

INSTRUCTION MANUAL

MODEL 620

MULTI-PURPOSE ELECTROMETER
AND ACCESSORIES

WARRANTY

We warrant each of our products to be free from defects in material and workmanship. Our obligation under this warranty is to repair or replace any instrument or part thereof, except tubes, transistors, fuses, and batteries, which, within a year after shipment to the original buyer, proves defective on examination.

DAMAGE IN SHIPMENT

Be sure to include the instrument model number and serial number in all communications.

If the instrument is damaged when received, or fails to operate properly, a claim should be filed with the carrier. Upon receipt of the claim agent's report, we will inform you regarding repair or replacement.

REPAIRS

When returning an instrument for repair or recalibration, it should be securely packed against shipping damage and sent to the factory, freight prepaid. A brief letter describing the difficulty should accompany the instrument.

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SECTION I - INTRODUCTION

The Keithley Model 620 Electrometer is an ultra-high impedance voltmeter with full-scale ranges of 0.1, 0.3, 1.0, 3.0 and 10 volts.

The maximum input resistance is greater than 10^{14} ohms; in addition, the input resistance may be varied in decade steps from 10^6 to 10^{10} ohms by means of the shunt resistors built into the instrument. Thus, the 620 is not only appropriate for measurement in high-impedance circuits, but also can be used with decreased input impedance where a high input impedance would merely introduce unwanted pickup.

The 620 may be used as a direct-reading ammeter from 10^{-5} to 10^{-11} amperes full scale. This 6-decade range is covered in overlapping 3x and 10x scales. Two current measuring methods are available to the user of the 620. Normally, current is determined by measuring the voltage drop across a resistor shunted from input to ground. Alternately, on the 10^{-7} to 10^{-11} ampere ranges, negative feedback can be applied to the input of the voltmeter through the current measuring resistor. This largely eliminates the input drop and increases measuring speed, particularly on the more sensitive ranges.

The 620 measures 10^5 to 10^{11} ohms full scale with a two-terminal input. Unlike conventional ohmmeters, the resistance is read on the same linear scales used for current and voltage.

As a dc preamplifier, the 620 has gains of 0.1, 0.3, 1, 3, and 10. Continuing gain stability is assured by a large feedback factor on all ranges.

The output is 1 volt, open circuit, with an internal impedance of 16.67K for full scale input on all ranges. Thus, the output may be used for driving oscilloscopes or pen recorder amplifiers, or the output may be shunted down to provide 10- or 50-mv outputs for servo-rebalance recorders. Note that a phase reversal occurs from input to output.

SECTION II - SPECIFICATIONS

Ranges:

- (a) Voltage: 0.1, 0.3, 1, 3, and 10 volts full scale.
- (b) Current: 10^{-5} to 10^{-11} amperes full scale in 1x and 3x overlapping ranges.
- (c) Ohms: 10^7 ohms to 10^{11} ohms full scale on linear 1x and 3x overlapping ranges.
- (d) Meter Scales: Left Zero 0 to 3 and 0 to 10.

Accuracy:

- (a) Voltage: 2% of full scale on all ranges.
- (b) Current: 3% of full scale from 10^{-5} amperes to 10^{-9} amperes. 4% of full scale from 3×10^{-9} to 10^{-11} amperes.
- (c) Ohms: 4% of full scale from 10^4 ohms to 10^9 ohms. 5% of full scale from 3×10^9 ohms to 10^{11} ohms.

Resistance Standards:

10^6 , 10^7 , 10^8 ohms, 1% accuracy; 10^9 and 10^{10} ohms, 2% accuracy. The 10^9 and 10^{10} ohm resistors may be expected to decrease in value at about $\frac{1}{2}\%$ per year.

Input Impedance:

On the VOLTS position, the input impedance is greater than 10^{14} ohms resistive, shunted by approximately 30 micromicrofarads.

Drift:

Less than 3 millivolts per hour after 2 hours warm-up.

Recorder Output:

One volt for full scale meter deflection, $16.67K$ source impedance.

Amplifier:

Frequency response is DC to 100 cycles on all ranges. Maximum gain is 10. Noise is less than 2% peak to peak of full scale.

Front Panel Controls and Terminals:

INPUT connector is a teflon insulated UHF type receptacle. An accessory binding post which plugs into the center of the connector is furnished. A ground binding post is mounted on the panel above the input connector.

RANGE switch is located in the center of the front panel. This control selects VOLTS, OHMS, or AMPERES. On the AMPERES position,

a shunt resistor whose value is the reciprocal of the designated range may be used to decrease the input resistance as well as to measure current.

MULTIPLIER switch, located in the center of the front panel above the RANGE switch, determines the voltage sensitivity of the dc amplifier, and sets the voltage range when the RANGE is set on VOLTS. On OHMS or AMPERES, the setting of this knob multiplied by the OHMS or AMPERES setting gives the full scale meter reading.

ZERO control, located at the left under the meter, is used to set the meter to zero.

METER-BATTERY switch, at the right under the meter, turns the instrument on, determines meter polarity, and tests the batteries.

ZERO CHECK-OPERATE switch, located at the bottom right, shorts the input terminal through 5 megohms while the amplifier input is shorted.

Rear Panel Controls:

OUTPUT receptacle for external recorders, Amphenol 80PC2F; Mating plug Amphenol 80PC2M.

Normal-Fast control is locked in NORMAL position. In FAST position, current measurements are made with feedback around the shunt resistor.

COARSE ZERO is used to bring the front panel ZERO control in range if the amplifier is quite badly unbalanced.

Tubes:

One 5886, two 6418

Cabinet:

6 $\frac{1}{2}$ " wide by 9 $\frac{1}{2}$ " high by 6 $\frac{3}{4}$ " deep. Weight 5 $\frac{3}{4}$ lbs.

Batteries:

<u>Battery</u>	<u>Type</u>	<u>Expected Life</u>
B1	Mallory RM12R or equivalent (3 req'd)	350 hours
B2, B3, B4	Eveready #412 or equivalent	500 hours

SECTION III - OPERATION

A. PREPARING THE INSTRUMENT FOR OPERATION

(1) Set controls as follows:

MULTIPLIER: 10

RANGE SWITCH: VOLTS

ZERO CHECK SWITCH: Zero check position (horizontal).

(2) Turn the METER switch to meter +. The instrument should come to zero in approximately 5 seconds.

(3) Rotate the MULTIPLIER switch toward the high sensitivity end, adjusting ZERO as required. If it is impossible to zero the meter with the front panel ZERO control use COARSE ZERO control on rear panel to bring the instrument within range of the ZERO control.

(4) Connect leads as required for measurement. If high impedance is involved, the input should be shielded using a coaxial connection or shielded enclosure. The various 600 series accessories may be used. See Section V.

If the impedance is low (below about 10^{10} ohms) and leads can be kept short, the binding post adapter furnished with the instrument may be used.

B. MEASURING VOLTAGE

Place RANGE switch at VOLTS. Turn MULTIPLIER switch to expected sensitivity and check meter zero. If the sensitivity of the instrument is increased, recheck the zero reading.

C. MEASURING CURRENT

(1) NORMAL method (10^{-5} amperes to 10^{-11} amperes full scale).

Turn RANGE switch to desired AMPERES range. Make sure the switch at the rear of the instrument is on the NORMAL position. Connect current source to the input. Full scale sensitivity is the product of the settings of the RANGE switch and MULTIPLIER. Check zero with the ZERO CHECK switch and then read the unknown current. The full scale voltage drop is the setting of the MULTIPLIER switch.

(2) FAST method (10^{-7} to 10^{-11} amperes full scale).

Proceed as above except with the FAST-NORMAL switch at FAST. The input drop is now negligible and the input circuit time constant is reduced at least 100 times. Observe the following cautions:

(a) Use only the ZERO CHECK switch to check zero. Do not short the input.

(b) The low side of the output is no longer at ground. Therefore, a recorder attached to the output must not be grounded to the Model 620.

(c) Do not use this method for the measurement of capacitor leakage.

D. MEASURING OHMS

(1) NORMAL method (10^5 to 10^{11} ohms full scale).

Turn RANGE switch to desired OHMS range. Make sure that NORMAL-FAST switch is in the NORMAL position.

Connect resistance sample to be measured only after ZERO CHECK switch has been returned to zero check position (horizontal). The test voltage at full scale is the setting of the MULTIPLIER switch. Before reading OHMS, turn RANGE switch to the approximate range of the unknown resistance. By manipulating the MULTIPLIER and the RANGE switch, the sample can be tested at a number of test potentials, if desired.

(2) EXTERNAL VOLTAGE method.

Any dc voltage may be used. The unknown is connected between the external source and the electrometer input. The RANGE switch is set to AMPERES and the resistance may be calculated from the applied voltage and the indicated current.

Proceed as follows:

(a) Set the ZERO CHECK switch in the zero check (horizontal) position.

(b) Connect unknown between INPUT terminal and source of potential. A switch should be connected in the high voltage line so that when the sample is disconnected from the potential, the low impedance end of the sample is grounded.

(c) FAST-NORMAL switch should be at NORMAL.

(d) Set RANGE switch at 10^{-6} AMPERE. Apply potential to sample before setting the ZERO CHECK switch to OPERATE. Advance the sensitivity until a reading is obtained.

If the potential applied is at least 100 times the ammeter drop (the setting of the MULTIPLIER switch), the resistance is equal to:

POTENTIAL APPLIED
CURRENT READING

If the potential applied is not large compared to the ammeter drop, the resistance is equal to:

$$\frac{\text{POTENTIAL APPLIED} - \text{INPUT DROP (VOLTS)}}{\text{CURRENT READING}}$$

(e) If the noise in the source is low enough it is possible to have the FAST-NORMAL on FAST and the input drop need not be considered in the calculation.

E. BATTERY CHECK

Turn METER-BATTERY switch to B1, B2, etc. All batteries should read half scale or higher on the meter.

All batteries are tested directly. B1 consists of three 1.34 volt batteries in series and all three should be replaced if the reading in B1 position is less than half scale.

F. USING EXTERNAL INDICATORS

The output of the Model 620 may be used to drive servo rebalance recorders as well as high impedance devices such as oscilloscopes and dc amplifiers.

(1) For use with servo rebalance recorders:

The output circuit consists of a 16.67K resistor through which 60 microamperes flow for full scale deflection of the panel meter. Shorting the output does not affect the meter reading of the Model 620; low impedances placed across the output terminals will lower the terminal voltage for full scale deflection. Thus, if it is desired that the output voltage for full scale of 50 millivolts is required, 878 ohms should be used.

(2) For use with oscilloscopes and high impedance dc amplifiers, the output is one volt for full scale input on any range, with a phase inversion.

The frequency response is dc to 100 cycles on all ranges. The maximum amplitude which can be delivered by the amplifier is approximately 2 volts peak to peak.

G. CURRENT SOURCE

When measuring ohms, the instrument is designed to supply a constant current to any device placed across its input terminals. The magnitude of the current is equal to the reciprocal of the designation on the OHMS segment of the RANGE switch. Therefore the instrument may be used as a current source for calibration of other instruments if desired.

Turn RANGE switch to OHMS and ZERO CHECK switch to OPERATE. The current that is supplied on each range is the reciprocal of the OHMS

setting, and is not affected by the setting of the MULTIPLIER switch.

H. STATIC CHARGE MEASUREMENTS

The instrument is zeroed and the RANGE switch placed on VOLTS. The MULTIPLIER is placed at 3 or 10 volts full scale. The charged object is then brought near the uncovered, unshielded input connector of the 620. Depending on the distance between the charge and the instrument a voltage will be induced on the input terminal and can be read on the panel meter. The instrument zero should be checked frequently since accumulation of charge due to the electrometer tube grid current will cause a slow drift of input voltage.

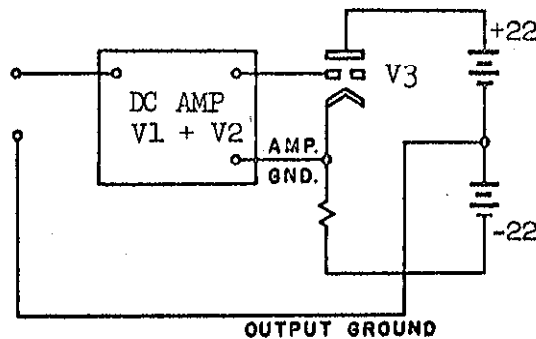
Connecting a capacitor across the input reduces the drift due to grid current and also the sensitivity to charge. An electrode connected to the INPUT terminal which increases the capacitance between the INPUT terminal and the charged object will increase the sensitivity to charges.

SECTION IV - CIRCUIT DISCUSSION

The basic element of the Model 620 is a highly accurate, stable dc voltmeter with a full scale sensitivity of 100 millivolts and an input impedance greater than 10^{14} ohms shunted by 30 micro-microfarads. The various connections necessary for current and resistance measurements will be discussed following the detailed description of the voltmeter.

A. VOLTMETER

Refer to DR 13364C at the rear of the manual.



The amplifier proper consists of V1 and V2. V3 is a cathode follower which drives the amplifier at the same instantaneous potential as the input signal. In other words the neutral or low impedance terminal of the amplifier is not grounded but is attached to the output cathode follower. Fig. 620-1 shows this diagrammatically.

FIGURE 620-1

Since the amplifier proper is driven by the cathode follower, the plus and minus 22 volt batteries for the cathode follower are referred to input ground while the battery supplies for the amplifier are referred to amplifier ground which is "floating". In subsequent discussion, reference will be made to the amplifier ground as "floating ground" and to cathode follower ground as "output ground".

The amplifier input consists of a 5886 electrometer tube. The filament is operated in series with V2 and V3 from battery B1. The control grid of V1, the electrometer tube, is protected by R102, a 1000 Megohm resistor, bypassed for high frequencies by C102.

The ZERO controls set the output to zero by adjusting the dc voltage on the screen of the electrometer tube.

The voltmeter sensitivity is determined by the value of the feedback resistor selected by S4, the MULTIPLIER switch. With full scale input on any range a current of 60 microamperes will flow thru R136 producing an output of one volt.

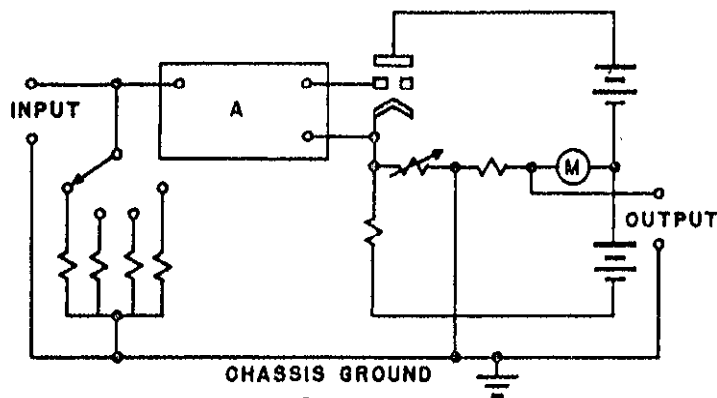


FIGURE 620-2

(1) Shunt Resistor Method (NORMAL)

In the normal operating connection as shown in Fig. 620-2 current is measured by placing a resistor across the input terminals and measuring the voltage drop. Currents from 10^{-5} to 10^{-11} amperes may be measured by this method since the range switch selects resistors ranging from 10^6 to 10^{10} ohms in decade steps. The voltage drop is selected by the MULTIPLIER switch; the setting is the input voltage drop for full scale meter deflection.

(2) Feedback Method (FAST)

In the voltmeter discussion above, floating ground is driven by the cathode follower and output ground is connected to the low impedance side of the input connector. In the FAST connection, the amplifier ground is connected to the low impedance side of the input; the output ground floats, and negative feedback is applied to the input through the shunt resistor.

In the Model 620 it is possible to use this connection with currents of 0.1 microamperes or less. To change the connection, remove the lock from NORMAL-FAST switch at the bottom of the rear panel and change it to the FAST position. The advantages of this connection are:

- (a) The effect of input capacity is largely neutralized, that is, the time constant of the input and cable capacity and the shunt resistor used will be decreased at least 100 times as compared to the NORMAL connection, corresponding to a 100-fold increase in response speed.
- (b) The input drop will be reduced about 100 times.

It will be seen that this connection converts the 620 into an operational amplifier with a resistor from the output to the input. Therefore, the following cautions apply:

- (a) The input cannot be shorted since this will remove the feedback.
- (b) The internal impedance of the current source being measured should not be less than about one-tenth of the value of the feedback resistor used for measurement.
- (c) This connection should not be used for measuring the leakage current of capacitors since the connection of a capacitor to the

input causes the circuit to be transformed into a differentiator with the resultant extreme sensitivity to very small voltage transients. For this measurement the NORMAL should be used.

C. OHMMETER

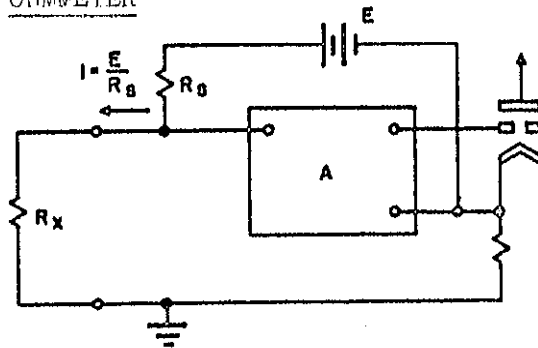


FIGURE 620-3

The Model 620 employs a linear scale to provide a megohmmeter of high accuracy. The linear ohms scale is achieved by supplying a constant current to the sample and measuring the voltage drop across it. The method is shown in Fig. 620-3.

(3) Use of External Voltage Supply

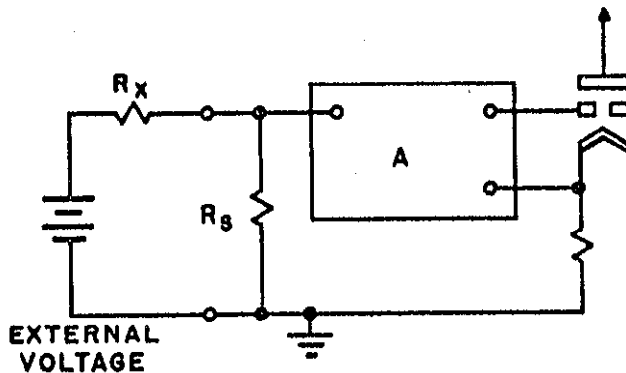


FIGURE 620-4

With the constant current method of measuring resistance, the voltage across the unknown may not be arbitrarily selected, and the time of measuring capacitor leakage tends to be long, since constant-current charging is slower than the exponential charge available with an RC circuit.

Due to these facts, it may be desirable to use an external voltage supply and measure the leakage current on the AMPERES scale (NORMAL operation).

The unknown is connected between the input terminal of the electrometer and the source of voltage. This is shown in Fig. 620-4. If the applied voltage is large compared to the voltage drop across the electrometer (so that the voltage across the sample is substantially the applied voltage) the resistance is simply equal to the voltage applied divided by the current measured. If the voltage drop is an appreciable fraction of the applied voltage, the resistance equals the voltage applied minus the input drop divided by the current measured. It will be rarely necessary to correct for the input drop of the electrometer due to the excellent voltage sensitivity of the Model 620.

It is advisable to use the NORMAL micro-microammeter connection for the measurement of leakage resistance of capacitors in this manner, since instability is likely to occur using the FAST connection. However, in cases where the capacity shunted across the sample is small, it will be possible to realize a considerable increase in speed of response by utilizing the FAST connection.

Some precautions are recommended when testing capacitors. Be sure that capacitors have discharged before removing from test circuit. With the ZERO CHECK switch in the zero check position the input is shorted to ground through 4.7 megohms providing a discharge path for the capacitor.

It should be further noted that capacitor measurement is likely to be a slow process in any case due to the fact that it may take considerable time for the molecular orientation of the dielectric to take place at the testing potential. It may take minutes or even hours in some cases to achieve a stable reading.

SECTION V - ACCESSORIES

MODEL 6101A ACCESSORY PROBE:

The Model 6101A probe consists of an input connector, 3 feet of low noise cable and a shielded probe head. Its purpose is to allow convenient connection to the electrometer input.

MODEL 6102A - 10:1 DIVIDER PROBE:

The Model 6102A divider probe is intended for general purpose measurements where an extension of the upper voltage range of the 620 is desired. The division ratio is 10:1 correct to 1% and the probe input resistance is 10^{10} ohms. The probe is supplied with a mating connector and 3 feet of cable.

MODEL 6103A - 1000:1 DIVIDER PROBE:

The Model 6103A probe is intended for very high voltage measurements at high impedance. The division ratio is 1000:1 correct to 3% and the probe input resistance is 10^{12} ohms. The probe is supplied with a mating connector and 3 feet of cable.

MODEL 6104 TEST ADAPTER:

The Model 6104 Test Adapter is intended for use in making measurements wherein complete shielding of the component under test is required. External terminals are provided for either grounded tests, or a test requiring an external voltage source.

SECTION VI - MAINTENANCE

No periodic maintenance is required other than checking the batteries as provided for by the front panel control. The method of performing these checks is outlined in Section III - E.

The calibration of the voltmeter is set by R119 located on the vertical printed circuit board. This is set at the factory and should not require adjustment. If recalibration is performed, an accurate voltage source should be used.

A. TROUBLE SHOOTING

The circuit is completely described in Section IV. Study of that section will facilitate any trouble shooting.

The most usual trouble encountered is that on the most sensitive voltage range, with the input shorted, it is not possible to bring the meter pointer to zero. However, before assuming that the instrument is at fault make sure that resetting the COARSE ZERO control at the rear of the instrument will not bring the instrument back into balance. If this does not work it will be necessary to remove the instrument cover to gain access to all circuitry. The instrument cover is removed by unscrewing the three screws on each side of the instrument and lifting the cover. With the cover removed, follow this procedure:

- (1) Short floating ground to output ground, removing the negative feedback. This is most conveniently done by shorting the two ends of the FAST-NORMAL switch on the rear panel. The instrument will become very sensitive and it will be difficult to keep the meter on scale with the zero control.
- (2) Measure the plate voltage of V1 as indicated on the voltage resistance diagram. If it is possible to swing the plate voltage thru the correct value with the zero control the first stage is working properly.
- (3) Check V2 and then V3 in the same manner. When a stage is found that will not give the correct voltage check the tube itself and then the associated components.
- (4) Since the tube filaments are in series all stages will be inoperative if any one filament is open. With the instrument on measure the individual filament voltages. The defective tube will have the full 3.6 volts across its filament terminals.

CHANGE NOTICE

MODEL 620

<u>Circuit Desig.</u>	<u>Change To</u>	<u>Part No.</u>
R109	Resistor, Deposited Carbon, 750 K, 1%, .5 watt	R12-750K
R141	Resistor, Deposited carbon, 30 K, 1%, 15 watt	R12-30K
S-2	Switch, check zero	SW-110
S-3	Switch, Coarse Zero	SW-106
S-4	Switch, Multiplier	SW-104
S-5	Switch, Fast -- Normal	SW-45
S-6	Switch, Meter -- Battery	SW-105

REPLACEABLE PARTS LIST - MODEL 620

Circuit Desig.	Description	Part No.
R120	Resistor, Composition 10M 10% .5 watt	R1-10M
R121	Resistor, composition 22M 10% .5 watt	R1-22M
R122	Resistor, deposited carbon 15K 1% .5 watt	R12-15K
R123	Resistor, deposited carbon 3.3M 1% .5 watt	R12-3.3M
R124	Resistor, Deposited Carbon 680K 1% .5 watt	R12-680K
R125	Resistor, Deposited Carbon 390K 1% .5 watt	R12-390K
R126	Resistor, Composition 12M 10% .5 watt	R1-12M
R127	Resistor, composition 22M 10% .5 watt	R1-22M
R128	Resistor, composition 4.7K 10% .5 watt	R1-4.7K
R129	Potentiometer 20K	RP12-20K
R130	Resistor, Deposited Carbon 220K 1% .5 watt	R12-220K
R131	Resistor, Deposited Carbon 1.667K 1% .5 watt	R12-1.667K(*)
R132	Resistor, Deposited Carbon 5K 1% .5 watt	R12-5K
R133	Resistor, Deposited Carbon 16.67K 1% .5 watt	R12-16.67K
R134	Resistor, Deposited Carbon 50K 1% .5 watt	R12-50K
R135	Resistor, Deposited Carbon 166.7K 1% .5 watt	R12-166.7K
R136	Resistor, Deposited Carbon 16.67K 1% .5 watt	R12-16.67K
R137	Resistor, Composition 150K 5% .5 watt	R19-150K
R138	Resistor, Composition 750K 5% .5 watt	R19-750K
R139	Same as R138	
R140	Same as R138	
S-1	Switch, Range	SW-103
S-2	Switch, Coarse Balance	SW-106
S-3	Switch, Multiplier	SW-104
S-4	Switch, Fast -- Normal	SW-45
S-5	Switch, Meter -- Battery	SW-105

NOTE: (*) indicates nominal value subject to variation in individual instruments.

REPLACEABLE PARTS LIST - MODEL 620

Circuit Desig.	Description	Part No.
V-1	Tube, Vacuum 5886 selected	EV-5886-5
V-2	Tube, Vacuum 6418	EV-6418
V-3	Same as V-2	

