I. L. 3832

Westinghouse

Fundamental Electronic Circuits

ELEMENTARY DISCUSSION

INTRODUCTION

Although most people recognize an electronic tube, at sight, comparatively few are familar with their characteristics and the many useful ways in which they may be applied. Therefore the word "electronics" sounds somewhat mysterious to many people who are very familar with other electrical apparatus. It may be well therefore to discuss and illustrate as simply as possible the fundamentals of "electronics" and then consider some of the simple control schemes in which they may be used.

We know that the term "electron" has been given to a very small NEGATIVELY charged particle of matter. For more detailed information on characteristics of an electron, your attention is directed to any good text on atomic physics or elements of electricity. For the discussion to follow, we shall only need to assume that such things as "electrons" do exist, and that they are NEGATIVELY charged particles of matter.

For our purpose, we shall discuss two common means of obtaining "free" electrons; mainly

1. By Thermionic Emission
2. By Photo-Emission

THERMIONIC EMISSION

The process of driving electrons out of a material through the application of more or less heat to that material is known as "Thermionic Emission". This process may be accomplished by increasing the current through a piece of high resistance wire until the I^2R loss in the wire is sufficient to raise this wire to a temperature in the neighborhood of 2200°C (for Tungsten wire) assuming, of course, that the wire does not melt at this high temperature. In order to prevent the chemical action, known as "oxidation", from seriously changing the wire chemically at this

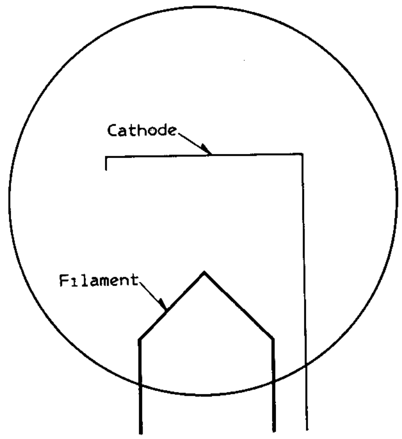

Fig. 1

temperature, it is common practice to insert the resistance wire in an evacuated glass or metal shell, which we shall simply designate as a glass or metal "tube". This resistance wire is known as the "filament", and is often referred to as an "element" within the tube.

However, experience and research have taught us that the number of electrons driven out of the heated material —(the resistance wire in this case)— is comparatively small for a given amount of heat energy applied to the heated material. We have learned that one material will permit the loss of umpty-ump million electrons for a given amount of applied heat energy, while another material will "emit" $(\text{Bumpty-ump})^2$ million electrons for the same amount of applied heat energy. Unfortunately, those materials which have the higher resistances and which have sufficient physical rigidity at these exceedingly high temperatures, are not the best electron emitters as far as quantity of electrons is concerned. However, many oxides (such as Barium, calcium and thorium oxides,) will emit enormous quantities of electrons with very little applied heat energy. Of course the natural step in development of filaments is to thinly apply these oxides to the high resistance material. The filament is then called "an oxide coated filament" and higher electron emission is made possible even at lower filament temperatures. Is it seen that this means longer tube life and vastly improved efficiencies?

It is quite difficult and expensive to properly apply commercially the oxide coatings to the filaments. However, if we add another "element" to the tube, such that this new oxide coated element is in very close proximity to the filament, we can cause electrons to be emitted from the oxide-coated surface of this element. We shall call this added element the "cathode". Note that there need not be any electrical contact between the filament and the cathode. The cathode simply emits electrons because of the heat energy radiated or conducted from the nearby filament. The filament does not necessarily have to emit electrons now.

Up to this point we have been discussing the means of emitting electrons from filaments and from cathodes **in an evacuated tube,** i.e., a tube whose gas pressure is intended to approach zero as closely as commercial practice will permit. We speak of this type of tube as a "VACUUM" tube, or a "hard" tube.

Referring to Fig. 1, we show the accepted symbol for a vacuum tube having a filament and a cathode. Let us now assume that we have supplied **electrical** energy to the filament, which supplies **heat** energy to the cathode, which, in turn, drives off electrons. What happens to these electrons? Well, many of these electrons would lose much of their "electron energy" in this emitted state, and would fall back into the cathode. Further, we know that NEGATIVELY charged bodies or particles repel each other under definitely related natural laws. Therefore, as soon as electron #1 is driven out of the cathode, electron #1, being NEGATIVELY charged, seriously opposes any other

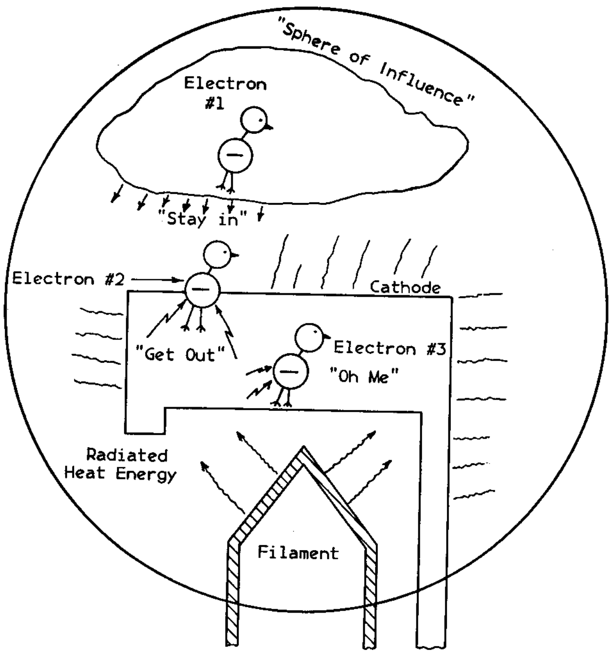

FIG. 2

electron which attempts to get into its "sphere of influence", or immediate vicinity. This "selfish attitude" on the part of Electron #1 is called the "space charge effect". For example, in Fig. 2 is shown Electron #1 which has been driven out of the cathode. Electron #1 is now a "free" particle, and like all free people, he intends to fight for his freedom. But Electron #2 finds living conditions in the cathode slightly unbearable and decides to move. However, Electron #1 says "don't move into my sphere of influence". So Electron #2, being a law abiding body in this universe, does not attempt to break into Electron #1 "Sphere of Influence", and puts up with the little "abuse." However, if the "abuse" becomes more serious, Electron #2 might risk a fight with Electron #1, and this quite often happens if the cathode becomes unbearably hot. Quite often it is not to our advantage to permit Electron #1 to have too much "Sphere of Influence". Therefore, we shall find means of "moving" Electron #1 into another pre-determined path and thus considerably reduce the effect of the Space Charge, and permit the emission of more electrons.

Suppose we add another element to the tube and for the sake of a better name we shall call it the "Anode". Further, we shall charge this anode POSITIVELY. To Electron #1 this is the same as hanging out the "Welcome Home" sign. As shown in Fig. 3, Electron #1 takes advantage of the anode's hospitality, with the result that Electron #1 quickly **MOVES** to the Anode;—"Sphere of Influence," and all! Now Electron #2, who has been waiting for this opportunity, immediately breaks the lease and moves out into the "space charge" area. But life is so terribly insecure in "Space", and lo and behold there is a "Welcome Home" sign on the Anode's porch! Need we say where Electron #2 goes in a terrible hurry? And on and on toward the unknown, venture these electron rascals. The higher the charge on the anode, the greater the attraction, hence the more electrons flow toward it. Because we don't know any better, let us call this electron migration "electric current." Now the anode's cocktail lounge can only handle a few of these migratory electrons at a time, so we shall have to introduce a law enforcing body into the tube, and we shall call it the "Grid". Yes, the grid is the policeman in the tube. He directs the flow of electron traffic. How does he do this? Well when we want to stop electron movement, we simply charge him NEGATIVELY with a sign which says "Measles". Thus the NEGATIVELY charged electrons are repelled by the NEGATIVELY charged grid, and since there are few law-breaking "electrons" only these negligible few sneak past the Grid to get to the Anode. This is shown in Figs. 4 and 5. In Fig. 5 we see how the Grid being positively charged, can help the electrons along to the Anode.

Symbolically the tube now looks like Fig. 6. Isn't it quite simple how those elements work now? Of course there may be other grids in a tube, but they just play special "heck" with the electrons so we'll ignore them in this simple discussion. Suppose we answer the following questions for our own satisfaction:

1—What is the filament and what function does it play in a tube?

2—What is the cathode and why is it used?

3—Need there be an electrical connection between the cathode and filament?

4—What is "the space change"?

5—How could you increase electron flow by working on the filament in the tube?

6—How could you increase electron flow by working on the anode of the tube?

7—What is the anode for?

8—What is the grid for?

PHOTO-EMISSION

We shall now discuss another means of obtaining electron emission. About 50 years ago it was observed that certain materials, (metallic oxides, in general) had the property of emitting electrons

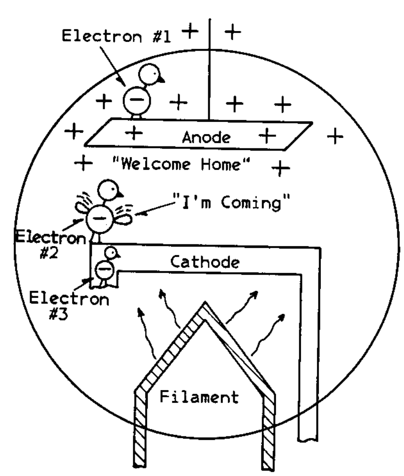

FIG. 3

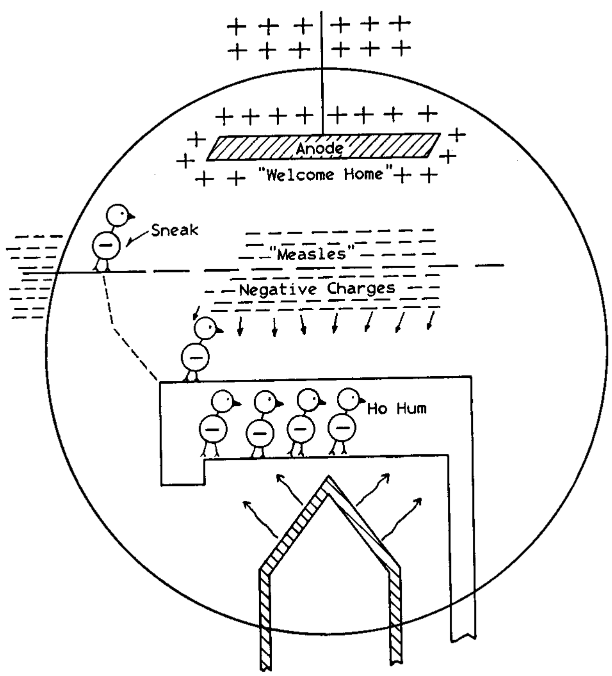

FIG. 4

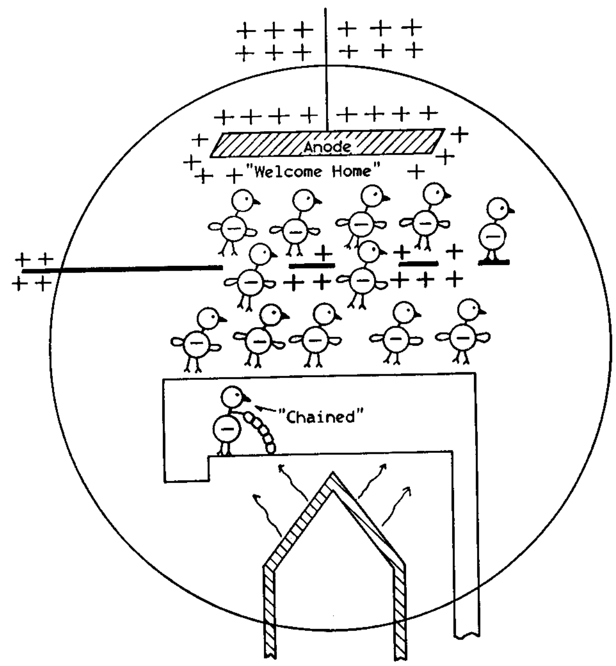

FIG. 5

when a beam of light was played upon the materials. You will rmember that LIGHT is a form of ENERGY. Under the previous heading, "Thermionic Emission", we discussed how HEAT energy drove electrons out of the cathode. In a similar manner, the LIGHT energy "irritates" the electrons and causes them to "jump" out of the cathode material. To be sure, they are relatively few in number, but nevertheless there **is** electron emission. Further, we have assumed that the flow per second of a certain number of electrons past a given point is called an "electric current." (For the "accepted" proof—See any good text in Atomic Physics.)

Suppose we place a cathode material, coated with caesium-oxide (a good electron emitter), in an evacuated glass tube. Directing a beam of light upon this cathode will cause electrons to be emitted. However, equilibrium is soon reached because the emitted electrons soon provide a "space charge effect" which prevents further electron emission. This is exactly the same as in the thermionic tube as per Fig. 2.

Now suppose we introduce into the tube our friend, the anode, with its POSITIVE charge. Is it clear that the NEGATIVELY charged electrons, emitted by the LIGHT energy striking the cathode, will be attracted to the POSITIVELY charged anode? Further, it may be stated that in a VACUUM tube, the number of electrons emitted is directly proportional to the light falling upon the cathode, until we reach the point where no more electrons can be emitted from the cathode. This point is called "saturation." In other words, "you can't get what ain't there." The symbol for a VACUUM photo emissive tube or "Phototube" is shown in Fig. 7.

GAS FILLED TUBES

Previously, we have been concerned only with elements placed in a highly evacuated glass or metal tube. What happens if you use gas in a tube? If the gas is chemically active, it will com-

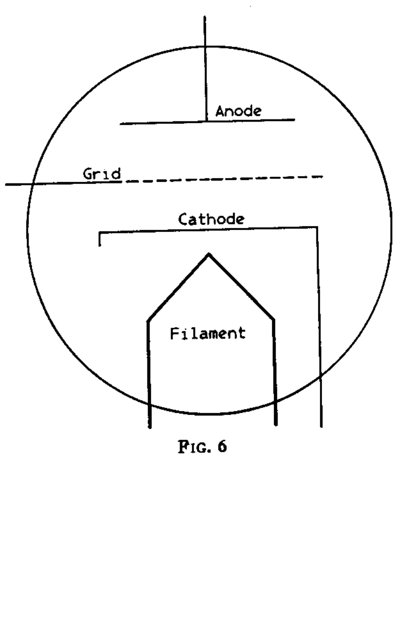

FIG. 6

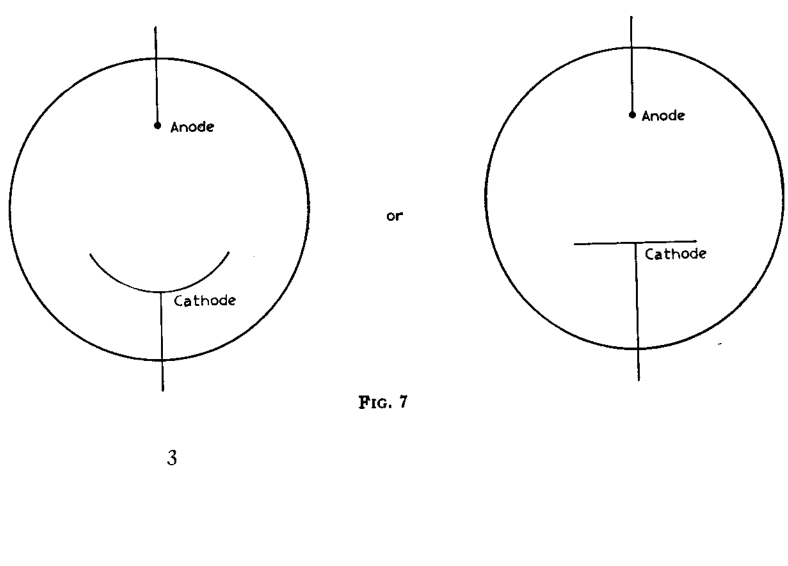

FIG. 7

bine with the tube elements, and build up the gas pressure in the enclosure until no more electrons can be driven off, or until the tube life is seriously impaired. Sometimes the gas is absorbed by the enclosing chamber or by the elements within the tube. However, if we are careful, and introduce into the tube an INERT gas, such as argon, under a pressure of approximately 2 thousandths of a millimeter of mercury, we get startling results.

Molecules of the INERT gas "fill" every nook and corner of this enclosure. Now, let us assume we have a properly "filled" gas tube with a heated filament and an anode, as shown in Fig. 8. We charge the anode POSITIVELY. The NEGATIVELY charged electrons are emitted by the filament and are immediately attracted by the POSITIVELY charged anode. Did you ever try running very fast down a crowded sidewalk? How many people did you bump into? Or is it easier to count those you missed? Well, that's the condition the fast moving electrons have to contend with when you put those great, big, slow-moving, neutrally charged molecules in their way. You can imagine what happens. An electron hits a molecule and knocks it for a "loop". Then that same electron is deflected and soon smacks into another molecule, then another and another on its way to the anode. Of course the electron slows up a bit with each collision just as a halfback does when he has the wind knocked

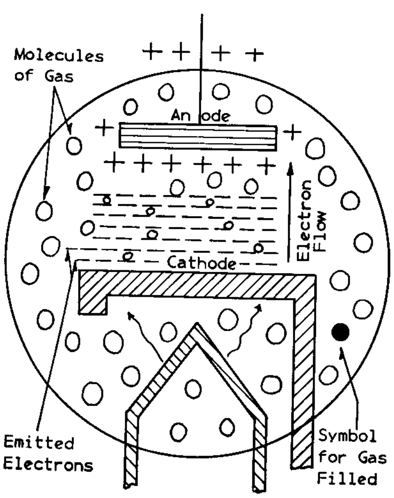

FIG. 8

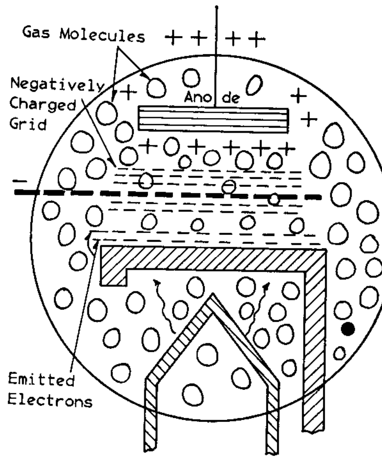

FIG. 9

out of him a few times. But what happens to the molecule?

Well, molecules are big and clumsy, so when the electrons traveling at enormous velocities hit them, the molecules lose one or more of their electrons which make up their construction. But this knocked-off electron is NEGATIVELY charged, so the molecule is left POSITIVELY charged, if we assume the molecule was neutrally charged before the collision. Let's see now. Won't the POSITIVELY charged molecule be attracted toward the NEGATIVELY charged electrons in the "space charge area", and near the filament? So there you see, there just isn't much space charge left because it is neutralized by the POSITIVELY charged molecules. We call this POSITIVELY charged molecule an "ION" and when we get enough ions in the partially evacuated enclosure so that we can conduct comparatively heavy currents we call the gas in this state "IONIZED". The "electrical resistance" of ionized gas is very much less than for un-ionized gas. These positively charged bodies or IONS, passing a given point per second, also represent an "electric current." Now we have an "electric current" composed of the original electron flow from the cathode, the electron flow composed of those electrons knocked out of the gas molecules, and the ion flow. Under these conditions we can get hundreds of thousands of times more current flow than we can in a plain Vacuum Tube. A gas-filled tube is sometimes called a "soft" tube.

THYRATRON TUBE

Any gas-filled, **grid-controlled,** hot cathode tube is known commercially as a "Thyratron". Let us place a grid element in Fig. 8 to make Fig. 9. If the grid is negative **BEFORE** the positive charge is placed on the anode, no electrons get over to the anode, hence no "electric current" flows. However, if we charge the grid positively, electrons can flow to the anode—in fact, they are helped along by the positive charge on the grid as in Fig. 10.

Suppose we try to stop the current flow in Fig. 10. We make the grid negative, but current DOES NOT stop! Why? Well, the positive ions surround the negative grid and it has no effect on the electrons. How do we stop this electron flow? The only way to stop current flow once a gas-filled tube has become ionized is to have the anode charge drop to zero, or open up the anode circuit. REMEMBER THIS!

The Function Played by Electronic Tubes

It might be well to start this discussion by stating that for most of our industrial applications, the electronic tubes are used simply as single pole, single throw switches. If it were possible to make a single pole, single throw knife switch fast enough and to operate in a partial vacuum from a few microwatts power, then there would be no need for

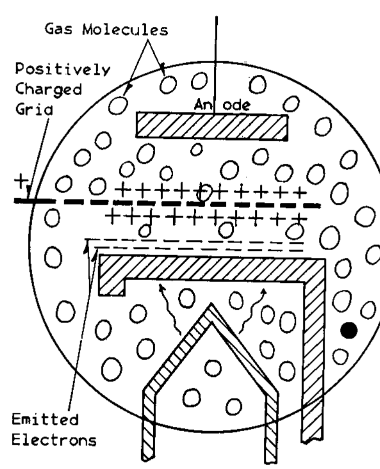

FIG. 10

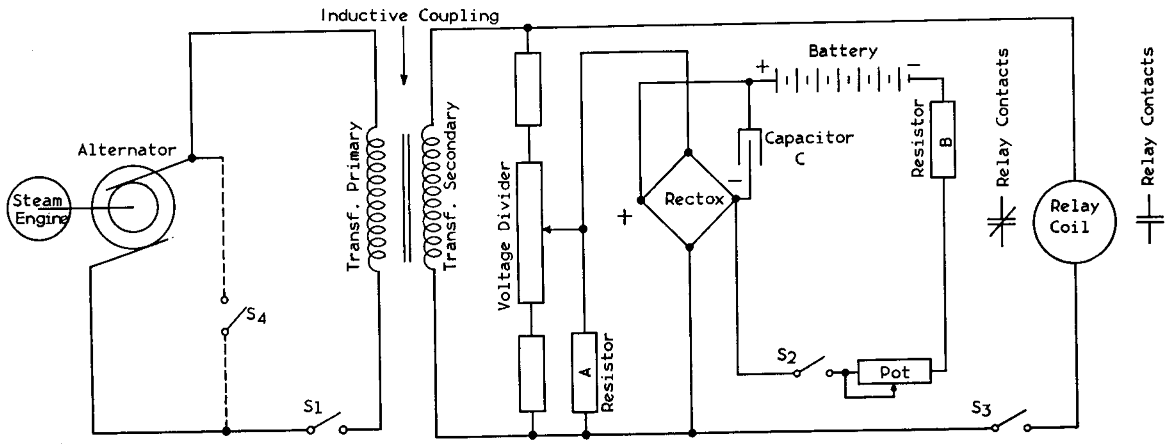

FIG. 11

electronic tubes. However, to move a knife switch blade as fast as an electron requires millions of watts of power and therefore is impractical.

We have two general classifications of electronic tubes. One class is built to handle a few watts load, and these tubes should be considered as replacing sensitive relays. Most of the vacuum tubes, and the smaller thyratron tubes are in this class. The other class is built to handle many watts and even many kilowatts, and should be considered as replacing larger relays or contactors. This class includes the larger thyratron tubes, but especially the ignitron and other high power tubes. You see, tubes are built in various sizes to handle various loads the same as relays and contactors are built in various sizes to handle various loads.

Let us emphasize once more that a tube in a circuit simply replaces a relay or a contactor. If we get this fundamental thought down in our minds, the circuits will be infinitely easier to understand. To be sure, we can do one or two fancy tricks to tubes to make them "think" for us, but that is of secondary importance to us at this moment.

The Components of an Electric Circuit

We shall describe a simple tube circuit, but first, what makes up a circuit? There are at least two parts to every useful circuit we shall use, mainly:

(1) The "source" of power supply, and

(2) The "load" or part in the circuit which "consumes" the energy supplied by the source.

The "source" of power supply may be one, or a combination of any two or more of the following:

(a) An alternating current generator.

(b) A transformer winding.

(c) A battery.

(d) A rectifier (either a rectox or an electronic tube).

(e) Any coupling action between two circuits such as capacity coupling, inductive coupling, resistor coupling, etc.

The "load" or power consuming device may be one, or a combination of any two or more of the following:

(a) A resistor or potentiometer.

(b) A reactor or a transformer primary.

(c) A capacitor.

(d) A relay.

(e) A rectifier.

To impress these various devices on our minds, let us break the following circuit, Fig. 11, into its various parts. A steam engine drives an alternator which sends an alternating electric current through the primary of the transformer. Thus, the alternator is the first source of supply of electrical energy. The transformer is the "load". Due to electro-magnetic induction, electrical energy is produced in the transformer secondary. This secondary winding is then the source of supply for the rest of the circuit. It feeds two loads, mainly, (1), the Voltage Divider, and (2) the Relay Coil. The voltage divider then becomes the source of supply for the load consisting of the rectox rectifier and the resistor A. Now the rectox rectifier has become a source of supply for the remainder of the circuit. It feeds a load consisting of the capacitor, resistor B, the potentiometer and the battery. The battery is also a source of supply in this circuit, acting to either increase the voltage across resistor B and the potentiometer, or to decrease this voltage depending on how it is connected in the circuit.

To properly control any of the above circuits, we could insert the switches S1, S2, S3. Therefore for proper control of any circuit, we may need switches. Switches may be relays, contactors, knife switches, etc., but they may also be **electronic tubes.**

Not any of us would thoughtfully connect a switch, S4, across a source of supply as in Fig. 11 without having a load in series with the switch. We all know the sound—"POOFF"—sniff—sniff—"something is burning!" Now **REMEMBER**, an electronic tube is a **SWITCH!**

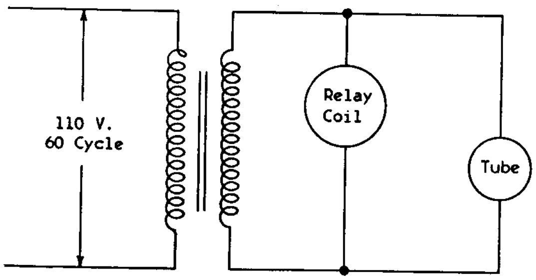

FIG. 12

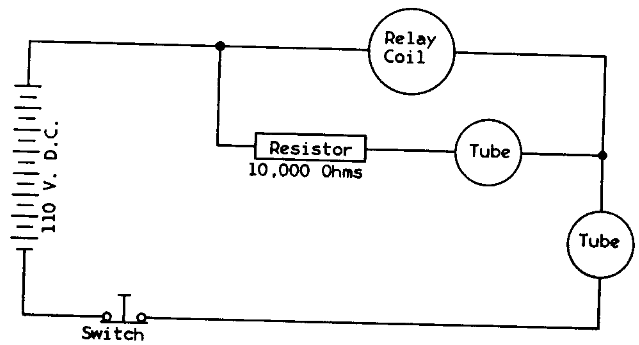

FIG. 13

What is wrong with Fig. 12. How would you improve it? What is wrong with Fig. 13. How would you improve it?

A Simple Electronic Tube Circuit

We shall now discuss a simple electronic tube circuit. We need (1) a source of supply, (2) a load, (3) a switch (our tube). These elements are shown properly connected in Fig. 14. This is the simplest circuit we have.

The source of supply—a battery.

The load—a resistor.

The switch—a thyratron tube.

Note that the anode of the tube is connected through the load to the + side of the battery. The tube could just as easily have been connected as shown in the auxiliary position ahead of the load resistor. The Grid-Cathode circuit has been connected up **first.** **Then** the anode-cathode circuit was connected up. Under these conditions the **grid** is 20 volts **more negative** than the **cathode,** so the tube **does not "fire"**, or does not become ionized. (The "Switch" is open.) We could also say the tube does not fire because the **cathode** is 20 volts **more positive** than the **grid.** (This terminology is sometimes very confusing, so we should do our best to master it NOW. Memorize the above circuit and you can't go wrong. It is rather convenient to remember that when the **grid** and **anode** are higher in voltage than the cathode, the tube will fire. If **grid** and **anode** are lower in voltage than the cathode, the tube **will not** fire. If the grid is lower than cathode, in general the tube will not fire. Always remember that the **grid** must be **more** than about 6 volts more negative than the **cathode** to prevent firing. This is called a "characteristic" of the tube.)

Let us close the initiating switch in Fig. 14. What happens? Well, let's see.

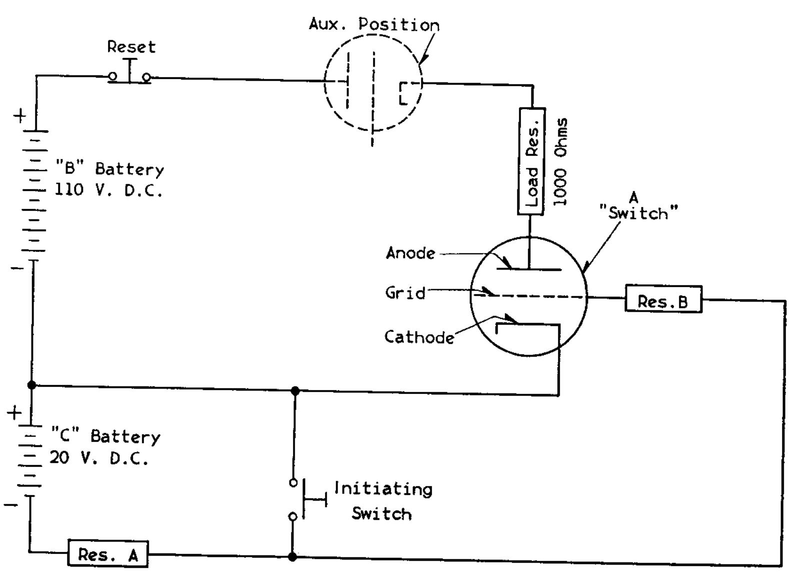

FIG. 14

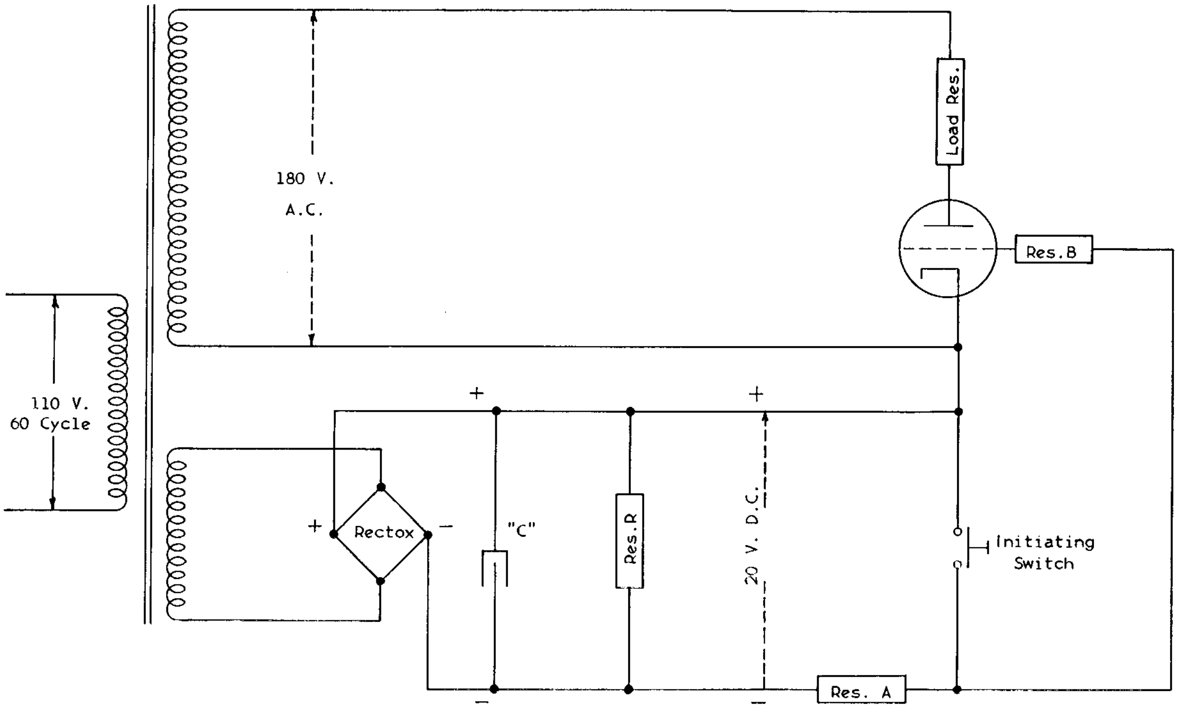

Fig. 15

The grid is now "tied" to the cathode, hence is not negatively charged. Current now flows in one **continuous** path in the direction from + of battery through resistor (load) to tube anode, through switch (the tube) to the tube cathode, thence to the negative side of the battery and through the battery to the + terminal. (This current flow is in conventional sense).

Now open the initiating switch. Oh, Oh! what is the trouble? The tube continues to fire and we can't stop it by opening the initiating switch. Why? Well, let's see. In order for the tube to stop firing once it has started, one of two things must happen. Either the voltage across the tube must drop to approximately zero, or the current must drop to zero. The current may take a long time to reach zero (when the battery is discharged) so we have to lower the voltage across the tube to almost zero (less than about 15 volts—the arc-drop voltage of the tube.) The only practical way to lower the voltage across the tube is to open the "Reset" switch. Remember what we have done here. This **always** happens when the Tube is a switch in a **Direct Current** circuit. What are Resistors A and B for? This circuit is called a "Trigger" circuit.

The Most Common Way of Getting Rid of the Reset Switch

Quite often we want to have the thyratron tube quit conducting when we open the initiating switch. A convenient way to do this is to replace Battery B, Fig. 14, by an alternating current power supply, the transformer winding in Fig. 15. We don't have to, but for convenience let us replace the battery C by a rectox rectifier for obtaining a D-C. voltage on the grid. Note that as far as the tube is concerned, the arrow marked "20 V D-C." could be a battery, and we could omit the rectox. The capacitor "C" is used to smooth out the full wave ripples from the rectifier.

We close the initiating switch to fire the tube. Upon opening the initiating switch, the tube seems to go out instantly. Why? Well, let's see. To "stop" the tube (or make it "non-conducting") we must lower the current

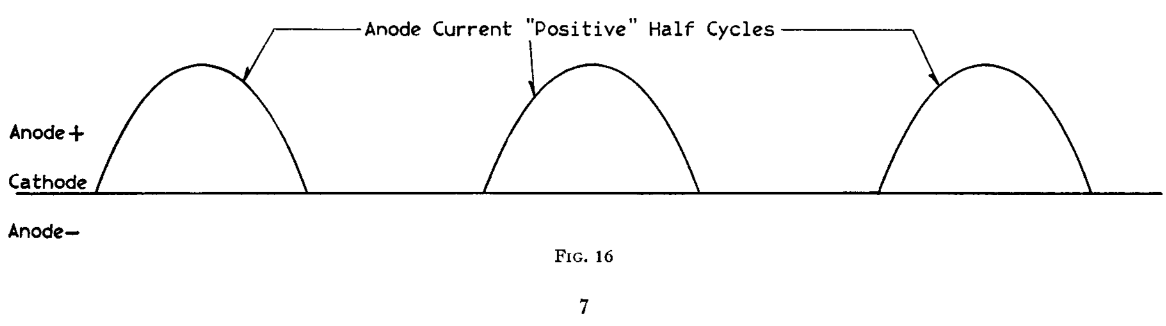

Fig. 16

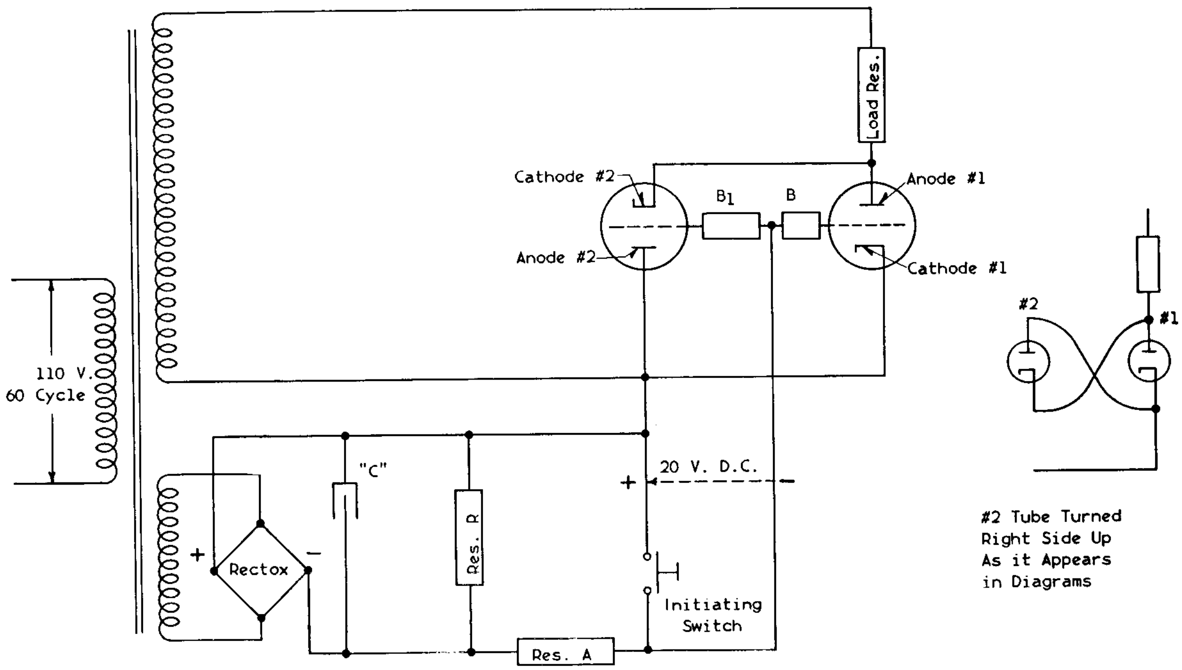

FIG. 17

to zero or lower the voltage across the tube to almost zero. We did neither of these things, but the tube went out. Why? Oh, but did we have to do anything—doesn't the alternating current go through zero twice each cycle? We open the initiating switch, then the very instant the alternating current decreases to zero, the tube **automatically goes out!**

There is one other important thing to notice about this circuit. We have an alternating current voltage across the anode-cathode of the tube. Every **odd** half cycle the anode is positive relative to the cathode. Let us, **by convention,** call this the positive half cycle. Please note that we **arbitrarily** call this the "positive" half cycle. Current can pass from **anode** to **cathode** if the grid permits it. But every **even** half cycle, the anode is negative (at a lower voltage) relative to the cathode. You will remember that no current can **normally** be conducted from the cathode to the anode (in conventional sense of current flow.) Hence we pass a current which looks like Fig. 16, through the tube and **through the load.**

Therefore, it must be remembered that the tube acts like a rectifier, in that only half wave current is passed to the load.

How to Conduct Alternating Current to the Load

It is not always best to conduct half wave current to the load. Half wave current is nothing more or less than pulsating direct current, and we know that direct current **may** saturate transformers or other electrical equipment. However, we do use a lot of half wave circuits. But in heavier work, or where efficiency is important, full wave current flow to the load is advisable.

Note in Fig. 16 that the anode becomes alternately plus and minus relative to the cathode. The current is only passed through the tube when the anode is positive. Suppose we connect another thyratron in parallel with the one in Fig. 15, but we shall connect the **anode** of this second tube to the **cathode** of the original tube. Also, we shall connect the **cathode** of this second tube to the **anode** of the original tube. This connection of the tubes is shown in Fig. 17, and is commonly called a "back-to-back" connection, or an "inverse parallel" connection.

Full wave alternating current is passed by this connection as shown in Fig. 18.

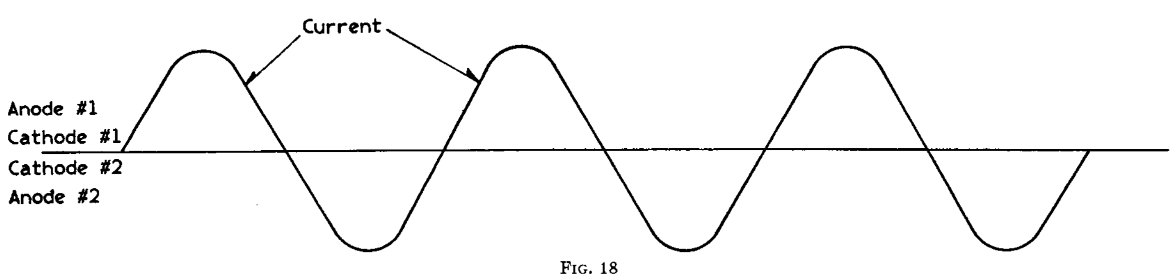

FIG. 18

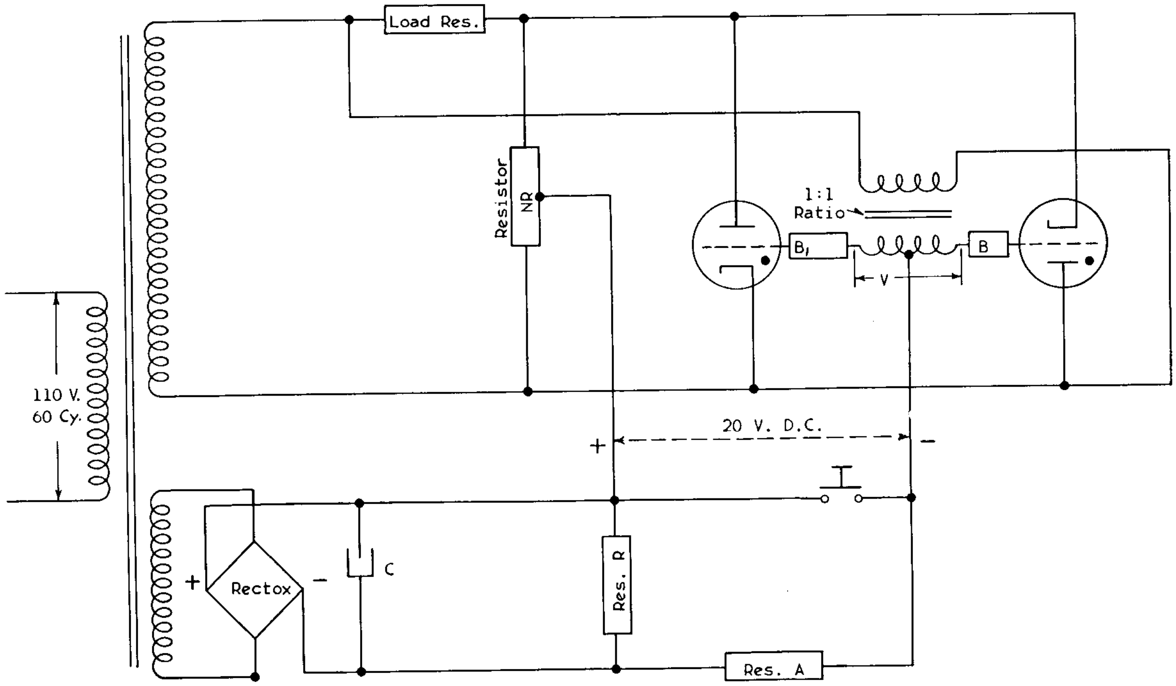

FIG. 19

However, with only 20 volts negative on the grid, and with, say, 180 volts across the anode-cathode circuit of Fig. 17, it would be impossible to stop total current flow in this circuit by opening the initiating switch. This comes about from the fact that even though the 20 volts negative is applied to the grid of tube #1, and this tube **would** become de-ionized, the grid voltage of tube #2 is still 235 volts more or less positive than the cathode. (Sine wave peak voltage of 180 x 1.414–20 volts D-C. = 235 volts at maximum point of wave). Thus tube #2 would remain ionized even though the initiating switch is opened.

To get around this peculiarity, it is common practice to use a "nullifying" resistor — transformer connection as shown in Figure 19. Here the midpoint of the voltage drop across resistor NR (line voltage across anode-cathode of each tube) is connected to the PLUS side of the 20 volt D-C. grid "biasing" supply, while the mid-point of the grid transformer is connected to the NEGATIVE side of this D-C. supply. Thus the A-C. voltage across resistor NR is "cancelled" by the A-C. voltage V on the grids as shown in Figure 20. Therefore the 20 volts D-C. is effective when the initiating switch is opened causing BOTH tubes to become non-conductive upon opening of the initiating switch.

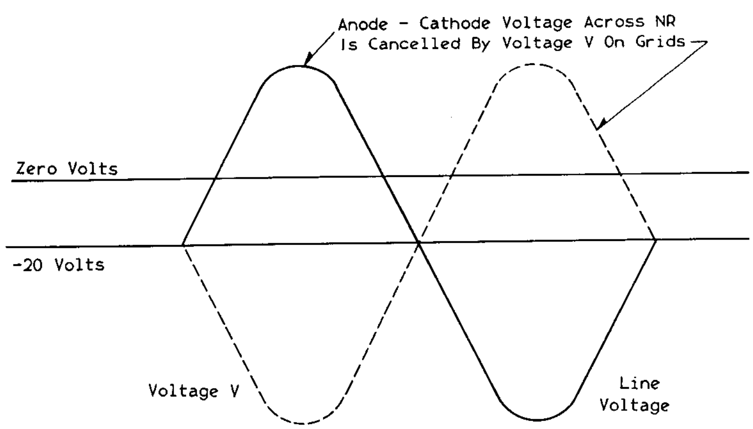

FIG. 20

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MEMORANDUM

(Use Ink)

WESTINGHOUSE ELECTRIC & MANUFACTURING COMPANY

Headquarters—306 4th Ave., Pittsburgh, Pa. P.O. Box 1017

*AKRON, OHIO, 106 South Main St.
*ALBANY, N. Y., 456 No. Pearl St.
*ALBUQUERQUE, NEW MEXICO, 219 First Nat'l. Bank Bldg.
*ALLENTOWN, PA., 522 Maple St.
*APPLETON, WISC., 210 N. Appleton St., P.O. Box 206
①¶#†*ATLANTA, GA., 1299 Northside Drive, N. W.
xATTICA, N. Y.
*†AUGUSTA, MAINE, 9 Bowman St.
*BAKERSFIELD, CALIF., 2224 San Emedio St.
¶*BALTIMORE, MD., 118 E. Lombard St.
†BALTIMORE, MD., 4015 Foster Ave.
xBALTIMORE, MD., 2519 Wilkens Ave.
†BATON ROUGE, LA., 128-134 So. Sixteenth St.
*BEAUMONT, TEXAS, 1213 American National Bank Bldg.
*BINGHAMTON, N. Y., Suite 704, Marine Midland Bldg., 86 Court St.
*BIRMINGHAM, ALA., 1407 Comer Bldg.
¶*BLUEFIELD, W. VA., 208 Bluefield Avenue
¶*BOSTON, MASS., 10 High St.
†#BOSTON, MASS., 235 Old Colony Ave., So. Boston, Mass.
¶*†BRIDGEPORT, CONN., 540 Grant St.
¶*BUFFALO, N. Y., 814 Ellicott Square
†#BUFFALO, N. Y., 1132 Seneca St.
*BURLINGTON, VER., 208 Flynn Ave.
*BUTTE, MONTANA, 129 West Park St.
#BUTTE, MONTANA, Iron & Wyoming Sts.
*CANTON, OHIO, 120 W. Tuscarawas St.
xCANTON, OHIO, Raff Road, S.W., P.O. Box 710
*CEDAR RAPIDS, IOWA, 361 21st St., S.E., P. O. Box 148
*CHARLESTON, S. C., 2 Greenhill St., P.O. Box 303
*CHARLESTON, W. VA., 1415 Oakmont Rd., P. O. Box 865
*†#CHARLOTTE, N. C., 210 East Sixth St.
*CHATTANOOGA, TENN., Volunteer State Life Bldg., Georgia Ave. & East Ninth St.
¶*CHICAGO, ILL., 20 N. Wacker Drive, P.O. Box B
†#CHICAGO, ILL., 2211 W. Pershing Road, P.O. Box 1103
¶*†#CINCINNATI, OHIO, 207 West Third St.
¶*#CLEVELAND, OHIO, 1216 W. Fifty-Eighth St.
†CLEVELAND, OHIO, 5901 Breakwater Avenue. Station A
*COLUMBIA, S. C., 125 S. Waccamaw Ave.
*COLUMBUS, OHIO, 85 E. Gay St.
*DALLAS, TEXAS, 209 Browder St.
#DALLAS, TEXAS, 1712 Laws St.
*DAVENPORT, IOWA, 206 E. Second St., P.O. Box 55
*DAYTON, OHIO, 30 North Main St.
¶*DENVER, COLORADO, 910 Fifteenth St.
#DENVER, COLORADO, 1700 Sixteenth St.
†DENVER, COLORADO, 988 Cherokee St.
xDERRY, PA.
*DES MOINES, IOWA, 1400 Walnut St.
¶*†#DETROIT, MICH., 5757 Trumbull Ave., P.O. Box 828
¶*DULUTH, MINN., 10 East Superior St.
x#EAST PITTSBURGH, PA.
*EL PASO, TEXAS, Oregon and Mills St.
#EL PASO, TEXAS, 450 Canal St.
①#*†EMERYVILLE, CALIF., 5915 Green St.
*ERIE, PA., 1003 State St.
①*EVANSVILLE, IND., 201 N. W. First St.
*†FAIRMONT, W. VA., 10th and Beltline Sts. P.O. Box 1161
*FORT WAYNE, IND., 1010 Packard Ave.
*FRESNO, CALIF., 872 Peralta Way, P.O. Box 1249
*GARY, IND., 846 Broadway
*GRAND RAPIDS, MICH., 511 Monroe Ave., N. W.
*GREENSBORO, N. C., Apartment H-3, Country Club Apartments
*GREENVILLE, S. C., 110 W. Tallulah Drive, P.O. Box 1591
*HAMMOND, IND., 235 Locust St.
*HARTFORD, CONN., 36 Pearl St.
*HONOLULU, T. H., Hawaiian Elec. Co. Agt.
¶*HOUSTON, TEXAS, 1314 Texas Ave.
#HOUSTON, TEXAS, 2301 Commerce Ave.
†HOUSTON, TEXAS, 2315 Commerce Ave.
¶†*#HUNTINGTON, W. VA., 1029 Seventh Ave.
¶*INDIANAPOLIS, IND., 137 S. Penna. St.
†INDIANAPOLIS, IND., 551 West Merrill St.
*ISHPEMING, MICH., 433 High St.
*JACKSON, MICH., 212 West Michigan Ave.
*JACKSONVILLE, FLA., 37 South Hogan St., P.O. Drawer K
*†JOHNSTOWN, PA., 107 Station St.
¶*KANSAS CITY, MO., 101 W. Eleventh St.
①#KANSAS CITY, MO., 2020-2024 Walnut Street, c/o Walnut Warehouse, Inc.
*KNOXVILLE, TENN., Gay & Clinch St.
①*LAS VEGAS, NEV., P.O. Box 712, 125 South Second St.
xLIMA, OHIO
¶*†#LOS ANGELES, CALIF., 420 So. San Pedro St.
*LOUISVILLE, KY., 332 West Broadway
xLOUISVILLE, KY., P.O. Box 1860
*MADISON, WISC., 1022 E. Washington Ave.
xMANSFIELD, OHIO, 246 E. Fourth St.
*MEMPHIS, TENN., 130 Madison Ave.
*MIAMI, FLA., 11 N. E. Sixth St., P.O. Box 590
¶*MILWAUKEE, WISC., 538 N. Broadway
†MILWAUKEE, WISC., 4560 No. Port Washington Rd.
¶†*#MINNEAPOLIS, MINN., 2303 Kennedy St., N.E.
*MONROE, LA., 1503 Emerson St., P.O. Box 1851
*NASHVILLE, TENN., 219 Second Ave., N.
*NEWARK, N. J., 1180 Raymond Blvd.
†#NEWARK, N. J., Haynes Ave. & Lincoln Highway
xNEWARK, N. J., Plane & Orange Sts.
*NEW HAVEN, CONN., 42 Church St., P. O. Box 1817
¶*NEW ORLEANS, LA., 333 St. Charles St.
#NEW ORLEANS, LA., 527 Poydras St.
¶*NEW YORK, N. Y., 40 Wall St.
*NIAGARA FALLS, N. Y., 253 Second St.
*NORFOLK, VA., 320 City Hall Ave.
*OKLAHOMA CITY, OKLA., 120 N. Robinson St.
#OKLAHOMA CITY, OKLA., Third & Alie Sts.
*OMAHA, NEB., 409 South Seventeenth St.
*PEORIA, ILL., 418 S. Washington St.
¶*†#PHILADELPHIA, PA., 3001 Walnut St.
*PHOENIX, ARIZONA, 11 West Jefferson St.
#PHOENIX, ARIZONA, 425 Jackson St.
xPITTSBURGH, PA., Nuttall Works, 200 McCandless Ave.
¶z*PITTSBURGH, PA., 306 4th Ave., Box 1017
#†PITTSBURGH, PA., 543 N. Lang Ave.
¶*PORTLAND, OREGON, 309 S. W. Sixth Ave.
†PORTLAND, OREGON, 2138 N. Interstate Ave.
#PORTLAND, OREGON, 720 N. Thompson St.
¶*†PROVIDENCE, R. I., 16 Elbow St.
*RALEIGH, N. C., 803 North Person St., P.O Box 2146
*RICHMOND, VA., 301 S. Fifth St.
*ROANOKE, VA., 726 First St., S. E.
*ROCHESTER, N. Y., 1048 University Ave.
*ROCKFORD, ILL., 130 South Second St.
*SACRAMENTO, CALIF., Twentieth & "R" Sts.
¶*ST. LOUIS, MO., 411 North Seventh St.
①†ST. LOUIS, MO., 717 South Twelfth St.
①#ST. LOUIS, MO., 710 N. Twelfth Blvd., c/o Central Terminal Co.
§*SALT LAKE CITY, UTAH, 10 West First South St.
①†SALT LAKE CITY, UTAH, 346 A Pierpont Ave.
①#SALT LAKE CITY, UTAH, 520 West Second South St.
*SAN ANTONIO, TEXAS, 115 W. Travis St.
*SAN DIEGO, CALIF., 861 Sixth Ave.
¶*SAN FRANCISCO, CALIF., 1 Montgomery St.
§SAN FRANCISCO, CALIF., 1355 Market St.
¶#†*SEATTLE, WASH., 3451 East Marginal Way
§SEATTLE, WASH., 1051 First Ave., So.
xSHARON, PA., 469 Sharpsville Ave.
①*SIOUX CITY, IOWA, 2307 Kennedy Drive
*SOUTH BEND, IND., 216 East Wayne St.
xSOUTH PHILA. WKS., Essington, Pa. First-class mail, P.O. Box 7348, Phila., Pa.
*SPOKANE, WASH., 158 S. Monroe St.
*SPRINGFIELD, ILL., 601 E. Adams St., Box 37
¶*†SPRINGFIELD, MASS., 395 Liberty St.
xSPRINGFIELD, MASS., 653 Page Boulevard
*SYRACUSE, N. Y., 420 N. Geddes St.
*TACOMA, WASH., 1115 "A" St.
*TAMPA, FLA., 417 Ellamae Ave., Box 230
*TOLEDO, OHIO, 245 Summit St.
xTRAFFORD, PA.
*TULSA, OKLA., 303 East Brady St.
¶*†#UTICA, N. Y., 113 N. Genesee St.
¶*WASHINGTON, D. C., 1434 New York Ave N. W.
*WATERLOO, IOWA, 328 Jefferson St., P.O. Box 147
*WICHITA, KANSAS, 233 S. St. Francis Ave.
¶*†WILKES-BARRE, PA., 267 N. Pennsylvania Ave.
*WORCESTER, MASS., 507 Main St.
*YORK, PA., 143 So. George St.
*YOUNGSTOWN, OHIO, 25 E. Boardman St.

Where address and P. O. box are both given, send mail to P. O. box, telegrams to address indicated.

WESTINGHOUSE AGENT JOBBERS

Westinghouse Electric Supply Company—Headquarters—150 Varick St., New York, N. Y.

Fully equipped sales offices and warehouses are maintained at all addresses.

ALBANY, N. Y., 454 No. Pearl St.
ALLENTOWN, PA., 522 Maple St.
①ATLANTA, GA., 1299 Northside Drive, N. W.
AUGUSTA, MAINE, 90 Water St.
BALTIMORE, MD., 40 South Calvert St.
BANGOR, MAINE, 175 Broad St.
BINGHAMTON, N. Y., 87 Chenango St.
BOSTON, MASS., 88 Pearl St.
BURLINGTON, VT., 208 Flynn Ave.
BUTTE, MONTANA, 50 East Broadway
CHARLOTTE, N. C., 210 East Sixth St.
CHICAGO, ILL., 113 North May St.
CLEVELAND, OHIO, 6545 Carnegie Ave.
COLUMBIA, S. C., 915 Lady St.
CORPUS CHRISTI, TEXAS, North end of Mesquite St.
DALLAS, TEXAS, 405 No. Griffin St.
DAVENPORT, IOWA, 402 E. Fourth St.
DES MOINES, IOWA, 1400 Walnut St.
DETROIT, MICH., 547 Harper Ave.
DULUTH, MINN., 308 W. Michigan St.
①ERIE, PA., 1013 State St.
EVANSVILLE, IND., 201 N. W. First St.
FORT WAYNE, IND., 612 S. Harrison St.
FORT WORTH, TEXAS, 210 Jones St.
GRAND RAPIDS, MICH., 511 Monroe Ave. N. W.
GREENVILLE, S. C., 226 Pendleton St.
HOUSTON, TEXAS, 1903 Ruiz St.
INDIANAPOLIS, IND., 137 S. Pennsylvania St.
JACKSONVILLE, FLA., 37 South Hogan St.
LOS ANGELES, CALIF., 905 East Second St.
MADISON, WISC., 1022 E. Washington Ave.
MEMPHIS, TENN., 366 Madison Ave.
MIAMI, FLA., 11 N. E. Sixth St.
MILWAUKEE, WISC., 546 N. Broadway
MINNEAPOLIS, MINN., 215 South Fourth St.
NEWARK, N. J., 49 Liberty St.
NEW HAVEN, CONN., 240 Cedar St.
zNEW YORK, N. Y., 150 Varick St.
NORFOLK, VA., 320 City Hall Ave.
OAKLAND, CALIF., Tenth & Alice Sts.
OKLAHOMA CITY, OKLA., 850 N. W. Second St.
OMAHA, NEB., 117 North Thirteenth St.
PEORIA, ILL., 412 S. Washington St.
PHILADELPHIA, PA., 1101 Race St.
PHOENIX, ARIZONA, 315 West Jackson St.
PITTSBURGH, PA., 575 Sixth Ave.
PORTLAND, OREGON, 134 N. W. Eighth Ave.
PROVIDENCE, R. I., 66 Ship St.
RALEIGH, N. C., 319 W. Martin St.
READING, PA., Fourth and Elm Sts.
RICHMOND, VA., 301 South Fifth St.
ROANOKE, VA., 726 First St., S. E.
ROCHESTER, N. Y., 1048 University Ave.
SACRAMENTO, CALIF., 20th and "R" Sts.
ST. LOUIS, MO., 1011 Spruce St.
ST. PAUL, MINN., 145 East Fifth St.
SALT LAKE CITY, UTAH, 235 West South Temple St.
SAN ANTONIO, TEXAS, 1211 E. Houston St.
SAN FRANCISCO, CALIF., 260 Fifth St.
SEATTLE, WASH., 1051 First Ave., So.
SIOUX CITY, IOWA, 1005 Dace St.
SPOKANE, WASH., 152 So. Monroe St.
SPRINGFIELD, MASS., 46 Hampden St.
SYRACUSE, N. Y., 961 W. Genesee St.
TACOMA, WASH., 1115 "A" St.
TAMPA, FLA., 417 Ellamae St.
TERRE HAUTE, IND., 234 So. Third St.
TOLEDO, OHIO, 1920 N. Thirteenth St.
TRENTON, N. J., 444 S. Broad St.
TULSA, OKLA., 307 East Brady St.
UTICA, N. Y., 113 N. Genesee St.
WASHINGTON, D. C., 1216 "K" St., N. W.
WATERLOO, IOWA, 328 Jefferson St.
WHEELING, W. VA., 1117 Main St.
WICHITA, KANSAS, 233 So St. Francis Ave.
WILLIAMSPORT, PA., 348 W. Fourth St.
WILMINGTON, DEL., 216 E. Second St.
WORCESTER, MASS., 17 Mulberry St.
YORK, PA., 143 S. George St.

* Sales Office † Mfg. and Repair Shop x Works # Warehouse § Merchandising Products Only z Headquarters ¶ District Eng. and Service Dept.

January, 1942

①Changed or added since previous issue.

Supersedes Issue dated November, 1941

R-816 Business Address