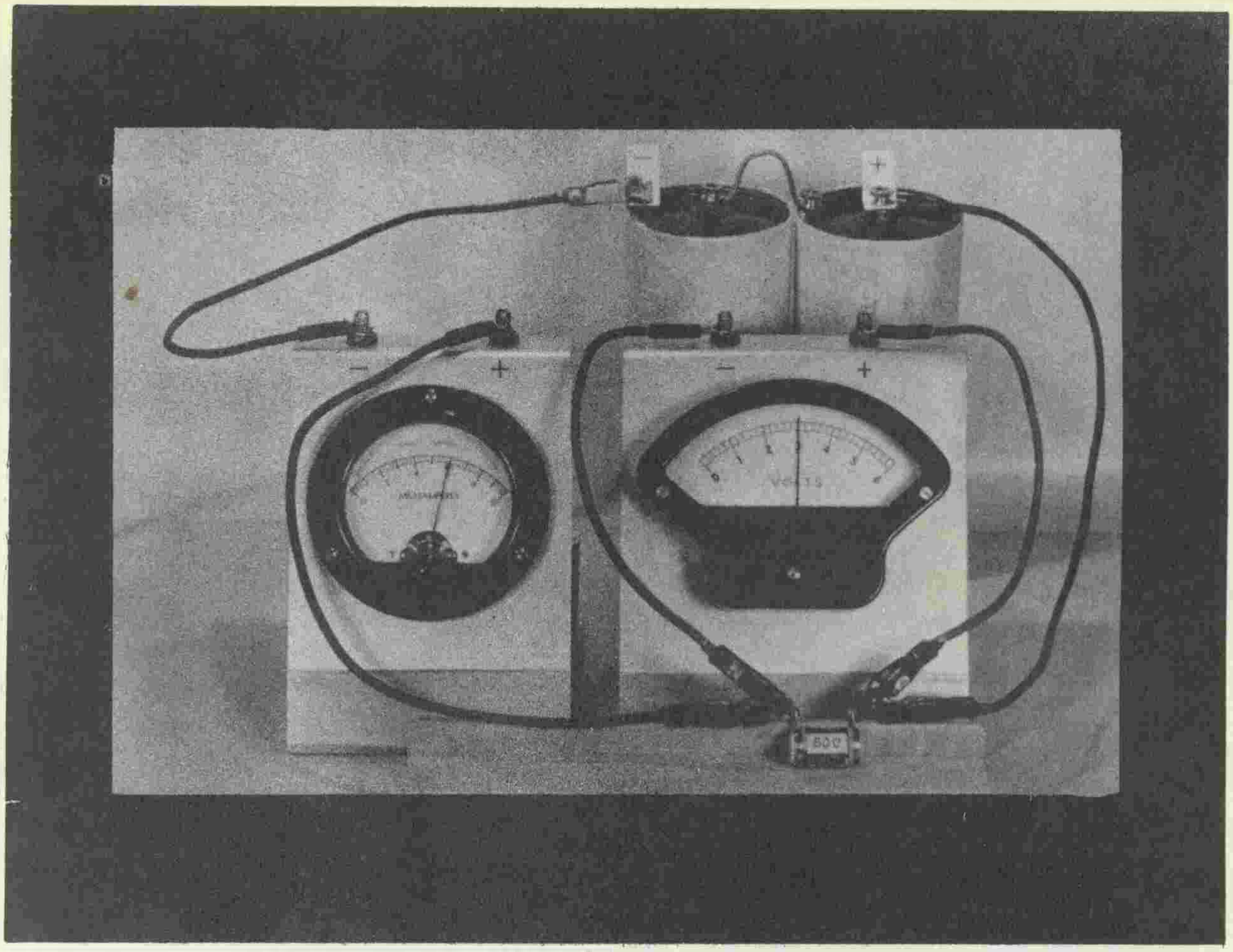

LESSON
5 RA

RESISTANCE
POTENTIAL AND CURRENT

RADIO-TELEVISION TRAINING SCHOOL, INC.
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RESISTANCE, POTENTIAL AND CURRENT

In radio and television receivers we have resistors. Across these resistors there are potentials which cause the flow of current and current is the movement of electrons. In this lesson you will learn more about Ohm's Law. For example, you will learn how to determine the amount of current flowing when we know the potential as well as the resistance in the circuit.

RESISTANCE

Resistance is that electrical property of an item which opposes the flow of electrons in a circuit. It is very much like the opposition which may be offered by the small openings in a pipe of a radiator connected to a water heating system. The small pipes which serve as the radiator do not allow water to flow through the system easily. They offer resistance to the flow of water. Now, this mechanical analogy may give you a little better understanding of the term resistance. However, we are causing electrons to flow through a solid metal conductor rather than the flow of water. The ohms is the unit of electrical resistance in a circuit.

CURRENT

Current is the flow of electrons in a circuit. The number of electrons which flow through the circuit are, to some extent, dependent upon the size of the conductor. Mechanically this is also true for the flow of water through a water pipe. The smaller the diameter, the lower will be the rate of flow. Electrical current flow is measured in the unit known as the ampere.

POTENTIAL

Potential is the pressure, that is, the electrical pressure which exists in the circuit. In referring to our mechanical analogy, a water pump will cause water pressure. Electrically the potential is measured in the unit known as the volt. It is customary to speak about this pressure as voltage and also the potential difference.

RELATIONSHIPS

Now, when we know any two of these three values written below we can find the third or the unknown value and you will learn how this is done using Ohm's Law.

RESISTANCE	CURRENT	POTENTIAL

The amount of resistance in a circuit controls the amount of current flow when the voltage is held at a constant or fixed value. Under this condition the lower the resistance the greater will be the current flow. It is, of course, understood the higher the resistance the lower will be the current flow.

The amount of current flowing in a circuit will increase if we lower the resistance in the circuit and hold the voltage constant on or a fixed value. Then too, if we raise the voltage and maintain the original value of resistance the current will increase. It is also understood that the current will decrease if we raise the resistance in the circuit.

For all practical purposes the potential applied to a circuit is dependent upon its original source value.

Let us take a more practical example and one that you may have already worked out. For instance, let us have a problem where we want to know how much money you can earn in a 40 hour week when you are paid at the rate of two dollars per hour. You would more than likely say, $80.00 - of course. You wouldn't stop to say that your pay-check would be equal to your hourly rate multiplied by the total number of hours worked. Nevertheless, this is a rule. To apply this rule we multiply. Therefore, 2 x 40=80 or $80.00 is the amount you would earn in a week. In radio and television circuits we also have rules which assist us in understanding the servicing of sets and they are just as correct as the one presented about the amount of money you would earn in a week. In this practical example we have two known values; the hourly rate and the number of hours. You can also determine the hourly rate when you know the number of hours and the amount of the pay-check, because the amount of the pay-check divided by the number of hours worked will give you the hourly rate. For example: 80 divided by 40 equals two or two dollars. Two dollars is, therefore, your hourly rate.

TYPICAL AMPLIFIER CIRCUIT

To assist you in remembering the relationship between the three electrical values resistance, current and the potential we shall study a typical plate circuit of an amplifier of a radio set and make some measurements. You shall also learn other facts about circuits in sets.

Fig. 1 is a picture of all of the parts which are in the plate circuit of an amplifier tube. The same circuit, in the form of a diagram drawn with symbols, is shown by Fig. 2. The tube at the left is a rectifier, which delivers direct current when

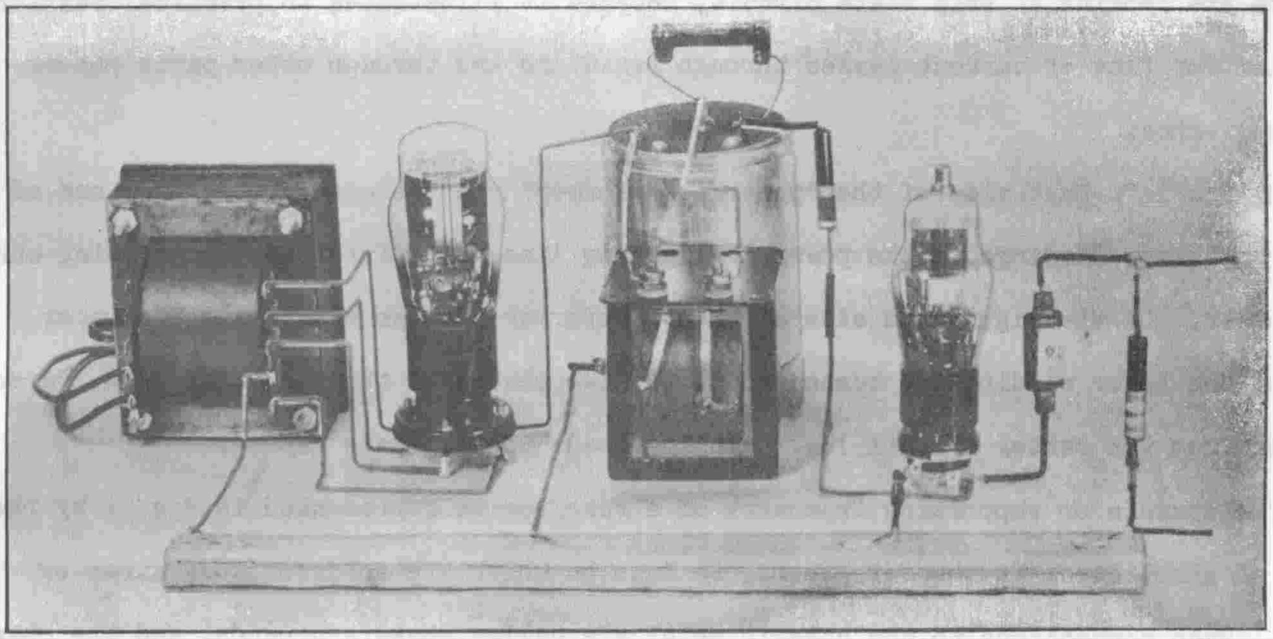

Fig. 1. Here are all of the parts which are in the plate circuit of the amplifier tube which is at the right.

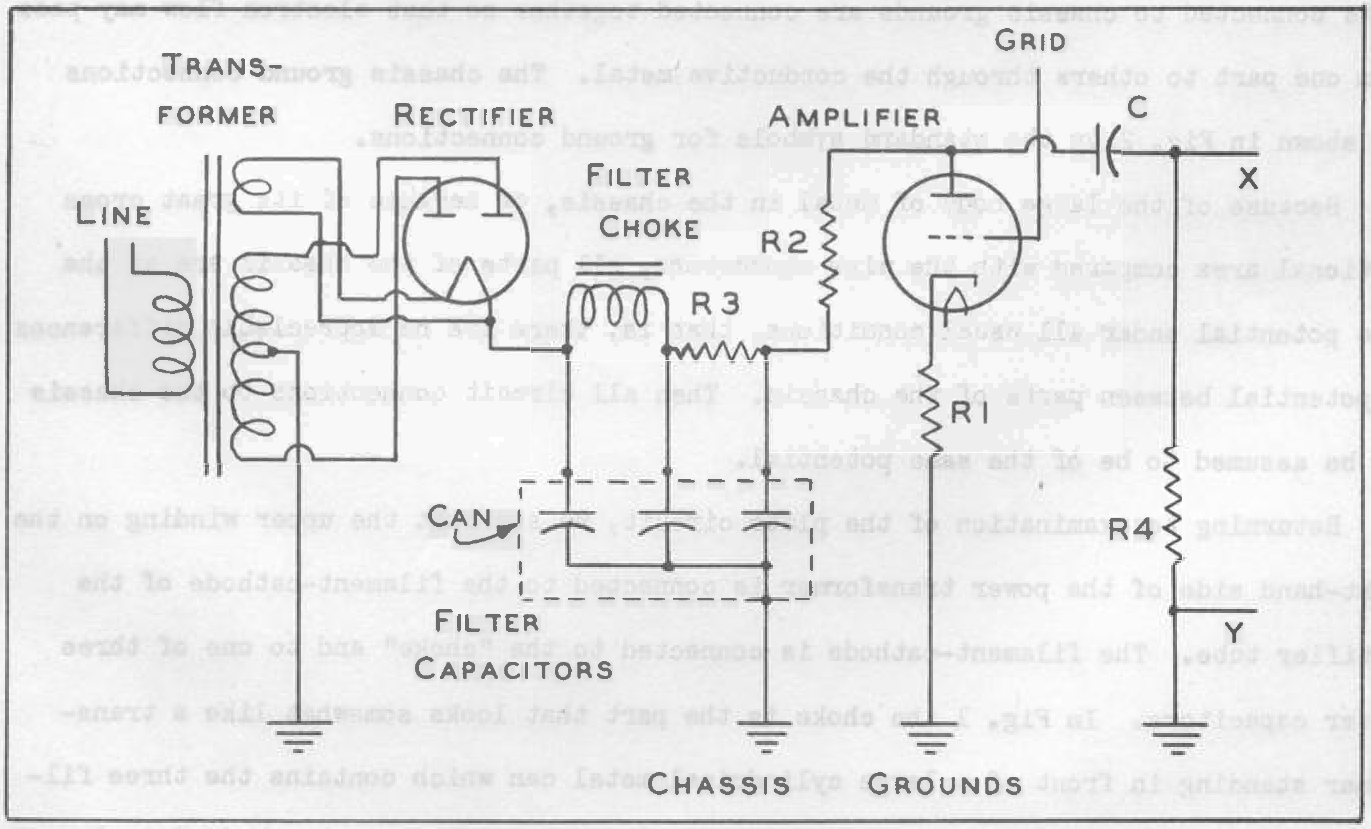

Fig. 2. A circuit diagram showing all connections in the plate circuit.

alternating potentials are applied to it. The tube at the right is the amplifier. The plate circuit of a tube includes all of the paths through which passes the electron flow that issues from the cathode and goes to the plate of the amplifier tube.

We are looking at this plate circuit, because it illustrates in practical fashion how electron flow or current passes through resistors and through other parts possessing resistance.

On the left-hand side of the "power transformer" are the connections from one of the transformer windings to the power or lighting line which furnishes alternating-current power. On the right-hand side of the transformer are two windings. The outer ends of the lower winding are connected to the two plates of the rectifier tube. A connection from the center of this lower winding leads to a chassis ground.

The chassis or supporting framework of a receiver is represented in Fig. 1 by the piece of sheet steel in the foreground, to lugs on which are soldered four wires or leads. Such connections to the chassis metal are called chassis grounds, and the chassis metal itself is called a ground. Since the chassis metal is a conductor, all circuits connected to chassis grounds are connected together so that electron flow may pass from one part to others through the conductive metal. The chassis ground connections are shown in Fig. 2 by the standard symbols for ground connections.

Because of the large body of metal in the chassis, or because of its great cross sectional area compared with the wire conductors, all parts of the chassis are at the same potential under all usual conditions, that is, there are no appreciable differences of potential between parts of the chassis. Then all circuit connections to the chassis may be assumed to be of the same potential.

Returning to examination of the plate circuit, we see that the upper winding on the right-hand side of the power transformer is connected to the filament-cathode of the rectifier tube. The filament-cathode is connected to the "choke" and to one of three filter capacitors. In Fig. 1 the choke is the part that looks somewhat like a transformer standing in front of a large cylindrical metal can which contains the three filter capacitors. One side of each capacitor is attached to a terminal embedded in insulation on top of the can. The other sides of the capacitors are connected together and to the metal of the can itself. The can is grounded to the chassis. The resistor that stands up above the capacitor can in Fig. 1 is marked R3 in Fig. 2.

The three capacitors, the choke, and resistor R3, form what we call a filter. To this filter are applied the successive pulses of one-way (direct) electron flow that comes through the rectifier tube when alternating potential from the transformer is applied to that tube. The effect of the filter is to change these intermittent pulses of electron flow into a relatively continuous and unvarying flow, which is what we need in the plate circuits and other circuits of a receiver. We shall make a more detailed examination of filters in other lessons.

Now let us trace the path of electron flow in our plate circuit. We shall start from the heated filament-cathode of the rectifier tube. Electron flow is first to one plate and then to the other as the applied alternating potential causes first one and then the other plate to become positive with reference to the cathode. From the rectifier plates the electron flow goes through the lower winding of the transformer to the center (tap) connection leading to a chassis ground.

The electron flow passes through the chassis metal (ground) to the ground connection for the amplifier tube, then through resistor R1 to the amplifier cathode, from this cathode through the tube space and the grids to the amplifier plate, and through resistor R2 to one end of filter resistor R3. The flow goes through resistor R3, then through the winding of the filter choke, and back to the filament-cathode of the rectifier tube, which is the point at which we considered the flow as starting.

RESISTANCES IN THE PLATE CIRCUIT

Once more we shall follow the path of electron flow in the plate circuit, and consider the various resistances in which there will be drops of potential. In the space between cathode and either plate of the rectifier tube there is "plate resistance" equivalent to about 500 ohms in the type of tube pictured. Electron flow from either plate goes through half of the lower right-hand winding of the power transformer. In each half of this winding there is a resistance of two or three ohms; so small that it may be disregarded.

Now we come to resistor R1, whose purpose is to make the control grid of the amplifier tube remain more negative than the cathode of this tube, thus preventing the flow of electrons in the grid circuit. Through connections not shown, the control grid connects to a chassis ground. Consequently, the control grid is at the same potential as the chassis, and is at the same potential as the lower end of resistor R1 in Fig. 2, which is connected to a chassis ground. Electron flow is upward in R1, and since electron flow always is from negative to positive, this means that the lower end of R1 is more negative than the upper end. Then, since the control grid is at the potential of the lower end of R1, while the cathode is at the potential of the upper end, to which it connects, the control grid is maintained more negative than the cathode. Here we have touched on the important subject of "control grid bias", which is something to be investigated later on.

In the space between cathode and plate of the amplifier tube the electron flow has to overcome opposition equivalent to many thousands of ohms, and there is a proportionately great drop of potential in this tube. The resistance of R2 is about 250,000 ohms. The resistance of R3 may be between a few hundred ohms and several thousand ohms, all depending on the current requirements of the apparatus. The resistance of the winding in the filter choke may be a few hundred ohms.

In Fig. 3 we are measuring the resistance of the filter choke. Yes, what is the resistance of the filter choke as measured in the unit, the ohm? Here we see four items; the batteries, the milliampere meter at the left, the filter choke and the voltmeter at the right. We employ two meters which will give us two known values, the current is indicated by the meter at the left and the voltage by the meter at the right. When we know the current and the voltage we can find out what the resistance will be using the following rule. The circuit resistance is equal to the voltage divided by the current. This rule may be written as follows:

$$R = \frac{E}{I}$$

Fig. 4 shows schematically the items pictured in Fig. 3. Note the two cells of the battery are indicated by a short vertical line for the negative terminal and a longer vertical line for the positive. The amperemeter I is connected in series with the negative battery lead. This meter is called an ammeter by technicians. The voltmeter E is connected across the filter choke L. The latter is shown schematically by a number

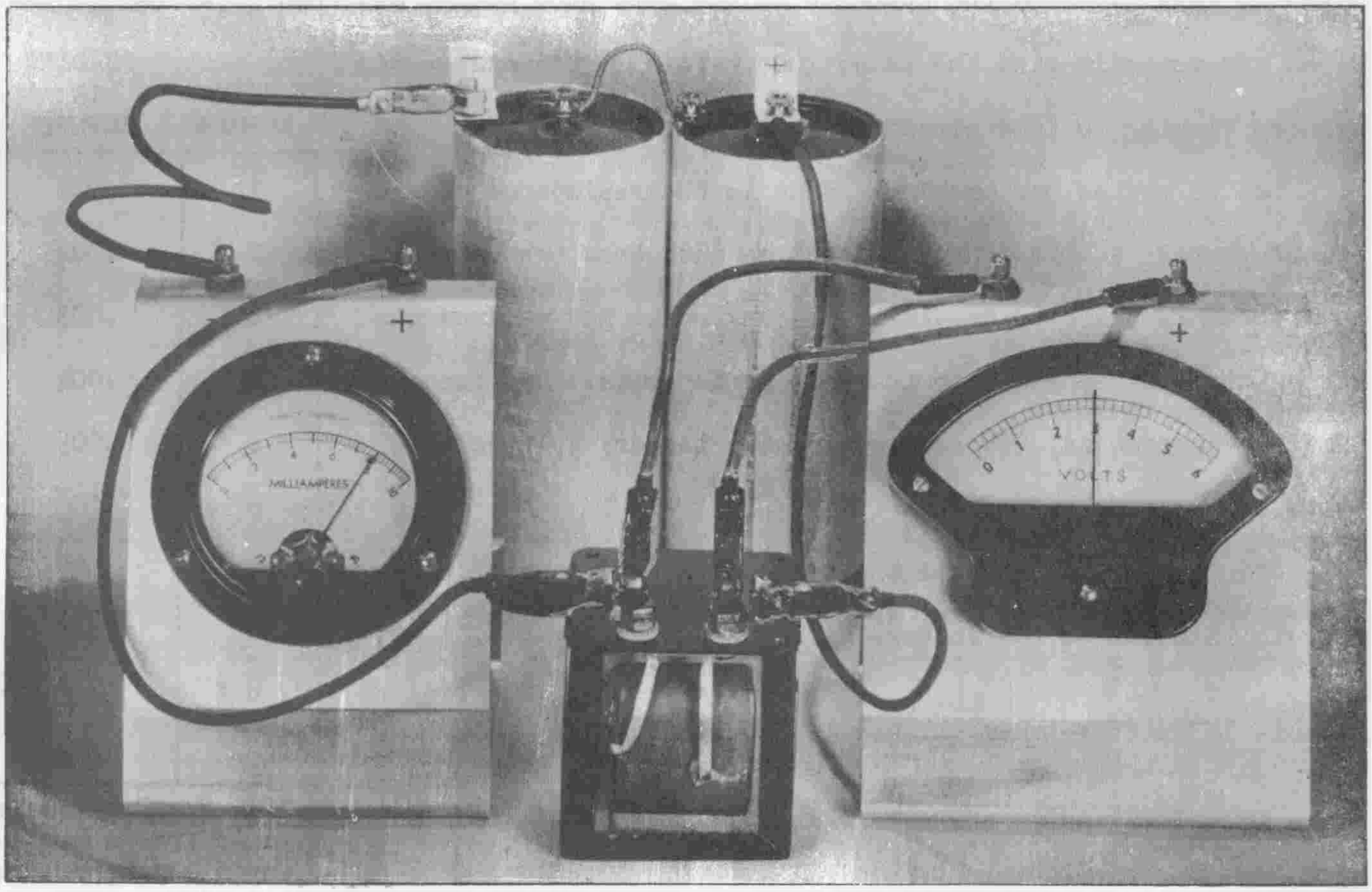

Fig. 3. Measuring the resistance of the choke used in the filter system.

of turns under which are 3 parallel horizontal lines.

Again referring to Fig. 3 we find that the meter at the left indicates the current in milliamperes instead of amperes. This meter is reading8 or 8 milliamperes. Our rule says that I is the current expressed in the unit, ampere. Inasmuch as the circuit current, as shown on the face of the meter, is expressed in milliamperes; that is, thousandths of an ampere, we must make the proper allowance in our rule or use a table to convert milliamperes to amperes. You should become familiar with the conversion method used by many radiomen: Remember that the decimal point moves 3 places to the left when converting milliamperes to amperes. For example: The reading of 8 milliamperes is converted into amperes by moving the decimal point 3 places to the left, giving us .008 amperes.

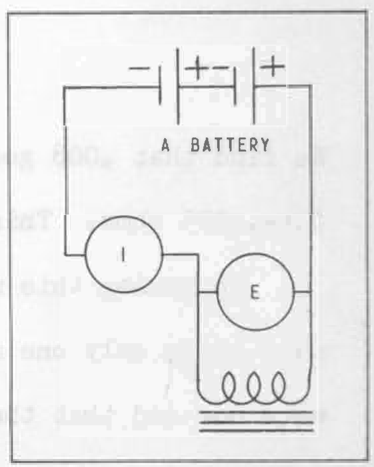

Fig.4. The schematic circuit diagram for measuring the resistance of the filter choke.

Then, too, remember that we can convert amperes to milliamperes by moving the decimal point 3 places to the right. If you want to check this conversion method, use the table shown in Fig. 5. Find the number 8 in the left hand column and then go across to the right and you will find the value .008. This is the number of amperes flowing in this circuit.

METER READING	READING IN AMPERES
1	.001
2	.002
3	.003
4	.004
5	.005
6	.006
7	.007
8	.008
9	.009
10	.010

Fig. 5. Conversion table for converting milliamperes to amperes.

Let us review our problem: What is the resistance of the filter choke? As previously stated, we must know two circuit conditions in order to determine the unknown. Now we know the current in amperes and also the voltage in volts. We found that the current is .008 amperes and the battery voltage is 3 volts.

Once again let us state the rule - "The resistance in the circuit is equal to the voltage divided by the current". The formula is written: $R = \frac{E}{I}$. Now let us substitute, that is, place actual values in the rule. $R = \frac{3}{.008}$. We will now have to divide .008 into the number 3.

This is done by the following process:

375.
.008/3000.
24
60
56
40

We find that .008 goes into 3 over 300 times - actually 375 times. Our answer is, therefore, 375 ohms. This is the resistance of the filter choke.

In making this measurement we employed two meters. We could have made the measurement using only one meter, the milliampere meter, if we had assumed that the 2 batteries were new and that they provided 3 volts. This is the working principle of the radio and television serviceman's ohmmeter. It uses but one meter, however, its scale is calibrated directly in ohms and thus eliminates the need for all of these calculations. It is also faster this way. In fact, it is very interesting to work with a multimeter.

You now know how a meter can be used to aid in measuring the resistance of an item in any circuit.

PARALLEL CONNECTIONS

Up to the present we have been investigating electron flow in series circuits. A series circuit is one in which all of the electron flow in any one part of the circuit passes also through every other part of the circuit. But, many times, parts are connected in such a way that the electron flow in one part does not pass through any other part, so that each part carries only its own particular electron flow. Parts so connected are said to be connected in parallel with one another.

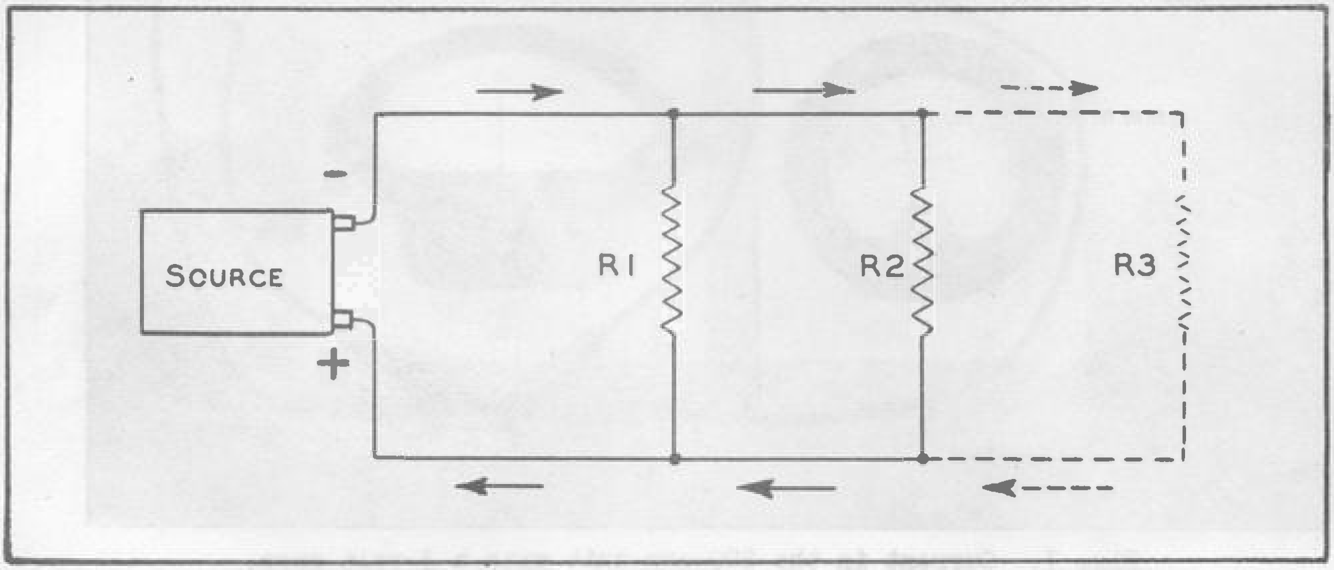

Fig. 6. The principle of parallel connections of resistances.

The elementary principle of parallel connections is shown by Fig. 6, where resistors R1 and R2 are in parallel with each other, and where any number of additional resistors, such as one at R3, might be similarly connected. Assuming the upper terminal of the source to be negative, electron flow from this terminal will go through the connecting wires or other conductors to the upper ends of all the resistors which are in parallel. Part of the total electron flow from the source will pass downward through R1 and will return to the positive terminal of the source. Another portion of the total electron flow will go to and through R2, and back to the source. If there are additional paralleled units, still other portions of the total electron flow will go through those other units.

It is apparent that none of the electron flow passing through unit R1 passes through any of the other paralleled units, and that none of the flow going through the other units goes through R1.

We shall assume that the resistance of the conductors between the source and the several paralleled units of Fig. 6 is so small as to cause negligible voltage drop. Thus the potential all along the upper conductors is the same as at the negative term-

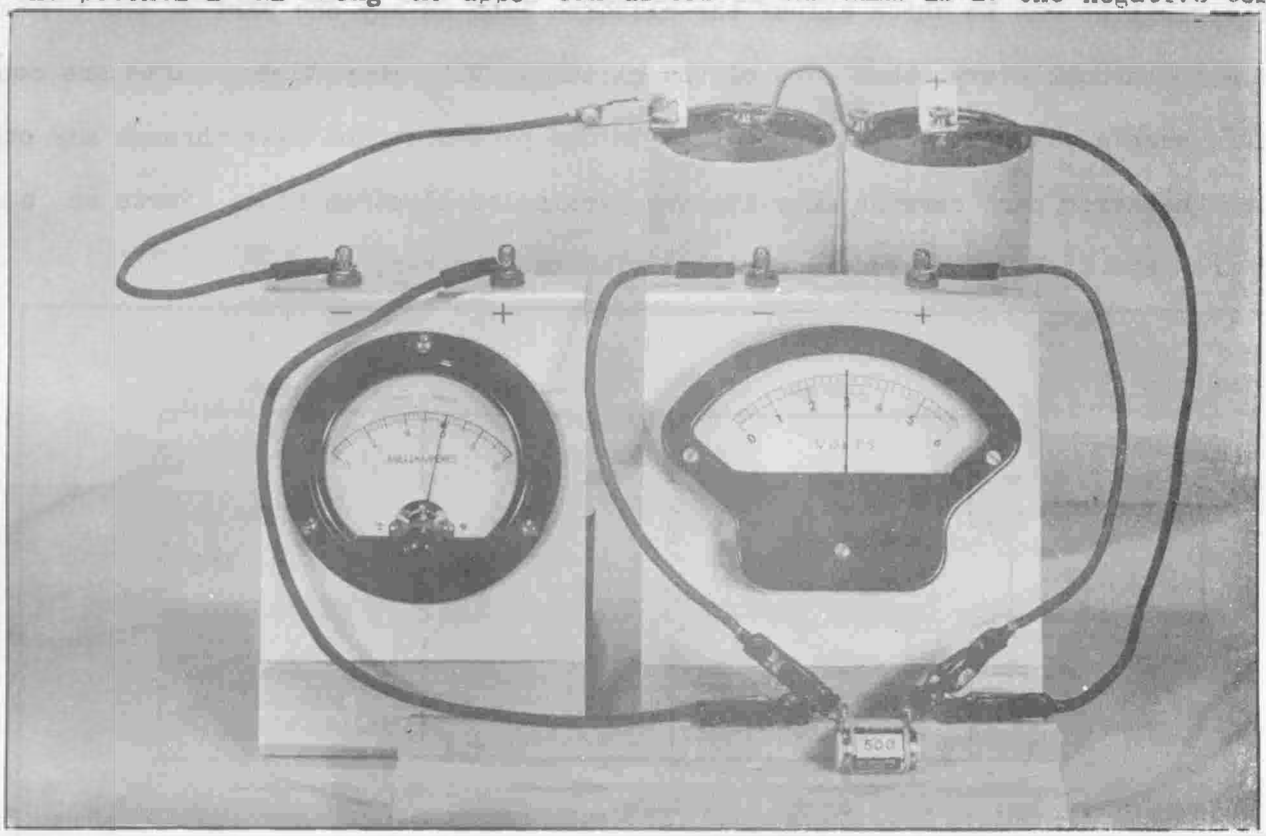

Fig. 7. Current in the 500-ohm unit with a 3-volt drop.

inal of the source, and the potential all along the lower conductors is the same as at the positive terminal of the source. The potential difference across each of the paralleled resistors, or other paralleled units, is the same as the potential difference at the terminals of the source. All units in a parallel connection have applied across them the same potential difference.

While all paralleled units are subjected to the same potential difference, they all carry separate and different amounts of current when they contain different amounts of resistance. Compare this statement with one for series connections, where all series units carry the same current, but all may have separate potential differences.

Fig. 7.	500 ohms.	6 milliamperes or	.006 amperes
Fig. 8.	1500 ohms.	2 milliamperes or	.002 amperes
Fig. 9.	2000 ohms.	11/2 milliamperes or	.0015 amperes

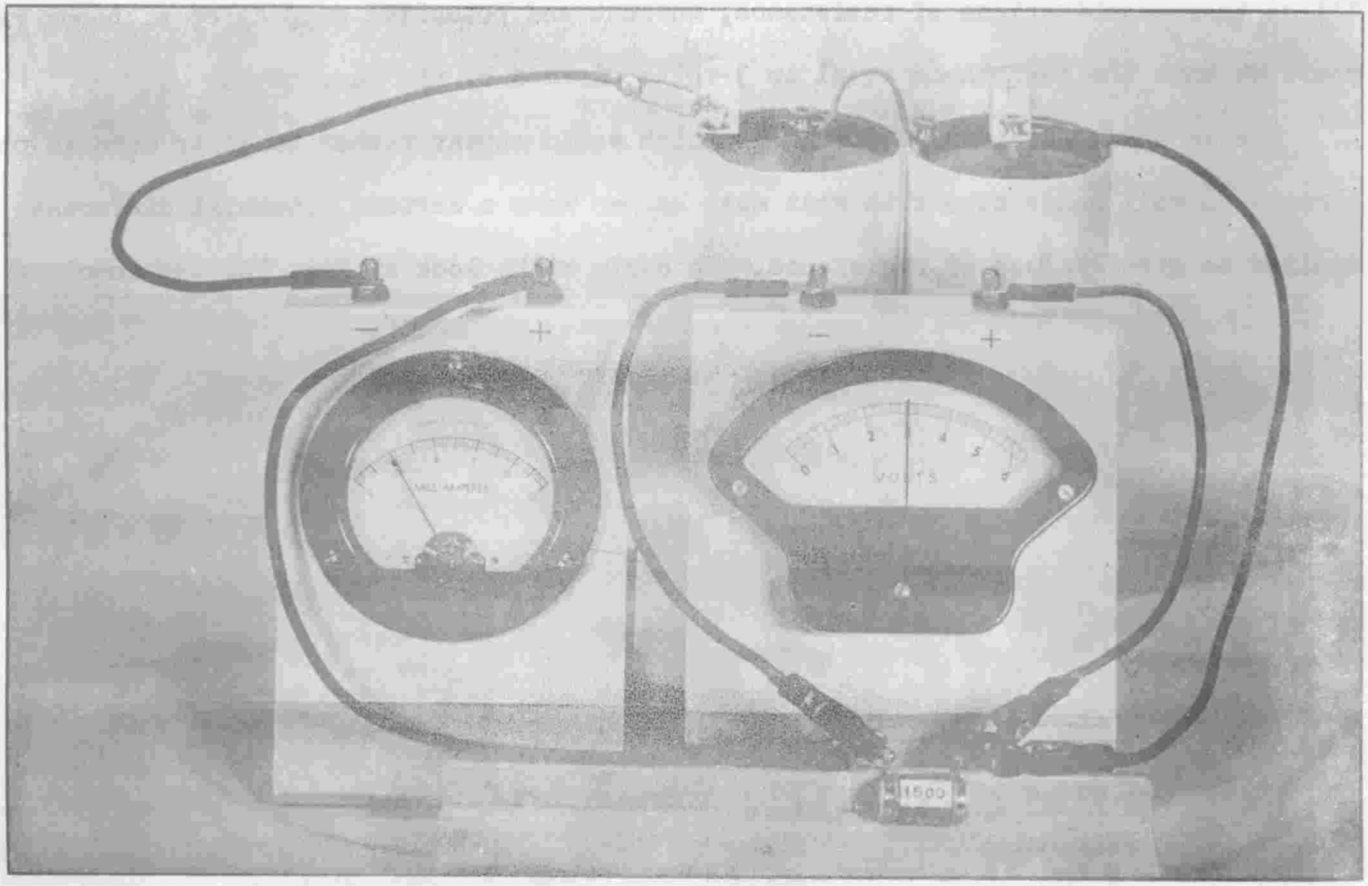

Fig. 8. Currentin the 1500-ohm unit is smaller than in the 500-ohm unit.

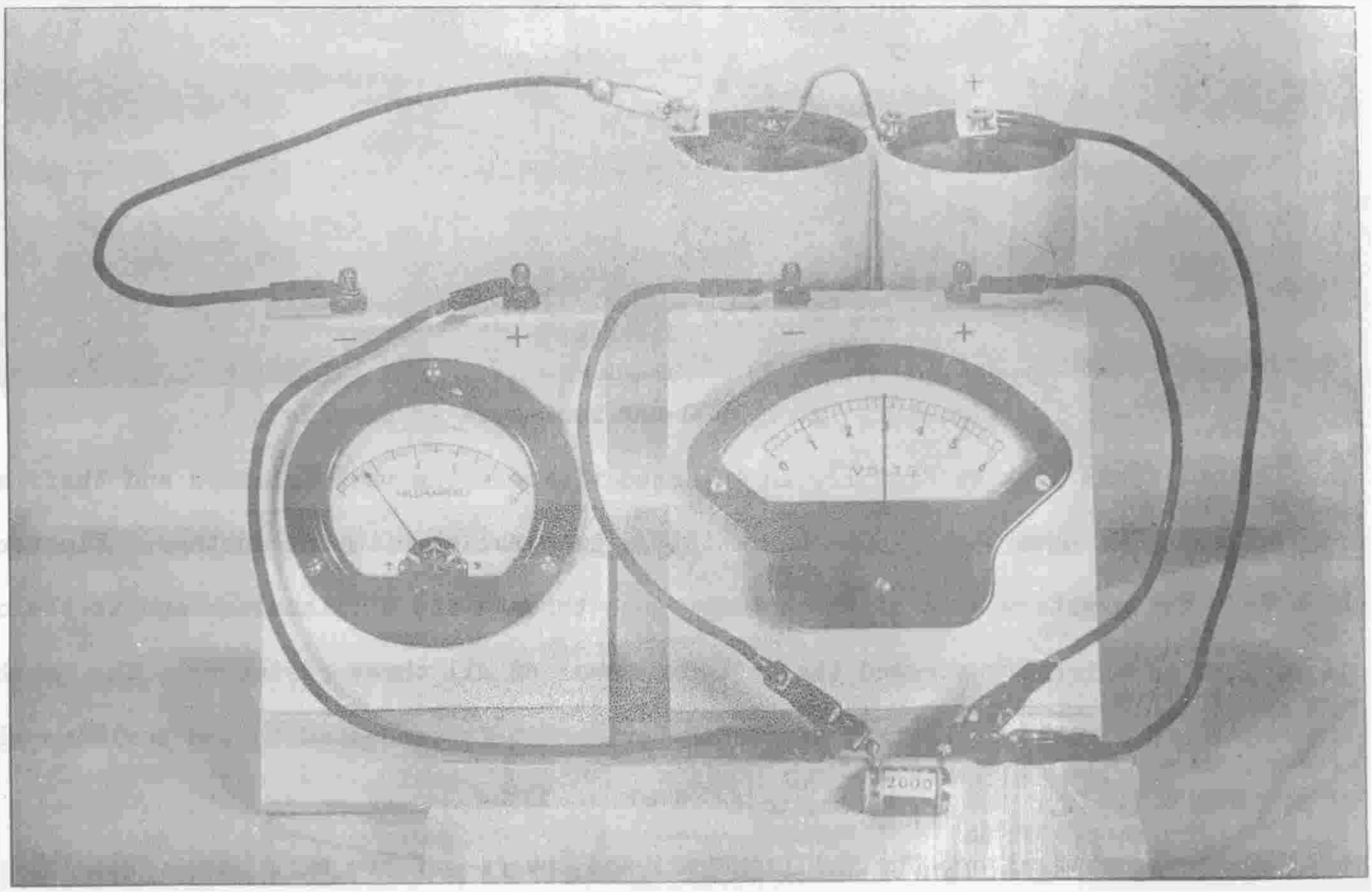

Fig. 9. Current in the 2000-ohm unit is still smaller.

All of these combinations of resistance, current and potential drop agree with our rule where we have the resistance equal to 3 volts divided by the current I.

Now we shall see some performances which would appear rather peculiar were we not already so well acquainted with what must happen when a certain potential difference is applied to given values of resistance. To begin with, look at Fig. 10, the complete

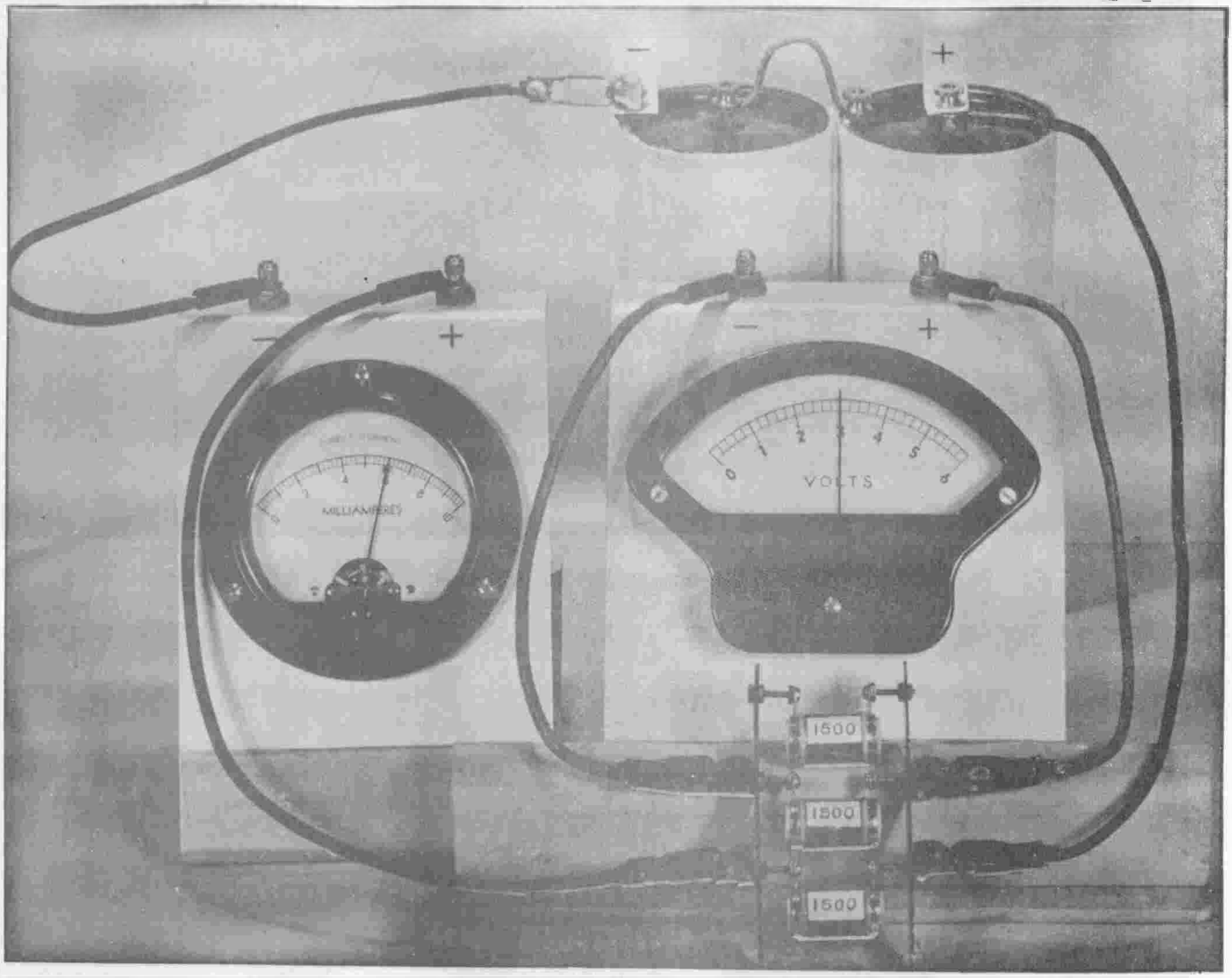

Fig. 10. Three 1500-ohm resistors in parallel.

test setup. Then look at Fig. 11, an enlarged view showing the resistors and their end connections. We have three 1500-ohm resistors in parallel with one another. Electron flow from the negative side of the battery goes through the milliammeter and to the conductor bar to which are screwed the left-hand ends of all three resistors. The right-hand ends are screwed to another conductor bar, which is connected to the positive side of the battery.

The connecting wires, the milliammeter, and the conductors bars have negligible resistance and negligible voltage drops. The 3-volt potential of the battery is applied across each of the three paralleled resistors. The voltmeter is connected across the conductor bars, thus indicating the potential drops (or single potential drop) across all three resistors. The current meter reads 6 milliamperes.

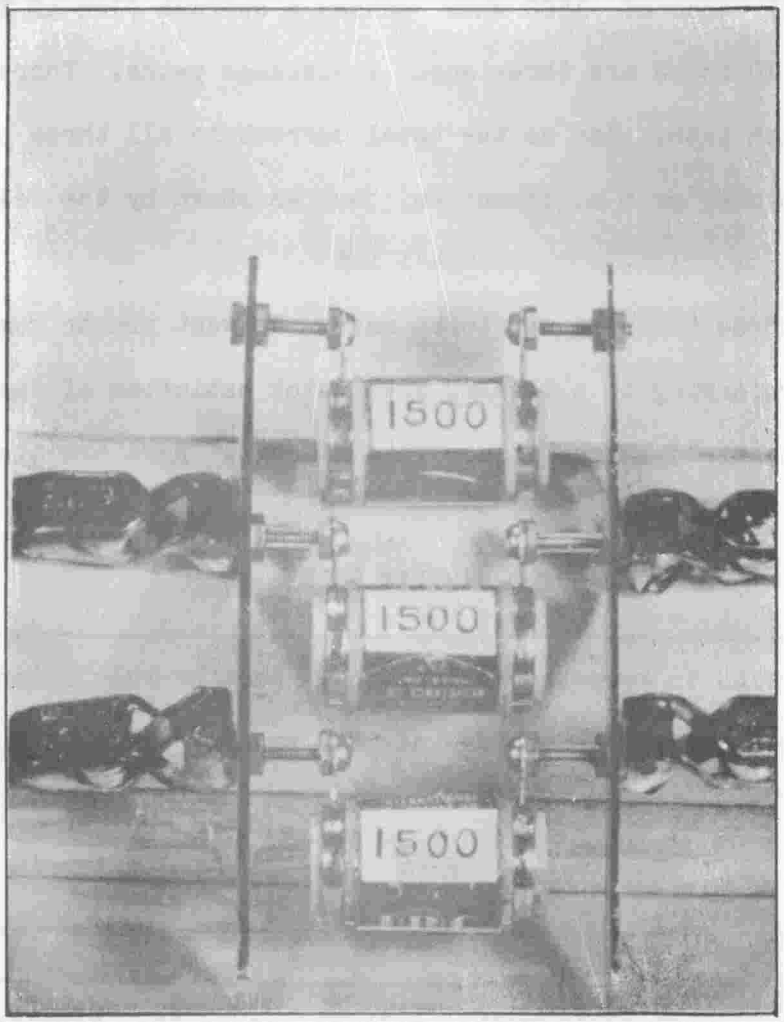

Fig. 11. Here is an enlarged view of the resistors and their end connections as shown in Fig. 10.

Go back to our list of readings for Figs. 7, 8 and 9; in which of these have we a current of 6 milliamperes, just as in Fig. 10? Yes, we have the <u>same current</u> with a resistance of 500 ohms in Fig. 7. Then it is apparent that the "<u>parallel resistance</u>" of three 1500-ohm resistors must be 500 ohms, because our rule would give 500 ohms of resistance for the 3 volts drop and the current of 6 milliamperes, as shown in Fig. 7 and also in Fig. 10.

Now we may make up a new rule for the combined resistance of paralleled units: the combined resistance of any number of equal resistances connected in parallel is found by dividing the resistance of one unit by the number of units. In other words, to compute the resistance of three 1500-ohm resistances in parallel, we simply divide 1500 by 3, and get 500 ohms for the answer. Remember this rule.

Before leaving Fig. 10 note these facts. We know that a potential difference of 3 volts across a resistance of 1500 ohms causes a current flow of 2 milliamperes (from Fig. 8). In Fig. 10 there are three such resistance paths. There must be a flow of 2 milliamperes in each path. And so the total current in all three paths together must be 3 times 2 milliamperes, or 6 milliamperes, just as shown by the test in Fig. 10.

OHM'S LAW

A review of three rules is now to be made. We want you to remember them so that you can, without referring to a lesson, make quick estimates of the relative amount current, voltage (potential) or resistance in a circuit. Here are the three rules you should remember.

OHM'S LAW RULES

When we want to know the resistance we use the rule which says that the resistance is equal to the voltage divided by the current. It is written as follows:

$$R = \frac{E}{I}$$

Whenever we want to know the voltage across the terminals of a circuit we use the rule which says that the voltage is equal to the current multiplied by the resistance. It is written as follows:

$$E = I \times R$$

We can find the current in the circuit by using the rule which says that the current is equal to the voltage divided by the resistance. This rule is written as follows:

$$I = \frac{E}{R}$$

-END OF LESSON-