All-Purpose Power Transformers

LESSON 22 R

THE ELECTRIC POWER UNIT

RADIO-TELEVISION TRAINING SCHOOL, INC. · ESTABLISHED 1922 · LOS ANGELES

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THE ELECTRIC POWER UNIT

The vacuum tubes as used in radio receiving sets of today require two sources of electrical energy - an A-power unit for supplying a low voltage current to heat the filament so that the necessary electrons can be liberated, and a B-power unit for furnishing a high positive potential to be impressed on the plate of the tube. Some tubes require direct current for heating the filament, while others are designed for use with alternating current. But all tubes are alike in that they all need a smooth and direct high voltage on the plate. An alternating voltage cannot be used on the plate, for only a loud hum would result due to the pulsating plate current flow.

The most common source of this high plate pressure has been a number of small dry cells connected in series and grouped into what is known as a B-battery. No better plate voltage supply can be had than a good B-battery, for with all the individual cells in good condition a perfectly smooth and uninterrupted direct voltage will be had. But with the larger multitube receiving sets the plate current demand is so heavy that the B-batteries soon become exhausted and require replacement. Frequent installation of new B-batteries is rather costly, and a more economical plate voltage supply had to be developed. Naturally attention was turned to the electric power that is used for house lighting purposes. But this in most cases is alternating current at a pressure of 110 to 120 volts.

The power supply, therefore, is merely a device for changing the current from the electric light wires so that it can be used effectively for operating the plate circuits of the vacuum tubes. It contains first of all a transformer to step up the voltage to the desired value, a rectifier tube for changing the alternating to a direct current, a filter for smoothing out the current ripples, and a voltage divider for dividing the total voltage output into the various values required for operating the radio receiver. The advantages of a well constructed power supply are evident, for there is constantly available a plentiful supply of energy for operating the tubes in an efficient manner. If the filter is properly designed, the current flow will be almost as smooth and steady as with B-batteries. Also the operating and maintenance costs are comparatively small.

COMPONENT PARTS OF A POWER UNIT

As was suggested above, a power supply consists essentially of four units in the order illustrated in Fig. 1. The transformer is used to raise or lower the alternating line voltage to the various values needed for operating the different tubes or amplifiers with which it is to be used. It consists of a primary winding which is connected directly across the power line, and several secondary windings.

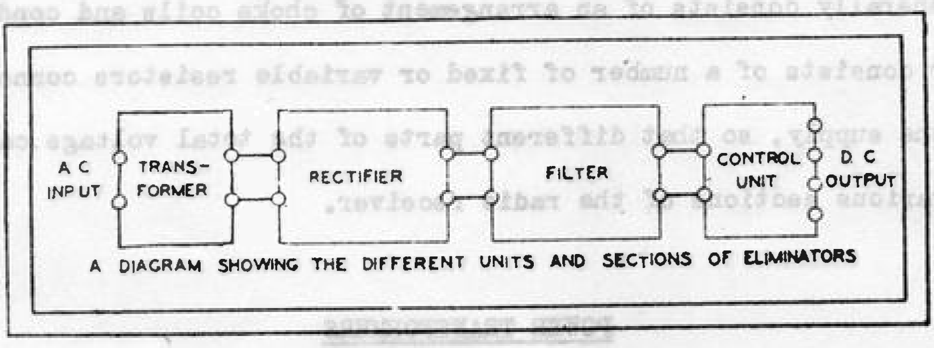


Fig. 1

The rectifier tubs is the unit that converts the alternating current to direct current.

The tubes as usad in the power supply are of two kinds. One is the heated filament rectifier, which operates on the same principle as the diode vacuum tube. In these tubes a filament which is impregnated with a material rich in electrons is heated to a high temperature, and the space within the tube becomes conductive. There is also a second element known as the plate. Electrons can then flow from the filament to the plate, but not in the opposite direction. As a result of this one-way conductivity, these tubes form excellent rectifiers. They are made both for half-wave and full-wave rectification. The 80 and the 81 rectifying tubes are of this type, and are discussed in greater detail later on.

The other type of rectifier tube represented by the Raytheon tube, employs no heated filament, but has within it a special gas that breaks down when subjected to the proper electrical conditions and permits the passage of electrons in only one direction through it. These tubes are designed for full wave rectification, and when properly constructed render very satisfactory and efficient service. Raytheon power supplies are discussed in detail in a later paragraph.

The filter is the unit of the power supply circuit that receives the rectified pulsating current and smooths out the ripples so that a steady and uniform current flow results. It generally consists of an arrangement of choke coils and condensers. The voltage divider consists of a number of fixed or variable resistors connected across the output of the supply, so that different parts of the total voltage can be used for operating the various sections of the radio receiver.

POWER TRANSFORMERS

The power transformer serves to provide the various voltages that are needed for operating the power supply and receiving set with which it is to be used. It consists of a primary winding which is connected directly to the power supply lines, and several secondary windings depending upon the kind of rectifying tube with which it is to be used.

At "A" in Fig. 2 is illustrated a typical transformer such as is used with the familiar Raytheon rectifying tube. It has a primary winding "P" and two secondary windings. S-1 is a 550-volt center-tapped winding which furnishes the high voltage for the power supply output, while S-2 is a 5-volt tapped winding that can be used for lighting the filament of one or two power tubes in the receiver. At "B" is shown a transformer such as is used with the type 80 full wave rectifying tube. S-1 is a

20-volt center-tapped winding and S-2 is a 5-volt winding for heating the filament of the rectifying tube. At "C" is shown a transformer such as is used with a type 81 half wave rectifying tube. Here S-1 is a tapped 750-volt high potential winding, while S-2 is a $7\frac{1}{2}$-volt winding for heating the filament of the rectifying tube. The transformer illustrated at "D" is similar except that it has a second filament winding for supplying one or two power tubes in the receiver or power amplifier.

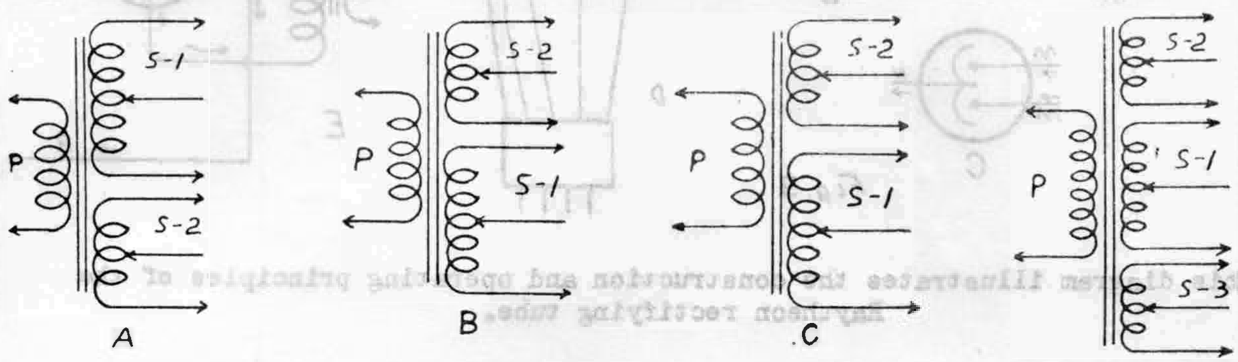
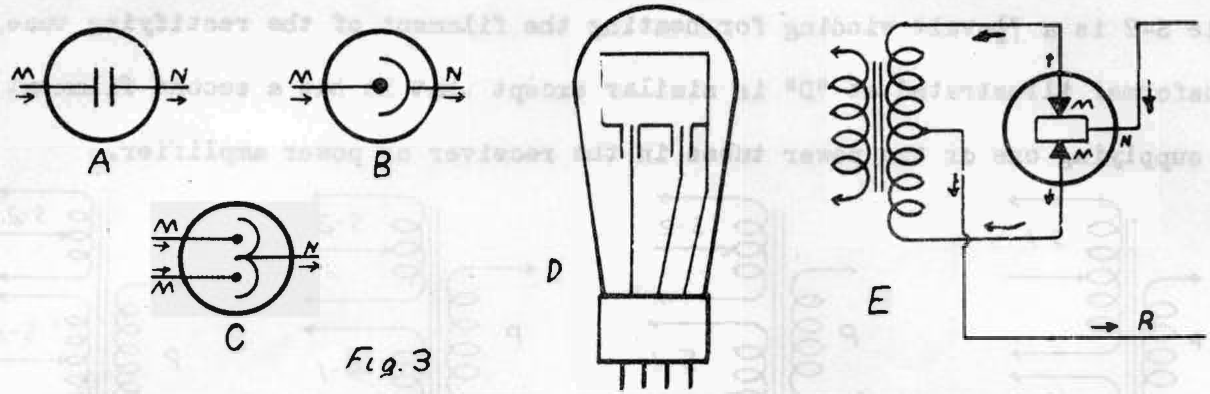


Fig. 2

In this diagram are illustrated some of the different windings that are used on transformers for power units.

THE RAYTHEON RECTIFYING TUBE

The Raytheon tube is a full-wave rectifying tube that employs no filament, is economical in operation, and can deliver an ample output at sufficiently high voltages to meet the requirements of presentday power tubes. It operates on the principle of unilateral or one-way conductivity of a low-pressure gas between electrodes of different sizes. For example, if we let "A" in Fig. 3 represent a container that is filled with helium gas at a low pressure and if a high alternating potential is impressed across the two similar electrodes "M" and "N", an alternating current will flow across the gap which seemingly is a perfect insulator. This current can flow as a result of the gas breaking down and permitting the electrons to jump across. But if one electrode is very small compared to the other, as "M" and "N" in part "B", the action is different. During the half cycle that "M" is positive, current can easily flow from "M" to "N"; t when "M" is negative with respect to "N", the current flow from "N" to "M" is so small that it is negligible. Therefore the arrangement acts as an excellent alternating current rectifier. If two small electrodes are used as is illustrated at "C", full wave rectification can be obtained.



This diagram illustrates the construction and operating principles of the Raytheon rectifying tube.

The Raytheon tube, as is illustrated at "D" in Fig. 3, consists of a glass bulb filled with rarefied helium gas and mounted on a standard base that fits both the standard and octal sockets. In the tube are also mounted three electrodes, two small and one large. The two small positive electrodes are mounted in glass tubes imbedded in a lava insulating support and project a slight amount into an inverted cup that forms the negative electrode. The cup is filled with helium gas at a very low pressure, and the electrodes are so designed and spaced that the rectifying action will take place in the proper manner. The two positive prongs are connected to what otherwise would be the filament prongs and the negative electrode to the plate prong. The grid prong is left free.

A Raytheon tube and its power transformer are generally represented as is illustrated at "E". The two black triangles represent the positive electrodes; in the horizontal block, the negative electrode is represented. As the electrodes "M" are alternately positive and then negative, current flows out of one plate when it is positive out through the center tapped coil to the load and back to the negative return to the tube marked "N".

THE ELECTRICAL FILTER CIRCUIT

The output of the rectifier of a power supply is in the nature of a pulsating direct current consisting of a succession of half waves. If these were applied directly to the plates of the tubes, a loud hum would result. It is therefore necessary to smooth out these ripples so that a steady and uniform current flow will be had. This is accomplished by the filter circuit.

The electrical filter circuit consists of an arrangement of choke coils and condensers as is illustrated in Fig. 4. Generally two choke coils and three large condensers are used. The choke coils permit the free passage of direct current but retard the flow of alternating or pulsating current. The condensers on the other hand permit the passage of alternating current but completely block the flow of direct current. At the same time they also act as storage tanks or reservoirs in which the energy can build up and not dissipate itself immediately.

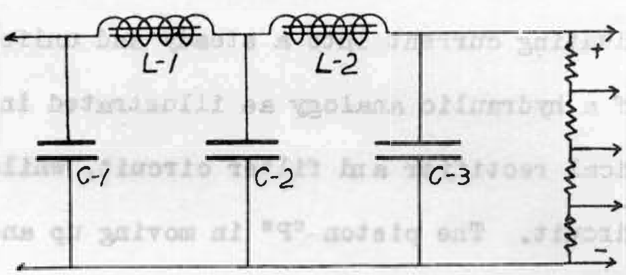


Fig. 4

Investigation has shown that the action of each of the three condensers of a 2-section filter such as is illustrated in Fig. 4 is different. The first condenser nearest the rectifier, C-1, does not have much influence on the hum or smoothing of the output current, but serves rather as a regulator for the rectifier. It becomes charged as the voltage rises and discharges when the voltage drops. As a result of this storage action it maintains the output at a steady voltage in spite of the fluctuating current drain. The next condenser C-2 controls the degree of hum, and the larger the condenser (up to a certain limit) the more is the hum suppressed. The third condenser C-3 controls the tone quality in that it acts as a stabilizer or electrical fly-wheel for the supply. It stores up energy and thus provides an ample reserve to meet any unusual demands made on the power supply. The reproduction of louder signals or low notes requires more energy, and therefore C-3 must be quite large in order to avoid distortion which would otherwise result if sufficient plate energy were not available. A condenser of at least 8 Mfds. should therefore be used for C-3. But a capacity of 2 Mfds. is quite satisfactory for condensers C-1 and C-2, and larger capacities would hardly produce any improved results. The choke coils should have an inductance of from 25 to 30 henries. In a filter system that will employ one choke and two electrolytic condensers, we usually use two condensers with an 8 Mfd. capacity.

HYDRAULIC ANALOGY OF AN ELECTRIC FILTER

Just how a filter consisting of an arrangement of choke coils and condensers is capable of smoothing a pulsating current into a steady and uniform flow, is more easily understood with the aid of a hydraulic analogy as illustrated in Fig. 5. At "A" is again illustrated the typical rectifier and filter circuit, while at "B" is the corresponding hydraulic circuit. The piston "P" in moving up and down within the cylinder causes a back and forth movement of the liquid corresponding to the alternating current supplied by the high voltage secondary of the power transformer. The values V-1 and V-2 correspond to the rectifying tubes T-1 and T-2. The coil of pipe "L" corresponds to the choke coil "L", while the containers C-1 and C-2 correspond to the condensers C-1 and C-2. The liquid and the electric current flow in the directions indicated by the arrows. The containers C-1 and C-2 are divided in two by means of the flexible membranes "M".

As the piston moves down, the liquid is forced out through valve V-2 into the external circuit. The back pressure on V-1 keeps it closed, and the return current enters the upper section of the cylinder through V-3. When the piston reaches the bottom, it comes to a stop and then moves upward. Now the liquid is forced out through V-1 while V-2 is held shut, and the return liquid enters the lower section of the cylinder through V-4. When the top is reached, the piston again reverses and the entire process is repeated. As a result of this up and down motion of the piston, a pulsating uni-directional current flow is sent into the external circuit at "A". It is now that the filter comes into action and smooths this pulsating current into a uniform and steady flow.

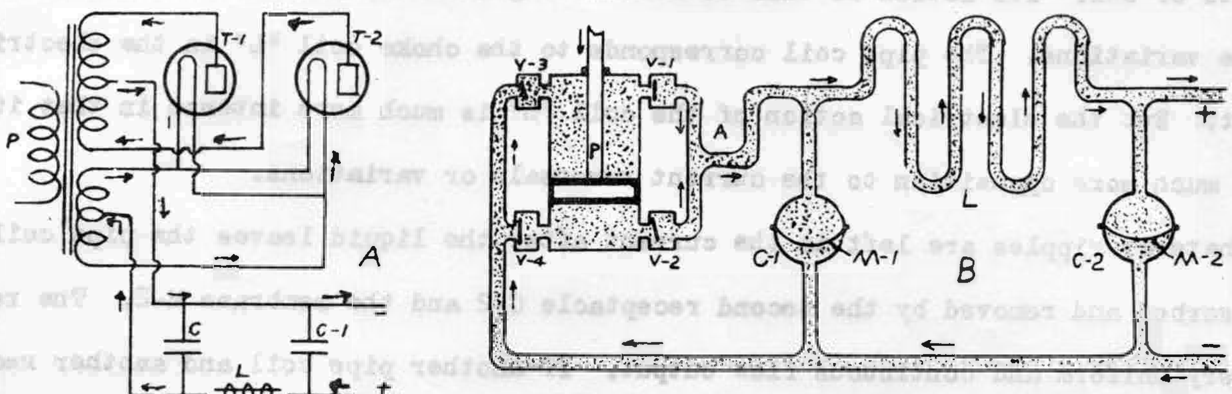


Fig 5

Here the electrical action of a filter circuit is illustrated with a hydraulic analogy. The filter receives the energy as a pulsating flow and delivers it as a uniform flow at a steady pressure.

With the downward motion of the piston a pressure is exerted upon the liquid which is forced out through "A". This pressure also is imparted to the liquid in C-1, causing the membrane M-1 to become stretched as illustrated. When the movement of the piston slackens at the end of the stroke, the pressure exerted also decreases. Immediately the membrane tends to return to its normal position and in this manner maintains the pressure and also the current flow. When the piston moves in the opposite direction, pressure is again exerted and the membrane distorted. At the upper extremity of its path when the exerted pressure again diminishes, the membrane returns to normal and tends to maintain the pressure. The distortion of the membrane is equivalent to charging the condenser C-1 - as the electric pressure increases during a cycle the condenser becomes charged, and during the second half of the cycle as the pressure diminishes, the condenser discharges and tends to maintain the pressure. The action of a filter condenser is thus to smooth the variations in voltage (pressure) and to maintain it at a uniform value.

To make the flow still more even, the liquid is passed through the pipe coil "L" which has many bends and thus offers much resistance. This resistance retards both the flow of liquid and also the rate at which the membrane can discharge the contents of C-1. Its action is thus to further regulate the current flow and to iron out the variations. The pipe coil corresponds to the choke coil "L" in the electrical circuit. But the electrical action of the coil "L" is much more intense in that it offers much more opposition to the current reversals or variations.

Whatever ripples are left in the current after the liquid leaves the pipe coil, are absorbed and removed by the second receptacle C-2 and the membrane M-2. The result is a very uniform and continuous flow output. If another pipe coil and another receptacle were used, the regulating action would be still more and a still smoother current flow would result. Of course, this improvement would be obtained only at the expense of additional energy loss in overcoming the frictional resistance of the system.

This hydraulic comparison also brings out very clearly the principles that the condensers serve to smooth out the voltage variations, while the choke coils smooth out the current variations. The condensers act like an energy reservoir that is alternately charged and discharged.

A RAYTHEON POWER AND FILTER CIRCUIT

A typical Raytheon power supply circuit is illustrated in Fig. 6. Complete building specifications are also given here, and if a power unit is constructed along these lines, most satisfactory service will be obtained from it.

"T" is a standard Raytheon power transformer. The terminals of the high voltage secondary winding are connected to the filament terminals of a standard socket into which a type "BH" Raytheon tube is placed. This tube has an output of 125 milliamperes. The two condensers "C" and "C" are known as buffer condensers, and each has a capacity of 0.1 Mfd. They are connected directly across the two sections of the transformer secondary, and balance any small inequalities that may occur in the two sections of the transformer winding. In this way the performance of the rectifier is greatly stabilized.

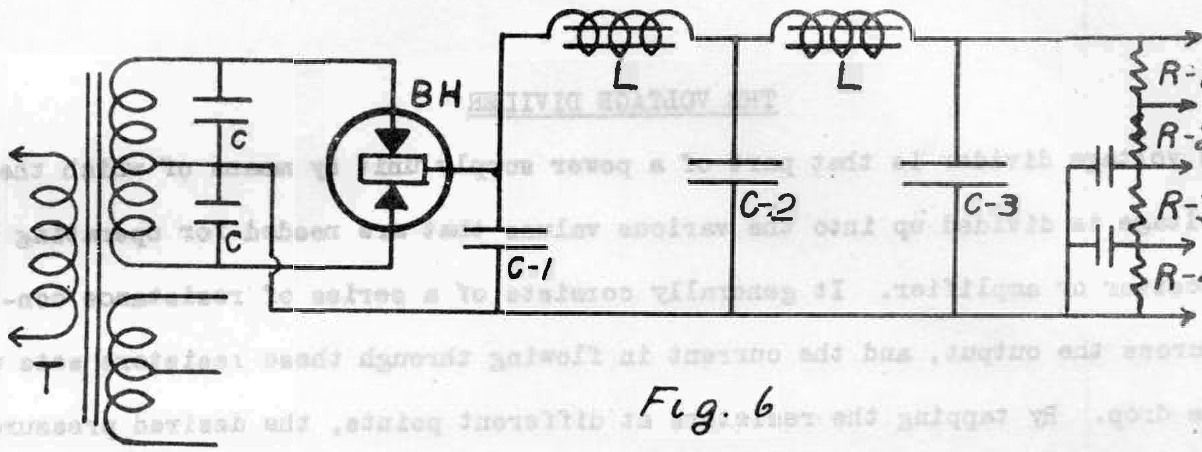


Fig. 6

This is a typical illustration of a Raytheon power supply circuit showing the buffer condensers "C", the "BH" rectifying tube, the filter circuit consisting of the two choke coils and the three condensers, and the voltage divider composed of a series of fixed resistors.

The next part is the filter circuit. This consists of two choke coils having an inductance of from 25 to 30 henries, and three filter condensers. The condenser C-1 has a capacity of 2 Mfds. and serves as a voltage regulator for the output of the power supply. The second condenser C-2 also has a capacity of 2 Mfds. and its chief effect is to absorb the voltage ripples. The third condenser C-3 is larger and has a capacity of 8 Mfds. Its duty is to serve as an energy reservoir or storage receptacle to take care of heavy demands that may be made in the power supply when loud signals are needed when deep base notes are being reproduced.

In the voltage divider which is used to separate the total voltage output into the various values that are needed for operating the radio receiver, a number of fixed resistors are shown connected in series. If the power supply is to be used with the average 5 or 6-tube set, the resistors should have the following values: R-1 equals 2000 ohms, R-2 equals 2300 ohms, R-3 equals 3500 ohms and R-4 equals 4000 ohms. Each resistor is shunted by a 1-Mfd. by-pass condenser to further absorb any hum that may be present. In the construction of any power supply it does not pay to skimp on the size or quality of the condensers, for these really determine the quality of the power supply output.

THE VOLTAGE DIVIDER

The voltage divider is that part of a power supply unit by means of which the total voltage is divided up into the various values that are needed for operating the radio receiver or amplifier. It generally consists of a series of resistance connected across the output, and the current in flowing through these resistors sets up a voltage drop. By tapping the resistors at different points, the desired pressures are obtained for operation of the receiver.

In some power supplies variable resistors are used, while in others fixed resistors are used. Both have their advantages and disadvantages. The chief objections to the variable resistors are that when they come into the hands of inexperienced persons they are adjusted and turned back and forth with the result that incorrect voltages are impressed on the radio circuits and the tubes cannot function properly. To measure the output voltages special high resistance voltmeters are necessary. With fixed resistors, on the other hand, these difficulties are overcome, and the set owner has no chance to tamper with any adjustment knobs. But the objection to the use of fixed resistors is that they must be specially designed for the set with which they are to be used, or the correct voltages will not be had. Slight variations in voltage, however, are not serious, for present day vacuum tubes are not so critical as to plate voltage and current, and therefore reasonably close values are satisfactory. Another feature in favor of the fixed resistors is that the output terminals of the power supply can be definitely marked, and consequently the power unit can be connected up like B-batteries without having to worry about any voltage adjustments.

A typical voltage divider circuit is illustrated in Fig. 7. Here a series of fixed resistors are shown connected across the output terminals with taps taken off at different intervals. Let it be assumed that the supply is to be used with a typical 5-tube T.R.F. set using a 171A power tube in the output stage. Measurements will show that the currents consumed by the various tubes are as follows: Power tube 18 milliamperes, first audio tube 2.5 milliamperes, detector 1.5 milliamperes and the two radio frequency tubes 7 milliamperes. The total consumption is thus 29 milliamperes. But it has been common practice to design the power supplies so that the total filtered current will be approximately 40 to 45 milliamperes, for best performance seems to be obtained under these conditions. Since the required current amounts to only 29 milliamperes, the remaining 11 milliamperes (40-29) will form a parasitic current that is put to no useful purpose, except that it helps to stabilize the action of the entire unit.

If the circuit is analyzed, the following conditions will be found to exist. A total of 40 milliamperes flow from the filter circuit toward point "A". Here the current divides and 18 milliamperes flow out at the 180-volt tap to the plate of the power tube. The remaining 22 milliamperes flow through resistor R-1 toward point "C". Since the resistance of R-1 is 4000 ohms, the voltage drop experienced here will be 4000 x .022 or 88 (approximately 90) volts. At "C" the current divides further and 9.5 milliamperes flow out at "D", the 90-volt tap, to the first audio and the two radio frequency tubes. The balance of 12.5 milliamperes (22-9.5) flows through R-2 toward "E". The voltage drop in R-2 is 3600 x .0125 or 45 volts. At "E" 1.5 milliamperes leave at the 45-volt terminal for the plate of the detector tube, and the remaining 11 milliamperes flow through R-3 toward "G". It is these 11 milliamperes that are put to no useful purpose.

The voltage drop in R-3 is 4000 x .011 or 44 (approximately 45) volts. At "G" the current again unites, 29 milliamperes returning from the set and combining with the 11 so that 40 milliamperes return to rectifier.

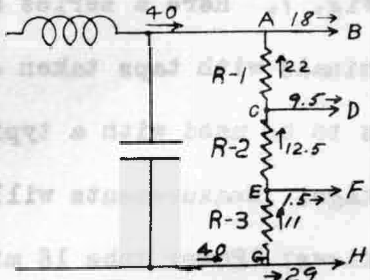


Fig. 7

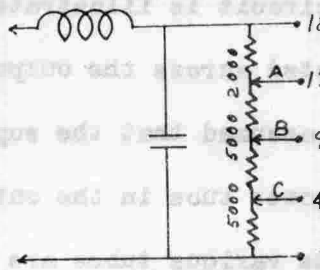


Fig. 8

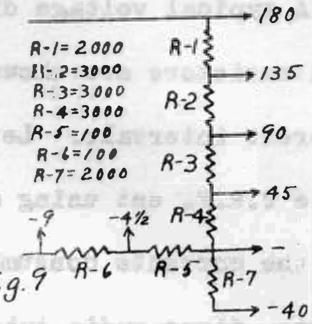


Fig. 9

From the above analysis it can be seen that if the plate current requirements of the receiving set are changed, the voltage drops in the various resistors will also be altered, and the terminal voltages at "D" and "F" will not be the same. But the differences will not be great enough to interfere seriously with the proper performance of the tubes. Of course, for best results the resistors should be designed in accordance with the current requirements of the radio set.

In Fig. 8 is illustrated another voltage divider circuit, this one being provided with variable resistors. It is evident that by adjusting the movable contacts at "A", "B" and "C", suitable voltage variations can be made to compensate for any changes in current requirements when the power unit is used with different receiving sets. Of course, as stated before it takes an experienced person to adjust these resistors correctly and also a high resistance voltmeter is required to measure the terminal voltages. Fig. 8 has three taps so that an intermediate pressure of 135 volts can be had for purposes where it may be needed.

A very important advantage of the voltage divider circuits illustrated in Figs. 7 and 8, is that on account of the idle current that always flows the voltage rise of the rectifier is limited when the external load is thrown off. There is consequently less danger of the condensers being punctured due to high peak voltages. This all refers to the design and manufacture of the radio receiver.

ELIMINATING THE C-BATTERY

A power transformer used with a Raytheon tube is usually designed to give a secondary voltage of 220 volts at the output of the filter circuit. With this pressure available the circuit can be arranged so that 180 volts of it are used for plate pressure purposes and 40 volts for "C" biasing purposes. Such a voltage divider circuit is illustrated in Figure 9. Four plate voltage taps are shown and three "C" biasing voltages. The action of resistors, R-1, R-2, R-3 and R-4 is as was explained in the previous paragraph. In series with the negative return lead are the two biasing resistors R-5 and R-6. Assuming that the total current is between 40 and 45 milliamperes, a voltage drop of about 4½ volts (100x .045) will take place across R-5 and a similar drop across R-6, making the total drop 9 volts. By bringing the plate return of the power tube through resistor R-7, a 40-volt drop will take place across it, and this then becomes the C-biasing voltage for the tube.

A RAYTHEON HIGH VOLTAGE ELIMINATOR

Power tubes of the 210 type function best when plate pressures of from 350 to 425 volts are used, for only then can real advantage be taken of their maximum output capacity. But the standard power supply employing the gaseous rectifying tube is limited to an output voltage of from 180 to 220 volts, and therefore it cannot be used directly.

It is an easy matter, however, to combine two such power supplies into one, that is connect them in series, and in this manner obtain the desired higher voltages. A combination employing two rectifying tubes is illustrated in Fig. 10. As can be seen, two similar power transformers, T-1 and T-2, are employed, and across each one is connected a pair of 0.1 Mfd. buffer condensers. The rectified output of the first rectifier tube V-1 instead of being sent out into the line, is fed into the input of the second transformer. Here it is added to the output of the other rectifier V-2 with the result that double the output voltage is obtained. By using two type "BH" Raytheon tubes an output of 85 milliamperes can be obtained at a pressure of 435 volts.

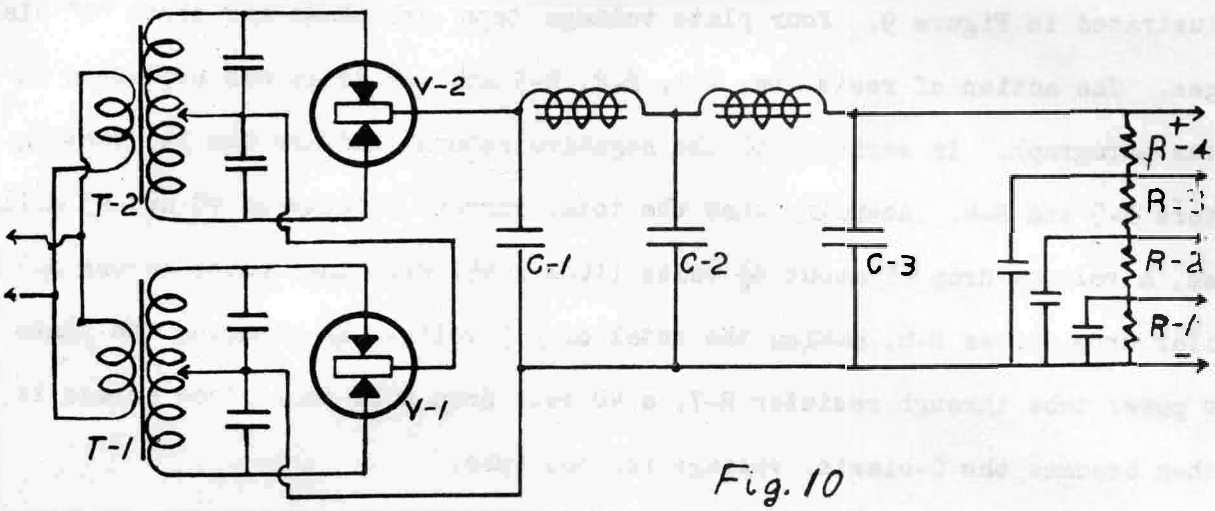


Fig. 10

This circuit diagram illustrates a high voltage Raytheon power supply in which two standard Raytheon tubes V-1 and V-2 are connected in series. In this way the voltage output of the two tubes are added, and a high plate pressure is made available.

The condenser capacities are of the same values as used in the standard Raytheon circuit, that is C-1 and C-2 are 2 Mfds. each and C-3 is 8 Mfds. However, the condensers should be built for a working voltage of 750 volts. This is necessary so that they will be able to stand up under the high voltages to which they may be subjected in case the load is taken off the power unit, such as when the filament of the 210 power tube is not lighted. Therefore, care should always be taken that the filament of the power tube is turned on while the power supply unit is on.

Any desired voltage taps can be obtained by the use of suitable resistance units and bypass condensers. If the power unit is to be used with a 5 or 6-tube set employing a 210 power tube in the output stage, a variable resistor having a range of from 0 to 20,000 ohms should be used for R-1 and fixed resistors of 10,000 ohms each for R-2 and R-3 and 18,000 ohms for R-4. The by-pass condensers should have a capacity of 1 mfd. each. The main thing to observe is to protect the unit against high peak voltages.