# KS-5651-02 RECTIFIER UNIT
# RELAY TYPE OUTPUT CONTROL
# OPERATING METHODS

## 1. GENERAL

**1.01** This section covers the operation of a regulated metallic type rectifier unit using a saturable reactor control. It was designed to provide regulated d-c power from an a-c power service, for use in 301-type and 302-type telephone power plants. It is available in ratings of 44 to 65 volts, 100 amperes, 22 to 33 volts, 100 amperes, and 22 to 33 volts, 200 amperes, direct current. The input power requirement is 210 volts, ±8 per cent, 3-phase, 60 cycles ±2 per cent, alternating current, but, with transformers, it may be connected to 230- or 250-volt power service. The output is automatically adjusted by the operation of relays in response to signals from the connecting circuit.

> ***Caution: Voltages inside the rectifier case are over 150 volts to ground. Avoid all contact with terminals. Do not allow a test pick to touch two metal parts at the same time, or destructive or dangerous short circuits may occur. The door switches, when open, disconnect the 3-phase power from the transformers, but leave the incoming terminals of contactor AC connected. They also disconnect battery from the main rectifier elements, but leave the CHG fuse and certain other equipment connected. Battery voltage will be present on the terminals of switch S3 and elsewhere in the rectifier when fuse CHG is removed. The door switches are provided for the protection of personnel and should not be made inoperative.***

**1.02** This section is reissued to incorporate material from the addendum in its proper location. In this process marginal arrows have been omitted.

**1.03** A metallic rectifier cell is an elementary rectifier having one positive electrode, one negative electrode, and one rectifying junction. A rectifying element is a circuit element which has the property of conducting current effectively in one direction only and may consist of a group of metallic rectifier cells connected in parallel or series arrangement, or both. The term varistor, as used in apparatus coding includes, one or more rectifier cells. Rectifying elements may be made up of one or more varistors. A rectifier unit is an assembly consisting of a rectifying element and associated auxiliaries such as transformers, filters, and switches.

**1.04** In this section, the term capacitor is used for all apparatus coded as either a capacitor or a condenser and the term resistor is used for all apparatus coded as either a resistor or a resistance.

**1.05** The abbreviations CW and CCW, used herein, refer to clockwise and counterclockwise rotation, respectively.

**1.06** Keeping the ventilating passages and rectifier cells clean is especially important to prevent 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 liable to interfere with service. Checks and adjustments, other than those required by trouble conditions, should be made during a period when they will cause the least unfavorable reaction to service.

**1.08** The instructions are based on drawing SD-81115-01, Figures 1 and 3. For detailed description of the operation, see the corresponding circuit description.

**1.09** More detailed information on the operation and maintenance of individual pieces of apparatus, such as instruments, and switches is given in other sections and the attendant should of course be familiar with them. All ap-

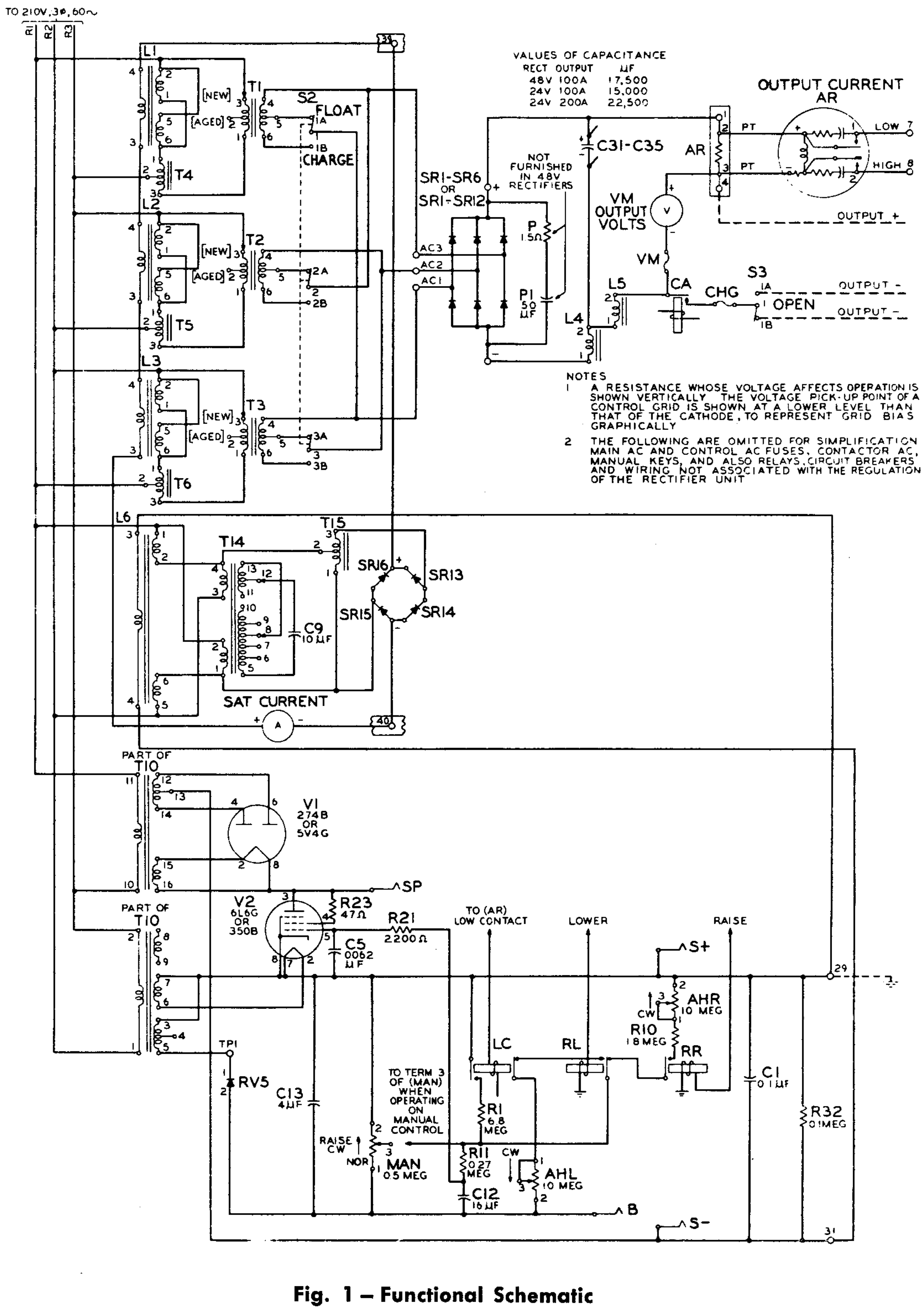


Fig. 1 — Functional Schematic

paratus is assumed to have been adjusted in accordance with these sections and with the circuit requirements table or the circuit description associated with the circuit drawing.

**1.10** At installation, and periodically thereafter, the pointer of voltmeter VM should be set, by means of the zero adjuster, so that its indication agrees exactly with that of an accurate KS-8039 voltmeter, or equivalent, connected in parallel with it. The zero adjuster screw should then be sealed with wax or adhesive tape over the screwdriver slot to discourage unauthorized changes.

**1.11** Information in this section is arranged under the following headings:



**1.12** ***List of Gauges*** (Equivalents may be substituted)

| CODE OR SPEC NO. | DESCRIPTION |
|---|---|
| — | Meter, M9B |
| KS-8039 | Volt-milliammeter |
| — | Test set, 35 type |

## 2. OPERATION

### How the Rectifier Unit Works (See Fig. 1 – Functional Schematic)

**2.01** Three-phase power is fed, either directly or through input autotransformers T7 to T9 (not shown), through windings 2-3 of regulating autotransformers T4 to T6, to step-down transformers T1 to T3 which deliver alternating current to the rectifying element, varistors SR1 to SR12 (SR7 to SR12 are not always furnished) where it is rectified to direct current. Windings 1-2 of autotransformers T4 to T6 are connected through the a-c windings of saturable reactors L1 to L3 to opposite phases of the power supply. The voltage across windings 2-3 of autotransformers T4 to T6 determines the voltage applied to the primary windings of transformers T1 to T3. This, in turn, is controlled by the voltage across the a-c windings of reactors L1 to L3 which depends on the saturation in their cores. As the saturation increases, the impedance of the reactor decreases and more voltage is applied to the rectifying elements, increasing the rectifier output. Conversely, a decrease in saturation reduces the rectifier output. The saturation is dependent on current from the magnetic amplifier, the d-c input of which comes from the saturating control current circuit. The current from the control circuit is varied through the agency of signals from the connecting circuit, to maintain the output voltage constant. Means are also provided for manual control.

**2.02** Reactors L1 to L3 have three windings, each. In each reactor, windings 1-2 and 6-5 are connected in parallel and the combination is connected, in series with winding 1-2 of the associated regulating autotransformer (T4 to T6), across one phase of the power supply. The third windings, 3-4, of the three reactors are connected in series, in the d-c output circuit of the magnetic amplifier. The current in this circuit is indicated by milliammeter SAT CUR.

**2.03** The magnetic amplifier consists of saturable reactor, L6, a regulating autotransformer T15, and a rectifying element, varistors SR13 to SR16. There is also a transformer, T14, with windings in series with the a-c windings of L6 and a third winding, equipped with taps, which supplies a capacitor, C9.

### Regulation

**2.04** The saturating control current circuit is, essentially, an auxiliary rectifier unit. Four windings of transformer T10 furnish the required currents. Saturating current is rectified in tube V1, filtered by capacitor C1, and controlled by series tube V2. The resistance of V2 depends upon its grid-to-cathode voltage which is controlled by the voltage across capacitor C12, which, in turn, is determined by the state of its charge. Before starting, C12 will be in a discharged condition and the grid of V2, highly negative. As soon as contactor AC (not shown) closes, capacitor C13 charges to the full output voltage of varistor RV5 and tubes V1 and V2 are connected to the power supply and begin heating. Capacitor C12 charges slowly from C13, through R11, R1, and the back contacts of relay LC, making the grid of V2 less negative. The output voltage of the main rectifier unit rises and when it is high enough to operate contactor CA, the latter closes the output through to the battery and the output current ammeter relay AR opens its LOW contact, releasing relay LC. The output is now under control of the connecting circuit. If a "lower" signal is received relay RL operates, allowing the charge on C12 to drain off through R11 and potentiometer AHL. The latter is adjustable to regulate the speed of lowering the output. If a "raise" signal is received relay RR operates, increasing the charge on C12 through R11, resistor R10, and potentiometer AHR. The latter is adjustable to regulate the speed of raising the output.

**2.05** The CHG-FLOAT switch changes taps on transformers T1 to T3. In the FLOAT position adequate voltage is available for floating and charging the battery. The CHG position provides the additional voltage necessary for charging the main battery plus the emergency cells. This switch should be operated to the desired position while the rectifier unit is shut down for changing the S3 switch to the desired battery connection.

**2.06** The AHL and AHR potentiometers are provided for adjusting the rate of lowering or raising, respectively, the output of the main rectifier unit. The adjustments are made for the purpose of minimizing fluctuations in battery voltage and great care is required to insure that the change in output is great enough for the purpose but not so great as to produce hunting. In general lowering should be slightly faster than raising. Local conditions determine these adjustments, and readjustments should be made as required by changes in the character of the office load. Turning the shaft of the potentiometer in a CW direction will increase the speed of the correction.

**Manual Control**

**2.07** The MAN potentiometer is used to control the rectifier manually. With this potentiometer in the NOR position, operate the MAN-TEST key (not shown) to MAN. Rotate the potentiometer CW until the desired output is obtained. The output will remain at this setting, without drift, but is sensitive to line voltage variations. The potentiometer should be returned to NOR before returning the key to its normal position.

**2.08** The MAN-TEST key, when operated to the TEST position, permits manual control by the use of the RAISE-LOWER key (not shown) to operate the RR and RL relays. In this position the key cuts off any "lower" signals which may come from the connecting circuit.

**2.09** Aging taps are provided on transformers T1 to T3, for use when the main rectifier element has aged, usually after a long period of use. The connections should not be changed from taps 3 to taps 2 until the rated output cannot be obtained from the rectifier and until a thorough check has been made to be sure that there are no other troubles. If rated output can be obtained with manual control, it will indicate that the transformer taps do not need to be changed. There is no similar provision of aging taps for varistors SR13-SR16 in the magnetic amplifier. In this case, the varistors should be replaced as a group, when replacement is necessary, as is indicated by inability to obtain sufficient saturating current under manual control. After the new varistors are installed it will be necessary to select the correct taps on transformer T14. To do this, operate the rectifier at no load (S3 switch on OPEN) under MAN control, with the MAN potentiometer in the minimum (NOR) position. Select those taps which will give the lowest output voltage, as indicated by the OUTPUT VOLTS VM. This value will be considerably lower than normal output voltage.

> ***Caution: When changing taps disconnect the rectifier from the power supply before touching terminals.***

**2.10** Jacks, mounted on the front panel, provide connections for a voltmeter when checking the voltage in various parts of the circuit when locating troubles.

**Preparing to Start**

**2.11** When putting the rectifier unit into service initially, check against the SD circuit drawing, to see that:

(a) The ON-OFF key is in the OFF position.

(b) The MAN-TEST key is in the normal position.

(c) If input transformers are provided, the taps used are correct for the power supply voltage.

(d) Correct tubes are in the sockets.

(e) The correct CHARGE and VM fuses are in place.

(f) The correct AC CONTROL fuses are in place in the rectifier, and the supply fuses are in the supply panel.

(g) Potentiometers MAN and AHR are, each, in its extreme CCW position, and potentiometer AHL is set at a point 1/4 of its travel away from its CCW position.

(h) CHG-FLOAT switch is operated to the CHG position.

(i) Switch S3 is operated to connect the rectifier unit to battery, including the emergency cells, if any.

***Caution: Except as indicated in 2.09, do not start the rectifier unit with S3 on OPEN.***

(j) Covers and doors are tightly closed so that the door switches are operated.

(k) Circuit breakers, CONT and CHG ALM are closed.

(*l*) There is available, sufficient office load to fully load the rectifier, or a variable load of adequate capacity.

(m) Voltmeter VM has been calibrated in accordance with 1.10.

(n) A 35-type test set is available.

**Initial Adjustments**

**2.12** Observe the directions in 2.11. Operate the MAN-TEST key (not shown in Fig. 1) to MAN and the ON-OFF key (not shown) to ON. ʿe the shaft of the MAN potentiometer slowly CW, observing the SAT CURRENT milliammeter, the OUTPUT VOLTS voltmeter, and the OUTPUT CURRENT ammeter relay. Add load to the battery or reduce the output of other rectifiers or generators supplying it, as required to avoid service reactions. Bring the output up to its full rated value. Reverse the operation, finally bring potentiometer MAN to its NOR position. Operate MAN-TEST to TEST, and bring the rectifier unit up to its rating, using the RAISE key (not shown).

**2.13** Adjust the ***overload limit*** feature. For the external millivoltmeter to be used for measuring the output current, use a 35-type test set, connecting its BAT and GRD terminals, respectively to terminals 3 and 2 of shunt AR. Bring up one of the sliders to somewhat more than 25 ohms and strap terminals T and R together. Under manual control bring the rectifier output to 90 per cent of its full-load current, as indicated by the ammeter relay and adjust the slider to give an indication of 9 milliamperes on the 15 milliampere scale. Leave the slider undisturbed. Full load will be indicated by 10 milliamperes and 110 per cent by 11 milliamperes.

**2.14** Bring the output down to zero, using the LOWER key (not shown), meanwhile reducing the load previously added to the battery, or increasing the output of other rectifiers or generators supplying it in order to maintain normal service. Shut down the rectifier and restore the MAN-TEST key to its normal position.

**2.15** While carrying out the adjustments covered in the foregoing paragraphs, it may appear that the speed of response under control of RAISE or LOWER keys is too slow. Correct, as seems desirable, by rotating the shaft of the AHL or AHR potentiometer CW but avoid making the speed too great. This adjustment should be reviewed when the rectifier is put into regular operation under automatic control, supplying the regular office load. See 2.06.

**Routine Adjustments** (Normal Operation)

**2.16** For normal operation, under control of the connecting circuit, the MAN-TEST key should be in its normal position and the ON-OFF key in the ON position. Operation of the MAN-TEST key to either position removes the rectifier from the control of the connecting circuit. The output is then under manual control and the rectifier may be connected to supply and load by the ON-OFF key. The CHG-FLOAT switch and switch S3 should be operated only when the rectifier is shut down. Never, in normal operation, turn the rectifier ON before battery or load is connected as, otherwise, the metallic rectifying cells may be punctured and fail. The current indicated on the SAT CURRENT milliammeter is in the order of 85 milliamperes for half-load and will range between the extremes of 15 and 225 milliamperes.

## 3. ROUTINE CHECKS

**3.01** Routine checks of the vacuum tubes should be made periodically with the vacuum tube tester available in the office, in accordance with the standard information on that tester.

**3.02** The relays should be inspected occasionally for adjustment and condition of contacts, making sure that they are in accordance with the Circuit Requirements and BSP's which apply.

## 4. TROUBLES

**4.01** In general, the only items likely to become defective with use are the tubes V1 and V2, which are subject to aging but should have long life.

**4.02** The control potentiometers, the KS-15119 switches, and the KS-5649 door switches should be replaced if they become defective in any respect.

**4.03** The saturating current, although it may vary widely in extreme conditions, when observed in daily routine can serve as a guide to the causes of unusual operation or trouble conditions.

**4.04** Varistors will age with use, and after a period of years may require changing the connection from the NEW to the AGED tap, where this arrangement is available. In other cases the varistor (RV5) or the rectifying unit (SR13-SR16) must be replaced. Because it is not practicable to retighten the bolt to the original pressure, no attempt should be made to replace part of the rectifier cells in a stack or bolt assembly. See 2.09.

### Trouble Chart

**4.05** Should any of the following troubles develop, it is suggested that the possible cause be checked in the order given. If the trouble is not found, look for loose or open connections or short circuits due to foreign matter lying across wiring terminals. If a check of the possible causes listed below or the use of the point-to-point voltage table does not lead to the location of the trouble, it is advisable to make resistance measurements with the circuit completely de-energized, comparing the measured values with the values shown on Fig. 1.

| TROUBLE | POSSIBLE CAUSE |
|---|---|
| No d-c output current | Power failure<br>Blown a-c supply or control fuse<br>Blown CHG fuse<br>Door switch open<br>Failure of tube V1 or V2<br>Shorted capacitor C31-C35<br>Plant voltage regulator out of adjustment<br>Relay RL operated continuously<br>Relay AC, CA, ST not operated<br>Relay LC not operated or make contact failing |
| Low d-c output current<br>Low saturating current | Plant voltage regulator out of adjustment<br>Low line voltage<br>Tube V2 failure<br>Tube V1 or V2 low emission or aged<br>Varistors SR13-SR16 aged<br>Relay RL break contact failing<br>Relay RR make contact failing |
| Rated output current not obtainable with saturating current maximum, under MAN control | One of three line leads open or high resistance connection in line circuit<br>CHG-FLOAT switch on FLOAT when charging, especially emergency cells<br>Main rectifier cells high resistance due to aging |

| TROUBLE | POSSIBLE CAUSE |
|---|---|
| High d-c output current<br>High saturating current | Plant voltage regulator out of adjustment<br>High line voltage<br>Relay RR operated continuously<br>Relay RL make contact failing<br>Relay LC break contact failing<br>Grid emission in tube V2<br>Near zero grid voltage in tube V2 caused by failure of a component in relay control circuit |
| Low d-c output<br>High saturating current | Unbalance in a-c line voltages<br>The a-c voltages applied to the rectifying element (terminals AC1, AC2, AC3) differ by more than 5 per cent<br>CHG-FLOAT switch on FLOAT when charging, especially emergency cells<br>Main rectifier cells high resistance due to aging |
| Output excessively noisy | The a-c voltages applied to the rectifying element (terminals AC1, AC2, AC3) differ by more than 5 per cent<br>Filter condensers aged or defective<br>Filter condenser connections loose or open<br>Defective cells in one or more of the stack assemblies constituting the main rectifying element |
| Cannot reduce d-c output current to zero with saturating current minimum under MAN control | CHG-FLOAT switch on CHG instead of FLOAT<br>High line voltage |
| Output voltage varying | Potentiometer AHR or AHL not correctly adjusted |

## 5. POINT-TO-POINT VOLTAGES

**5.01** Point-to-Point voltages are intended for use when unsatisfactory operation is encountered in which case they may prove useful in locating the cause. They are not operating requirements to be checked in routine and are not needed while the rectifier unit is operating satisfactorily. As given in the tables, they are approximate and typical of a unit connected to normal power supply, adjusted to the float voltage of the battery and carrying load as indicated.

**5.02** High voltages over 600 volts to ground are present within the rectifier unit and every precaution should be observed to avoid any contact with exposed metal parts or terminals when the rectifier unit is in operation.

*Caution:* ***When using any portable instrument, the leads should be carefully examined to make sure the insulation is undamaged. The leads should be connected at the instrument before making contact with the circuit to be tested. If connections are to be changed from one instrument jack to another, the alternating current 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.***

**5.03** Readings may be made with the M9B meter, the resistance of which is 2,000 ohms per volt, or with any available instrument having higher resistance. Values of voltage are given in the tables as obtained with an M9B meter and with a volt-ohm-milliammeter, the resistance of which is 20,000 ohms per volt. They apply to the specified rectifier unit operating at its normal float voltage, with the output current at the values specified in the table. The output of the rectifier will not be appreciably affected by connecting either of these instruments to check the values given in the tables. In general, door switches are not intended for use in disconnecting power, but for convenience, they may be so used during the infrequent taking of point-to-point voltages. Where the 600V jack is specified for the M9B meter, and the available M9B meter has no 600V jack, the connection should be made using a multiplier (D-176926 plug) plugged into the 300V jack, or 600,000 ohms may be connected in the lead to the 300V jack.

**5.04** ***Tables of Point-to-Point Voltages***

(1) Typical values of voltage between jacks or between terminals of apparatus are given below:

**RATED OUTPUT 100 AMP., 24 VOLTS**

| VOLTAGE ACROSS | INSTRUMENT CONNECTIONS + TERM. APP. | + TERM. TERM. | − TERM. APP. | − TERM. TERM. | AC/DC | M9B METER V JACK | VOLTS AT 10 AMP | VOLTS AT 50 AMP | VOLTS AT 100 AMP | 20,000 OHMS/V INST. RANGE | VOLTS AT 10 AMP | VOLTS AT 50 AMP | VOLTS AT 100 AMP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| V2 | Jack | SP | Jack | S+ | DC | 600 | 380 | 345 | 300 | 1000 | 380 | 345 | 300 |
| Sat. Ckt. | Jack | S+ | Jack | S− | DC | 150 | 8 | 13 | 21 | 50 | 8 | 12 | 21 |
| SR13 to | T15 | 3 | T15 | 1 | AC | 150 | 74 | 130 | — | 250 | 74 | 130 | — |
| SR16 | TS | 39 | TS | 40 | DC | 150 | 29 | 80 | — | 250 | 32 | 81 | — |
| Main | Term. | AC1 | Term. | AC2 | AC | 30 | 21.4 | 22.3 | — | 50 | 19.5 | 20 | — |
| Rectifying | Term. | AC2 | Term. | AC3 | AC | 30 | 21.6 | 22.5 | — | 50 | 19.5 | 20 | — |
| Element | Term. | AC3 | Term. | AC1 | AC | 30 | 21.5 | 22.4 | — | 50 | 19.5 | 20 | — |
| | Term. | + | Term. | − | DC | 30 | 26.1 | 26.3 | — | 50 | 26.4 | 26.5 | — |

**RATED OUTPUT 200 AMP., 24 VOLTS**

| VOLTAGE ACROSS | + APP. | + TERM. | − APP. | − TERM. | AC/DC | V JACK | 20 AMP | 100 AMP | 200 AMP | RANGE | 20 AMP | 100 AMP | 200 AMP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| V2 | Jack | SP | Jack | S+ | DC | 600 | 375 | 340 | 295 | 1000 | 375 | 340 | 295 |
| Sat. Ckt. | Jack | S+ | Jack | S− | DC | 150 | 11 | 19 | 25 | 50 | 10 | 16 | 23 |
| SR13 to | T15 | 3 | T15 | 1 | AC | 150 | 77 | 143 | — | 250 | 70 | 142 | — |
| SR16 | TS | 39 | TS | 40 | DC | 150 | 35 | 93 | — | 250 | 35 | 91 | — |
| Main | Term. | AC1 | Term. | AC2 | AC | 30 | 20.4 | 22 | — | 50 | 19.5 | 20 | — |
| Rectifying | Term. | AC2 | Term. | AC3 | AC | 30 | 20.4 | 22 | — | 50 | 19.5 | 20 | — |
| Element | Term. | AC3 | Term. | AC1 | AC | 30 | 20.4 | 22 | — | 50 | 19.5 | 20 | — |
| | Term. | + | Term. | − | DC | 30 | 26.5 | 26.7 | — | 50 | 25.5 | 26 | — |

**RATED OUTPUT 100 AMP., 48 VOLTS**

| VOLTAGE ACROSS | + APP. | + TERM. | − APP. | − TERM. | AC/DC | V JACK | 10 AMP | 50 AMP | 100 AMP | RANGE | 10 AMP | 50 AMP | 100 AMP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| V2 | Jack | SP | Jack | S+ | DC | 600 | 380 | 345 | 300 | 1000 | 380 | 345 | 300 |
| Sat. Ckt. | Jack | S+ | Jack | S− | DC | 150 | 7 | 14 | 23 | 50 | 8.5 | 14 | 23 |
| SR13 to | T15 | 3 | T15 | 1 | AC | 150 | 70 | 136 | — | 250 | 70 | 140 | — |
| SR16 | TS | 39 | TS | 40 | DC | 150 | 29 | 83 | — | 250 | 29 | 81 | — |
| Main | Term. | AC1 | Term. | AC2 | AC | 150 | 39 | 40 | — | 50 | 40 | 41.3 | — |
| Rectifying | Term. | AC2 | Term. | AC3 | AC | 150 | 39 | 40 | — | 50 | 40 | 41.3 | — |
| Element | Term. | AC3 | Term. | AC1 | AC | 150 | 39 | 40.5 | — | 50 | 40 | 41.6 | — |
| | Term. | + | Term. | − | DC | 150 | 48.4 | 48.3 | — | 50 | 49.5 | 49 | — |