

**RECTIFIER**  
**KS-15999 L2**  
**OPERATING METHODS**

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**1. GENERAL**

**1.01** This section covers the operation of the KS-15999 L2 semiconductor-type rectifier. Regulation in the rectifier is obtained by using a ferroresonant circuit operating into a series transistor regulator circuit.

**1.02** This rectifier is intended for use in the following systems.

- 40AC1 and 43A1 Carrier Telegraph
- 01 Carrier Terminal

**1.03** The KS-15999 L2 rectifier is rated as follows.

*AC Input*

117/230 volts, 50/60 cycles, single phase

*DC Output*

120/130/150 volts, 3 amperes continuous

**1.04** The rectifier is equipped with a removable front cover. The VOLT ADJ control, ac input fuse, and jacks for measuring the dc output voltage are accessible without removal of the cover. See Fig. 1. Inside the unit, screw-type terminals are provided for the necessary connection

adjustments for the proper ac input voltage and frequency and dc output voltage as required.

**1.05** *Caution: The voltages inside the rectifier case are higher than 117 volts to ground. Avoid all contact with terminals as high voltages may be present. Do not allow a test pick to touch two metal parts at the same time or destructive and dangerous short circuits may occur. Any open or reversed windings on the ferroresonant transformer may cause dangerously high voltages on the other windings. Disconnect the alternating current supply before working on the unit except when necessary to make tests.*

**1.06** Keeping the ventilating passages and rectifying elements clean is especially important to avoid excessive heating.

**1.07** Routine checks are intended to detect defects, particularly in infrequently operated parts of the equipment, and, insofar as possible, to guard against circuit failures which interfere with service. Checks and adjustments, other than those required by trouble conditions, should be made during a period when there will be a minimum interference with service.

**1.08** For more detailed information on the operation and maintenance of individual equipment or apparatus, refer to the appropriate Bell System Practice.

**2. TOOLS AND TEST APPARATUS**

CODE OR SPEC NO.	DESCRIPTION
<b>TOOLS</b>	
—	3-Inch C Screwdriver
<b>TEST APPARATUS</b>	
KS-14510 L1	Volt-Ohm-Milliammeter
—	Weston Model 281 DC Ammeter or Equivalent
—	Variable Resistance Load Capable of Carrying 3 Amperes or More at 150 Volts

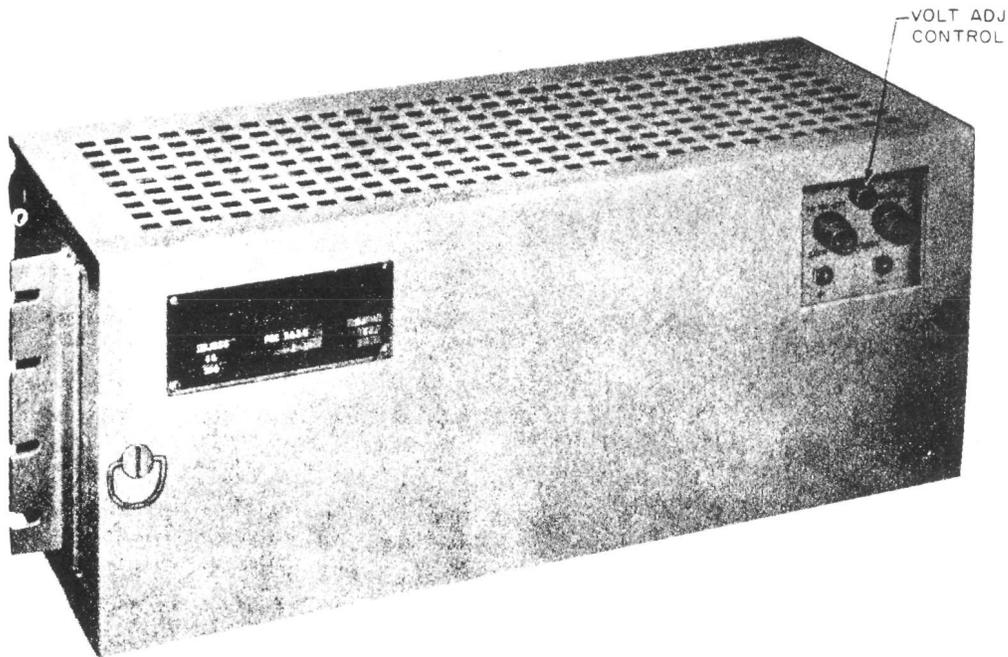


Fig. 1 - KS-15999 L2 Rectifier

### 3. OPERATION

#### How the Rectifier Unit Works

**3.01** Fifty- or sixty-cycle power is connected to the primary of the T1 ferroresonant transformer which provides a substantially constant output voltage with large variations of input line voltage. The direct current output voltage, however, is unregulated for load current changes and, therefore, any increase in the load current will reduce the output voltage. The T1 transformer consists essentially of the primary coil and a nonlinear coil magnetically coupled by being wound on a common portion of the core. The primary and the nonlinear coil are partially separated by a shunt magnetic path of high reluctance. This arrangement serves to partially decouple the primary coil from the nonlinear coil and introduces a high leakage reactance. (The equivalent circuit may be represented as a linear coil connected in series with a nonlinear coil where the high leakage reactance is considered as having the characteristic of a linear coil.) The C1 capacitor is connected across the nonlinear winding of the T1 transformer.

**3.02** In operation, when an alternating voltage of low value is impressed upon the circuit, the parallel combination of the nonlinear inductor of the T1 transformer and the C1 tuning capacitor acts as a capacitive reactance in series with the inductive reactance. This effective capacitive reactance is smaller than the inductive reactance. As the impressed voltage is increased, the series combination of the linear inductive reactance and the nonlinear inductor in parallel with the capacitor passes through resonance due to the decreasing inductance of the nonlinear inductor. This causes a further reduction of the nonlinear inductance which carries the series-parallel combination further from resonance in a continuing process so that the nonlinear coil approaches saturation. After the series-parallel circuit passes through resonance, the voltage across the parallel combination rises to a very much higher value than the voltage developed before resonance. Variations of the impressed voltage change the degree of saturation of the nonlinear coil so that the variation in the effective capacitive reactance of this portion of the circuit tends to maintain an essentially constant voltage across its terminals. The output consists of a portion of the nonlinear winding voltage.

**3.03** This type of circuit has an inherent output current limiting characteristic. As the load is increased, the effective capacitive reactance of the parallel circuit is reduced and the resultant change in voltage across the parallel combination is comparatively small until the point is reached where the capacitive reactance of the circuit falls below the value required to maintain the series-parallel combination above the resonant value. When this happens, the nonlinear coil comes out of saturation and the high voltage developed across the parallel combination coming out of saturation falls to a low value.

**3.04** The secondary of the T1 ferroresonant transformer consists of three isolated windings connected to three separate full-wave rectifiers. The main output winding is connected to the CR1, CR2, CR3, and CR4 full-wave bridge rectifier. The output of this winding is filtered by the C6 through C10 capacitors. Since the dc voltage at the output is higher than the limits of standard transistor circuitry, another isolated winding is connected to the CR5 and CR6 center tap rectifier. The output of this center tap rectifier is filtered by the C4 and C5 capacitors and is connected in series with the main rectifier through the R16 current limiting resistor. By this means, the series transistor regulator operates only on the lower voltage part of the two series rectifiers.

**3.05** The series transistor regulator consists of the following circuit elements.

- (a) Voltage reference.
- (b) Error detector.
- (c) Error amplifier.
- (d) Series transistors.

**3.06 Voltage Reference:** The voltage reference circuit consists of the CR10 zener diode biased in the reverse direction through the R10 current limiting resistor.

**3.07 Error Detector:** The Q1 and Q2 transistors are arranged as a differential detector. The base terminal of the Q1 transistor is connected to the reference voltage output and the base terminal of the Q2 transistor is connected to the variable voltage divider consisting of the R11, R12, R13, and R15 fixed resistors and the R14 (VOLT ADJ) variable resistor. The

desired voltage output, 120V, 130V, or 150V, is selected by making connection from the output terminals to the proper resistor in the divider circuit. The emitter terminals are connected together and to the positive (+) output terminal through the R2 current limiting resistor. Any difference between the voltage on the base of the Q1 transistor and the voltage on the base of the Q2 transistor is called the error voltage. The error voltage causes a change in the flow of current in the base-emitter circuit of the Q2 transistor. Any such change causes an amplified change of current in the emitter-collector circuit of the Q2 transistor. The base-collector circuit of the Q2 transistor is part of the loop circuit including the base-emitter circuit of the Q3 transistor.

**3.08 Error Amplifier:** The Q3 transistor is a medium powered transistor whose function is to develop sufficient driving power to operate the parallel arrangement of the Q4 through Q9 transistors.

**3.09 Series Transistors:** The Q4 through Q9 transistors are capable of absorbing the voltage difference between the partially regulated dc voltage at the collector terminals and the completely regulated output at the emitter terminals. The current through the emitter-collector paths of the Q4 through Q9 transistors is controlled by the current in the emitter-base paths of these transistors.

**3.10** The CR8 and CR9 rectifier diodes provide bias to the error detector circuit for initial starting and are connected to the output of the CR5 and CR6 rectifier diodes by the CR7 blocking diode.

**3.11** The regulation of the rectifier is accomplished by an error signal proportional to any change in output voltage. With the rectifier adjusted at a particular load condition, the base-emitter voltage on the Q1 and Q2 transistors is equal. If the voltage at the output is decreased for any reason such as an increased load, the current in the base-emitter circuit of the Q2 transistor is decreased. The change of current in the base-emitter circuit of the Q2 transistor is amplified in the emitter-collector circuit of this transistor. The emitter-collector circuit of the Q2 transistor is part of the loop circuit including the base-emitter circuit of this transistor. The base-emitter circuits of the Q4 through Q9

series regulating transistors are part of the loop circuit including the emitter-collector circuit of the Q3 transistor; therefore, the increase in loop current causes an amplified increase in current from the collector-emitter circuits of the Q4 through Q9 transistors. This increase in current in the collector-emitter circuit appears as a reduction in effective resistance and causes the voltage at the output to increase until balance is developed and no error voltage is produced. An increase in output voltage caused by a decrease in the load would produce similar correction in the reverse direction. The C11 capacitor provides a low frequency cut off to prevent instability due to the high gain in the transistor amplifier.

#### Preparing to Start Initially

**3.12** When preparing to put the unit into service initially, check that:

- (a) There is nothing in, on, above, or below the rectifier to interfere with operation or prevent free ventilation.
- (b) The correct size ac input fuse is available.
- (c) The connections inside the unit are correct for the ac input voltage and frequency and dc output voltage.

**Note 1:** A circuit label (schematic diagram of the rectifier prepared by the manufacturer) is attached to the inside of the front cover. The circuit label shows the required connections for the ac input voltage and frequency and dc output voltage. Connecting adjustments inside the unit are made to screw-type terminals.

**Note 2:** Use the KS-14510 voltmeter for measuring the ac input power voltage.

**Caution:** When using any portable instrument, the leads should be carefully examined to make sure the insulation is undamaged. The leads should be properly connected to the instrument before making any contact with the circuit to be tested. If connections are to be changed from one instrument range to another, the power should first be disconnected from the equipment being tested or, if test picks are being used, they should be removed from the equipment under test.

(d) The VOLT ADJ control is in the maximum counterclockwise position (minimum voltage output).

(e) All external connections are made in accordance with the SD drawing covering the associated circuit of which the unit is a part.

(f) An adequate office load or an adjustable load capable of carrying 3 amperes at 150 volts is available.

(g) Meters and test apparatus are available for checking input and output voltages.

#### Initial Adjustments

**3.13** Proceed as follows.

**Caution:** When using any portable instrument, the leads should be carefully examined to make sure the insulation is undamaged. The leads should be properly connected to the instrument before making any contact with the circuit to be tested. If connections are to be changed from one instrument range to another, the power should first be disconnected from the equipment being tested or, if test picks are being used, they should be removed from the equipment under test.

- (a) Connect the KS-14510 voltmeter to the (+) and (-) test jacks.
- (b) Connect the Weston Model 281 DC Ammeter and the load in series across the output terminals.
- (c) Insert the ac input fuse
- (d) Adjust the VOLT ADJ control clockwise to secure the proper output voltage at full load or maximum office load.

#### Routine Adjustments

**3.14** The rectifier has no disconnecting switches and is connected to both ac power and the load when the ac input fuse is in place. If it is necessary to take a rectifier out of service, remove the fuse. To restart, replace the fuse and adjust the VOLT ADJ control, as required, to secure the proper output voltage for the office load.

**4. ROUTINE CHECKS**

**4.01** The following should be performed.

- (a) The output voltage should be checked from time to time with the KS-14510 voltmeter to make certain that it is correct under typical office load.
- (b) The office load should be checked from time to time with the Weston Model 281 DC Ammeter to make sure that the load does not exceed the rating of the rectifier.
- (c) Electrolytic capacitors should be maintained in accordance with Section 032-110-701.

**5. TROUBLES**

**5.01** Any replacements of the T1 ferroresonant transformer and the associated C1 tuning capacitor should be made at the factory of the supplier. All other components can be replaced in the field.

**Diode and Transistor Replacement**  
(see Section 032-173-301)

**5.02 Silicon Diodes:** When replacements are required, to avoid unbalance in a multiple rectifying element, proceed as follows.

- (a) Replace all the diodes in the multiple element.
- (b) Do not combine diodes of different manufacturers.

**Trouble Chart**

**5.03** Should any of the following troubles develop, it is suggested that the possible causes listed be checked. If the trouble is not found, look for loose or open connections or short circuits due to foreign matter lying across wiring terminals. A loose connection generally causes heating. Any one of the following troubles may be caused by an open or short circuit or by aging or drift in the constants of some faulty component.

*Caution: The ac voltage across the terminals of the C1 tuning capacitor exceeds 500 volts. When making tests inside the unit, take care to avoid any contact with the leads and terminals of this capacitor.*

TROUBLE	POSSIBLE CAUSE
(a) No output voltage	Failure or disconnection of the input power Blown or missing ac input fuse Defective transformer Shorted capacitors and/or resistors Defective CR8 and/or CR9 diodes
(b) Low output voltage	Low input power voltage Incorrect transformer and/or output tap connections Excessive load on rectifier output Breakdown of any or all filter capacitors Defective C1 capacitor Defective transformer Defective rectifying elements (CR1 through CR4 and/or CR5, CR6) Defective CR10 voltage reference diode Defective Q3 transistor Defective Q1 and/or Q2 transistor Incorrect adjustment of VOLT ADJ control
(c) High output voltage	High input power voltage Incorrect transformer and/or output tap connections Defective transformer Open R17 resistor Defective series transistors (Q4 through Q9) Defective CR10 voltage reference diode Defective Q1 and/or Q2 transistors Incorrect adjustment of VOLT ADJ control

**SECTION 169-703-301**

<b>TROUBLE</b>	<b>POSSIBLE CAUSE</b>
(d) Erratic output voltage	Fluctuating input power voltage  Intermittent open or short in any component  Defective connections

<b>TROUBLE</b>	<b>POSSIBLE CAUSE</b>
(e) High ripple voltage	Open filter capacitor Defective rectifying elements (CR1 through CR4 and/or CR5, CR6) Defective series transistors (Q4 through Q9)