DC-TO-DC CONVERTER

KS-19304

OPERATING METHODS

CONTENTS **PAGE**

1. GENERAL

1.01 This section covers the operation of the KS-19304 L1 dc-to-dc converter which is primarily intended as a power supply for the 651A power plant. This converter is a dc voltage multiplier which enables a positive or negative 130-volt dc supply to be obtained from a 48-volt battery. It is designed to mount on a 23-inch relay rack.

1.02 This section is reissued to include a procedure to clarify the low-voltage alarm check and the high-voltage cutoff check and to correct technical errors. This section does affect the Equipment Test List.

1.03 The KS-19304 L1 converter is designed to operate on 44 to 52 volts dc, 20 amperes. The output is adjustable from 120 volts to 140 volts dc, 5 amperes at full load. The dc output is transformer-isolated from dc input so that either positive or negative output can be grounded or both sides of dc output can be left ungrounded, regardless of input ground polarity. A removable power amplifier assembly and plug-in component card assemblies are used for ease in servicing. See Fig. 4 and 5.

1.04 Two or more converters may be connected in parallel to provide additional current to the 130-volt dc load. Each converter is self-protected against overload; in the event of overload, the dc output voltage will decrease as necessary to limit the output current to a safe value. When two converters of the same list number are operated in parallel, the settings of the output voltage adjustment should be identical.

1.05 Keep the ventilating passages of the converter unobstructed. This is especially important to ensure adequate cooling during operation.

1.06 The abbreviations cw and ccw refer to clockwise and counterclockwise rotation, respectively.

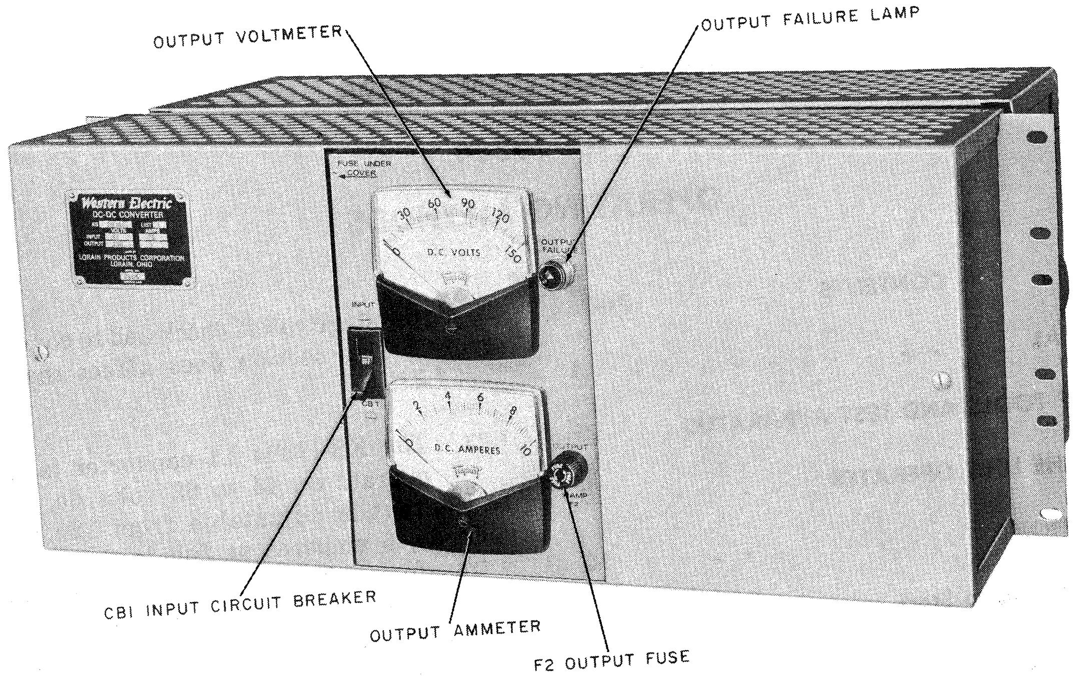


Fig. 1—KS-19304 L1 DC-to-DC Converter

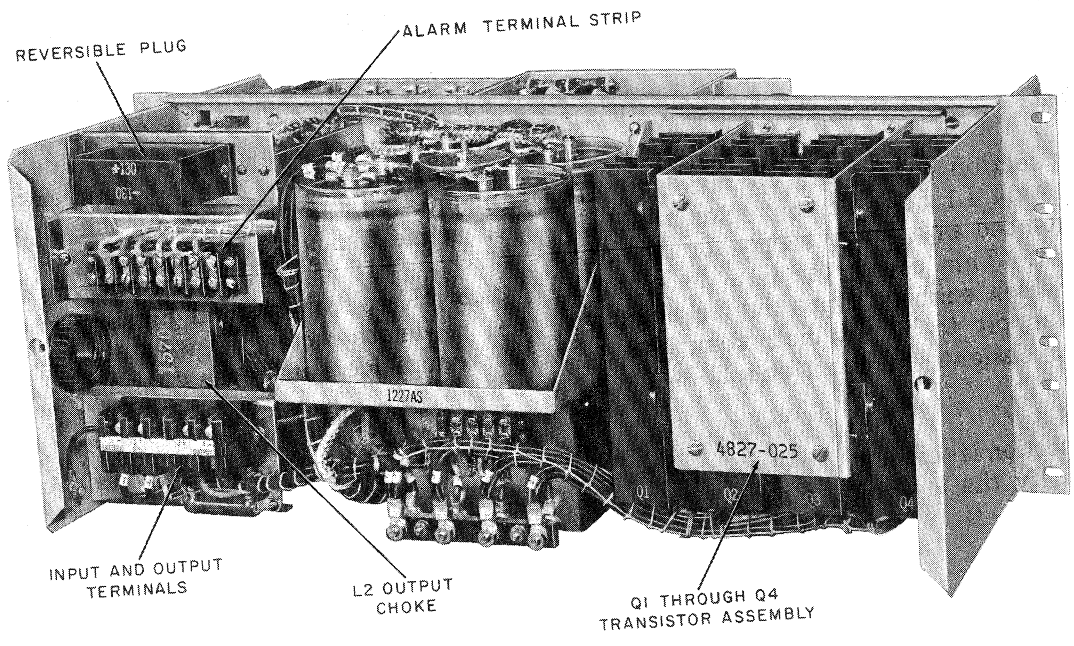


Fig. 2—KS-19304 L1 (Rear View—Cover Removed)

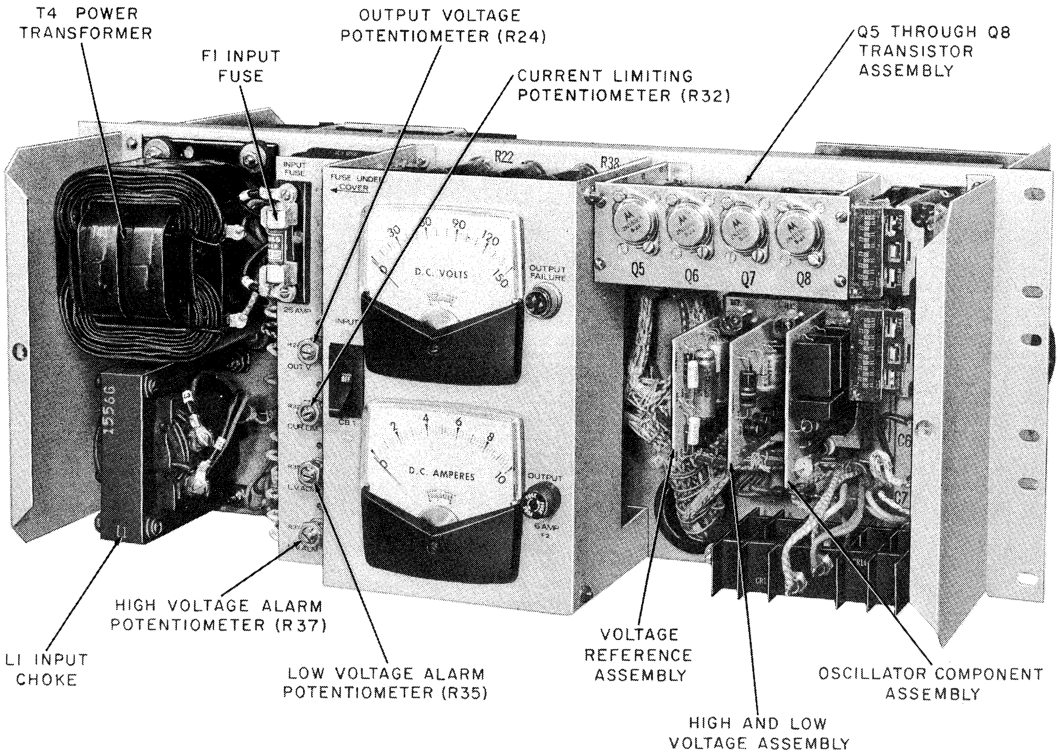


Fig. 3—KS-19304 L1 (Front View—Cover Removed)

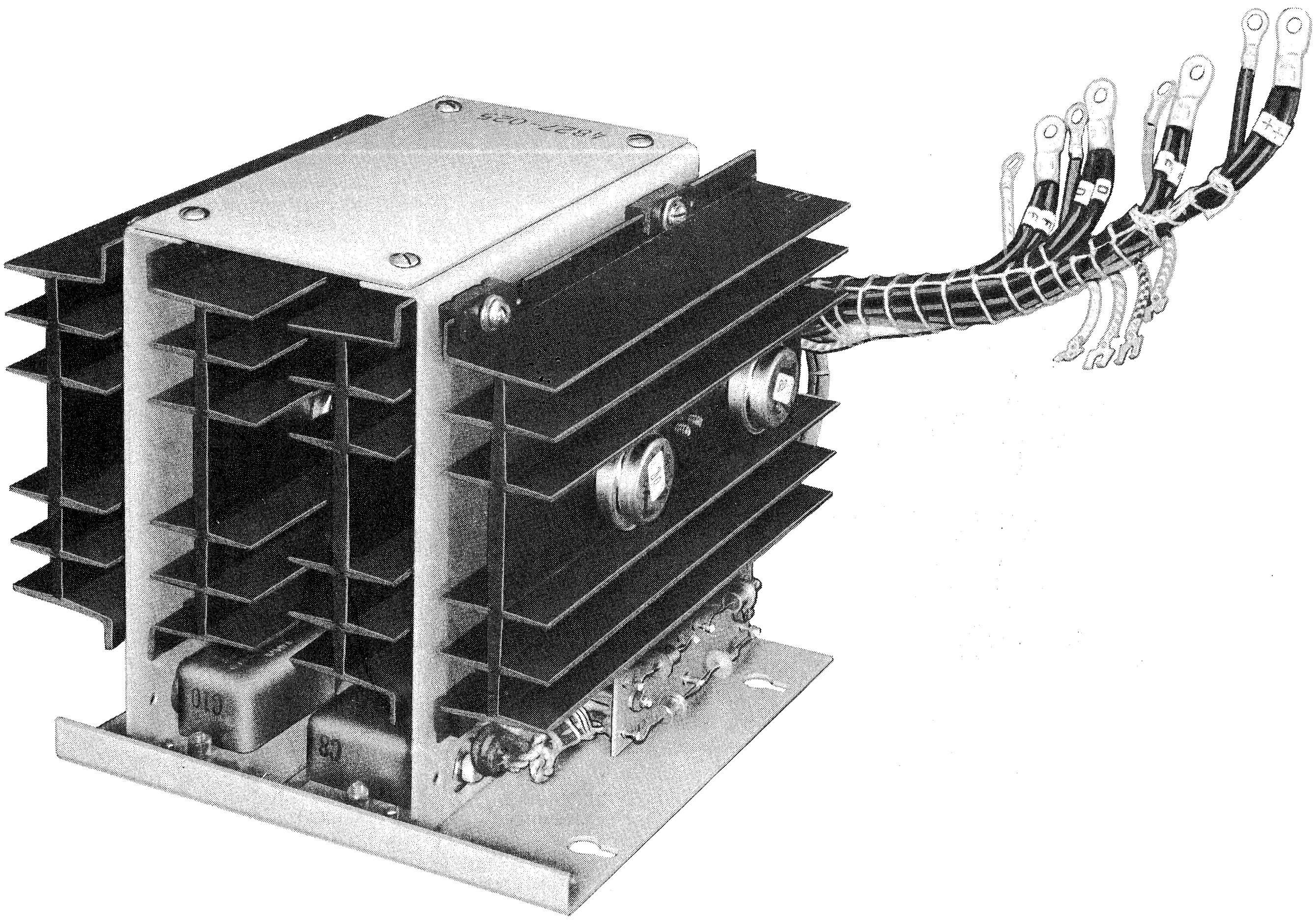
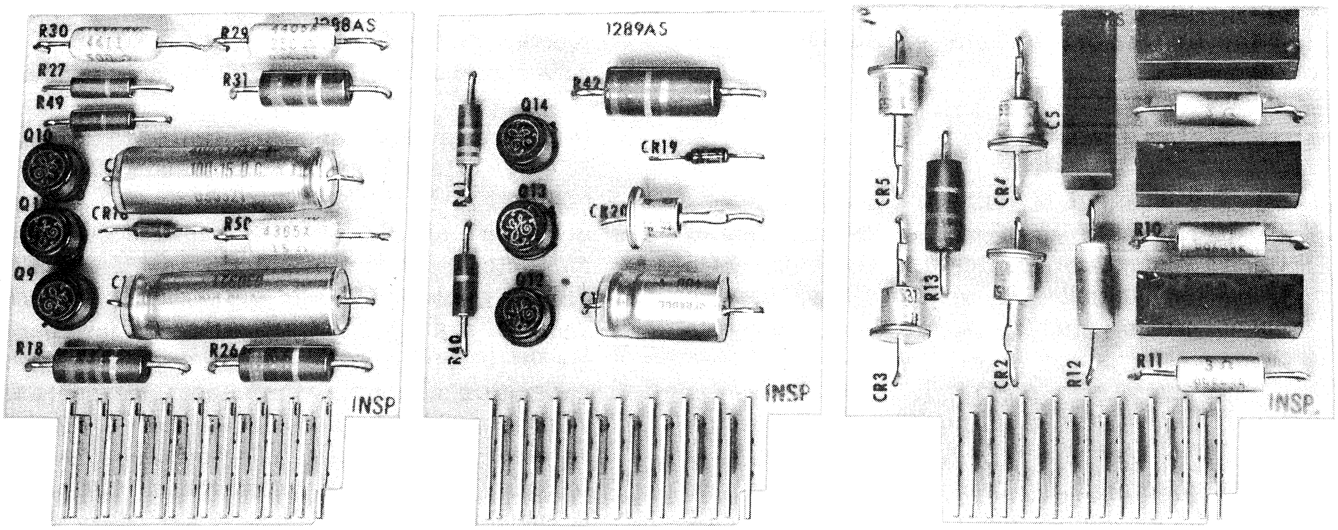


Fig. 4—Q1A Through Q4B Transistor Assembly



VOLTAGE
REFERENCE CARD
LORAIN PRODUCTS CORP.
PART NO. 1288 AS

HIGH AND LOW
VOLTAGE CARD
LORAIN PRODUCTS CORP.
PART NO. 1289 AS

OSCILLATOR
COMPONENT CARD
LORAIN PRODUCTS CORP.
PART NO. 1290 AS

Fig. 5—Component Card Assemblies

2. LIST OF TOOLS AND TEST APPARATUS

CODE OR SPEC NO.	DESCRIPTION
TOOLS	
KS-16346 L2	Soldering Copper
—	3-Inch C Screwdriver
—	P-Long-Nose Pliers
TEST APPRATUS	
KS-14510 L1	Volt-Ohm-Milliammeter

3. HOW THE UNIT OPERATES

3.01 *General*

(a) This dc-to-dc converter includes an inverter (oscillators and power amplifier) which changes nominal 50-volt dc input to alternating current, a power transformer which steps up inverter output voltage, and a power rectifier which changes ac to 130-volt dc.

(b) An output voltage regulator, actuated by a voltage-sensing network connected across dc output, supplies control current to a magnetic amplifier which then causes effective inverter output voltage to vary as necessary to correct against any variation of dc output voltage.

(c) As dc output current increases, voltage developed across a resistor in series with dc output also increases. When dc output current increases beyond its rated maximum value, this voltage causes an output current limiter to decrease magnetic amplifier control current and prevent further increase of dc output current.

(d) An alarm and cutoff circuit automatically turns off the dc-to-dc converter, gives an alarm if dc output voltage should increase to 135 volts, and gives an external alarm if dc output voltage should decrease to 125 volts or if output failure occurs.

3.02 ***Input Circuit:*** F1 input fuse opens to break negative dc input if some unsatisfactory circuit condition should cause input current to become excessive. CB1 input circuit breaker is controlled by an alarm and cutoff circuit, described below, to break negative dc input if dc output voltage should increase to 135 volts. L1 choke and C1 capacitor form an input filter which prevents transmission of noise to input battery. CR1 diode, connected across L1, clamps transistor collector supply voltage to input dc voltage to prevent damage to transistors from excessive forward voltage peaks.

3.03 ***Master Oscillator***

(a) The dc input is connected across a series circuit made up of emitter and collector of Q5 transistor and emitter and collector of Q6 transistor. Initially, either Q5 or Q6 will assume dominance and conduct; assume that Q5 conducts to start oscillation.

(b) Current flows from positive input through Q5 emitter and collector, primary windings between terminals 5 to 6 and terminals 15 to 16 of T1 master oscillator transformer, and C7 capacitor to negative input. Primary current in T1 transformer induces voltage in T1 feedback windings between terminals 7 to 8 and terminals 17 to 18; negative base-emitter voltage is supplied to Q5 to increase Q5 base current and drive Q5 to maximum conduction; positive base-emitter voltage is applied to Q6 to prevent flow of Q6 base current and drive Q6 to cutoff.

(c) Once T1 primary current begins to flow, it increases rapidly until T1 becomes saturated. At this time, the voltage developed across T1 primary windings decreases sharply and Q5 prevents further increase of T1 primary current; this causes T1 feedback voltage to decay so that T1 no longer furnishes base drive current to sustain conduction of Q5. When Q5 ceases to conduct, T1 primary current decays and causes polarity of T1 feedback voltage to reverse so Q6 is driven to maximum conduction and Q5 is driven to cutoff.

(d) When Q6 conducts, current flows from positive input through C6 capacitor, T1 primary windings between terminals 16 to 15 and terminals 6 to 5, and Q6 emitter and collector to negative input. A portion of Q6 collector current also flows to C7 capacitor to partially discharge C7. Note that direction of T1 primary current has now reversed; this current continues to induce feedback voltage which maintains Q6 at maximum conduction and Q5 at cutoff. Again, primary current increases rapidly until T1 becomes saturated, causing T1 primary voltage to decrease sharply, at which time Q6 limits primary current to cause another similar reversal. This cycle is repeated approximately 500 times per second; it causes square-wave current to flow between junction of C6-C7 capacitors and junction of Q5 collector-Q6 emitter through T1 primary windings.

(e) R9 and R10 resistors limit Q5 and Q6 transistors base drive current. C2 and C3 capacitors furnish low-impedance paths to drive-current transients to improve switching characteristics of Q5 and Q6. CR2 and CR3 diodes protect Q5 and Q6 against inverse collector-emitter voltage. After initial charge has been applied to C6 and C7 capacitors, these capacitors alternately increase and decrease charge on alternate oscillator half-cycles, as necessary, to maintain collector supply voltage to each of Q5 and Q6 transistors at one-half of dc input voltage.

3.04 ***Slave Oscillator***

(a) Emitter and collector of Q7 transistor and emitter and collector of Q8 transistor are also connected in series across dc input. Square-wave voltage developed between Q5 transistor collector-Q6 emitter junction-C6-C7 capacitor junction is applied to a series circuit made up of outer-leg gate windings of T5 magnetic amplifier, described below, and primary windings between terminals 1 to 2 and terminals 5 to 6 of feedback T2 transformer. T5 magnetic amplifier transmits a trigger pulse to T2 transformer at some instant during each master oscillator half-cycle.

(b) Trigger pulses supplied through T5 to T2 are in alternate directions on alternate master oscillator half-cycles. The resulting T2 primary current induces voltage peaks in alternate directions in T2 feedback windings between terminals 3 to 4 and terminals 7 to 8. During master oscillator half-cycles in which Q5 transistor conducts, T2 supplies a negative base-emitter voltage pulse to Q7 transistor to cause Q7 base current to flow and drive Q7 to conduction and furnishes a positive base-emitter voltage pulse to Q8 transistor to prevent flow of Q8 base current and drive Q8 to cutoff. During alternate master oscillator half-cycles when Q6 transistor conducts, voltage pulse polarities induced in T2 feedback windings are reversed so Q8 is driven to conduction and Q7 is driven to cutoff. These voltage pulses serve as a trigger to cause keyed oscillation of Q7 and Q8 transistors.

(c) When Q7 conducts, current flows from positive input through Q7 emitter and collector, primary windings between terminals 12 to 11 and terminals 6 to 5 of slave oscillator T3 output transformer, and C7 capacitor to negative input. When Q8 conducts, current flows from positive input through C6 capacitor, T3 primary windings between terminals 5 to 6 and terminals 11 to 12, and Q8 emitter and collector to negative input. Note that direction of T3 primary current reverses on alternate half-cycles.

(d) Primary voltage of T3 output transformer is supplied through R13 feedback resistor to primary windings of T2 feedback transformer. The voltage maintains T2 primary current throughout each half-cycle and sustains drive voltage supplied by T2 feedback windings to Q7 and Q8; hence, it causes Q7 and Q8 to produce a square wave.

(e) R11 and R12 resistors limit Q7 and Q8 base drive current. C4 and C5 capacitors furnish low-impedance paths to drive current transients to improve switching characteristics of Q7 and Q8. CR4 and CR5 diodes protect Q7 and Q8 against inverse collector-emitter voltage. Q7 and Q8 transistor-collector current also alternately increases and decreases charge of C6 and C7 capacitors, as necessary, to maintain Q7 and Q8 collector supply voltage at one-half of dc input voltage.

3.05 ***Power Amplifier***

(a) Q1A through Q4B transistors are connected as a bridge-type power amplifier. Secondary windings of T1 master oscillator transformer drive Q1A, Q1B, Q4A, and Q4B which form two legs of this amplifier bridge, while secondary windings of slave oscillator T3 output transformer drive Q2A, Q2B, Q3A, and Q3B which form two additional legs.

(b) This power amplifier is driven to large signal (switching) operation: Odd-numbered transistors are driven to maximum conduction while even-numbered transistors are driven to cutoff; then, during alternate half-cycles, even-numbered transistors are driven to maximum conduction while odd-numbered transistors are driven to cutoff.

(c) During half-cycles in which odd-numbered transistors conduct, current flows from positive input through R1A and R1B resistors, Q1A and Q1B emitters and collectors, primary windings between terminals 3 to 4 of power T4 transformer, R3A and R3B resistors, Q3A and Q3B emitters and collectors, and contacts of K3 relay to negative input. During alternate half-cycle, current flows from positive input through R2A and R2B resistors, Q2A and Q2B emitters and collectors, T4 primary between terminals 4 to 3, R4A, R4B resistor, and Q4A and Q4B emitters and collectors, and contacts of K3 relay to negative input. Thus, Q1A through Q4B transistors switch dc input in alternate directions to furnish alternating current to T4 power transformer.

(d) R14 through R17 base resistors limit transistor base drive current. Emitter R1A through R4B resistors are degenerative to compensate against any difference of gain in parallel-connected transistors. CR10 through CR13 diodes protect Q1A through Q4B against inverse collector-emitter voltage. The R5-C8-CR6, R6-C9-CR7, R7-C10-CR8, and R8-C11-CR9 resistance-capacitance-diode networks absorb switching transients to reduce power dissipation in Q1A through Q4B. Initially, dc input is supplied through the R47 resistor to charge the C18 capacitor. When C18 has become charged, the K3 relay operates and the C18 capacitor discharges through the R48 resistor. R46 resistor decreases collector supply voltage of Q1A through Q4B until K3 relay has operated, as necessary, to assure that both master oscillator and slave oscillator will be in normal operation before full power amplifier collector voltage is applied.

3.06 ***DC Power Circuit***

(a) T4 power transformer is a step-up transformer which increases inverter output voltage to a higher ac voltage. The bridge-type rectifier made up of CR14 through CR17 diodes changes the alternating current supplied by T4 to direct current, which is then supplied to the 130-volt dc load.

(b) Output F2 fuse, CR21 diode, and an output ammeter can be connected in series with positive output if negative 130-volt load is grounded or in series with negative output if positive 130-volt load is grounded. These options are selected by means of a reversible plug.

(c) CR21 output diode permits current to flow from the converter to the dc load but, in the event of output failure, this diode blocks to prevent flow of output current from any parallel-connected unit. Thus, CR21 diode assures that an output failure alarm will be given.

(d) L2 and L3 chokes in series with negative output, and C13 capacitor with C14 capacitor bank, across dc output, form an output filter which smoothes ac ripple from output of CR14 through CR17 diodes so the converter output will more nearly approach pure dc. R21-C12 resistance-capacitance network protects CR14 through CR17 diodes against voltage peaks.

3.07 ***Magnetic Amplifier***

(a) T5 magnetic amplifier is controlled by an output voltage regulator and an output current limiter, described below, to cause increase or decrease of effective ac voltage supplied to T4 power transformer. This regulates dc output voltage and prevents increase of output current beyond a safe value.

(b) T5 magnetic amplifier has a 3-legged core which carries two gate windings, one on each of its two outer legs, and one bias winding and one control winding on its center leg.

(c) As noted above, square-wave voltage developed between C6-C7 capacitor junction and junction of master oscillator-transistor Q5 collector-Q6 emitter is applied to a series circuit which consists of T5 gate windings and primary windings of feedback T2 transformer. Each time square-wave voltage changes polarity (start of each master oscillator half-cycle), T5 is initially unsaturated and this voltage appears almost entirely across T5 gate windings. Gate winding current then increases slowly until T5 becomes saturated, at which time gate winding voltage decreases sharply and T5 transmits a trigger pulse to T2.

(d) Bias current flows from positive dc input through a T5 winding between terminals 8 to 7 and R19 and R20 resistors to negative input. This current aids saturation of T5 by gate winding current. R19 resistor is adjusted so, with only gate winding current and bias current supplied to T5, T5 will remain unsatuated until each master oscillator half-cycle has been nearly completed.

(e) Control current flows through a T5 winding between terminals 6 to 5. This current aids bias current. When it increases, it causes T5 to become saturated earlier during each master oscillator half-cycle and, when it decreases, it causes T5 to remain unsaturated for a greater portion of each half-cycle.

3.08 ***Output Voltage Regulator***

(a) During each master oscillator half-cycle, when T5 magnetic amplifier transmits a trigger pulse to feedback T2 transformer, T5 initiates a polarity change (start of a half-cycle) at slave oscillator output. When T5 remains unsaturated during almost a complete master oscillator half-cycle, it delays this trigger pulse and causes slave oscillator output to be almost completely out of phase with master oscillator output. As control current increases, however, T5 becomes saturated earlier during each master oscillator half-cycle so the resulting earlier trigger pulses cause slave oscillator output to become more nearly in phase with master oscillator output.

(b) As noted above, Q1A, Q1B, Q4A, and Q4B transistors are driven by master oscillator output, while Q2A, Q2B, Q3A, and Q3B transistors are driven by slave oscillator output. When master oscillator output has driven Q1A and Q1B to conduction, current cannot flow to T4 power transformer until slave oscillator output has driven Q3A and Q3B to conduction. Likewise, when master oscillator output has driven Q4A and Q4B to conduction, current cannot flow to T4 power transformer until slave oscillator output has driven Q2A and Q2B to conduction.

(c) When T5 control current increases and causes T5 to shift slave oscillator output more nearly in phase with master oscillator output, it causes T4 primary current to flow for a greater portion of each master oscillator half-cycle. This increases effective T4 primary voltage. Similarly, when T5 control current decreases and causes T5 to shift slave oscillator output farther out of phase with master oscillator output, it decreases the portion of each master oscillator half-cycle during which T4 primary current flows. This decreases effective T1 primary voltage.

(d) R23, R24, R43, and R25 resistances are connected in series across 130-volt dc output so that voltage developed across R23 resistor and adjacent portion of R24 potentiometer is proportional to dc output voltage. This R23-R24 voltage is applied across CR18 zener diode and emitter to base of Q11 transistor, causing Q11 base current to flow. Q11 is driven to conduction. When Q11 conducts, current flows from positive dc output through CR18, Q11 emitter and collector, and R27 and R28 resistors to negative dc output.

(e) Note that CR18 zener diode conducts in reverse direction. Characteristics of CR13 are such that, once this occurs, essentially constant voltage will appear across CR18 while any increase or decrease of dc output voltage will appear across other circuit elements. Constant voltage developed across CR18 holds Q11 emitter potential constant with respect to positive dc output. R24 potentiometer OUT. V. is adjusted so that R23-R24 voltage will slightly exceed constant CR18 voltage to maintain negative base-emitter potential supplied to Q11. Q11 will continue to conduct.

(f) Constant CR18 voltage, plus voltage developed across Q11 emitter and collector, is applied across R29 resistor and emitter to base of Q10 transistor. This voltage causes Q10 base current to flow and drives Q10 to conduction. Q10 transistor collector current flows from positive dc output through R29, Q10 emitter and collector, control winding between terminals 6 to 5 of magnetic amplifier T5, and R28 resistor to negative dc output, as necessary, to cause voltage developed across R29 to approach CR18-plus-Q11 emitter-collector voltage.

(g) If dc voltage decreases, R23-R24 resistor voltage also decreases. This reduces negative base-emitter potential supplied to Q11, decreases Q11 base current, and reduces conduction of Q11 to increase Q11 emitter-collector voltage. Increased Q11 emitter-collector voltage causes Q10 base-emitter voltage to increase, increasing Q10 base current, to drive Q10 to greater conduction. Collector current, supplied by Q10 as control current to T5 then increases until R29 voltage again approaches CR18-plus-Q11 emitter-collector voltage. Increased control current causes T5 to increase effective ac voltage furnished to power transformer T4 and increase in dc output voltage.

(h) Similarly, if dc output voltage increases, conduction of Q11 transistor increases, conduction of Q10 decreases, and reduced T5 control current causes T5 to decrease dc output voltage.

(i) R26-C15 resistance-capacitance network prevents abrupt changes of Q11 collector current to avert a hunting condition (oscillation of dc output voltage or output current).

3.09 ***Output Current Limiter***

(a) R22 resistor is connected in series with positive dc output so that voltage developed across R22 will increase or decrease in accordance with increase or decrease of dc output current. This voltage is applied across R32 potentiometer and emitter to base of Q9 transistor,.causing Q9 base current to flow, to drive Q9 to conduction.

(b) In usual operation, dynamic resistance of R32-plus-Q9 emitter-collector is sufficiently high so that CR18-plus-Q11 emitter-collector voltage prevents flow of Q9 collector current. R32 potentiometer is adjusted so, when dc output current increases beyond its rated value, this dynamic resistance will decrease sufficiently to cause current to flow from positive dc output (ahead of R22) through R32, Q9 emitter and collector, and R27 and R28 resistors to negative dc output.

(c) When Q9 transistor collector current flows, voltage developed across R27 and R28 prevents further increase of CR18-plus-Q11 emitter-collector voltage; hence, drive voltage supplied across Q10 base-emitter and R29 is limited. Successively, this prevents further increase of Q10 base current and Q10 collector current supplied as control current to T5. With T5 control current held at a maximum value, T5 prevents further increase of effective ac voltage furnished to T4. This limits dc output current to a safe value.

Alarm, Cutoff Circuits

3.10 ***Low-Voltage Alarm***

(a) R42 resistor and CR19 zener diode are connected in series across dc output. CR19 diode is similar to CR18 diode, described above. CR19 conducts in reverse direction and CR19 voltage remains essentially constant, while any increase or decrese of dc output voltage is developed across R42. Voltage which appears across CR19 holds emitter potential of Q14 transistor constant with respect to negative dc output.

(b) R34 resistor and R35 potentiometer (L.V. ALM.) are also connected in series across dc output so that voltage developed across that portion of R35 between its slider and negative output is proportional to dc output voltage. Under usual conditions, this R35 voltage exceeds constant CR19 voltage and applies positive base emitter potential to Q14 transistor. Base current flows and drives Q14 to conduction. When Q14 conducts, current flows from positive dc output through R38 resistor, coil of K2 relay, Q14 collector and emitter, and CR19 to negative dc output, operating K2 relay. As long as Q14 continues to conduct, K2 relay remains operated.

(c) R35 potentiometer (L.V. ALM.) is adjusted so that if dc output voltage decreases to 125 volts, its slider-to-negative output voltage will no longer be sufficient to drive Q14 to conduction. This releases K2 relay. Contacts of K2 relay, released, furnished ground to light OF lamp and give an external minor alarm connected at either of alarm terminals 5 or 6 and supply closed loops between alarm terminals 7 to 8 and 9 to 10 to give an external major alarm.

(d) C17 capacitor is normally charged by voltage difference between Q14 collector and base. If a sudden increase of output current should cause dc output voltage to instantaneously decrease to less than 125 volts, C17 capacitor discharges through Q14 base and emitter to maintain Q14 in conduction until this momentary condition is corrected. This prevents a false alarm.

3.11 ***High-Voltage Cutoff***

(a) CR19 zener diode also holds emitter potential of Q13 transistor constant with respect to negative dc output. R36 resistor and R37 potentiometer are connected in series across dc output so that voltage developed across a portion of R37 between its slider and negative output is proportional to dc output voltage. Under usual conditions, this R37 voltage is lower than constant CR19 voltage so negative base-emitter potential prevents flow of Q13 base current and maintains Q13 at cutoff. R37 potentiometer (H.V. ALM.) is adjusted so, if dc output voltage increases to 135 volts, its slider-to-negative output voltage will increase to a value greater than CR19 voltage. This applies positive base-emitter potential to Q13, causes Q13 base current to flow, and drives Q13 to conduction.

(b) When Q13 conducts, current flows from positive dc output through R38, R40, and R41 resistors, Q13 collector and emitter, and CR19 to negative dc output. Voltage developed across R40 applies negative base-emitter potential to Q12 transistor, causes Q12 base current to flow, and drives Q12 to conduction. Current then flows from positive dc output through R38, Q12 emitter and collector, and coil of K1 relay, causing the relay to operate. Contacts of K1 relay operated supply ground to input CB1 circuit breaker and cause CB1 to open, turning off the converter.

(c) When dc output voltage is not present, a low-voltage alarm is given, as described above.

4. OPERATION

Preparing to Start

4.01 When preparing to put the converter into service check that:

(a) All external connections are made in accordance with the SD drawing covering the associated circuit of which the unit is a part. To gain access to the input and output terminals on the KS-19304 L1 converter, release the two twist-type fasteners and remove the rear cover. (See Fig. 2.)

Caution 1: Before making electrical connections, be certain the CB1 input circuit breaker is in the OFF position.

Caution 2: Inductive filtering should not be used between the 48-volt battery and the converter input since an input filter may cause voltage peaks which would damage transistors.

Note: Positive dc input (terminal 2) is connected to chassis ground by a jumper. This protects transistors against damage in case input battery polarity is incorrect. If desired, this jumper can be removed once the proper input connections have been made.

(b) The reversible plug designated "+130" and "−130" (see Fig. 2) is positioned as follows:

(1) For use in a positive (negative-ground) system, the "+130" designation shall read upright; the F2 output fuse, CR12 diode, and the ammeter will then be in series with positive dc output. (See Fig. 6.)

(2) For use in a negative (positive-ground) system, the "−130" designation shall read upright; the F2 output fuse, CR12 diode, and the ammeter will then be in series with negative dc output. (See Fig. 6.)

(c) 130-volt dc load at OUTPUT terminals 3 (positive) and 4 (negative) is connected.

(d) Nominal 50-volt dc at input terminals 1 (negative) and 2 (positive) is connected.

(e) To cause OUTPUT FAILURE lamp to light in event of high or low dc output voltage alarm terminal strip. (See Fig. 2 and 6.) Alarm terminals 5 and 6 furnish positive 50-volt ground, while terminals 7 and 8 and terminals 9 to 10 each supply a closed loop to give an external alarm in event of any alarm conditions. If two converters are operated in parallel, closed-loop alarm terminals of each unit can be connected in series to give an external major alarm.

(f) F2 output fuse is connected in series with either positive or negative dc output (option), as necessary, to cause it to protect whichever side of dc output is ungrounded. Since this converter is self-protected against overload, an overload condition will not cause either the F1 input fuse or F2 output fuse to open. F2 output fuse is carried in a bayonet-type fuse holder which is accessible at the front of the converter. To gain access to F1 input fuse, release two twist-type fasteners and remove the front cover. If necessary to replace either fuse, replace only with fuse type and size or equivalent as follows:

F1 INPUT fuse Bussman type BAF cartridge, 25 amperes

F2 OUTPUT fuse Bussman type MTH cartridge, 6 amperes

➧Starting

4.02 To start the converter, proceed as follows.

(1) Throw the toggle of INPUT circuit breaker CB1 to the ON position.

(2) Adjust the dc output voltage for an indication of 130 volts on the voltmeter. Rotate the OUT. V. potentiometer (R24) cw to increase and ccw to decrease the output voltage.

Note: To make adjustments, remove or pivot the front cover of the converter by releasing the two twist-type fasteners.

Stopping

4.03 To stop the converter, throw the toggle of INPUT circuit breaker CB1 to the OFF position. If the converter is to be out of service for an extended period of time, remove the F1 and F2 fuses.➧

5. ROUTINE CHECKS

5.01 As often as local experience demands, the relays should be inspected for adjustment and condition of contacts, making sure they are in accordance with Bell System Practices which apply.

5.02 The dc voltage and current should be checked periodically to make certain they are correct.

5.03 Electrolytic capacitors should be maintained in accordance with Section 032-110-701.

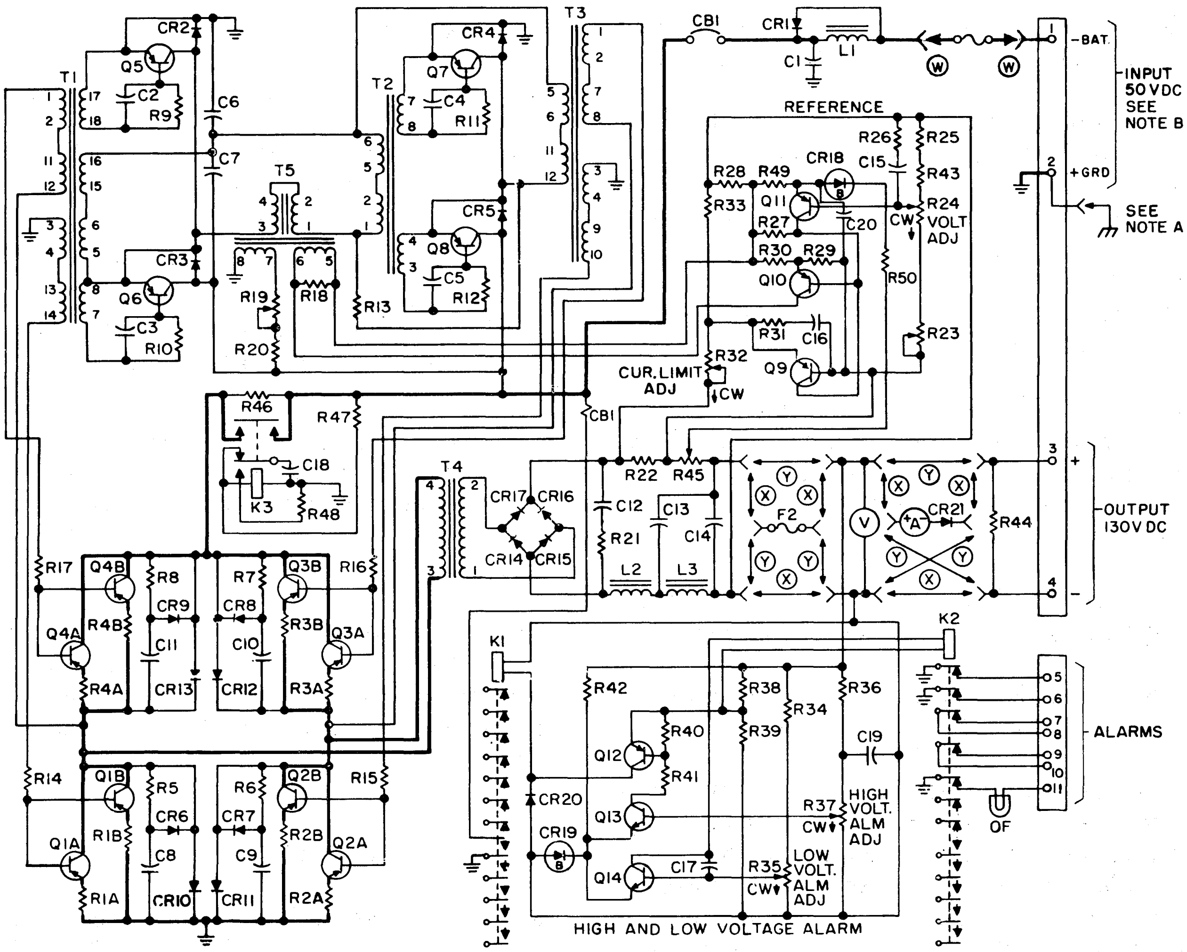
5.04 *Low-Voltage Alarm:* To adjust the low-voltage alarm, proceed as follows.

Caution: Before readjusting the low-voltage alarm circuit, provide back up power of sufficient capacity to power the load.

(1) ➧Operate the toggle of input circuit breaker CB1 to the OFF position.

(2) Disconnect the output leads.

(3) Operate the toggle of input circuit breaker CB1 to the ON position and record the voltmeter reading.



NOTES.

A POSITIVE GROUND TO CHASSIS PROVIDED BY JUMPER REMOVAL OPTIONAL AFTER INSTALLATION

B CONNECT INPUT TO BATTERY SIDE OF FILTER IN PLANTS HAVING DISCHARGE FILTER IN SERIES WITH LOAD.

C Ⓧ OPTION CAN BE OBTAINED BY HAVING REVERSIBLE PLUG IN "NEG GROUND" POSITION

Ⓨ OPTION CAN BE OBTAINED BY HAVING REVERSIBLE PLUG IN "POS GROUND" POSITION.

D Ⓦ OPTION PROVIDED ON LIST 1.

PARTS LIST

DESIG	DESCRIPTION
C1	(2) 6600MFD 75VDC ELECT. CAPACITOR
C2 - C5	1MFD 200VDC CAPACITOR
C6,C7,C18,C19	300MFD 50VDC ELECT. CAPACITOR
C8, C11	10MFD 150VDC CAPACITOR
C9, C10	5MFD 150VDC CAPACITOR
C12	0.1MFD 600VDC CAPACITOR
C13	290MFD 200VDC ELECT. CAPACITOR
C14	(2) 2500MFD 200VDC ELECT. CAP.
C15	5MFD 150VDC CAP. (YELLOW DOT)
C16, C20	100MFD 15VDC ELECT. CAPACITOR
C17	10MFD 25VDC ELECT. CAPACITOR
CB1	HEINEMANN CIRCUIT BREAKER
CR1	IN1342 SILICON DIODE
CR2-CR5	IN537 SILICON DIODE
CR6-CR9	IN1221 SILICON DIODE
CR10-CR13	IN1218 SILICON DIODE
CR14, CR15	IN.345RA SILICON DIODE
CR16, CR17	IN1345 SILICON DIODE
CR18, CR19	IN753A ZENER DIODE
CR20	IN537 SILICON DIODE
CR21	IN1344 6AMP 200PIV SILICON DIODE
F1	25AMP BAF FUSE
F2	6AMP MTH FUSE
K1, K2, K3	WECo WIRE SPRING RELAY
K3	SPST 50A CONTACTOR ASSY
L1	INPUT FILTER CHOKE
L2	1ST OUTPUT FILTER CHOKE
L3	2ND OUTPUT FILTER CHOKE
OF	48V .04AMP SWBD LAMP
Q1A-Q4B	2N174 TRANSISTOR
Q5 - Q8	2N1536A TRANSISTOR
Q9 - Q12	2N525 TRANSISTOR
Q13, Q14	2N333A TRANSISTOR
R1A-R4B	1-5/8" 15GA COPEL WIRE
R5 - R8	35Ω 5W RESISTOR
R9 - R12	3Ω 3W RESISTOR
R13	50Ω 1W RESISTOR
R14-R17	0.5Ω 20W RESISTOR
R18	220Ω 1/2W RESISTOR
R19	1500Ω 10W DIVIDOHM
R20	500Ω 10W RESISTOR
R21	100Ω 10W RESISTOR
R22	(2) 1Ω 25W RESISTOR
R23	200Ω 10W DIVIDOHM
R24	50Ω 2W POTENTIOMETER
R25	2000Ω 10W RESISTOR
R26	10Ω 1/2W RESISTOR
R27	2200Ω 1/2W RESISTOR
R28	3000Ω 10W RESISTOR
R29	350Ω 3W RESISTOR
R30	500Ω 3W RESISTOR
R31	100Ω 1/2W RESISTOR
R32	250Ω 2W POTENTIOMETER
R33	5000Ω 10W RESISTOR
R34, R36	6000Ω 5W RESISTOR
R35, R37	750Ω 2W POTENTIOMETER
R38	1500Ω 25W RESISTOR
R39	400Ω 5W RESISTOR
R40	1000Ω 1/2W RESISTOR
R41	3300Ω 1/2W RESISTOR
R42	20KΩ 2W RESISTOR
R43	1000Ω 5W RESISTOR LOW TEMP COEF
R44	3000Ω 10W RESISTOR LOW TEMP COEF
R45	1" 15GA COPEL WIRE
R46	3Ω 25W RESISTOR
R47	150Ω 5W RESISTOR
R48	22Ω 1W RESISTOR
R49	1500Ω 1/2W RESISTOR
R50	15Ω 3W RESISTOR
T1	MASTER OSCILLATOR TRANSFORMER
T2	FEEDBACK TRANSFORMER
T3	SLAVE OSCILLATOR TRANSFORMER
T4	POWER TRANSFORMER
T5	TRANSDUCTOR
A	0 - 10 AMP DC AMMETER
V	0 - 150 VOLT DC VOLTMETER

Fig. 6—Schematic Diagram KS-19304 L1—DC-to-DC Converter

(4) Rotate the LOW VOLT ALM (R35) potentiometer fully ccw.

(5) Adjust VOLT ADJ (R24) potentiometer to obtain a value of dc output voltage at which a low-voltage alarm is desired.

(6) Slowly rotate the LOW VOLT ALM ADJ (R35) potentiometer cw until the OUTPUT FAIL lamp just lights, an alarm is given, and the converter shuts down.

(7) Readjust the VOLTS ADJ (R24) potentiometer to obtain the voltmeter reading in (3).

(8) Operate the toggle of input circuit breaker CB1 to the OFF position.

(9) Reconnect the output leads.

5.05 ***High-Voltage Cutoff:*** To adjust the high-voltage shutoff, proceed as follows.

Caution: Before readjusting the high voltage cutoff circuit, provide back-up power of sufficient capacity to power the load.

(1) Operate the toggle of input circuit breaker CB1 to the OFF position.

(2) Disconnect the output leads.

(3) Operate the toggle of input circuit breaker CB1 to the ON position and record the voltmeter reading.

(4) Rotate the HIGH VOLTS ALM ADJ (R37) potentiometer fully cw.

(5) Adjust VOLT ADJ (R24) potentiometer to obtain a value of dc output voltage at which the high voltage cutoff is desired.

(6) Slowly rotate the HIGH VOLTS ALM ADJ (R37) ccw until the OUTPUT FAIL lamp just lights, an alarm is given, and the converter shuts down.

(7) Readjust the VOLTS ADJ (R24) potentiometer to obtain the voltmeter reading in (3).

(8) Operate the toggle of input circuit breaker CB1 to the OFF position.

(9) Reconnect the output leads.

5.06 ***Factory Adjustments***—Resistors R19 and R23, and the CUR. LIM. (R32) potentiometer are factory adjusted and it is recommended that no change be made in these adjustment settings.

6. TROUBLES

General

6.01 Various trouble symptoms and possible causes are listed in 6.05. A trouble test procedure opposite each cause will isolate the trouble to a few possible defective components. Since some unsatisfactory condition will damage more than one component, all checks listed under a given cause should be made, even though defective components are revealed before the entire check procedure has been completed.

6.02 Components test procedures are made with the converter disconnected from the external output circuit. Before testing the components, place the CB1 circuit breaker in the OFF position and remove the F1 and F2 fuses. Where necessary, momentarily shunt capacitors with a 100-ohm resistor to be certain they are completely discharged. If any charge is left on the capacitors, it may cause inaccuracy in resistance readings.

Caution: In making continuity checks, use the ohmmeter portion of the KS-14510 L1 meter. Do not use the X10,000 position for testing semiconductors, inasmuch as the higher voltage used may damage them.

6.03 Before disconnecting leads, mark or record the connection.

Caution: Soldering operation on semiconductors shall be done at the lowest possible temperature and in the shortest time practicable in order to localize the heating effect and thus prevent damaging the semiconductors. Because of its low operating temperature, use the KS-16346 L2 12-watt soldering copper. For the protection of the semiconductors, use the P-long-nose pliers as a heat sink.

6.04 Q1A through Q4B transistors, R1A through R4B resistors, R5 through R8 resistors, C8 through C11 capacitors, and CR6 through CR13 diodes make up a separately removable assembly. In the event of failure of any Q1A through Q4B transistor, it is recommended that this entire assembly be replaced (see Fig. 4). This assembly may be ordered from Lorain Products Corp., Part No. 4827-025.

Troubleshooting

6.05 Reference to input fuse shall be interpreted to mean the F1 fuse located on the converter.

A. Low-Voltage Alarm Given Continuously, Input Fuse Opens

POSSIBLE CAUSE	PROCEDURE
Short circuit of one or more of Q1A through Q4B transistors	Replace defective Q1A through Q4B transistor assembly (see 6.04), and check for the following: (1) C2 through C5 capacitors for short circuit. (2) R9 through R17 resistors for open circuit. (3) Associated wiring or R14 through R17 resistors for open circuit. (4) CR14 through CR17 diodes for short circuit; if two of the diodes are shorted, check R21 resistor for open circuit and C12 capacitor for short circuit. (5) Q9 transistor and R32 potentiometer for open circuit. (6) R46 resistor for open circuit; if open, check C18 capacitor for short circuit and R47 for open circuit. Replace defective components and repair defective wiring as necessary.
Short circuit of C1 capacitor bank	Check for and replace defective C1 capacitor.
Short circuit of two of CR14 through CR17 diodes	Check R21 resistor for open circuit; C12 capacitor and Q1A through Q4B transistors for short circuit; if necessary, replace defective components and transistor assembly.
Open circuit of Q9 transistor or R32 potentiometer or associated wiring, in combination with overload applied at dc output	Check for and replace defective Q9 transistor or R32 potentiometer; repair defective wiring as necessary.

B. Low-Voltage Alarm Given Continuously, CB1 Circuit Breaker Opens

POSSIBLE CAUSE	PROCEDURE
Temporary condition has caused CB1 circuit breaker to open	Throw toggle of CB1 circuit breaker to ON position to reset; if circuit breaker then remains closed, no further test or repair should be required. If CB1 again opens, proceed as follows: (1) Disconnect associated output circuit from converter.

POSSIBLE CAUSE	PROCEDURE
	(2) Turn R37 potentiometer to extreme cw position to obtain maximum value of automatic shutoff voltage. (3) Throw toggle of CB1 circuit breaker to ON position to reset.
Short circuit of Q12 or Q13 transistor; short circuit of CR19 zener diode	Failures at left will cause CB1 circuit breaker to again open; Q12, Q13, and Q14 transistors will be destroyed by open circuit of R39 resistor or associated wiring; check for and replace defective components and repair defective wiring as necessary.
Short circuit of Q10 transistor; open circuit of Q11 transistor and CR18 zener diode; open circuit of R11, R12, R13, R23, R25, R30, R42, R43, or R50 resistors, or R24 potentiometer, or associated wiring	With failures at left, CB1 circuit breaker will remain closed; open circuit of R11 or R12 resistor or associated wiring may destroy Q7 or Q8 transistor; open circuit of R23, R25, or R43 resistor, open circuit of R24 potentiometer, or open circuit of associated wiring will destroy Q11 transistor; open circuit of R42 resistor will cause CB1 circuit breaker to open when dc input is connected and disconnected repeatedly; check for and replace defective components and repair defective wiring as necessary.

C. Low-Voltage Alarm Given Continuously, Neither Input Fuse Nor CB1 Circuit Breaker Opens, Converter Does Not Emit Usual High-Pitched Hum

POSSIBLE CAUSE	PROCEDURE
Open circuit of dc input wiring	Make continuity check with KS-14510 L1 ohmmeter; repair defective wiring or reconnect as necessary.
Short circuit of any of Q5 through Q8 transistors	Check R9 through R12 resistors and associated wiring for open circuits; replace defective components and repair defective wiring as necessary.
Short circuit of any of CR2 through CR5 diodes	Check for and replace defective diode.
Short circuit of either C6 or C7 capacitor	Check for and replace defective capacitor.
Open circuit of wiring between dc input to C6 or C7 capacitor	Make continuity check with the KS-14510 L1 ohmmeter; repair defective wiring or reconnect as necessary.

D. Low-Voltage Alarm Given Continuously, Neither Input Fuse Nor CB1 Circuit Breaker Opens, Converter Emits Usual High-Pitched Hum

POSSIBLE CAUSE	PROCEDURE
High resistance of dc input connection	Tighten clamp screws of dc input terminals to obtain proper connection.
Poor contact of output polarity selector plug	Remove plug from receptacle, clean contacts as necessary; then insert plug into receptacle to obtain good contact.
Short circuit of either Q9 or Q11 transistor	Q11 transistor will be destroyed by open circuit of R23, R25, or R43 resistor, R24 potentiometer or associated wiring; check for and

POSSIBLE CAUSE	PROCEDURE
	replace defective components and repair wiring as necessary.
Short circuit of CR18 zener diode	Check for and replace defective CR18 zener diode.
Short circuit of any of C13, C16, C17, C18, or C20 capacitor; short circuit of C14 capacitor bank	Check for and replace defective capacitor.
Open circuit of any of R9, R10, R13, R19, R20, R29, R33, or R39 resistor; open circuit of associated wiring	Open circuit of R19 or R20 resistor will cause a continuous low-voltage alarm only after dc output current has increased sufficiently beyond its rated value; open circuit of R39 resistor or associated wiring destroys Q12, Q13, and Q14 transistors; check for and replace defective components, repair defective wiring as necessary.
F2 fuse open	Replace F2 fuse.
Open circuit of wiring between: dc input to Q1A through Q4B transistors, Q1A through Q4B transistors to T4 transformer, T4 transformer to CR14 through CR17 diodes, CR16-CR17 diode junction to positive dc output terminal, negative dc output terminal to CR14-CR16 diode junction	Make continuity check with the KS-14510 L1 ohmmeter; repair defective wiring as necessary.

E. Low-Voltage Alarm Given Only Momentarily, Neither Input Fuse Nor CB1 Circuit Breaker Opens

POSSIBLE CAUSE	PROCEDURE
Open circuit of R18, R19, or R20 resistor; open circuit in associated wiring	Such an open circuit may cause momentary low-voltage alarm when dc output current increases abruptly; check for and replace defective resistor, repair defective wiring as necessary.

F. False Low-Voltage Alarm Given, DC Output Voltage and Output Current Normal

POSSIBLE CAUSE	PROCEDURE
Open circuit of R34 resistor; open circuit of associated wiring	Check for and replace defective resistor, repair defective wiring as necessary.
Open circuit between slider of R35 potentiometer and R34 resistor or open circuit of associated wiring	Check for and replace defective R35 potentiometer, repair defective wiring as necessary.

G. DC Output Voltage Low, No Low-Voltage Alarm Given

POSSIBLE CAUSE	PROCEDURE
Short circuit of Q14 transistor	Q14 transistor can be damaged by open circuit between slider of R35 potentiometer and negative dc output or associated wiring, by short circuit of C17 capacitor or by open circuit of R39 resistor or associated wiring; open circuit of R39 resistor will also destroy Q12 and Q13 transistors; check for and replace defective components, repair

POSSIBLE CAUSE	PROCEDURE
	defective wiring as necessary.
Short circuit of CR21 diode (applies only if two or more converters are operated in parallel)	Check for and replace defective CR21 diode.

H. DC Output Current Zero, Indicated DC Output Voltage Normal, No Low-Voltage Alarm Given

POSSIBLE CAUSE	PROCEDURE
Open circuit of wiring between dc output terminal and dc load	Make continuity check with the KS-14510 L1 ohmmeter; repair defective wiring or reconnect as necessary.
Poor contact of output polarity selector plug	Remove plug from receptacle, clean contacts as necessary, then insert plug into receptacle firmly to obtain good contact.

I. DC Output Voltage High, CB1 Circuit Breaker Does Not Open

POSSIBLE CAUSE	PROCEDURE
Improper setting of high-voltage shutoff adjustment	Reset R37 potentiometer as instructed in 5.05.
Defective CB1 circuit breaker or open circuit of associated wiring	Check for and replace defective CB1 circuit breaker, repair defective wiring as necessary.
Open circuit of Q12 or Q13 transistor; open circuit of associated wiring	Q12 transistor will be destroyed by short circuit of CR20 diode; Q13 transistor will be destroyed by open circuit between slider of R37 potentiometer and negative dc output; Q12, Q13, and Q14 will be destroyed by open circuit of R39 resistor or associated wiring; check for and replace defective components, repair defective wiring as necessary.
Short circuit of CR20 diode	Short circuit of CR20 diode will destroy Q12 transistor; check for and replace defective CR20 diode and Q12 transistor.
Short circuit of C19 capacitor	Check for and replace defective C19 capacitor.
Open circuit of R36 or R41 resistor; open circuit of associated wiring	Check for and replace defective resistor, repair defective wiring as necessary.
Open circuit of R37 potentiometer; open circuit of associated wiring	Open circuit between slider of R37 potentiometer and negative dc output will destroy Q13 transistor; check for and replace defective components, repair defective wiring as necessary.

J. Noise Transmitted to 48-Volt DC Supply

POSSIBLE CAUSE	PROCEDURE
Short circuit of CR1 diode; open circuit of C1 capacitor bank or associated wiring; short circuit of L1 choke	Check for and replace defective component, repair defective wiring as necessary.

K. Noise Transmitted to 130-Volt DC Load

POSSIBLE CAUSE	PROCEDURE
Open circuit of C13 capacitor, C14 capacitor bank, or associated wiring; short circuit of L2 or L3 choke	Check for and replace defective component, repair defective wiring as necessary.