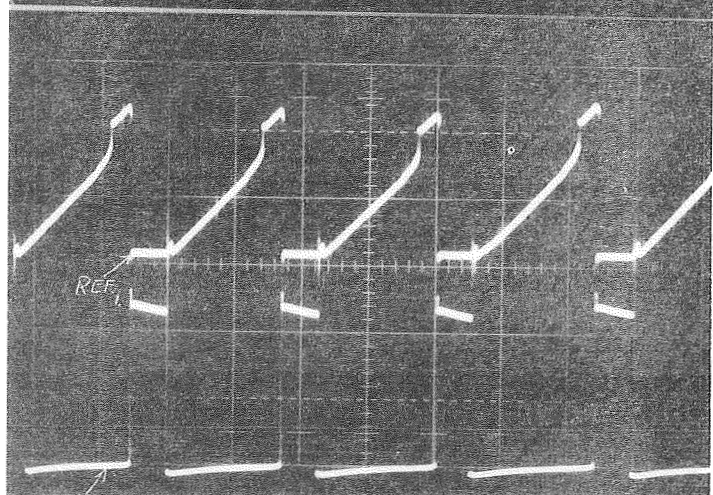


FIGURE 11

Vert. = 2 Volts/Cm

Horiz. = 500 μ s/Cm

Input = 60 Volts DC



Q1 V_{CE} Vs. I_C

FIGURE 12

Vert. 1 = 1 Amp/Cm

Vert. 2 = 20 Volts/Cm

Horiz. = 50 μ s/Cm

Input = 50 Volts DC

Load = Running

CODE IDENT NO.

06509

SIZE

A

SCALE

SHEET

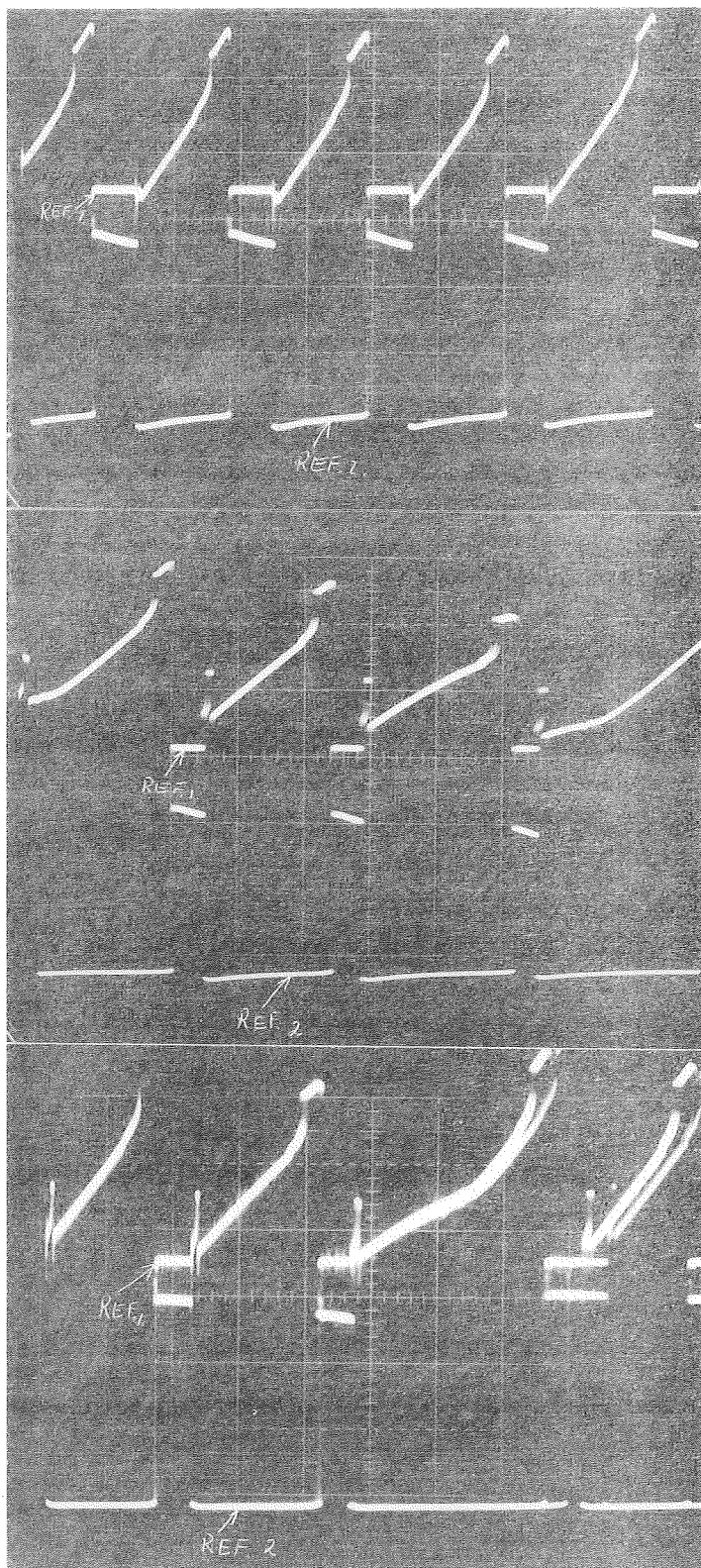


FIGURE 13

Vert. 1 = 1 Amp/Cm

Vert. 2 = 20 Volts/Cm

Horiz. = 50 μ s/Cm

Input = 60 Volts DC

Load = Running

FIGURE 14

Vert. 1 = 1 Amp/Cm

Vert. 2 = 20 Volts/Cm

Horiz. = 50 μ s/Cm

Input = 50 Volts DC

Load = Starting

FIGURE 15

Vert. 1 = 1 Amp/Cm

Vert. 2 = 20 Volts/Cm

Horiz. = 50 μ s/Cm

Input = 60 Volts DC

Load = Starting

CODE IDENT NO.	SIZE	
06509	A	
SCALE		SHEET

Q11 V_{CE} Vs. I_C

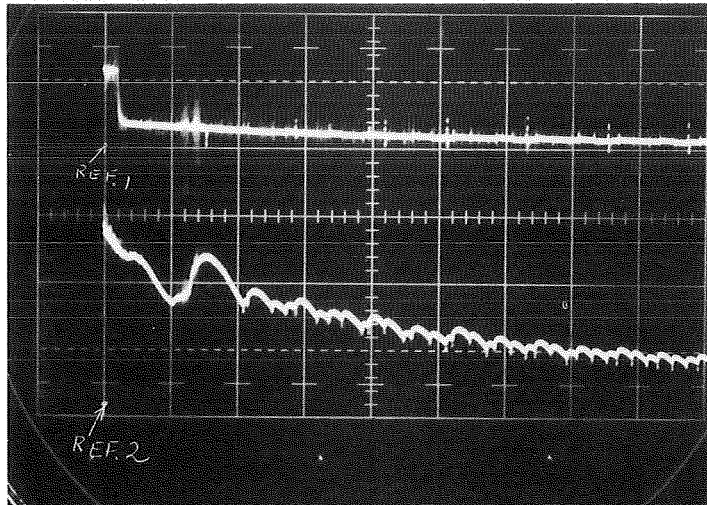


FIGURE 16

Vert. 1 = 0.5 Amp/Cm
Vert. 2 = 20 Volts/Cm
Horiz. = 2 MS/Cm
Input = 50 Volts DC
Load = Starting

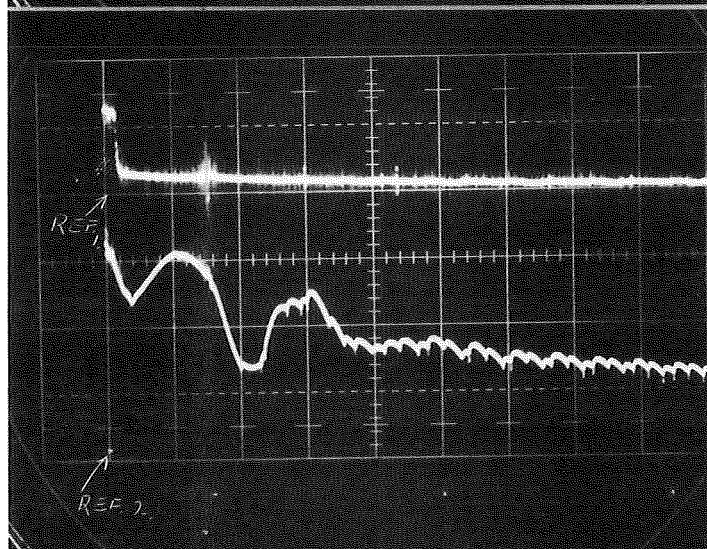
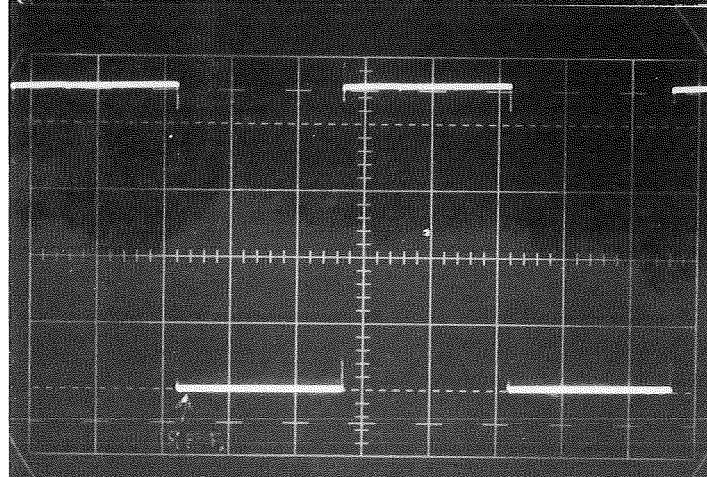


FIGURE 17

Vert. 1 = 0.5 Amp/Cm
Vert. 2 = 20 Volts/Cm
Horiz. = 2 MS/Cm
Input = 60 Volts DC
Load = Starting



Q13 V_{CE}

FIGURE 18

Vert. = 20 Volt/Cm
Horiz. = 500 μ s/Cm
Input = 60 Volts DC
Load = Running

CODE IDENT NO.

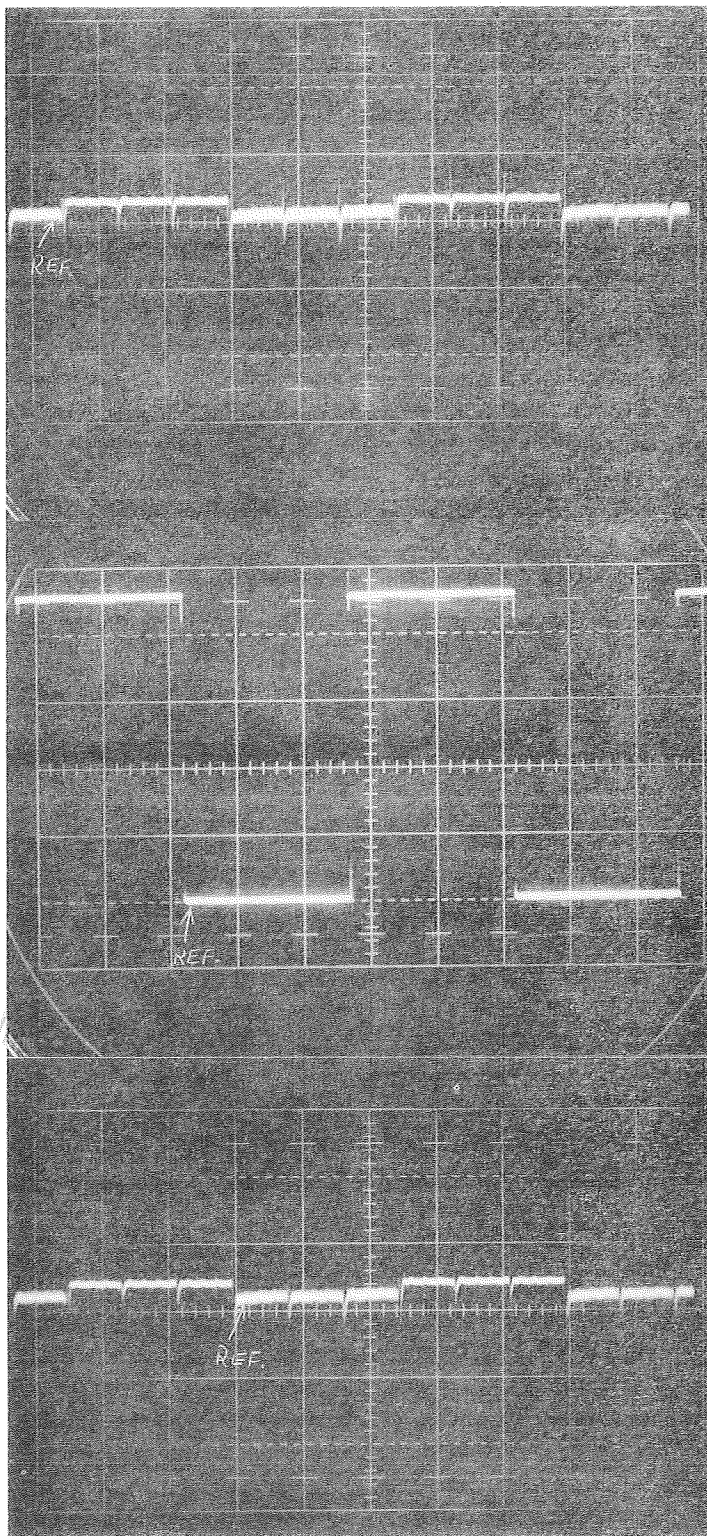
06509

SIZE

A

SCALE

SHEET



Q13 I_C

FIGURE 19

Vert. = 0.1 Amp/Cm

Horiz. = 500 μ s/Cm

Input = 60 Volts DC

Load = Running

Q13 V_{CE}

FIGURE 20

Vert. = 20 Volt/Cm

Horiz. = 500 μ s/Cm

Input = 60 Volts DC

Load = Starting

Q13 I_C

FIGURE 21

Vert. = 0.1 Amp/Cm

Horiz. = 500 μ s/Cm

Input = 60 Volts DC

Load = Starting

CODE IDENT NO.

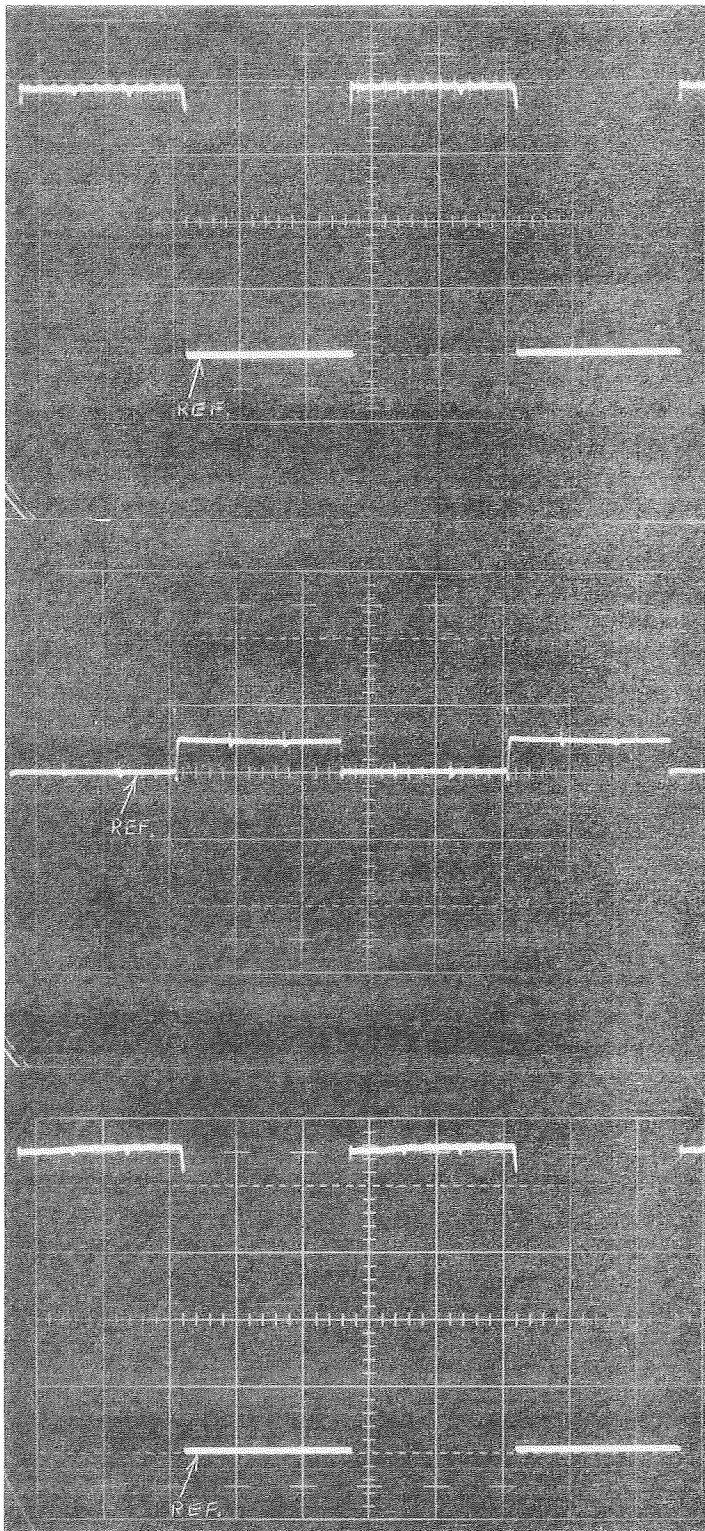
06509

SIZE

A

SCALE

SHEET



Q15 V_{CE}

FIGURE 22

Vert. = 20 Volts/Cm

Horiz. = 500 μ s/Cm

Input = 60 Volts DC

Load = Running

Q15 I_C

FIGURE 23

Vert. = 1 Amp/Cm

Horiz. = 500 μ s/Cm

Input = 60 Volts DC

Load = Running

Q15 V_{CE}

FIGURE 24

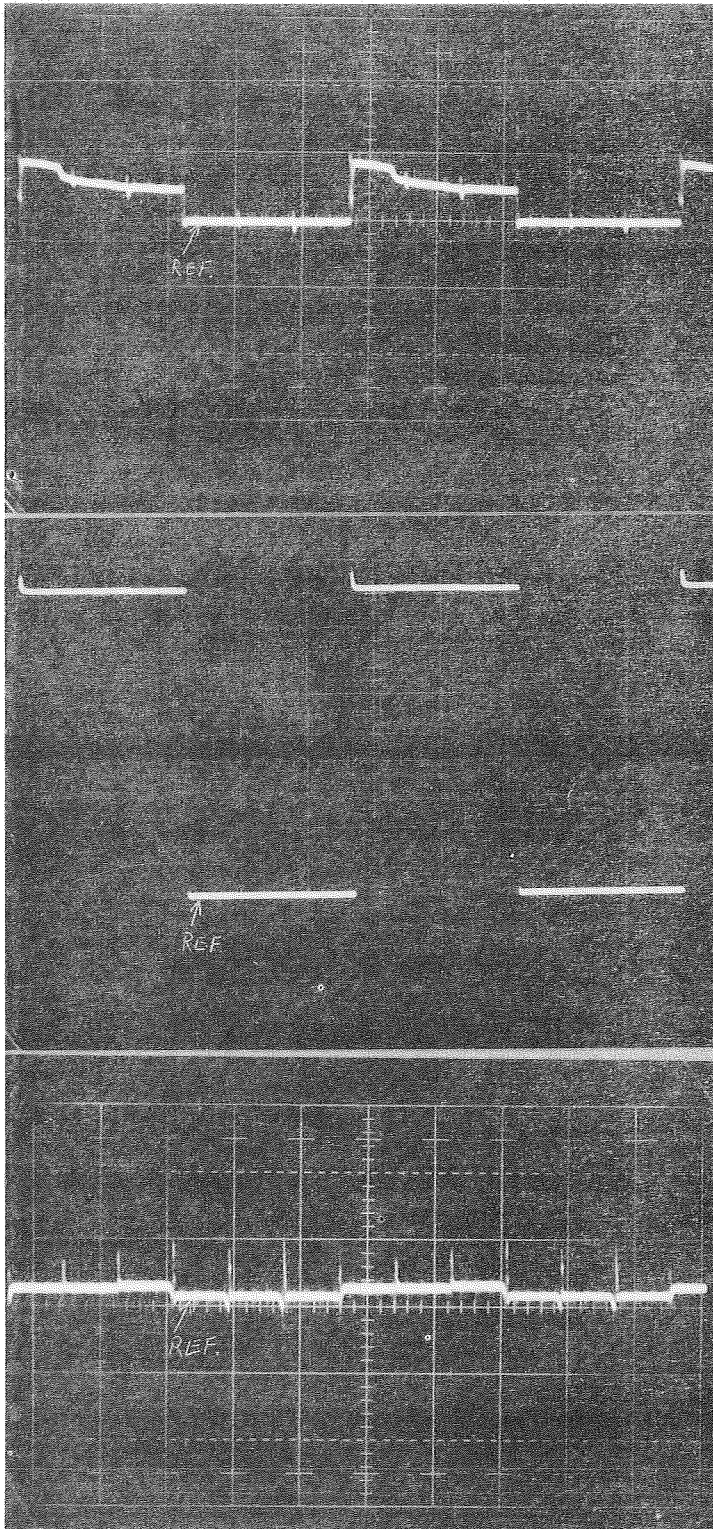
Vert. = 20 Volts/Cm

Horiz. = 500 μ s/Cm

Input = 60 Volts DC

Load = Starting

CODE IDENT NO.	SIZE	
06509	A	
SCALE		SHEET



Q15 I_C

FIGURE 25

Vert. = 1 Amp/Cm

Horiz. = 500 μ s/Cm

Input = 60 Volts DC

Load = Starting

Q17 V_{CE}

FIGURE 26

Vert. = 20 Volt/Cm

Horiz. = 500 μ s/Cm

Input = 60 Volts DC

Load = Running

Q17 I_C

FIGURE 27

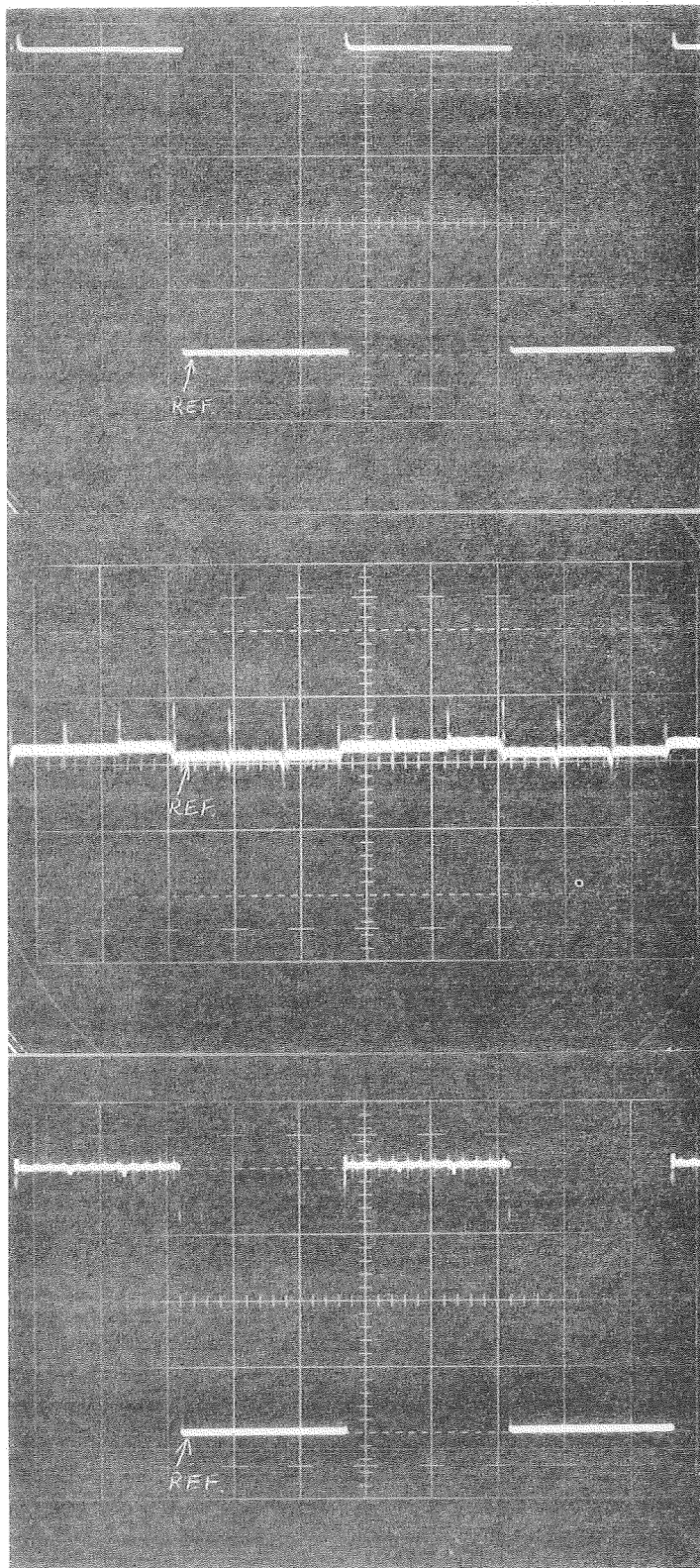
Vert. = 0.1 Amp/Cm

Horiz. = 500 μ s/Cm

Input = 60 Volts DC

Load = Running

CODE IDENT NO.	SIZE	
06509	A	
SCALE		SHEET



Q17 V_{CE}

FIGURE 28

Vert. = 20 Volt/Cm

Horiz. = 500 μ s/Cm

Input = 60 Volts DC

Load = Starting

Q17 I_C

FIGURE 29

Vert. = 0.1 Amp/Cm

Horiz. = 500 μ s/Cm

Input = 60 Volts DC

Load = Starting

Q19 V_{CE}

FIGURE 30

Vert. = 20 Volt/Cm

Horiz. = 500 μ s/Cm

Input = 60 Volts DC

Load = Running

CODE IDENT NO.

06509

SIZE

A

SCALE

SHEET

Q19 I_C

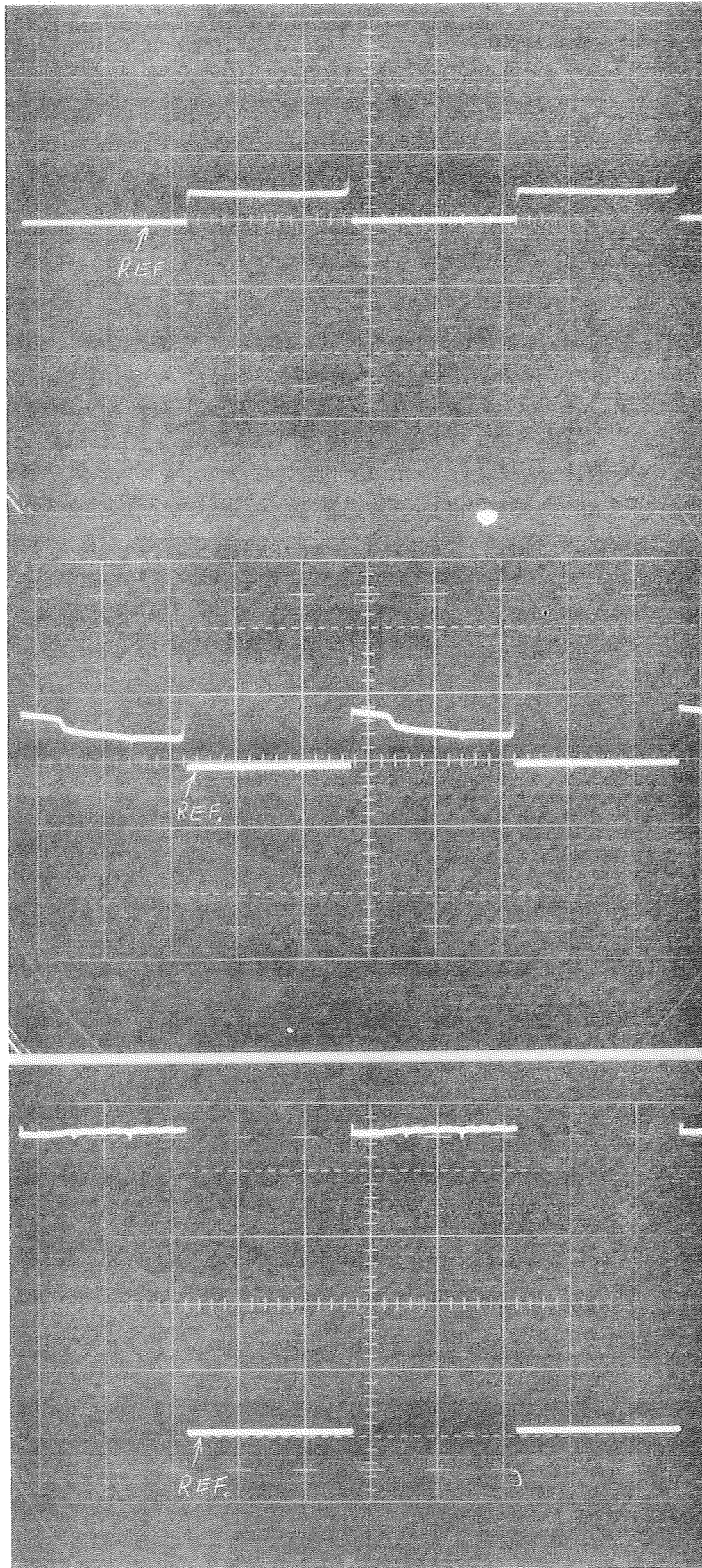


FIGURE 31

Vert. = 1 Amp/Cm

Horiz. = 500 μ s/Cm

Input = 60 Volts DC

Load = Running

Q19 I_C

FIGURE 32

Vert. = 1 Amp/Cm

Horiz. = 500 μ s/Cm

Input = 60 Volts DC

Load = Starting

Q19 V_{CE}

FIGURE 33

Vert. = 20 Volts/Cm

Horiz. = 500 μ s/Cm

Input = 60 Volts DC

Load = Starting

CODE IDENT NO.

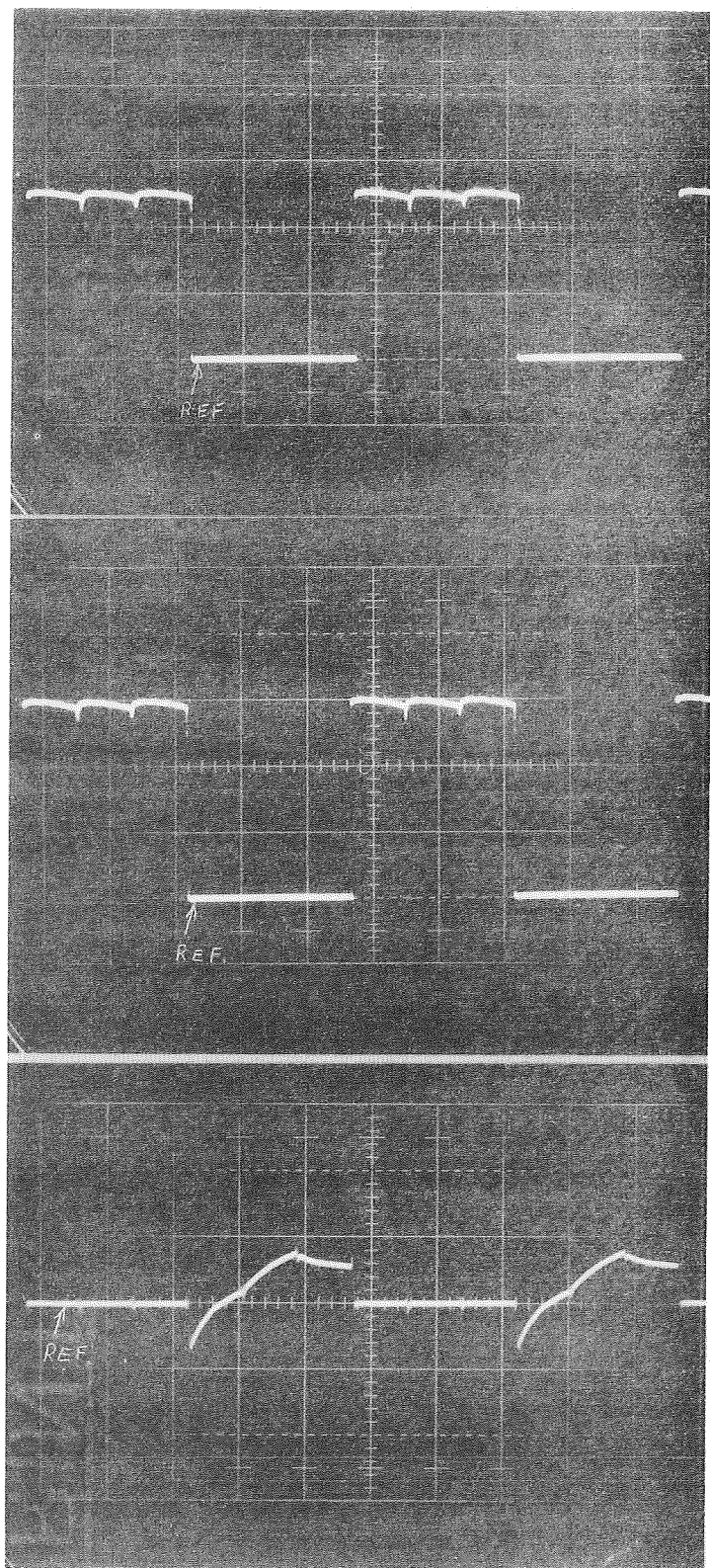
06509

SIZE

A

SCALE

SHEET



Q25 V_{CE}

FIGURE 34

Vert. = 20 Volts/Cm

Horiz. = 500 μ s/Cm

Input = 50 Volts DC

Load = Running

Q25 V_{CE}

FIGURE 35

Vert. = 20 Volts/Cm

Horiz. = 500 μ s/Cm

Input = 60 Volts DC

Load = Running

Q25 I_C

FIGURE 36

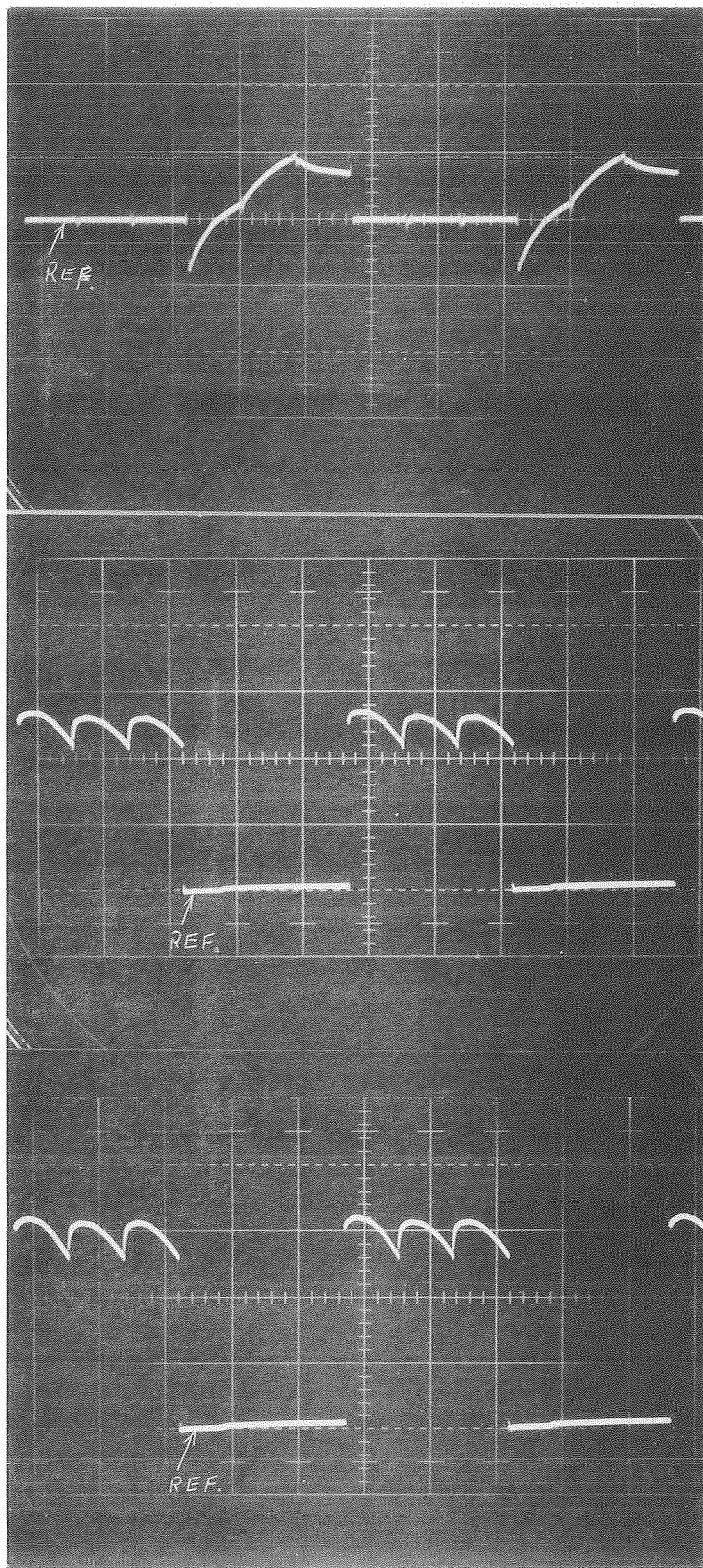
Vert. = 5 Amp/Cm

Horiz. = 500 μ s/Cm

Input = 50 Volts DC

Load = Running

CODE IDENT NO.	SIZE	
06509	A	
SCALE		SHEET



Q25 I_C

FIGURE 37

Vert. = 5 Amp/Cm

Horiz. = 500 μ s/Cm

Input = 60 Volts DC

Load = Running

Q25 V_{CE}

FIGURE 38

Vert. = 20 Volt/Cm

Horiz. = 500 μ s/Cm

Input = 50 Volts DC

Load = Starting

Q25 V_{CE}

FIGURE 39

Vert. = 20 Volt/Cm

Horiz. = 500 μ s/Cm

Input = 60 Volts DC

Load = Starting

CODE IDENT NO.

06509

SIZE

A

SCALE

SHEET

Q25 I_C

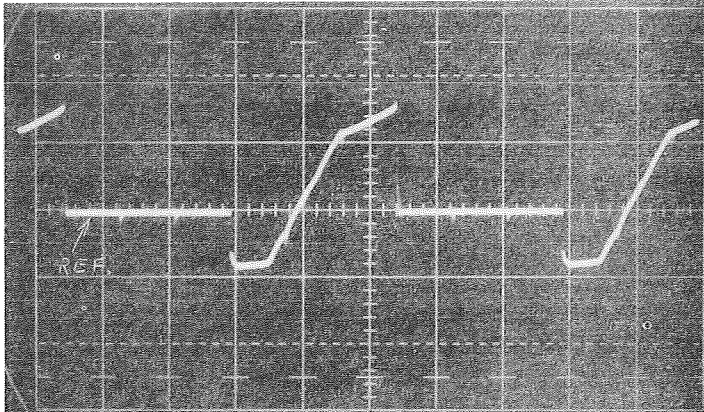


FIGURE 40

Vert. = 10 Amp/Cm

Horiz. = 500 μ s/Cm

Input = 50 Volts DC

Load = Starting

Q25 I_C

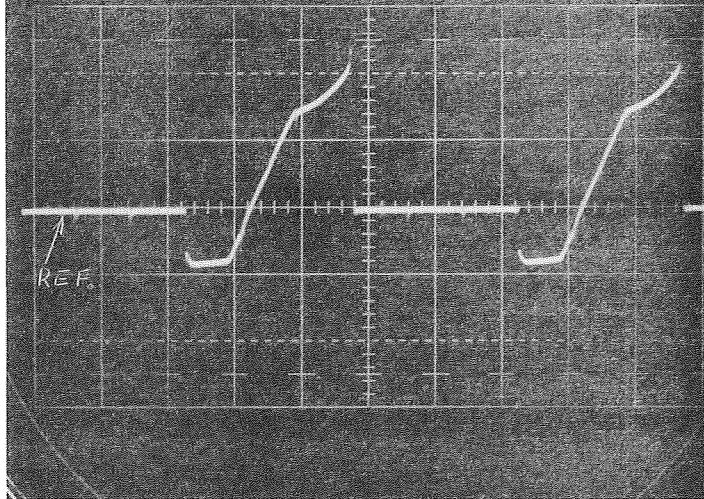


FIGURE 41

Vert. = 10 Amp/Cm

Horiz. = 500 μ s/Cm

Input = 60 Volts DC

Load = Starting

CR12 and 14 I_F

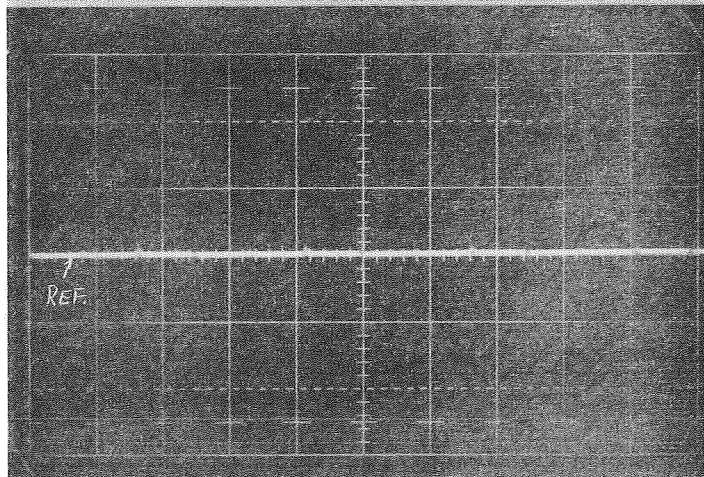


FIGURE 42

Vert. = 5 Amp/Cm

Horiz. = 500 μ s/Cm

Input = 50 Volts DC

Load = Running

CODE IDENT NO.

06509

SIZE

A

SCALE

SHEET

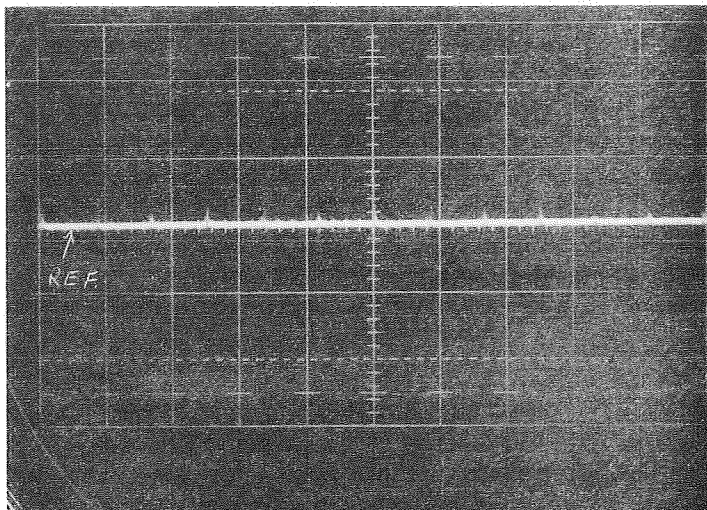


FIGURE 43

Vert. = 5 Amp/Cm

Horiz. = 500 μ s/Cm

Input = 60 Volts DC

Load = Running

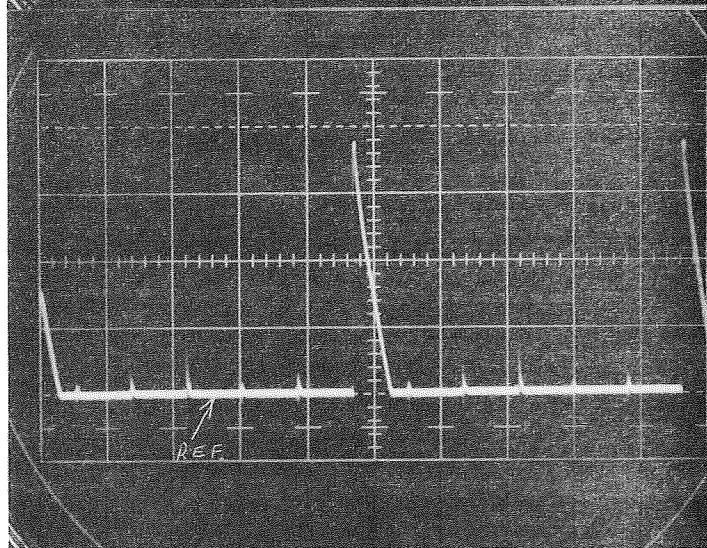


FIGURE 44

Vert. = 10 Amp/Cm

Horiz. = 500 μ s/Cm

Input = 50 Volts DC

Load = Starting

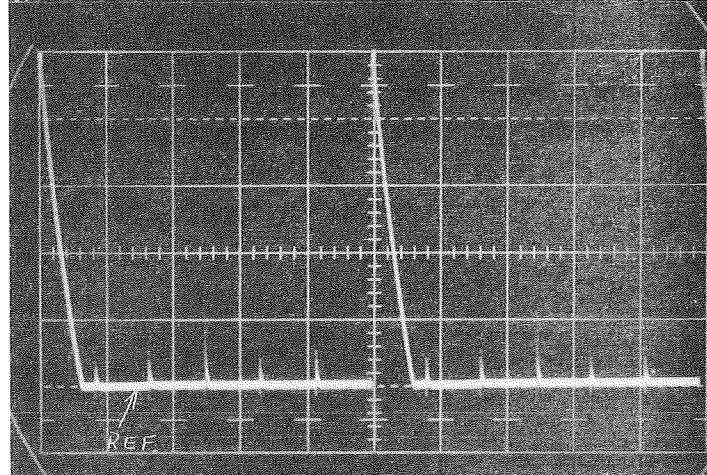


FIGURE 45

Vert. = 10 Amp/Cm

Horiz. = 500 μ s/Cm

Input = 60 Volts DC

Load = Starting

CODE IDENT NO.

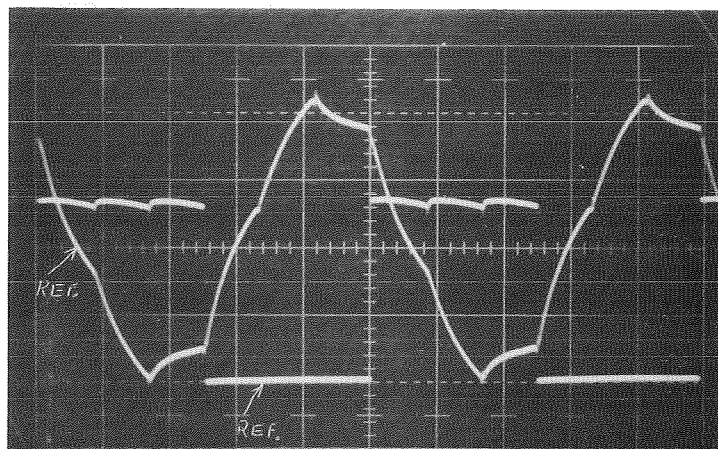
06509

SIZE

A

SCALE

SHEET



V_{CE} Vs. I_{line}

FIGURE 46

Vert. 1 = 10 Amp/Cm
 Vert. 2 = 20 Volt/Cm
 Horiz. = 500 μ s/Cm
 Input = 50 Volts DC
 Load = Running

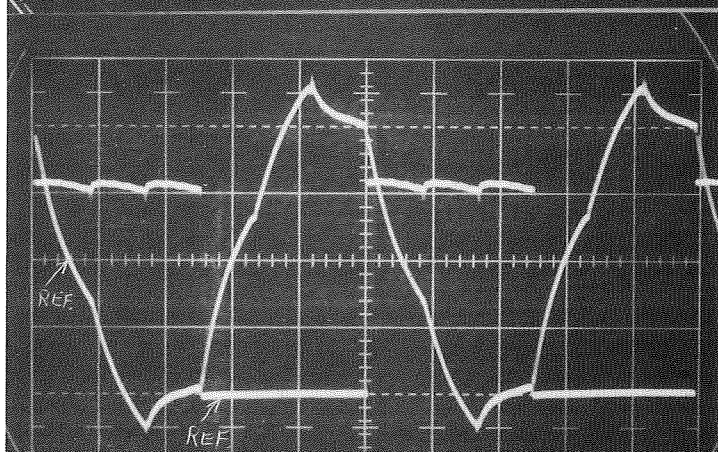


FIGURE 47

Vert. 1 = 10 Amp/Cm
 Vert. 2 = 20 Volt/Cm
 Horiz. = 500 μ s/Cm
 Input = 60 Volts DC
 Load = Running

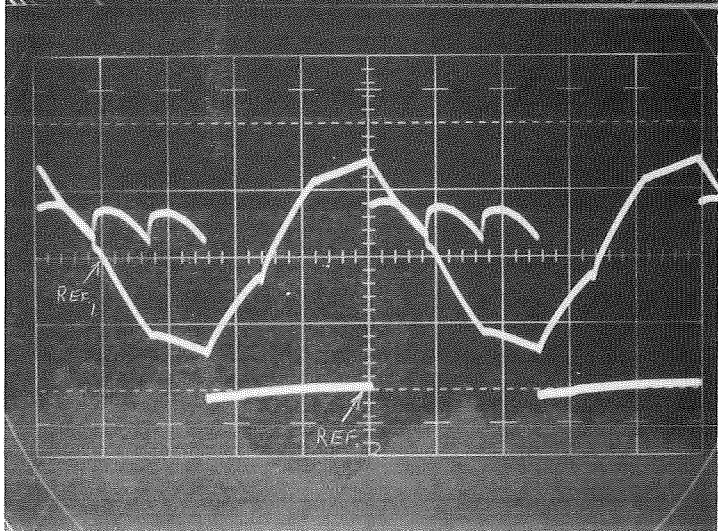


FIGURE 48

Vert. 1 = 50 Amp/Cm
 Vert. 2 = 20 Volt/Cm
 Horiz. = 500 μ s/Cm
 Input = 50 Volts DC
 Load = Starting

CODE IDENT NO.

06509

SIZE

A

SCALE

SHEET

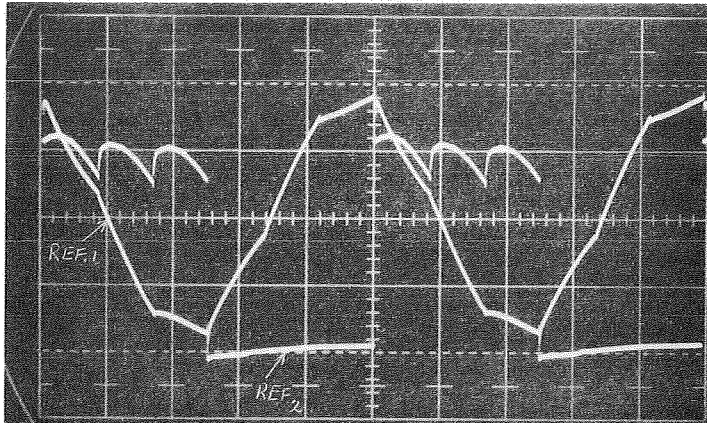
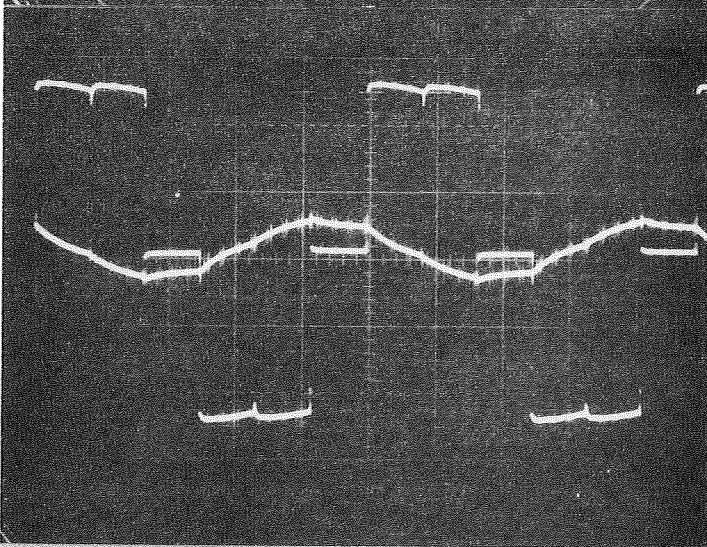


FIGURE 49

Vert. 1 = 50 Amp/Cm
 Vert. 2 = 20 Volt/Cm
 Horiz. = 500 μ s/Cm
 Input = 60 Volts DC
 Load = Starting



V_{AB} Vs. I_{line}

FIGURE 50

Vert. 1 = 20 Volt/Cm
 Vert. 2 = 50 Amp/Cm
 Horiz. = 500 μ s/Cm
 Input = 50 Volts DC
 Load = Running

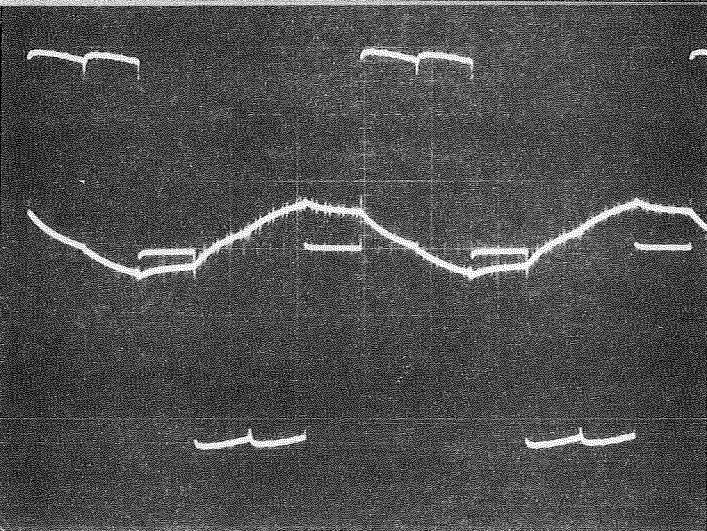


FIGURE 51

Vert. 1 = 20 Volts/Cm
 Vert. 2 = 50 Amp/Cm
 Horiz. = 500 μ s/Cm
 Input = 60 Volts DC
 Load = Running

CODE IDENT NO.	SIZE	
06509	A	
SCALE		SHEET

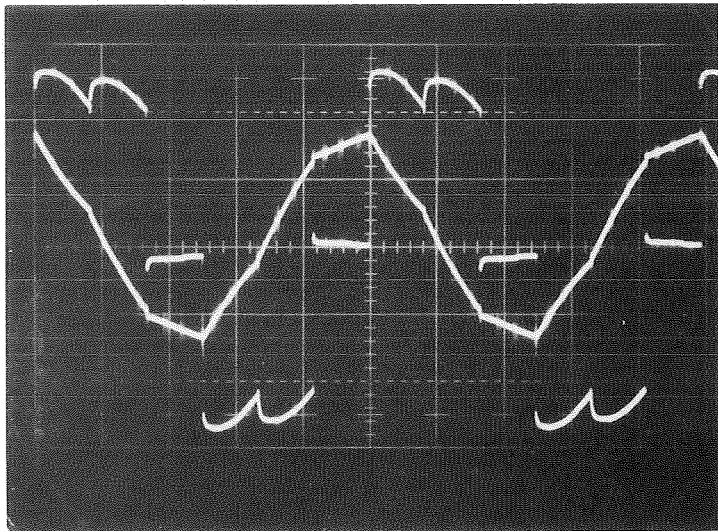


FIGURE 52

Vert. 1 = 20 Volt/Cm

Vert. 2 = 50 Amp/Cm

Horiz. = 500 μ s/Cm

Input = 50 Volts DC

Load = Starting

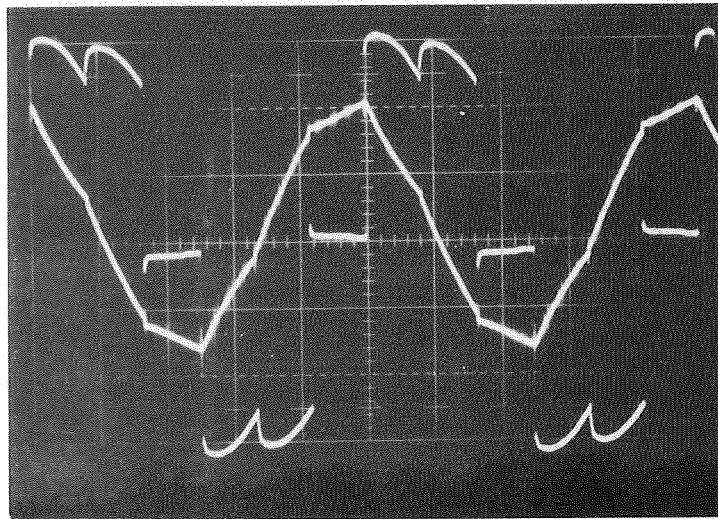


FIGURE 53

Vert. 1 = 20 Volt/Cm

Vert. 2 = 50 Amp/Cm

Horiz. = 500 μ s/Cm

Input = 60 Volts DC

Load = Starting

CODE IDENT NO.

06509

SIZE

A

SCALE

SHEET

GULTON INDUSTRIES, INC.
Engineered Magnetics Division
ENGINEERED MAGNETICS MODEL EMIU104D

DATE 11-27-68
SERIAL NUMBER 25506
TEMPERATURE 72°F

TECHNICIAN JED Penin
ENGINEER J. J. Penin
QUALITY ASSURANCE JA (EM 9)

1. EXAMINATION OF UNIT ✓ (Check if acceptable)

WEIGHT 2.5 lbs 3oz lbs (~~15.5~~ lbs maximum)
30.0 lbs per EC 23904

2. INSULATION RESISTANCE

CONNECTOR J1 PINS TO CASE GROUND 20K Megohms
TERMINALS T1 through T5 to CASE GROUND 21K Megohms } (20 megohms or greater)

3. BURN-IN ✓ (Check when completed)

4. LOW LEVEL VIBRATION

DISCONTINUITY AND DEVIATIONS

X AXIS ✓ None

Y AXIS ✓ None

(If none, state none)

DAMAGE OR STRUCTURAL DEFORMITY

None

(If none, state none)

Mechanical Engineers approval of test setup NA

(First Article Only)

FIGURE 1. ACCEPTANCE TEST RECORD FORM.

CODE IDENT NO. 06509	SIZE A	712954
SCALE		SHEET 18

GULTON INDUSTRIES, INC.
Engineered Magnetics Division
ENGINEERED MAGNETICS MODEL EMIU104D

DATE 11-27-68
SERIAL NUMBER 25506
TEMPERATURE 72°F

TECHNICIAN Ed Penn
ENGINEER ~~Ed Penn~~
QUALITY ASSURANCE Ja

5.1 OUTPUT FREQUENCY

DURING RUNNING LOAD

ØAB Output Frequency 399 Hz
ØBC Output Frequency 399 Hz
ØCA Output Frequency 399 Hz

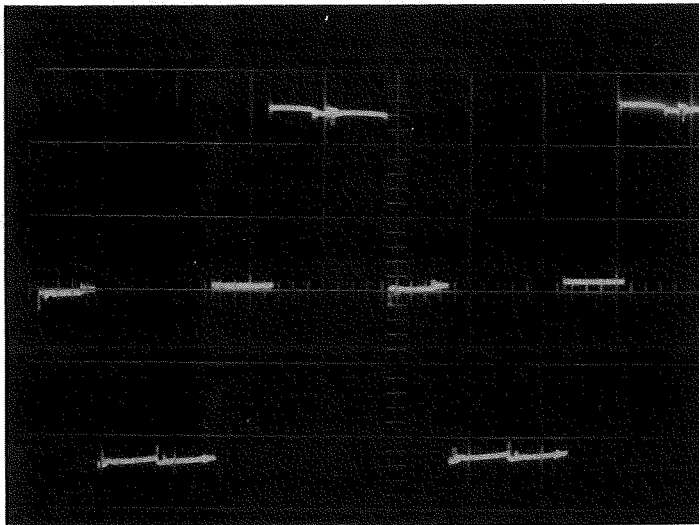
DURING STARTING LOAD

ØAB Output Frequency 399 Hz
ØBC Output Frequency 399 Hz
ØCA Output Frequency 399 Hz

ACCEPTABLE PERFORMANCE

The output frequency shall remain between 396 to 404 Hz.
The unit shall require no warm-up time.

5.2 OUTPUT WAVEFORM AND PHASE ROTATION



DURING RUNNING LOAD

DC REF Center Line

TIMEBASE 500 µ sec/cm

V/CM 20 VOLTS/cm

PHASE DISPLACEMENT

ØA-B 119.7 degrees.

ØB-C 120.1 degrees.

ØC-A 120.2 degrees.

PHASE ROTATION C.

(Check (✓) if acceptable)

ACCEPTABLE PERFORMANCE

1. The output waveform shall be a quasi-squarewave with a zero dwell time of 60 ± 5 degrees and the peaks of 120 ± 5 degrees.
2. The output phase displacement shall not exceed 120 ± 5 degrees.
3. The peak output voltage shall be approximately two volts less than the DC input voltage.
4. Phase rotation shall be A-B-C as observed by the phase rotation lights on the Load Bank.

FIGURE 2. ACCEPTANCE TEST RECORD FORM.

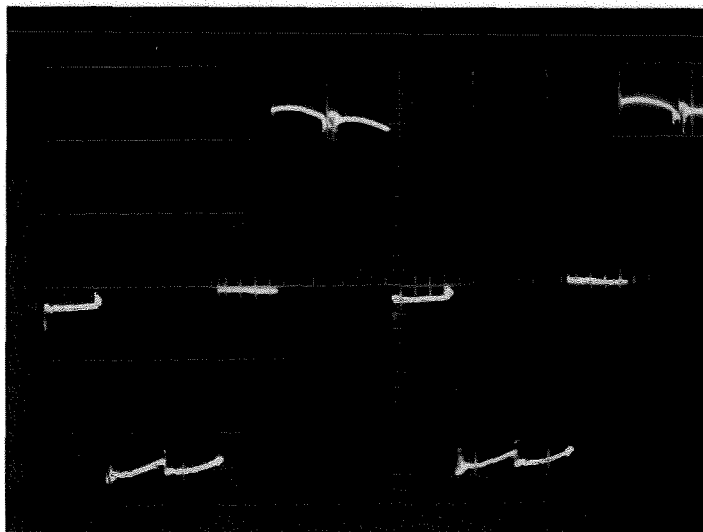
CODE IDENT NO. 06509	SIZE A	712954
SCALE		SHEET 19

GULTON INDUSTRIES, INC.
Engineered Magnetics Division
ENGINEERED MAGNETICS MODEL EMIU104D

DATE 11-27-68
 SERIAL NUMBER 25506
 TEMPERATURE 72°F

TECHNICIAN Ed. Papp
 ENGINEER A. C. Lechenmeier
 QUALITY ASSURANCE Ja (EM 9)

5.2 OUTPUT WAVEFORM AND PHASE ROTATION (CONT'D)
3.4.3 and 3.4.8)
(ATTACH PHOTOGRAPH HERE)



DURING STARTING LOAD
 DC REF CENTER LINE
 TIMEBASE 500 μsec/cm
 V/CM 20 VOLTS/cm
 PHASE DISPLACEMENT
 ØA-B 119.9 degrees.
 ØB-C 120.1 degrees.
 ØC-A 120.0 degrees.
 PHASE ROTATION ✓.
 (Check (✓) if acceptable)

1. The output waveform shall be a quasi-squarewave with a zero dwell time of 60 ± 5 degrees and the peaks of 120 ± 5 degrees.
2. The output phase displacement shall not exceed 120 ± 5 degrees.
3. The peak output voltage shall be approximately two volts less than the DC input voltage.
4. Phase rotation shall be A-B-C as observed by the phase rotation lights on the Load Bank.

FIGURE 3. ACCEPTANCE TEST RECORD FORM.

CODE IDENT NO. 06509	SIZE A	712954
SCALE		SHEET 20

GULTON INDUSTRIES, INC.
Engineered Magnetics Division
ENGINEERED MAGNETICS MODEL EMIU104D

DATE 11-27-68
SERIAL NUMBER 25506
TEMPERATURE 72°F

TECHNICIAN [Signature]
ENGINEER [Signature]
QUALITY ASSURANCE (EM)

5.3 EFFICIENCY

DC INPUT:

VOLTS 56 CURRENT 9.8 WATTS 548

ØA OUTPUT:

VOLTS 26.47 V^2 700 R_L 3.98 P_L 8.0 WATTS 175

ØB OUTPUT:

VOLTS 26.34 V^2 693 R_L 3.98 P_L 10.0 WATTS 171

ØC OUTPUT:

VOLTS 26.50 V^2 702 R_L 3.98 P_L 8.0 WATTS 176

EFFICIENCY: 95.2 %

ACCEPTABLE PERFORMANCE

The efficiency shall not be less than 85 percent at RUNNING LOAD.

5.4 OVERLOAD

ØA OUTPUT CURRENT 29.5 AMPS
ØB OUTPUT CURRENT 30.0 AMPS
ØC OUTPUT CURRENT 29.5 AMPS

ACCEPTABLE PERFORMANCE

The output current shall be approximately 51 amps per phase at 56 VDC input.

FIGURE 4. ACCEPTANCE TEST RECORD FORM.

CODE IDENT NO. 06509	SIZE A	712954	
SCALE		SHEET 21	

GULTON INDUSTRIES, INC.
Engineered Magnetics Division
ENGINEERED MAGNETICS MODEL EMIU104D

DATE 11-27-68
SERIAL NUMBER 25506
TEMPERATURE 72°F

TECHNICIAN Ed. Penix
ENGINEER A. B. Schenck
QUALITY ASSURANCE Ja

5.5 OUTPUT INSTRUMENTATION

ØCA Output Voltage 45.19 VAC rms STARTING LOAD
46.46 VAC rms RUNNING LOAD
ØA-C Output Voltage Sense 4.374 VDC STARTING LOAD
4.491 VDC RUNNING LOAD
ØA-C Output Voltage Sense Ripple 3.4 MV RMS (5 RMS MAX.) STARTING LOAD
3.3 MV RMS (5 RMS MAX.) RUNNING LOAD
Output Voltage Sense Accuracy Calculation:
(0.1 X ØCA Output Voltage VAC rms = ØA-C Output Voltage Sense
VDC ± 0.30) 0.1 X 45.19 = 4.519 STARTING LOAD
0.1 X 46.46 = 4.646 RUNNING LOAD
ØA-C Output Voltage Sense (Check if acceptable) ✓ STARTING LOAD
(Check if acceptable) ✓ RUNNING LOAD
ØAB Output Voltage 45.16 VAC rms STARTING LOAD
46.26 VAC rms RUNNING LOAD
ØA-B Output Voltage Sense 4.360 VDC STARTING LOAD
4.433 VDC RUNNING LOAD
ØA-B Output Voltage Sense Ripple 3.4 MV RMS (5 MV RMS MAX.) STARTING LOAD
3.3 MV RMS (5 MV RMS MAX.) RUNNING LOAD
Output Voltage Sense Accuracy Calculation:
(0.1 X ØAB Output Voltage VAC rms = ØA-B Output Voltage Sense
VDC ± 0.30) 0.1 X 45.16 = 4.516 STARTING LOAD
0.1 X 46.26 = 4.626 RUNNING LOAD
ØA-B Output Voltage Sense (Check if acceptable) ✓ STARTING LOAD
(Check if acceptable) ✓ RUNNING LOAD
Frequency Signal Amplitude 6.8 (6.25 + 1.400 - 0.000 V P-P) STARTING LOAD
6.8 (6.25 + 1.400 - 0.000 V P-P) RUNNING LOAD
Waveform (Check if acceptable) ✓ (Square wave) STARTING LOAD
(Check if acceptable) ✓ (Square wave) RUNNING LOAD
Frequency 399 Hz (400 Hz nominal) STARTING LOAD
399 Hz (400 Hz nominal) RUNNING LOAD

FIGURE 5. ACCEPTANCE TEST RECORD FORM.

CODE IDENT NO.	SIZE	
06509	A	712954
SCALE		SHEET 22

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