INSTRUCTIONS FOR PERFORMING RADIO EXPERIMENTS 31 TO 40

4 RK-AC

NATIONAL RADIO INSTITUTE

ESTABLISHED 1914

WASHINGTON, D. C.

PIONEER HOME STUDY RADIO SCHOOL

NRI

A COURSE IN PRACTICAL DEMONSTRATIONS OF RADIO FUNDAMENTALS

A PLAN FOR TODAY

I WILL AWAKEN: With a smile brightening my face; with reverence for this new day in my life and the opportunities it contains.

I WILL PLAN: A program which will guide me successfully past the many temptations and distractions of a busy day and bring me one step closer to my goal of success.

I WILL WORK: With my heart always young and my eyes open so that nothing worth while shall escape me; with a cheerfulness that overcomes petty irritations and unpleasant duties; with the purpose of my work always clearly in mind.

I WILL RELAX: When tired, so as to accumulate fresh energy and live long enough to enjoy the success my work will bring.

I WILL PLAY: With the thought that today is my day, never to be lived over again once it is ended; with relaxation and pure enjoyment as the only purposes of play; putting work and worldly worries out of mind for this short portion of my day.

I WILL RETIRE: With a weariness that woos sleep; with the satisfaction that comes from a day well lived, from work well done.

I WILL SLEEP: Weary but content; with tomorrow a vision of hope.

J. E. SMITH

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

1950 Edition

THIS EXPERIMENTAL MANUAL IS A PART OF THE N. R. I. COURSE WHICH TRAINS YOU TO BECOME A RADIOTRICIAN & TELETRICIAN
(REGISTERED U. S. PATENT OFFICE) (REGISTERED U. S. PATENT OFFICE)

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Instructions for Performing Radio Experiments 31 to 40

Introduction

THE next ten experiments, as well as later experiments, call for the use of a power pack which will supply a.c. and d.c. voltages having values corresponding to those encountered in actual radio receivers. Before beginning these experiments, you will assemble a power pack with the parts furnished you in Radio Kit 4RK-AC and in previous radio kits.

An a.c. source having some definite voltage and frequency is usually the main source of power for the vacuum tube system in a radio receiver, transmitter or public address system. This a.c. source is usually a wall outlet which is connected to a 115-volt, 50 or 60-cycle power line.

The main a.c. source of power cannot ordinarily be connected directly to vacuum tube circuits, for the requirements of the various tube electrodes are quite different.

Voltage Requirements of A.C. Receivers. First of all, the a.c. line voltage must be reduced to the correct lower a.c. values for heating the filaments of radio tubes. The rectifier tube in the power pack of an a.c. receiver usually requires a separate 5-volt or 6.3-volt a.c. source for its filament, and the rest of the tubes have their filaments connected in parallel to a common 6.3-volt a.c. source. (In older a.c. receivers, you may encounter tubes having 2.5-volt filaments.)

A secondary winding which is provided on the power transformer of an a.c. power pack for stepping down the line voltage to the required filament value is commonly called a *filament winding*. The power transformer which is supplied for your a.c. power pack has two filament windings, one being a 5-volt winding for the rectifier tube in the power pack, and the other being a 6.3-volt winding for the tubes which you will use in your experiments later on. Thus, you will be working with the same filament voltage values used in modern a.c. receivers.

Secondly, the a.c. line voltage must be converted to a high d.c. voltage value having as little a.c. ripple as possible, and various proportions of this maximum d.c. voltage must be distributed to the various grid and plate electrodes in the vacuum tube circuit. As you learned in your regular course, this voltage conversion is accomplished in three steps, by using a power transformer to step up the a.c. line voltage, rectifying the resulting high a.c. voltage with a rectifier tube, then filtering out the ripples in this pulsating d.c. output with a condenser-input filter system.

In addition to the two filament windings already described, the power transformer which is supplied you in Radio Kit 4RK-AC has a center-tapped 750-volt secondary winding which provides the required high a.c. voltage for the vacuum tube rectifier. This winding is commonly called the *high-voltage secondary winding*. The voltage between the center tap and each outer terminal of the winding is about 375 volts.

The a.c. power pack which you will build thus consists essentially of a power transformer, rectifier tube, choke coil and filter condensers, connected exactly like the power packs of a.c. radio receivers.

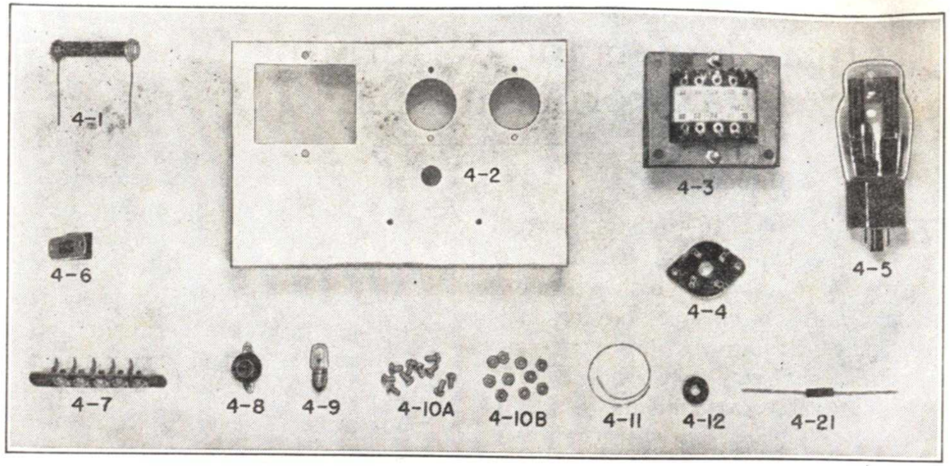


FIG. 1. The parts included in Radio Kit 4RK-AC are pictured above, and are identified in the list below. Some resistors may have a better tolerance (lower percentage tolerance) than that indicated here.

Part No.	Description
4-1*	One 50,000-ohm, 3-watt resistor with 20% tolerance (color-coded green, black, orange).
4-2	One cadmium-plated steel chassis bent to shape, with all holes already punched.
4-3	One power transformer for 115 volt, 50 or 60-cycle a.c. power.
4-4	One octal-type tube socket with four terminal lugs.
4-5	One type 5Y3G full-wave rectifier tube.
4-6	One slide-type power switch.
4-7	One 5-terminal, screw-type binding post strip.
4-8	One pilot lamp socket with rubber grommet.
4-9	One 6.3-volt pilot lamp.
4-10A	Ten ¼-inch long, 6-32 cadmium-plated binder-head machine screws.
4-10B	Ten cadmium-plated hexagonal nuts for 6-32 screws.
4-11	One 3-ohm length of nichrome resistance wire.
4-12	One small rubber grommet.
4-21	One 10-megohm, ½-watt resistor with 10% tolerance (color-coded brown, black, blue, silver).

* You may receive a 47,000-ohm, a 50,000-ohm, or a 51,000-ohm resistor as Part 4-1, depending on what we have in stock when we pack your kit. Use whatever value you receive for this part where the 50,000-ohm listed value is called for.

The following parts which were supplied to you in earlier radio kits will be used again in the next ten experiments, so assemble these parts along with the new parts received in Radio Kit 4RK-AC.

Part No.	Description
1-8D	One ⅝-inch soldering lug.
1-16	One 18,000-ohm, ½-watt resistor with 10% tolerance (color-coded brown, gray, orange, silver).
3-2A & B	Two .25-mfd., 400-volt paper condensers.
3-3	One dual 10-10-mfd., 450 working volts electrolytic condenser with bakelite mounting piece.
3-4	One 200-ohm, 1-watt resistor with 20% tolerance (color-coded red, black, brown).
3-5A	One 1,000-ohm, ½-watt resistor with 10% tolerance (color-coded brown, black, red, silver).
3-6A, B, C & D	Four 40,000-ohm, 3-watt resistors with 20% tolerance (color-coded yellow, black, orange).
3-10	One 10-henry choke coil with 25-ma. current rating.
3-11	One 5-foot power line cord with attached outlet plug.

Power Pack Experiments. With your a.c. power pack, you will demonstrate that the output voltage drops and ripple output goes up as the load on the power pack is increased. The first effect, in which the d.c. output voltage drops with load, is known as the *voltage regulation* of a power pack.

Your power pack is normally connected for full-wave rectification and a condenser-input filter system. You will disconnect one filter condenser to secure choke input, then disconnect one plate lead of the rectifier tube to secure half-wave rectification, and check the performance of the power pack with your N.R.I. Tester in each case. You will insert resistors to duplicate the practical conditions in which electrolytic condensers become defective, and make measurements which will enable you to recognize these same defects in actual receivers.

We have mentioned here only a few

of the highly practical power pack experiments presented in this manual. By the time you have completed Experiment 40, you will have a thoroughly practical understanding of power packs.

Contents of Radio Kit 4RK-AC

The parts included in your Radio Kit 4RK-AC are illustrated in Fig. *1* and listed in the caption underneath. Check off on this list the parts which you received, to be sure you have all of them. Do not destroy any of these parts until you have completed your entire N.R.I. course, for many of the parts will be used over and over again in later experiments.

IMPORTANT: If any part in your Radio Kit 4RK-AC is obviously defective or has been damaged during shipment, please return it to the Institute *immediately* for replacement.

Instructions for Assembling the A.C. Power Pack

Step-by-step instructions for assembling the a.c. power pack will now be given. Follow through these instructions slowly and carefully, doing the very best work of which you are capable, for you will use this power pack during the remainder of your practical demonstration course, and will want your unit to show professional workmanship in every soldered joint. To make sure that you do not miss any of the steps in the assembly procedure, make a check mark alongside each completed step as you go along.

The schematic circuit diagram for this power pack is presented in Fig. *2* for reference purposes. Later, you will be able to assemble radio apparatus from diagrams like this alone, but at the present stage in your course of training, we still recommend that you follow the pictorial diagrams which are presented in this manual to show each stage in the assembly procedure. Remember that we are ready to help you with advice if you should encounter any difficulty in assembling this power pack or in understanding the instructions.

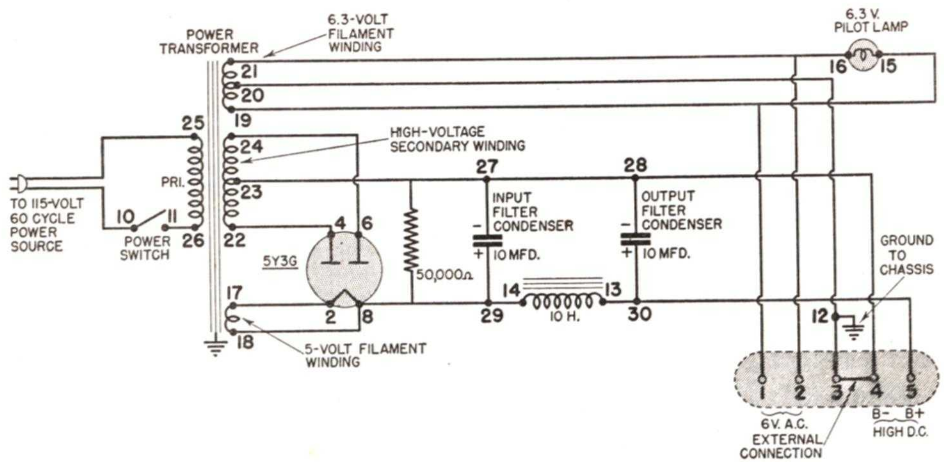


FIG. 2. Schematic circuit diagram for the a.c. power pack which you build before beginning the experiments in this manual. The terminals on this schematic diagram are numbered to correspond with the terminals shown on the semi-pictorial diagrams in Figs. *5* and *8*.

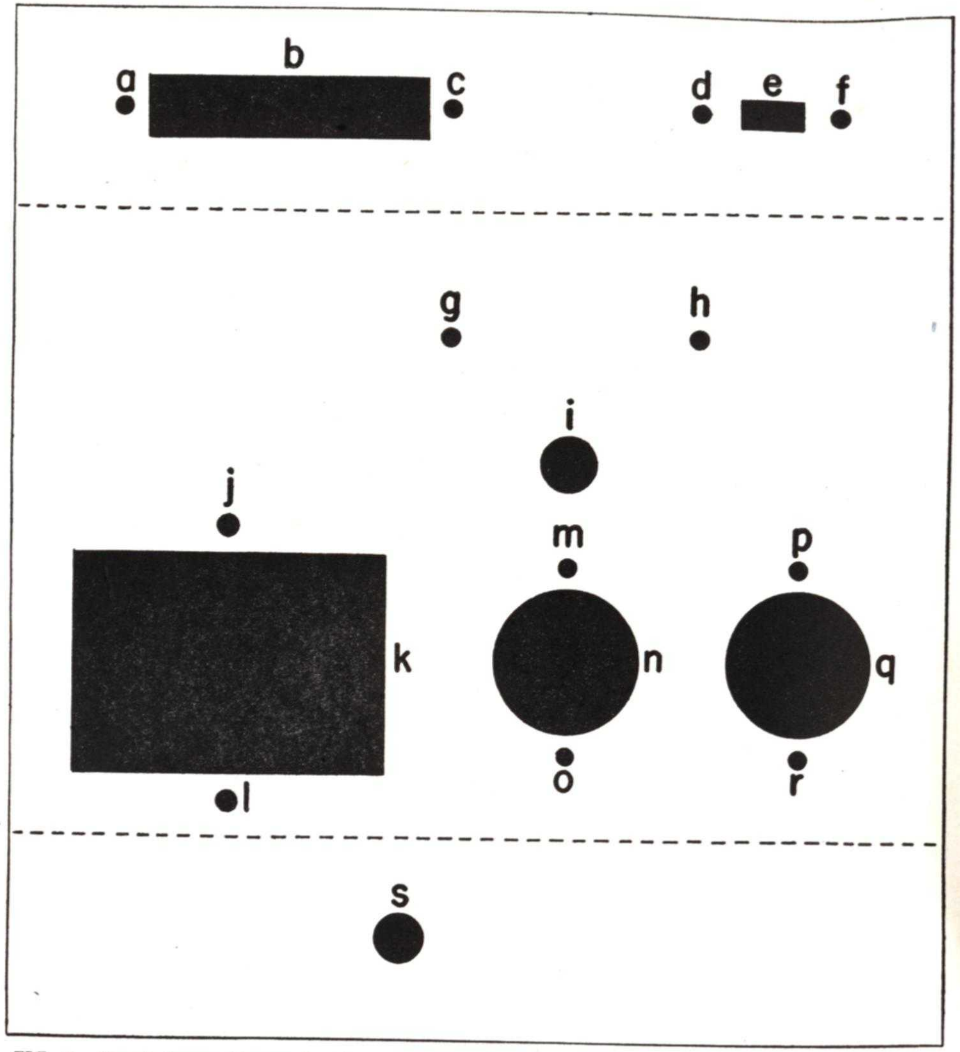


FIG. 3. Chassis layout diagram for the a.c. power pack, drawn to show what you would see if you looked at the bottom of the chassis while it was a flat sheet (before bending the sides). The holes are lettered here merely for your convenience in locating on your own chassis the correct mounting holes for the various parts; do not mark the holes in this manner on your chassis, for this diagram is entirely sufficient for assembly purposes.

Mounting the Parts on the Chassis

Step 1. To prepare for the assembly of the power pack, place before you the following parts:

50,000-ohm resistor (Part *4-1*).
Cadmium-plated steel chassis (Part *4-2*).
Power transformer (Part *4-3*).
Octal-type tube socket (Part *4-4*).
Type 5Y3G rectifier tube (Part *4-5*).
Slide-type power switch (Part *4-6*).
Five-terminal screw-type binding post strip (Part *4-7*).
Pilot lamp socket with grommet (Part *4-8*).
Pilot lamp (Part *4-9*).
Ten ¼-inch binder-head machine screws (Part *4-10A*) with ten hexagonal unts (Part *4-10B*).
Rubber grommet for power line cord (Part *4-12*).
⅝-inch soldering lug (Part *1-8D*).
Dual 10-10-mfd. electrolytic condenser with bakelite mounting piece (Part *3-3*).
Ten-henry choke coil (Part *3-10*).
Power line cord with plug (Part *3-11*).

Step 2. To mount in hole s the grommet for the power line cord, place the chassis before you in such a position that the holes correspond with the chassis layout diagram in Fig. *3*. Hole *s* should now be near the center of the side closer to you. Take the rubber grommet (Part *4-12*) and squeeze it into an oval shape while holding it with the thumb and forefinger of your right hand. Now place the grommet in hole *s* in the manner shown in Fig. *4*, with the chassis fitting into the groove in the grommet. Carefully push the remainder of the grommet into this hole with your fingers until half the grommet is on each side of the chassis, with the chassis fitting into the rubber groove in the grommet at all points. This grommet will now have the position shown in Fig. *5*.

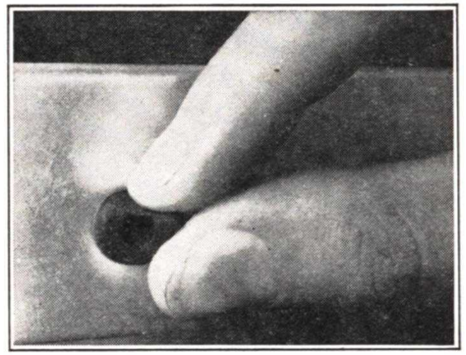


FIG. 4. Squeeze the grommet for the power line cord between your thumb and forefinger in the manner shown here while forcing it into hole *s* in the side of the chassis. This grommet can be placed in position with your fingers; it may take a little time at first, but you will soon get the "knack" of doing this radio job.

Step 3. To mount the pilot lamp socket in hole i on the chassis, first remove the large rubber grommet from the pilot lamp socket (Part *4-8*). Squeeze this grommet into an oval shape while holding it between the thumb and forefinger of your right hand, and work the grommet into hole *i* (see Fig. *3*) on the chassis in exactly the same manner as described in Step 2 for the power line grommet. To force the pilot lamp socket itself up through the grommet which you have now inserted in hole *i*, grasp the socket near its terminal lugs with your fingers, push the threaded part gently into the grommet from the bottom of the chassis as far as it will go without forcing, turn the socket in a clockwise direction until one of the lugs touches the grommet, then rotate the socket just enough farther to line up the lugs parallel to the sides of the chassis. When looking at the bottom of the chassis, the pilot lamp socket will now appear as shown in Fig. *5*.

Step 4. To mount the electrolytic condenser on the chassis, take the bakelite mounting piece for this condenser, and hold it against the *top* of the chassis over holes *p*, *q* and *r* in such a manner that the slots have the positions shown in Fig. *5*. Bolt the piece to the chassis with two machine screws and nuts (Parts *4-10A* and *4-10B*) inserted in holes *p* and *r*, with the screw heads above the chassis.

Now take the electrolytic condenser (Part *3-3*) and insert its lugs in the slots of the bakelite mounting piece from the top of the chassis in such a

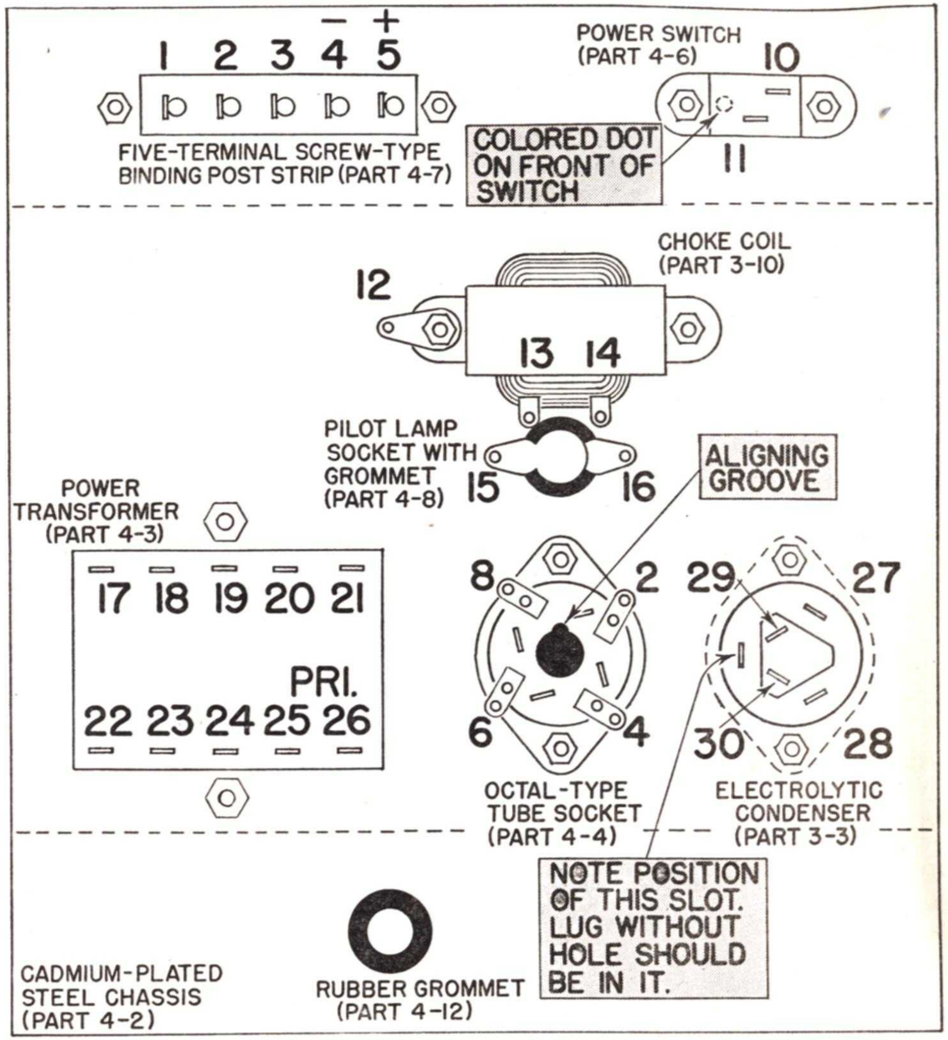


FIG. 5. Bottom view of chassis with sides spread out, showing exact positions of all parts which are mounted directly on the chassis, and showing positions of all numbers which you are to place on the chassis and on the parts with metal-marking crayon. The dotted lines indicate the positions of the bends in the chassis.

way that *the outer lug which has no hole* in it will be *next to hole n* on the chassis. If this condenser is inserted correctly, the two large inside lugs at the bottom of the condenser will be almost in line with the condenser mounting screws, as indicated in Fig. *5*.

With one hand holding the condenser in position against the top of the chassis, take a pair of ordinary pliers and twist each of the three outer lugs on the condenser a *small* amount, in the manner shown in Fig. *6*. This will hold the condenser securely in position on its mounting piece.

Step 5. To mount on the chassis the socket for the rectifier tube, take the octal-type tube socket (Part *4-4*) and hold it against the *bottom* of the chassis over holes *m, n* and *o* in such a way that the aligning groove in the

socket is next to the pilot lamp socket (see Fig. *5*). Fasten the socket to the chassis in this position with two machine screws and nuts (Parts *4-10A* and *4-10B*), keeping the screw heads above the chassis. (Although the rectifier tube which goes into this socket has five prongs, only four of them are used in this power pack circuit. Prong *1* on the tube is a dummy, used only in special applications which require shielding the tube and grounding the shield to the chassis through this prong.)

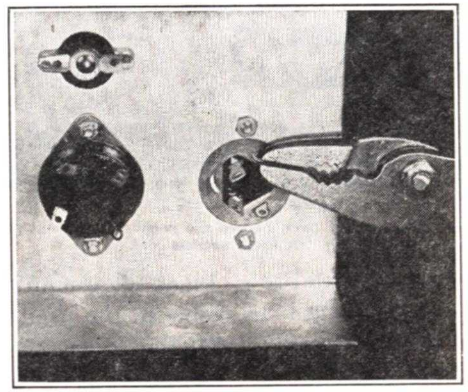


FIG. 6. This illustration shows the correct position of the bakelite mounting piece on the chassis, with the electrolytic condenser in position, and also shows how the outer lugs of the condenser are twisted with pliers to fasten the condenser unit to the bakelite mounting piece. Two of the lugs have already been twisted, and the last one is being twisted in this illustration.

Step 6. To mount the power switch on one side of the chassis, take the slide-type switch (Part *4-6*), set the sliding button to the position in which the colored dot shows, hold the switch against the *inside* of the chassis over holes *d, e* and *f* in such a position that the colored dot is nearer to the center of the chassis (nearer to hole *d*), then fasten this switch to the chassis with two machine screws and nuts (Parts *4-10A* and *4-10B*), keeping the heads of the screws on the outside of the chassis.

Step 7. To mount the terminal strip on the chassis, take the five-terminal screw-type binding post strip (Part *4-7*) and hold it against the *outside* of the chassis over holes *a, b* and *c* in such a manner that the numbers on the fiber strip are below the screws when the chassis is in its normal upright position, as shown in Fig. *7*. Fasten the strip to the chassis with two machine screws and nuts (Parts *4-10A* and *4-10B*), keeping the heads of the screws on the outside of the chassis.

Step 8. To mount the choke coil on the chassis, take the 10-henry choke coil (Part *3-10*) and hold it against the *bottom* of the chassis in such a way that its mounting tabs are over holes *g* and *h* and its terminal lugs are next to the pilot lamp socket, as shown in Fig. *5*. Fasten the choke coil to the chassis with two machine screws and nuts (Parts *4-10A* and *4-10B*). Keep the screw heads above the chassis, and place a ⅝-inch soldering lug (Part *1-8D*) under the nut for hole *g*, as shown in Fig. *5*.

Step 9. To mount the power transformer on the chassis, first take the

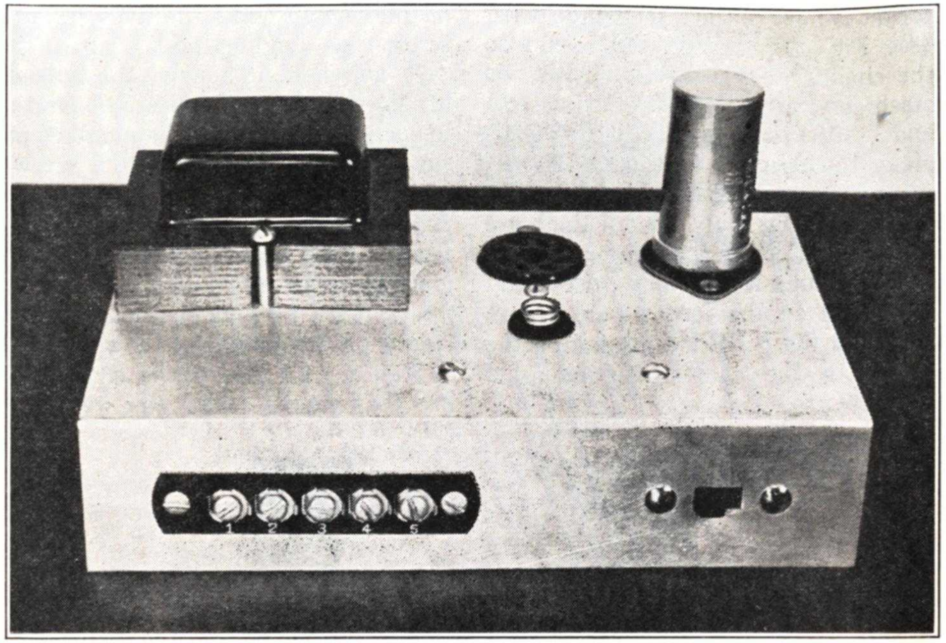


FIG. 7. View of the completed a.c. power pack before the rectifier tube and pilot lamp have been inserted in their sockets.

power transformer (Part *4-3*) and remove the nuts from the two long machine screws which go through the transformer core. Place the transformer on *top* of the chassis over holes *j*, *k* and *l* in such a way that the numbered terminals will appear in exactly the same position illustrated in Fig. *5*. Now insert the long machine screws through the power transformer mounting holes and through holes *j* and *l* respectively on the chassis. On each screw underneath the chassis, place a nut, and tighten the screws with a screwdriver, holding the nuts with ordinary pliers.

This completes the mounting of the large parts on the chassis. The top of the chassis should now appear as shown in Fig. *7*.

Step 10. To identify the terminals of the parts now mounted on the chassis, place alongside each terminal with metal-marking crayon the number indicated for that terminal in Fig. *5*. Place these numbers as nearly as possible in the positions shown in Fig. *5*. If the power transformer terminals are not marked, place the numbers on the fiber insulating material at the bottom of the transformer, or on the chassis beside the terminals. The choke coil lug numbers should be placed on the choke coil. All other numbers go directly on the chassis, as close as possible to the terminals in question. Place a — sign near output terminal *4*, and place a + sign near output terminal *5 on both sides* of the chassis.

Check your numbering carefully against Fig. *5* after you are finished, for errors in numbering will cause errors in wiring. Finally, check the terminal strip to be sure each lug is numbered the same on both sides of the chassis.

Step 11. To connect together the various terminals with hook-up wire, follow carefully the detailed step-by-

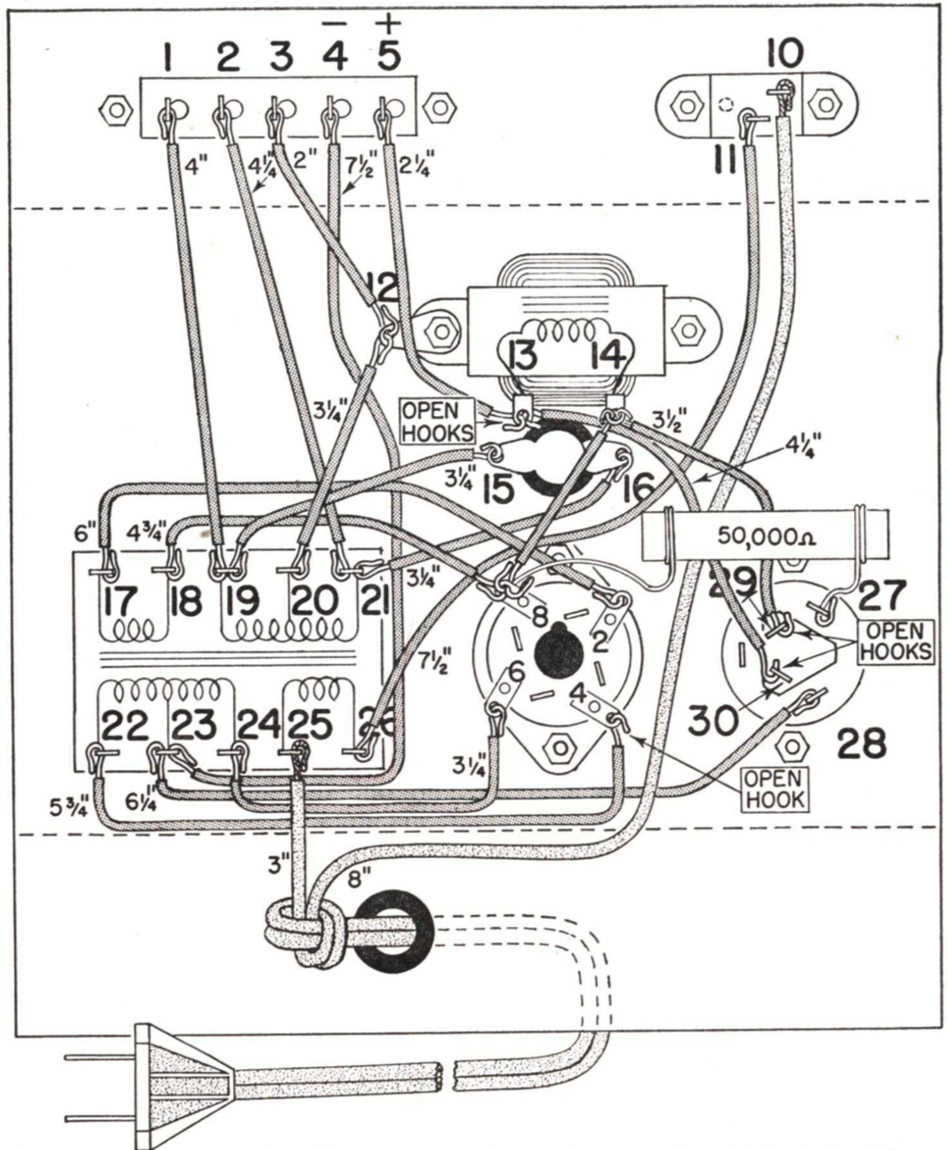


FIG. 8. Semi-pictorial wiring diagram showing how all connections are made under the chassis of the a.c. power pack. The sides of the chassis have been flattened out for clearness, but the wire lengths specified on this diagram are correct for the actual chassis.

step instructions which will now be given. Be particularly careful to make *temporary* soldered joints where specified. Use rosin-core solder (supplied in a previous kit) for all joints, and use *red* push-back hook-up wire throughout. Do not solder a joint until told to do so, for premature soldering will make it difficult for you to get additional wires into the hole in the lug. Use the semi-pictorial diagram in Fig. *8* and the photographic illustration in Fig. *9* as your guides for positioning the wiring.

Since the five terminals on the screw-type terminal strip are the output terminals of the power pack, we will refer to these terminals as the *output terminals*, to distinguish them from tube socket terminals having the same numbers.

a. Connect output terminal *4* to transformer terminal *23* with a 7½-inch length of hook-up wire, making permanent hook joints but soldering only terminal *4*.

b. Connect transformer terminal *23* to electrolytic condenser lug *28* with a 6¼-inch length of hook-up wire, making permanent hook joints and soldering both terminals this time.

c. Connect transformer terminal *17* to socket terminal *2* with a 6-inch length of wire, making permanent hook joints and soldering both terminals.

d. Connect transformer terminal *18* to socket terminal *8* with a 4¾-inch length of wire, making permanent hook joints but soldering only terminal *18*.

e. Connect transformer terminal *21* to pilot lamp socket terminal *16* with a 3¼-inch length of wire, making permanent hook joints but soldering only terminal *16*. Examine terminal *16* carefully after soldering, to be sure no part of this joint touches the chassis.

f. Connect transformer terminal *21* to output terminal *2* with a 4¼-inch length of wire, making permanent hook joints and soldering both terminals.

g. Connect transformer terminal *19* to pilot lamp socket terminal *15* with a 3¼-inch length of wire, making permanent hook joints but soldering only terminal *15*. Be sure the wire does not touch the chassis.

h. Connect transformer terminal *19* to output terminal *1* with a 4-inch length of wire, making permanent hook joints and soldering both terminals.

i. Connect transformer terminal *20* to grounding terminal *12* with a 3¼-inch length of wire, making permanent hook joints but soldering only terminal *20*.

j. Connect grounding terminal *12* to output terminal *3* with a 2-inch length of wire, making permanent hook joints and soldering both terminals.

k. Connect transformer terminal *24* to socket terminal *6* with a 3¼-inch length of wire, making permanent hook joints and soldering both terminals.

l. Connect transformer terminal *22* to socket terminal *4* with a 5¾-inch length of wire, making a *temporary* hook joint on socket terminal *4* and a permanent hook joint on terminal *22*. Solder both terminals.

m. Connect transformer terminal *26* to power switch terminal *11* with a 7½-inch length of wire, making permanent hook joints and soldering both terminals. Run this wire between the tube and pilot lamp sockets, as shown in Fig. *8*.

n. Connect choke coil terminal *13* to output terminal *5* with a 2¼-inch length of wire, making a *temporary* hook joint at terminal *13* and a permanent hook joint on terminal *5*. Solder only terminal *5*.

o. Connect choke coil terminal *13* to electrolytic condenser terminal *30* with a 4¼-inch length of wire, making *temporary* hook joints in both cases and soldering both terminals.

p. Connect choke coil terminal *14* to electrolytic condenser terminal *29* with a 3½-inch length of wire, making a *temporary* hook joint at terminal *29* and a permanent hook joint at terminal *14*, but solder only terminal *29*.

q. Connect choke coil terminal *14* to socket terminal *8* with a 2¼-inch length of hook-up wire, making per-

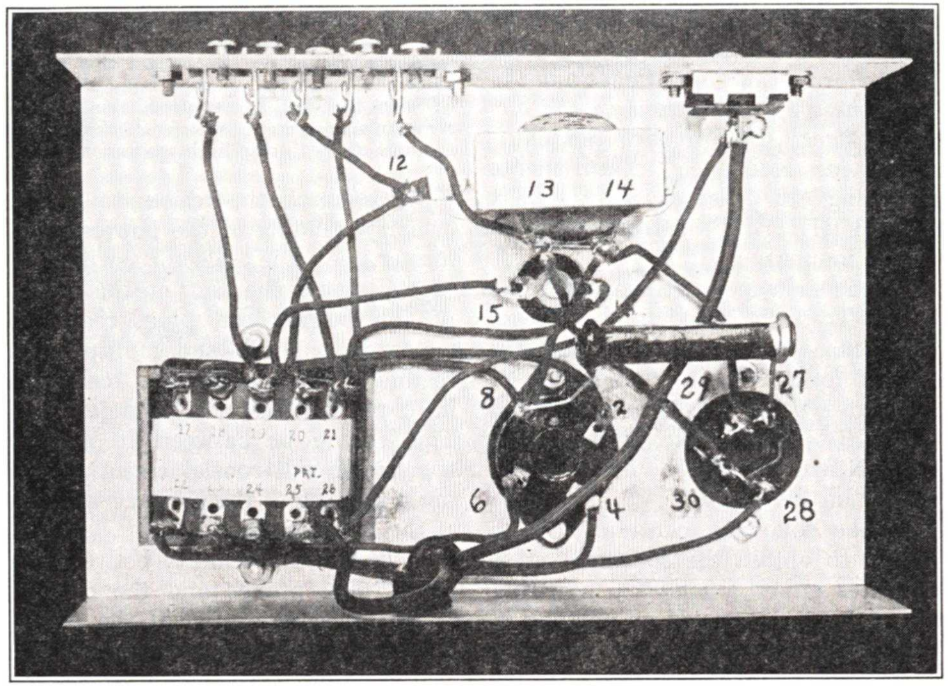


FIG. 9. Your a.c. power pack should look essentially like this under the chassis when you have completed all wiring. The positions of the various wires are not particularly important as long as they go to the proper terminals, hence some of the wires shown in this view may be in slightly different positions from corresponding wires in Fig. *8*.

manent hook joints in both cases but soldering only terminal *14*.

r. Connect the 50,000-ohm resistor (Part *4-1*) between socket terminal *8* and electrolytic condenser terminal *27*, after first shortening the resistor leads so they are each about one inch long. Make permanent hook joints and solder both terminals.

s. Insert the free end of the power line cord through the rubber grommet which is in hole *s*, starting from the outside. Pull at least a foot of the cord through the grommet, then tie a simple knot in the cord in the manner shown in Fig. *8* so that there are 8 inches of wire left beyond the knot. Split this 8-inch length down to the knot by pulling the two rubber-covered wires apart with your fingers. Connect one 8-inch length of wire to power switch terminal *10* by means of a permanent soldered hook joint, after first spreading out the strands of wire and scraping them lightly with the blade of a pocket knife, then twisting the strands tightly together so you can insert them through the hole in the lug. Run the wire between the tube socket and the electrolytic condenser, and go under the 50,000-ohm resistor and the two electrolytic condenser leads, as indicated in Fig. *8*.

t. Shorten the other 8-inch length of wire to a length of 3 inches, and remove about half an inch of insulation from this shortened end either by cutting or squeezing. Be careful not to nick or cut any of the copper strands when doing this. Spread out the strands and clean by scraping, then twist them together and connect this shortened end of wire to transformer terminal *25* by means of a permanent soldered hook joint.

Step 12. To make continuity tests with the ohmmeter in your N.R.I. Tester for the purpose of checking the correctness of connections in the a.c. power pack, first prepare the ohmmeter for resistance measurements according to the "OHMMETER MEASUREMENT" instructions given in this manual.

Whenever a measurement with the N.R.I. Tester is called for in the experiments, you are expected to refer to and follow the instructions given for that type of measurement in the "OPERATING INSTRUCTIONS FOR N.R.I. TESTER" boxes which appear in this manual.

In the following continuity tests, failure to obtain the specified result indicates either a mistake in wiring or a defective part. If no mistake in wiring can be found by checking against the semi-pictorial circuit diagram in Fig. *8*, check each individual part in the circuit under consideration. If you are certain that one of the parts is defective, return it to National Radio Institute immediately.

a. Insert the rectifier tube in its socket but leave out the pilot lamp. Set the power switch to the *OFF* position (the red dot alongside the sliding button shows when this switch is *ON* but not when it is *OFF*.)

b. Check continuity between the prongs of the power cord plug with the *MEG.* range by placing the red clip on one prong, placing the black clip on the other prong, and reading the resistance in megohms directly on scale *R*. The reading should be above 50 megohms (while switch is *OFF*).

c. Leave the clips on the power cord plug prongs, but *do not* insert the plug in an outlet. Snap *ON* the switch on the power pack chassis so that the red dot shows. The meter should now read zero on scale *R*. Leave the switch in the *ON* position.

Do not touch the metal parts of the test clips with your fingers while reading resistance values on the meter; this would place the resistance of your body in parallel with that being measured, resulting in erroneous readings when checking for grounds or measuring high resistance values.

d. To check the resistance of the primary winding of the power transformer, set the selector switch to *10* × *R*, leave the clips on the prongs of the power cord plug, read the meter on scale *R*, and multiply the reading by 10 to get the resistance in ohms of the circuit under test. This should be between 10 and 20 ohms, and will consist essentially of the resistance of the primary winding of the transformer.

e. To check continuity between the power plug prongs and the chassis, set the selector switch of the N.R.I. Tester at *MEG.*, place the black clip on the power pack chassis, and place the red clip in turn on each prong of the power cord plug. The meter reading should be higher than 50 megohms in each case.

f. To make sure that the high-voltage secondary circuit of the power transformer and the electrolytic condenser housing are not grounded, place the black clip on the chassis, place the red clip in turn on output terminal *4*, on socket terminal *4* and on socket terminal *6*, and measure the resistance in each case with the *MEG.* range of the N.R.I. Tester. A reading of 50 megohms or higher on scale *R* should be obtained in each case.

g. To make sure that the rectifier tube filament circuit is not grounded, place the black clip on the chassis, place the red clip on socket terminal *8*, and measure the resistance with the *MEG.* range. The meter should read higher than 50 megohms on scale *R*. Move the red clip to socket terminal *2*. Again the meter should read higher than 50 megohms.

OHMMETER MEASUREMENTS

1. Check the general calibration of your NRI Tester as instructed on page 14 of this Instruction Manual, and then plug the red test lead probe into the +R jack, plug the black test lead probe into the right-hand R jack, and set the selector switch at *Meg.*

2. To check the ohmmeter zero adjustment, hold the test lead clips together and turn the tester ON. The meter pointer should now indicate *O* at the right end of scale R. If it does not, adjust the tester potentiometer until it does so. *Do not, however, change the setting of the knob at the back of the meter.* IMPORTANT: Make the ohmmeter calibration as quickly as possible and then separate the test leads to prevent exhausting your batteries any more than absolutely necessary. *Before you make any ohmmeter tests, be sure to turn power OFF any equipment (preferably by removing the power cord plug) you want to check.*

3. Although you can start your ohmmeter measurements using any range of the tester, it is usually most convenient to start with the *10,000* × *R* range. Place the test lead clips on the terminals between which resistance is to be measured, being careful not to touch the metal part of the clips with your hands. Disregard polarity (as indicated by the colors of the test clips) unless otherwise instructed. When you check an electrolytic condenser, however, you should *fasten the red test clip to the negative terminal* of the condenser, and *connect the black test clip to the positive terminal* of the condenser.

4. On the *Meg.* range, the R scale is read directly in *megohms*. On the *10,000* × *R* range, multiply the R scale reading by 10,000 to get the resistance value in ohms. Resistance values in ohms on the *100* × *R* range are obtained by multiplying the meter reading by 100; and on the *10* × *R* range, by multiplying by 10.

5. If your first reading when using the *10,000* × *R* range is *O*, the resistance value under test may be anything from 0 to 10,000 ohms. To find the actual value, turn to the *lower* ranges and take your reading on the range which gives approximately mid-scale deflection. Actual zero ohms is indicated by a full-scale deflection only when the *10* × *R* range is used.

6. If your first test when using the *10,000* × *R* range produces only a small deflection of the meter pointer from its normal open circuit position at the left, turn to the *Meg.* range and read the value directly in megohms. If the meter pointer remains at the left end of the R scale when using the *Meg.* range, the circuit or part under test is "open." (Such a circuit or part is often said to have "infinite" resistance).

7. If you found it necessary to turn the tester potentiometer a considerable amount to get zero adjustment when holding the test clips together, use the range which brings the meter pointer into the right half of the scale. Should it be necessary to use the left half of the scale, calibrate the tester at 0 and 3 on scale DC as instructed on page 14 of this manual under the heading "Checking the Calibration."

8. To conserve battery life, turn the tester OFF and remove both test leads just as soon as you finish a series of resistance measurements.

h. To check filter circuit continuity, set the selector switch to *10,000* × *R*, then place the red clip on power transformer terminal *23* and place the black clip on socket terminal *8*. The reading should be somewhere between 40,000 and 60,000 ohms. Now move the black clip to output terminal *5*, and again measure the resistance. The reading should again be between 40,000 and 60,000 ohms.

i. To check wiring and continuity of the high-voltage secondary winding on the power transformer, measure the resistance between socket terminals *4* and *6* while using the *100* × *R* range of the N.R.I. Tester. You should obtain a reading somewhere between 400 and 700 ohms.

CHECKING THE CALIBRATION

Before using the NRI Tester for any series of measurements, check its calibration as follows:

1. **Remove both test probes, set the selector switch at** $100 \times V$ **and make sure the calibrating clip is on —9C. Turn the power switch ON and tap the meter gently with a finger. The pointer should be exactly at** *O* **on the DC scale. If it isn't, adjust the knob at the back of the meter as may be necessary to set the pointer at zero. Look squarely at the meter and don't tilt the tester during calibration or operation.**
2. **Now move the calibrating clip from —9C to —7½C and see if the meter reads 1.5 on scale DC. If necessary, adjust the potentiometer on the tester chassis to get this 1.5 reading.**
3. **Recheck the "zero" position again by moving the calibrating clip back to —9C. The calibration procedure described above, and in previous manuals, insures maximum accuracy only over the left half of the meter scale. The right half of the scale can be checked as follows:**
4. **First, hold the calibrating clip on —6C momentarily, and then on —4½C and note the meter reading at each position. The desired readings are 3 and 4.5 respectively on scale DC. The difference between these values and your readings represent the amount of error in this portion of the scale. If greater over-all accuracy is desired over the entire scale, calibrate at** *O* **and 3 on scale DC by using —9C and —6C respectively.**

Return the calibrating clip to —9C so that the meter reads zero before beginning your measurements. **Also, check the calibration from time to time during the course of an experiment to be sure accuracy is maintained.**

j. To check continuity and wiring of the 6.3-volt filament supply circuit in the power pack, measure the resistance between output terminals *1* and *2* with the $10 \times R$ range of the N.R.I. Tester. The reading should be only a fraction of an ohm (essentially zero). If this reading is around 1000 ohms and the reading obtained in Step *12i* is less than 1 ohm, write to us immediately and give your results for this test. Do not go any further with your experiments until you hear from us, if you obtained these reversed readings.

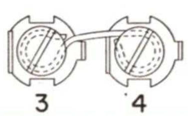


FIG. 10. Method of connecting output terminals ***3*** **and** ***4*** **together externally with a 1½-inch length of bare hook-up wire. Note that both hooks are closed, so that the wire will stay in position when the screws are loosened to permit connecting other wires to these terminals.**

k. Place the black clip on the chassis, place the red clip on output terminal *3*, and measure the resistance value with the N.R.I. Tester set to the $10 \times R$ range. The reading should be zero.

Step 13. To check the operation of the power pack, first place the chassis right side up with the terminal strip facing you, make sure the rectifier tube is firmly in its socket, insert the pilot lamp in its own socket, and push the switch to its *OFF* position (red button does not show).

Next, connect output terminal screws *3* and *4* together externally with a 1½-inch length of bare hook-up wire. Do this by forming a hook in one end of the wire, hooking this over screw *4* in a clockwise direction after loosening this screw, closing the hook with pliers, then bending the wire around screw *3* in a clockwise direction and cutting off surplus wire to give an S-shaped connection like that shown in Fig. *10*. Keep these two terminals connected together.

Connect to terminal *3* the ground wire you have provided at your bench for experimental purposes. This ground wire should go to a cold water pipe or other good ground.

Insert the power cord plug into a 115-volt a.c. outlet and turn on the power pack switch. The pilot lamp should now light up, and both filament wires of the rectifier tube should appear dull red when looking straight down on top of the tube. Turn off the power pack.

CAUTION: The ground connection to output terminals ***3*** **and** ***4*** **should be made whenever the power pack is used, to avoid getting a shock when touching the power pack chassis.**

Do not touch any terminals or parts underneath the chassis of the a.c. power pack while it is in operation. The voltages present at some of these terminals are high enough to give serious electrical shocks.

If neither the pilot lamp nor the rectifier tube glows, check your source of a.c. power by plugging a table lamp or other appliance into the outlet.

Step 14. To check the d.c. output voltage of the power pack when no load is connected, first prepare the N.R.I. Tester according to the "D.C. VOLTAGE MEASUREMENTS" instructions given in this manual.

To measure the d.c. output voltage between terminals *4* and *5*, place the red clip on screw terminal *5* after first loosening this screw about ⅛-inch. Place the black clip on the wire jumper which connects screw terminals *3* and *4*, *being sure that this clip does not touch the red clip.* Turn on the a.c. power pack, then turn on the N.R.I. Tester (be sure it is set to the $100 \times V$ range), read the meter on the *DC* scale, and multiply your reading by 100 to get the d.c. output voltage of the power pack in volts. This voltage should be approximately 450 volts if you have assembled the power pack correctly, all parts are in good condition, and you have a normal a.c. line voltage of about 115 volts.

Turn off the power pack while watching the meter. Note that it takes several seconds for the pointer to drop down to zero; this action occurs because the electrolytic filter

D.C. VOLTAGE MEASUREMENTS

1. **Plug the black probe into the** $-V_{DC}$ **jack on the panel, and plug the red probe into the** $+V_{DC}$ **jack.**
2. **Set the selector switch at** $100 \times V$**. Always start with the highest d.c. range, in order to prevent overloading of the meter.**
3. **While power is off, place the black test clip on the — terminal of the device whose voltage is being measured, and place the red clip on the + terminal.**
4. **Turn on your apparatus, then turn on the N.R.I. Tester. This order is important, as it prevents high initial voltages from making the meter pointer swing off-scale.**
5. **If the meter reading is low or zero, lower the selector switch setting one range at a time, until you reach the lowest range which does not overload the meter. IMPORTANT: When working with apparatus using heater-type vacuum tubes, wait long enough for the tubes to warm up (about half a minute is sufficient) before lowering the selector switch setting.**
6. **Read the meter on the** ***DC*** **scale, and multiply the reading by the correct factor for the range being used. For example, when using range** $30 \times V$**, multiply the scale reading by 30; when using range** $100 \times V$**, multiply by 100, etc.**
7. **Turn off the N.R.I. Tester first, then turn off the power source. Pull out the test probes when through using the N.R.I. Tester, to prevent draining of the C battery in case the test clips accidentally touch the tester panel or chassis.**

OPERATING INSTRUCTIONS FOR N.R.I. TESTER

OVERLOADING OF N.R.I. TESTER

If the pointer of the meter in the N.R.I. Tester vibrates around *0* or reads slightly backwards, but a definite up-scale reading is obtained when you switch to a higher range, this is an indication that the meter was being overloaded on the lower range.

An overload will usually shift the *0* position of the pointer. This condition will be corrected automatically the next time you make an approximately full-scale voltage reading, or can be corrected immediately by lifting up the calibrating clip and touching it momentarily to the —4½C terminal on the battery block. Be sure to return the clip to —9C.

If the pointer seems to stick at the right of the full-scale position, tap the meter lightly with the finger. On voltages near full-scale values, momentum of the pointer carries it farther than the final position, but tapping frees the pointer and often allows you to secure a reading without switching to the next higher range.

condensers hold their charges for that period of time after power is removed. Now turn off the N.R.I. Tester and pull out the power cord plug.

The d.c. output voltage of your power pack will vary slightly with the line voltage, and consequently any d.c. voltage value between about 400 volts and 500 volts can be considered satisfactory for this no-load d.c. output voltage measurement.

NOTE: Although the highest division on the *DC* scale is 4.5, corresponding to 450 volts when using the *100* × *V* range, voltages up to 500 volts d.c. can be safely measured. When the pointer is between the letters *D* and *C* at the right-hand end of the scale, read the meter as 5; multiplying by 100 then gives 500 volts. For pointer positions in between 4.5 and "5," estimate the reading just as you do between other divisions on the scale.

Discussion: The sole purpose of the pilot lamp in your a.c. power pack is to serve as an indicator that the power pack is on and is delivering a useful yet dangerously high voltage. Whenever this light is glowing, do not touch any terminal of the power pack or any voltage supply terminal of the equipment connected to the power pack. If you are making voltage measurements on any connected equipment with the N.R.I. Tester, be sure to hold the test clips by their insulated handles.

After turning off the power pack, wait at least five seconds for the condensers to discharge, before touching any terminals or parts with your fingers. The condensers may deliver an unpleasant shock while discharging, even though power is off.

INSTRUCTIONS FOR PERFORMING EACH EXPERIMENT

1. **Read the entire experiment, giving particular attention to the discussion.**
2. **Perform each step of the experiment and record your results. Whenever a measurement is specified, be sure to make it exactly according to the "OPERATING INSTRUCTIONS FOR N.R.I. TESTER" given in this manual for that type of measurement.**
3. **Study the discussion and analyze your results.**
4. **Answer the report statement for the experiment. It will always be on the last page of the manual.**

EXPERIMENT 31

Purpose: **To measure the high d.c. output voltage, the low a.c. output voltage, and the a.c. ripple voltage which is present at the d.c. output terminals of the a.c. power pack under no-load conditions.**

Step 1. To measure the d.c. output voltage of your power pack, first place the power pack in an upright position before you on the table, with the terminal strip facing you, and connect the ground wire at your workbench to output terminal screw *3*.

Check the calibration of the N.R.I. Tester by following the instructions given elsewhere.

Prepare the N.R.I. Tester to read d.c. voltages according to the "D.C. VOLTAGE MEASUREMENTS" instructions given previously. Place the black test clip on output terminal *4* of the power pack, and place the red clip on output terminal screw *5*. (Terminals *4* and *5* are the d.c. output terminals, with terminal *4* negative and terminal *5* positive.)

Insert the power cord plug into a convenient a.c. outlet, turn on the power pack switch, allow about half a minute for the power pack to reach normal operating conditions, then turn on the N.R.I. Tester and read the meter on the *DC* scale. Record your result in Table *31* as the d.c. output voltage in volts for no load.

CAUTION: As was previously pointed out, high voltages exist at some terminals underneath the power pack chassis when this unit is in operation. Therefore, do not touch any terminals under the chassis with your fingers while the power pack switch is on.

Turning off the power pack switch breaks the primary circuit of the power transformer, but the 115-volt a.c. line voltage is still present at the power transformer primary terminals and at both power switch terminals. This means that it will be necessary to pull the power cord plug out of the outlet every time you make a change in the wiring under the chassis. Remember—do not touch the two power transformer primary terminals or the power switch terminals even when the power pack switch is off, unless you have first pulled out the plug.

Step 2. To measure the a.c. filament voltages provided by your a.c. power pack, first prepare the N.R.I. Tester for a.c. voltage measurements by following the "A.C. VOLTAGE MEASUREMENTS" instructions given elsewhere in this manual.

Place the test clips on output terminals *1* and *2*, measure the a.c. voltage, and record your result in Table *31* as the a.c. output voltage in volts across the entire filament winding (between terminals *1* and *2*).

CAUTION: Always return the selector switch to the highest range (*100* × *V*) when through making a voltage measurement, to prevent overloading of the meter on the next measurement. Before making a new measurement, be sure the probes are in the correct jacks for that type of measurement.

Next, place the clips on output terminals *1* and *3*, measure the a.c. voltage, and record your result in Table *31* as the a.c. output voltage across one half of the filament winding (between output terminals *1* and *3*).

STEP	NATURE OF MEASUREMENT	YOUR VALUE IN VOLTS	N.R.I. VALUE IN VOLTS
1	D.C. OUTPUT VOLTAGE BETWEEN TERMINALS 4 AND 5		450
2	A.C. OUTPUT VOLTAGE BETWEEN TERMINALS 1 AND 2		6.7
	A.C. OUTPUT VOLTAGE BETWEEN TERMINALS 1 AND 3		3.5
	A.C. OUTPUT VOLTAGE BETWEEN TERMINALS 2 AND 3		3.4
3	A.C. RIPPLE VOLTAGE BETWEEN TERMINALS 4 AND 5		0

TABLE 31. Record your results here for Experiment 31. All power pack measurements in this table are for normal full-wave rectification and condenser input. No load is connected to the d.c. output terminals.

To measure the a.c. voltage across the other half of the filament winding, place the clips on output terminals *2* and *3*, read the meter on the *AC* scale, and record your result in Table *31* as the a.c. output voltage between terminals *2* and *3*.

Step 3. To measure the a.c. ripple voltage value which is present at d.c. output terminals 4 and 5, leave the tester set for a.c. voltage measurements. Review the "A.C. VOLTAGE MEASUREMENTS" instructions if in doubt. Place the black clip on output terminal screw *4*, place the red clip on output terminal screw *5* (polarity *is important* in this particular measurement, as pointed out in the discussion). Read the meter on the *AC* scale, and record your result in Table *31* as the a.c. ripple voltage in volts between output terminals *4* and *5*. If the pointer flickers back and forth continually, estimate its average position. If the pointer does not move at all from zero, record your result as zero volts.

Discussion: In Step 1, you repeat your measurement of the d.c. output voltage so that you can record this value in Table *31* along with the other output voltage values of your a.c. power pack. You will use the values which you record in this table for reference purposes in connection with later experiments.

Although a.c. line voltages in this country are ordinarily somewhere around 115 volts, these voltages will vary anywhere between 110 volts and 120 volts at times, due to changes in the loads on a power system and to other conditions at the power generating station. Each variation in the a.c. line voltage will cause a corresponding variation in the d.c. output voltage of your power pack. Thus, you may get a different value if you measure this d.c. output voltage tomorrow or next week.

In boosting the a.c. line voltage, your power pack inherently amplifies the variations in the line voltage. If you are located in an industrial community where there are large varying electrical loads on the power system, you may even be able to see this variation, in the form of a continual flickering of the meter pointer when measuring the d.c. output voltage of the power pack.

OPERATING INSTRUCTIONS FOR N.R.I. TESTER

A.C. VOLTAGE MEASUREMENTS

1. **Plug the black probe into the $-V_{AC}$ jack on the panel, and plug the red probe into the left-hand V_{AC} jack.**
2. **Set the selector switch at *100* × *V*.**
3. **Place the test clips on the terminals between which the a.c. voltage is to be measured. The black clip should go to the terminal which is closer to ground. When both terminals have essentially the same potential with respect to ground, the polarity of the test clip connections can be disregarded.**
4. **Turn on your apparatus, then turn on the N.R.I. Tester. This protects the tester against high-voltage surges which may exist when the apparatus is turned on.**
5. **Lower the selector switch setting, one range at a time, until you reach the lowest range which does not make the meter pointer swing off-scale.**

IMPORTANT: When working with apparatus using vacuum tubes, wait long enough for the tubes to warm up (about half a minute is sufficient) before lowering the selector switch setting. This applies whenever you use the entire a.c. power pack (with the rectifier tube in its socket).

6. **Read the meter on the *AC* scale, and multiply the reading by the correct factor for the range being used.**
7. **Turn off the N.R.I. Tester first, then turn off the power source. Pull out the test probes when through using the N.R.I. Tester, to prevent draining of the C battery in case the test clips accidentally touch the tester panel or chassis.**

NOTE: When the N.R.I. Tester is being used as an a.c. voltmeter on the *V* range, a meter reading may be obtained *when only one test clip is connected.* This is due to pick-up of stray a.c. energy by the test leads. Disregard this condition, as it has no effect on the readings when both test leads are connected.

OPERATING INSTRUCTIONS FOR N.R.I. TESTER

EXTENDING VOLTAGE RANGES

As your N.R.I. Tester has a resistance of 10 megohms, you can double the values for any a.c. or d.c. voltage range of the N.R.I. Tester by inserting in series with the tester and the voltage source the 10-megohm resistor which is supplied to you as Part *4-21*.

Simply connect this resistor temporarily in series with the ungrounded test lead. The true voltage reading will then be the meter reading multiplied by *twice* the multiplying factor indicated at the selector switch setting. Thus, when using this voltage multiplier on the *100* × *V* range, a meter reading of 2.4 would correspond to 480 volts.

When dealing with voltages between about 20 and 30 volts, the use of the voltage multiplier with the *3* × *V* range will give a more accurate measurement than could be obtained with the *30* × *V* range. This is particularly true in the case of a.c. measurements.

In Step 2, you use the N.R.I. Tester as a low-range a.c. voltmeter and measure the a.c. output voltages which are provided at the output terminals of your power pack for filament heating purposes. In connecting between output terminals *1* and *2* for the first measurement, you measure the voltage across the entire filament winding (between terminals *19* and *21* in Fig. *2*). Although this voltage should normally be about 6 volts a.c., for use with 6 or 6.3-volt vacuum tube filaments, you will measure a somewhat higher voltage under no-load conditions. This is entirely normal, for the voltage will drop when vacuum tube filaments are connected to these terminals.

The circuit diagram in Fig. *2* shows that the 6.3-volt filament winding has a center tap, going to output terminal *3*. For the second and third measurements, you measure between this center tap and each of the outer terminals of the 6.3-volt filament winding. If you secure essentially equal voltage values for these two measurements, you know that the center tap has been placed in the electrical center of the filament winding, as it should be. The sum of the voltages across the two halves of the filament winding is equal to the voltage across the entire winding, but voltage values measured with the N.R.I. Tester may differ as much as 10% when checked in this manner.

In Step 3, you set the N.R.I. Tester for use as an a.c. voltmeter and con-

OPERATING INSTRUCTIONS FOR N.R.I. TESTER

IF N.R.I. TESTER READINGS SEEM WRONG, CHECK THESE ITEMS

1. **Are the test clip, test probe and selector switch positions correct for the type of measurement you are making?**
2. **Are you reading the correct scale on the meter?**
3. **Are you multiplying the scale reading by the correct factor for the selector switch setting?**
4. **Is the calibrating clip placed on the correct permanent C battery terminal (—9C)? If through forgetfulness you leave the clip on the less negative terminal, all meter readings will be too high.**
5. **Did you follow *every step* of the instructions given in the manual for making the measurement in question?**

NOTICE: WHEN WRITING TO THE INSTITUTE REGARDING YOUR N.R.I. TESTER, BE SURE TO REFER TO IT AS THE "N.R.I. TESTER FOR EXPERIMENTS."

REDUCING LEAKAGE RESISTANCE EFFECTS

Leakage resistance in the grid circuit of the N.R.I. Tester can provide a path for direct current through the meter circuit when measuring the a.c. ripple voltage at the high-voltage d.c. output terminals, thereby giving a meter reading even when the a.c. ripple voltage is zero. The condenser which was supplied you for use between the $+V_{DC}$ jack and the left-hand V_{AC} jack behind the panel of the tester has an unusually high leakage resistance value, but moisture or dust on the condenser housing or on either side of the insulating strip which supports the jacks may provide sufficient leakage resistance to give a meter reading. Likewise, moisture or dirt on the tube base or tube socket of the N.R.I. Tester can cause grid-to-filament leakage and give the same effect. This leakage is particularly troublesome under conditions of extremely high humidity, such as in a damp basement.

To reduce the effects of leakage resistance to a minimum, turn off all apparatus, then remove the mounting screws for the jack strip on the N.R.I. Tester so you can wipe both sides of this strip with a clean cloth. Replace the jack strip, then wipe the housing of the .005-mfd. condenser carefully with the cloth, wipe the tube base between the prongs, and wipe the surface of the tube socket both above and below the chassis.

nect it to the d.c. output terminals of the power pack. When using the *AC* voltmeter range of the N.R.I. Tester in this manner, a .005-mfd. condenser in series with the measuring circuit inside the tester blocks the flow of direct current. Under this condition, the only voltage which can affect the meter reading under normal conditions is the a.c. ripple voltage which might be present at the d.c. output terminals.

Small variations in the line voltage can cause considerable flickering of the meter pointer while you are measuring the a.c. ripple voltage in the d.c. output. The power transformer increases the line voltage variations about four times, and the sudden charging and discharging of condensers in the filter system can amplify the variations still further, so that they are quite noticeable when measured with the lowest *AC* range of the N.R.I. Tester. Reading the average value over which the pointer flickers will eliminate these variations from your results.

Blistering of Paint on Resistors. The 50,000-ohm resistor under the power pack chassis develops considerable heat during normal operation of the power pack, for it is connected directly across a pulsating d.c. voltage of over 400 volts at the rectifier tube output. This heat may cause the paint on the resistor to become soft and develop blisters, but this will in no way affect the quality of the resistor or the operation of the power pack. This same blistering of paint may occur in the 40,000-ohm resistors which you use across the d.c. output terminals in the next experiment.

Bleeder Resistor. The 50,000-ohm resistor is connected across the input of the power pack filter system at all times, and serves to prevent high-voltage surges from damaging the electrolytic filter condenser when the power pack is first turned on and there is no load connected to the d.c. output terminals. This resistor is actually an internal load on the power pack, and is called a *bleeder resistor* because it draws or "bleeds" a current continuously for stabilizing purposes, regardless of what is connected externally to the power pack.

When reference is made to the power pack load, we always mean the load which is connected externally to the output terminals. You can neglect the presence of the internal bleeder resistor load during normal use of the power pack.

Instructions for Report Statement No. 31. In the preceding discussion, it was pointed out that the d.c. output voltage of your power pack will vary with the a.c. line voltage. To familiarize you with the proper and safe technique for measuring this line voltage, you are asked to make this measurement and record it in Report Statement No. 31, along with your measured value for the d.c. output voltage.

With the power pack plug pulled out, turn the power pack chassis on its back side, place one test clip on power switch terminal *10,* and place the other test clip on transformer terminal *25,* so that you will be measuring the voltage between the two leads of the power cord. Adjust the clips carefully so that they cannot loosen and touch other parts. Now prepare the tester for a.c. voltage measurements, as instructed elsewhere. Insert the power cord plug in the wall outlet, and turn on the N.R.I. Tester. Record your a.c. line voltage in volts in Report Statement No. 31. Pull out the power cord plug before touching the test clips.

Now repeat your measurement of the d.c. output voltage of the power pack, exactly as instructed in Step 1 of this experiment. Record this value also in Report Statement No. 31, as the d.c. output voltage corresponding to the line voltage value you measured. This output voltage may be different from that which you recorded in Table *31,* but you know now that this is due simply to line voltage variations.

EXPERIMENT 32

***Purpose:* To show that the d.c. output voltage of your a.c. power pack varies with the load.**

Step 1. To connect four 40,000-ohm resistors in parallel to the d.c. output terminals of the power pack so as to secure a 10,000-ohm load, first secure the four 40,000-ohm, 3-watt resistors (Parts *3-6A, 3-6B, 3-6C* and *3-6D*) which were supplied you in Radio Kit 3RK. Bend a hook in each lead of one resistor in the manner shown in Fig. *11A,* loosen the screws on output terminals *4* and *5* of the power pack, hook these resistor leads over screws *4* and *5,* then tighten the screws while holding the resistor with your fingers and exerting a gentle upward pull to keep the hooks under the screw heads. Now bend the resistor leads downward until the resistor is about on a level with the screws.

Take another 40,000-ohm resistor, tin the ends of its leads, and connect this resistor in parallel with the first one by means of temporary soldered joints after bending and arranging the leads as shown in Fig. *11B.*

Connect the remaining two 40,000-ohm resistors in parallel with the first two resistors by means of temporary soldered lap joints in the same manner, so that you now have a parallel combination of four resistors like that shown in Fig. *11C.* These give the desired equivalent resistance of 10,000 ohms.

Step 2. To measure the d.c. output voltage of your power pack with various load values, first check the calibration of the N.R.I. Tester, then prepare it for d.c. voltage measurements according to previous instructions. Place the red clip on the resistor lead which is attached to terminal *5,* bringing the clip up from under the lead as shown in Fig. *11C* to minimize chances of the clip touching the chassis. In the same manner, place the black clip on the lead which is attached to terminal *4.* Record your result in Table *32* as the d.c. output voltage when using a 10,000-ohm load.

To measure the d.c. output voltage for a 20,000-ohm load, remove two of the resistors from your parallel group by unsoldering one resistor lead in the manner shown in Fig. *11D*. The two 40,000-ohm resistors which are still connected to output terminals *4* and *5* give a load resistance of 20,000 ohms. Leave the clips connected as before, follow the "D. C. VOLTAGE MEASUREMENTS" instructions, and record the result in Table *32* as the d.c. output voltage in volts for a 20,000-ohm load.

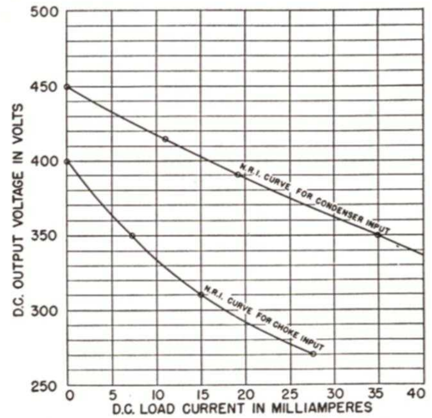
LOAD RESISTANCE IN OHMS	D.C. OUTPUT VOLTAGE IN VOLTS		D.C. LOAD CURRENT IN MILLIAMPERES	
	YOUR VALUE	N.R.I.	YOUR VALUE	N.R.I.
10,000		350		36
20,000		390		20
40,000		420		11
NO LOAD		450		0

TABLE 32. Record your results here for Experiment 32. All power pack measurements in this table are for normal full-wave rectification and condenser input. Load values are as indicated in the first column above. Always use pencil rather than ink for recording your values in the tables. Be sure you record each value in the correct position in the table.

To measure the d.c. output voltage for a 40,000-ohm load, unsolder one more resistor lead in the manner shown in Fig. *11E*, so that only one 40,000-ohm resistor is connected to terminals *4* and *5*. Record your result in Table *32* as the d.c. output voltage for a 40,000-ohm load.

To measure the d.c. output voltage for no load, remove the test clips, remove the entire resistor group from output terminals *4* and *5*, place the red clip on the screw of terminal *5*, place the black clip on the screw of terminal *4*, measure the d.c. output voltage exactly as you did in Experiment 31, and record your result in Table *32* as the no-load d.c. output voltage in volts. Pull out the power cord plug, remove the test leads entirely, and turn off the tester.

Step 3. To measure load currents for the three load resistance values used in Step 2, first connect the four 40,000-ohm resistors in parallel again by means of temporary soldered lap joints to secure a 10,000-ohm resistance. Connect one lead of this resistor group to output terminal screw *5*. Place the red test clip on the other lead of the resistor group, and place



GRAPH 32. Plot your results for Experiment 32 on this graph and draw a smooth line through the dots to secure a d.c. load current-d.c. output voltage curve which you can compare with the N.R.I. curve for condenser input. Later, you will use values obtained in Experiment 36 to plot another curve on this graph for a choke input type of filter circuit.

the black test clip on output terminal screw *4*, as shown in Fig. *11F*.

Prepare the tester for direct current measurements by placing the black test probe in the *—I* jack, placing the red test probe in the *+I* jack, and setting the selector switch at *10* × *I*. (This covers items 1 and 2 in the "DIRECT CURRENT MEASUREMENTS" box on page 25. The previous paragraph covered items 3 and 4, and the following paragraph here covers the remaining items—5, 6 and 7.)

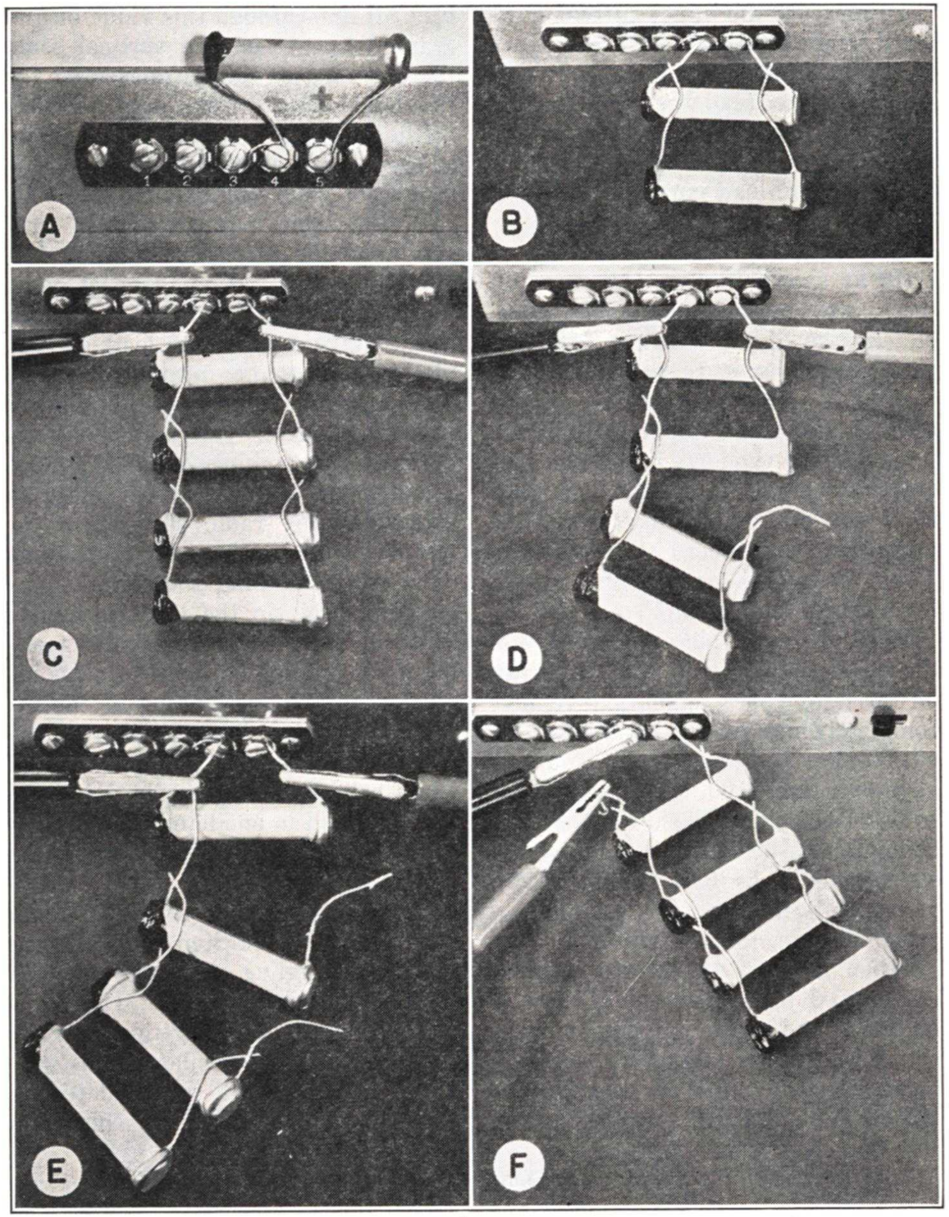


FIG. 11. Methods of connecting load resistors to the d.c. output terminals of your power pack for d.c. output voltage and d.c. load current measurements are illustrated here.

A—Method of connecting a single 40,000-ohm load resistor to d.c. output terminals *4* and *5*.

B—Two 40,000-ohm resistors connected in parallel to output terminals *4* and *5* as shown here will serve as a 20,000-ohm load.

C—Four 40,000-ohm resistors in parallel give a 10,000-ohm load. If the red and black test clips are attached in the manner shown here when making d.c. output voltage measurements, there is little possibility of the clips accidentally shorting together or touching the chassis.

D—Method of disconnecting two resistors temporarily to give a 20,000-ohm load.

E—Method of disconnecting three resistors temporarily to give a 40,000-ohm load.

F—Method of connecting the test clips for measurement of the d.c. load current through a 10,000-ohm load resistance. Note that current is measured at the grounded point (terminal *4*) in the load circuit; this keeps the chassis of the N.R.I. Tester at ground potential.

To measure the direct current flowing through the 10,000-ohm load, turn on the power pack and the tester, wait half a minute, read the meter on the *DC* scale, multiply the meter reading by 10, and record your result in Table *32* as the d.c. load current in ma. for a 10,000-ohm load.

While leaving the test probes exactly as shown in Fig. *11F*, turn off the power pack, and remove *completely* two of the resistors from the parallel group so as to secure a 20,000-ohm load. Now measure the current through this 20,000-ohm load in the same manner (you can follow the general instructions in the box on page 25 if you prefer, but *don't move the test clips)*, and record your result in Table *32* as the load current in ma. for a 20,000-ohm load.

With the test probes still exactly in the positions shown in Fig. *11F*, turn off the power pack again, and remove completely one of the remaining two 40,000-ohm resistors, so that you now have only one 40,000-ohm resistor left to serve as load. Measure the current through this 40,000-ohm load in the same manner as before, and record your result in Table *32* as the load current in ma. for a 40,000-ohm load.

When the last 40,000-ohm resistor is removed from terminal *5*, there is no load, and hence no load current can flow. *Do not make any measurement at all* for the no-load current box in Table *32;* just record a zero in this box.

Step 4. To plot a graph which will show how d.c. output voltage varies with load current, first plot on Graph *32* the d.c. output voltage you measured for no-load conditions, by placing a heavy dot at this voltage value on the vertical scale at the left of the graph. Next, locate on the horizontal scale the current value for the 10,000-ohm load, and draw a light *vertical* line through this value on the graph. Locate on the vertical scale the d.c. output voltage measured for this load value, draw a light *horizontal* line through this value, and make a heavy dot at the point where it intersects your vertical line.

In the same manner, plot in turn similar points for the 20,000 and 40,000-ohm loads. Now connect your four points together with a smooth line to give a curve of load current plotted against d.c. output voltage.

Discussion: Step 1 is a preliminary step which gives you additional experience in making the temporary soldered lap joints which are used so extensively by radio servicemen for test connections. You may have some difficulty in making these joints unless you first tin the leads individually; in fact, the professional technique for making lap joints always involves preliminary tinning of the individual parts. This eliminates the necessity for having to apply solder while actually soldering the joints, so you can hold in one hand the part being soldered, and hold the soldering iron in the other hand.

After making the six soldered lap joints called for in Step 1, check your work by wiggling the wires of each joint. Sometimes a joint which appears secure is held together only by rosin, which is an insulator; this wiggling procedure will reveal defective rosin joints by breaking the rosin bond.

When resistors of equal value are connected in parallel, the combined resistance is always equal to the value of one of the resistors divided by the number of resistors in parallel. This is a valuable rule to remember.

Although the 40,000-ohm resistors which you use in this experiment have a power-handling rating of 3 watts, it is entirely permissible to overload

DIRECT CURRENT MEASUREMENTS

1. Place the black test probe in the *—I* jack, and place the red test probe in the *+I* jack.
2. Set the selector switch at *10×I*.
3. Open the circuit at the point where current is to be measured. Although current can be measured anywhere in a circuit, it is best to make this measurement at a point which is at *ground* potential or as close as possible to ground potential. (Output terminal *4* of your power pack is at ground potential because the ground wire connects both to *3* and *4*.) Observance of this rule minimizes chances of getting a shock when touching the tester chassis with one hand and touching a grounded object like the power pack chassis with the other hand.
4. Place the black test clip on the grounded terminal (or lead) at the measuring point, and place the red test clip on the lead which you disconnected from this grounded terminal. This places your N.R.I. Tester *in series* with the circuit, just as it should be for all current measurements.
5. Turn on the voltage source and the N.R.I. Tester, wait about half a minute if there are any heater-type tubes in your set-up, then read the meter on the *DC* scale and multiply the reading by 10 to get the current in milliamperes.
6. If the current value is less than 4.5 ma., set the selector switch at the *I* range and read the direct current value in ma. directly on the *DC* scale.
7. Turn off the N.R.I. Tester, then turn off the power source. Pull out the test probes to prevent draining the C battery in case the test leads accidentally touch the tester panel or chassis.

IMPORTANT: For all direct current measurements, be sure to read the meter on the *DC* scale (not on scale I_M).

these resistors for short periods of time. The resulting heat may change the appearance (color) of a resistor and produce smoke, but this will not affect the electrical characteristics.

When working on this experiment, keep in mind that the load is increased by lowering (decreasing) the ohmic value of the load resistance. In other words, you have the greatest load on your power pack when all four resistors are connected in parallel to give a combined resistance of 10,000 ohms. You should therefore expect to secure the lowest d.c. output voltage when this load is employed. Increasing the value of the load resistance to 20,000 and then to 40,000 ohms reduces the loading effects, and consequently the measured d.c. output voltage should go up. Examine your results in Table *32* to verify this.

When you analyze your measured values of load current, you should find that the d.c. load voltage is the lowest and the load current is the highest for the 10,000-ohm load. When you plot the load current values on Graph *32* and draw the curve through the points, your resulting curve can be compared to the N.R.I. curve for condenser input in Graph *32*. You will see that the d.c. output voltage increases gradually to the no-load value as the load current is reduced by increasing the load resistance. Furthermore, with your curve you can determine what the d.c. output voltage will be for any intermediate value of load current.

Warning: Smoke coming from the N.R.I. Tester during direct current measurements means you have not made the correct series connection for a current measurement. Turn off the power pack at once, and move the test probes to the correct positions, as instructed in the box on page 25.

Load Current Computations. You can easily check your measured values of load current by means of Ohm's Law. To compute what the load current in amperes will be, divide the measured value of d.c. output voltage by the ohmic value of the load resistance employed. Multiplying the result by 1,000 will give you the load current in milliamperes. You can do this for one or two of the load values in Table *32* if you wish, to see how well your computed and measured values agree. Of course, you cannot expect perfect agreement because the actual ohmic values of the resistors may be as much as 20% off from rated values due to normal manufacturing tolerances.

Your a.c. power pack was designed to deliver at least 350 volts d.c. at a d.c. load current value of 25 ma., when connected to a standard 115-volt, 60-cycle power line. The curve of results obtained in the N.R.I. laboratory shows that the d.c. output voltage is well above 350 volts at this rated full-load current of 25 ma.

Your power pack is capable of delivering considerably more than the

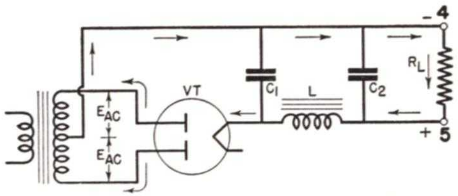


FIG. 12. Simplified schematic circuit diagram of the high-voltage section of your a.c. power pack, with arrows indicating the direction of electron flow. R_L represents an external load resistance connected to d.c. output terminals *4* and *5* of the power pack.

rated output current for *short* periods of time, as you actually demonstrated.

Review of Rectifier Action. Although the operating principles of rectifier circuits are fully covered in your regular course, now is an excellent time to review these important principles briefly, and see just why the d.c. output voltage drops as load is applied.

To explain the theoretical operation of your a.c. power pack, the simplified schematic circuit diagram in Fig. *12* will be easier to follow than the detailed schematic diagram in Fig. *2*. Rectifier tube *VT* in Fig. *12* allows each power transformer secondary voltage E_{AC} in turn to send electrons through load resistor R_L and choke coil *L* in one direction only, as indicated by arrows.

Input filter condenser C_1 (Fig. *12*) is charged by the pulsating d.c. voltage produced by the rectifier tube-transformer combination. When the pulsating d.c. source voltage drops below the condenser voltage, this condenser discharges through R_L and *L;* the condenser current then adds to the existing current flow over this path, thereby keeping the load current nearly constant despite the fact that the pulsating d.c. voltage is dropping to zero between each half cycle.

If the resistance values of *L* and R_L are reasonably high, the voltage across C_1 will more or less follow the peaks of the rectified voltage during this action.

Increasing the power pack load by reducing the resistance value of R_L affects the power pack circuit in three different ways, with each of these tending to make the d.c. output voltage drop.

First of all, an increased load makes C_1 discharge more completely in between the peaks of the pulsating d.c. voltage, with the result that the average d.c. voltage value across input filter condenser C_1 is reduced. This is one reason why the d.c. output voltage goes down as more load is applied.

Secondly, whenever direct current is drawn from the power pack, this current must flow through the d.c. resistance of the power transformer secondary winding, through the d.c. resistance of rectifier tube *VT*, and through the d.c. resistance of choke coil *L*. Increasing the load current increases the voltage drops across these three d.c. resistances, thereby reducing the amount of d.c. voltage available at output terminals *4* and *5*.

Finally, the a.c. voltage supplied by the power transformer secondary winding will drop when more current is drawn from this winding. The power transformer must supply more energy when the load is increased, and consequently the alternating currents flowing through both the primary winding and the high-voltage winding must increase when the load current increases. Each transformer winding has an a.c. resistance due to eddy current and hysteresis losses as well as normal copper losses; the increased flow of alternating current through these a.c. resistances lowers the a.c. voltage available at the terminals of the high-voltage secondary winding for rectification purposes.

Instructions for Report Statement No. 32. By referring to the curve which you plotted in Graph *32*, determine what the d.c. output voltage of your power pack will be for a d.c. load current of 25 ma. when using the condenser-input filter circuit shown in Figs. *2*, *8*, and *12*. This is done by tracing upward from 25 ma. on the horizontal scale until you intersect your curve, then tracing horizontally leftward to the vertical axis and reading the d.c. voltage value there. Record this voltage value in the space provided for this purpose in Report Statement No. 32 on the last page.

EXPERIMENT 33

***Purpose:* To demonstrate the voltage regulation characteristics of both the low and high-voltage secondary windings of the power transformer in your power pack.**

Step 1. To measure the full-load and no-load voltages of the low-voltage secondary winding in your power pack, first take the length of resistance wire which is supplied as Part *4-11* and connect it between output terminals *1* and *2* on the power pack by bending an open hook in each end of the wire, slipping one hook under the screw of output terminal *1* and tightening this screw, then slipping the other hook under the screw of output terminal *2* and tightening this screw. Bend the loop of resistance wire so that it does not touch the chassis or other nearby objects. This length of wire has a resistance of 3 ohms, which is the correct value for drawing full-load current from the 6.3-volt filament winding of the power pack.

Prepare the tester for a.c. voltage measurements and place the test clips on output terminals *1* and *2* underneath the chassis. (Under-chassis connections are used because it is difficult to make the clips grip the terminal screws while they are tightened over the resistance wire.) The chassis should be resting on its back side so that these terminals will be readily accessible. Measure the a.c. voltage between terminals *1* and *2*, and record your result in Table *33* as the voltage in volts at a.c. output terminals *1* and *2* for full load of 3 ohms.

Remove the length of resistance wire from terminals *1* and *2*, measure the a.c. voltage between output terminals *1* and *2*, and record your result in Table *33* as the no-load a.c. output voltage value in volts of the 6.3-volt filament winding (between terminals *1* and *2*).

CAUTION: Do not touch the re-

STEP	NATURE OF MEASUREMENT	A.C. VOLTAGE IN VOLTS	
		YOUR VALUE	N.R.I. VALUE
1	VOLTAGE AT A.C. OUTPUT TERMINALS 1 AND 2 FOR 3Ω LOAD		6.0
	VOLTAGE AT A.C. OUTPUT TERMINALS 1 AND 2 FOR NO LOAD		6.7
2	VOLTAGE AT TRANSFORMER TERMINALS 22 AND 23 FOR 10,000Ω LOAD		350
	VOLTAGE AT TRANSFORMER TERMINALS 22 AND 23 FOR NO LOAD		375

TABLE 33. Record your results here for Experiment 33. All power pack measurements in this table are for normal full-wave rectification and condenser input.

sistance wire with your fingers while the power is on, and allow ample time (about one minute) for the wire to cool after power is turned off. This wire becomes almost red hot, and can cause an unpleasant burn if touched. Use long-nose pliers if for any reason you have to handle the wire while still hot.

Step 2. To measure full-load and no-load a.c. voltages across one half of the high-voltage secondary winding, first connect a 10,000-ohm load to d.c. output terminals *4* and *5* by connecting the group of four 40,000-ohm resistors in parallel again with temporary soldered lap joints, then connecting the group between output terminals *4* and *5*. Be sure the resistor leads do not touch the chassis.

With the chassis resting on its back side to make the power transformer terminals accessible, measure the a.c. voltage between transformer terminals *22* and *23* and record your result in Table *33* as the a.c. voltage in volts across one half of the high-voltage secondary winding (between terminals *22* and *23*) for a 10,000-ohm load.

Remove the 10,000-ohm load from the power pack by disconnecting the group of four resistors from terminals *4* and *5*, measure the a.c. voltage again between terminals *22* and *23*, and record your result in Table *33* as the no-load a.c. voltage in volts across one half of the high-voltage secondary winding (between terminals *22* and *23*).

Discussion: In Step 1, you placed directly across the separate 6.3-volt filament winding in your power pack a resistance which draws from this winding its rated output current of about 2 amperes. When you measure the a.c. output voltage while this load is present, you find the voltage to be appreciably lower than for the corresponding no-load condition.

In Step 2, you again observe this same drop in voltage with load when you place a 10,000-ohm load across the output terminals of the power pack so as to increase the effective load on the high-voltage secondary winding of the power transformer. You have thus proved that the a.c. voltage at the high-voltage secondary winding drops when load is applied to the power pack, exactly as was pointed out in Experiment 32 (in the review of rectifier action), and have demonstrated for yourself one of the three reasons why the d.c. output voltage drops with load.

Transformer Theory. To understand why the secondary voltage of a power transformer drops as load is applied, we must review the basic action of an iron-core transformer.

Although a power transformer is one of the most efficient devices employed in the electrical and radio industries, it is by no means entirely perfect. A power transformer has copper losses, hysteresis losses and eddy current losses, and these along with the reactances of the windings serve to reduce the output voltage when the transformer is loaded.

Consideration of the equivalent transformer circuit shown in Fig. *13* will help you to understand the actions occurring in a practical transformer.

If a definite load voltage value V_L is required across load R_L in Fig. *13*, the secondary winding of the ideal transformer must supply a higher voltage E_S which will be equal to the vectorial sum of the load voltage V_L, the a.c. voltage drop across the secondary a.c. resistance value R_S, and the a.c. voltage drop across the secondary inductive reactance X_S. The higher the load current, the higher are the voltage drops across R_S and X_S, and the higher must E_S be to overcome these drops.

A definite transformer primary voltage E_P is required to provide secondary voltage E_S, assuming perfect coupling in this ideal transformer. The supply voltage E must be higher than this primary voltage, however, for it has to overcome the a.c. voltage drop across the primary a.c. resistance R_P and the a.c. voltage drop across the primary inductive reactance X_P.

We thus see that the voltage drops across the primary and secondary resistances and reactances in a power transformer make necessary a *higher* input voltage than would be required in a perfect transformer to secure a desired output voltage. This means that when the input voltage is fixed (as it is for the average power line connection), these voltage drops make the output voltage *lower* than that for a perfect transformer. Increasing the load makes these voltage drops increase, thereby reducing the output voltage still more if the input voltage remains constant.

Further study of the results you obtained in this experiment will show that at no load, the d.c. output voltage of the power pack is higher than the a.c. voltage across each half of the high-voltage secondary winding. Thus, the N.R.I. values show an a.c. secondary voltage of 375 volts and a no-load d.c. output voltage of 450 volts.

This does not mean, however, that we are getting voltage step-up in the filter circuit. The measured a.c. voltage value of 375 volts in the N.R.I. case is an *effective* or *r.m.s. value*, and the instantaneous voltage will actually swing up to 1.4 times this effective value on peaks. This means that the peak a.c. voltage value present across one half of the secondary winding is 1.4 × 375 volts, or 525 volts. This value of 525 volts represents the theoretical absolute limit of the no-load d.c. output voltage. By bridging the valleys between peaks, the filter condensers tend to make the d.c. output voltage approach this peak value during no-load conditions.

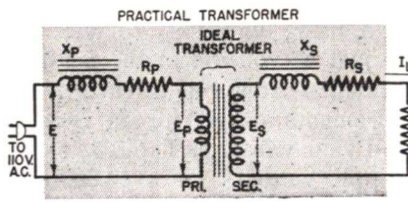


FIG. 13. Simplified equivalent circuit diagram for the primary winding and high-voltage secondary winding of a power transformer. The portion of the diagram designated as an ideal transformer has no losses. Parts X_P, R_P, R_S and X_S represent equivalent loss-producing resistances and reactances which are present in a practical iron-core transformer.

As load is applied to the power pack, the d.c. output voltage value drops, and may even go below the effective a.c. secondary voltage value, for increased load makes the input filter condenser discharge more completely during each rectified half cycle.

Instructions for Report Statement No. 33. In this experiment, you determine for yourself the effect which a load connected to the d.c. output terminals of your power pack has upon the a.c. voltage existing across one half of the high-voltage secondary winding of the power transformer. Report Statement No. 33 gives you a chance to express your own conclusion regarding this particular experiment, and at the same time tells us whether you have performed the experiment properly and mastered the important principle it is intended to demonstrate.

Turn to the last page, and place a check mark after the answer in Report Statement No. 33 which expresses the change you observed in the a.c. voltage across one half of the high-voltage secondary winding of the power transformer (between terminals *22* and *23*) when you applied a 10,000-ohm load to the d.c. output terminals of the power pack.

EXPERIMENT 34

***Purpose:* To show that most of the ripple voltage which is present across the input filter condenser of the power pack is dropped in the choke coil, and to show that the a.c. ripple voltage across the input filter condenser increases with load.**

Step 1. To measure ripple voltages in your a.c. power pack when a 40,000-ohm load is connected to the d.c. output terminals, first rest the chassis on its back side so that both the under-chassis connections and the output terminal screws are conveniently accessible. Take the group of four parallel-connected resistors used in the previous experiment, unsolder from the first resistor (the one having hooks in its lead) the other three resistors, then connect this single resistor to output terminals *4* and *5*.

Locate the 50,000-ohm bleeder resistor under the chassis (this is connected across the input of the power pack filter system, as shown in Fig. *2*). Measure the a.c. voltage across this resistor, being sure to place the black clip on the grounded resistor lead (place the black clip on the resistor

STEP	LOAD VALUE IN OHMS	A.C. VOLTAGE IN VOLTS ACROSS INPUT CONDENSER		A.C. VOLTAGE IN VOLTS ACROSS CHOKE COIL		A.C. VOLTAGE IN VOLTS AT D.C. OUTPUT TERMINALS	
		YOUR VALUE	N.R.I. VALUE	YOUR VALUE	N.R.I. VALUE	YOUR VALUE	N.R.I. VALUE
1	40,000		3.5		3.5		0
2	10,000		6.3		6.3		0

TABLE 34. Record your results here for Experiment 34. All power pack measurements in this table are for normal full-wave rectification and condenser input.

lead going to condenser terminal *27*, and place the red clip on the resistor lead going to socket terminal *8*). Record your result in Table *34* as the a.c. voltage in volts across the input filter condenser for a 40,000-ohm load. (The bleeder resistor is in parallel with the input filter condenser.) Wait a few seconds for the condensers to discharge before touching any terminals, after turning off the power pack.

To measure the a.c. ripple voltage across the choke coil, place one clip on choke coil terminal *14*, place the other clip on choke coil terminal *13*, read the meter on the *AC* scale, and record the result in Table *34* as the a.c. voltage in volts across the choke coil for a 40,000-ohm power pack load. Polarity of the test leads is unimportant in this case. However, this measurement is made in the hot side of the circuit. This places the tester chassis at a high potential with respect to ground, so do not touch the tester chassis and the power pack chassis at the same time while power is on.

To measure the a.c. ripple voltage at the d.c. output terminals of the power pack, place the red clip on output terminal screw *5* or on the resistor lead attached to this terminal, place the black clip on output terminal screw *4*, and record your result (even if it is *0*) in Table *34* as the a.c. ripple voltage at the d.c. output terminals for a 40,000-ohm power pack load.

Step 2. To measure a.c. ripple voltage values in your power pack when a 10,000-ohm load is connected to the d.c. output terminals, first solder your parallel-connected group of three 40,000-ohm resistors (left over from the previous experiment) in parallel with the 40,000-ohm resistor which is already connected to output terminals *4* and *5*, using temporary soldered lap joints just as you did in the previous experiment. Now, repeat each of the measurements called for in Step 1. Record your values in Table *34* as the a.c. ripple voltages for a 10,000-ohm power pack load.

Allow the 40,000-ohm resistors a few minutes to cool before touching them with your fingers; they become quite hot while serving as power pack loads.

When you have completed all measurements for this step, remove the 40,000-ohm resistors from output terminals *4* and *5*, but leave the resistors connected in parallel for the present.

Discussion: This experiment shows you that even though appreciable a.c. ripple may exist at the input of the filter system in the power pack (across the input filter condenser), the filter system reduces this a.c. ripple so much that the amount of ripple present at the d.c. output terminals is negligible and is so small that it cannot ordinarily be measured with the N.R.I. Tester. You also see for yourself how an increase in load makes the input a.c. voltage across the input filter condenser go up, with the choke coil still absorbing practically all of this voltage, so that the a.c. ripple at the d.c. output terminals is still too small to be measured.

In the regular lessons of your N.R.I. course, you learned that the input condenser of a filter circuit accepts electrons and charges up whenever the voltage delivered by the rectifier tube is higher than the existing voltage across this condenser. When the rectifier tube voltage is lower than that of the input filter condenser, the condenser cannot discharge in the reverse direction through the rectifier tube, and hence it discharges through the series circuit consisting of the choke coil and the power pack load. The rate at which this input filter condenser discharges is determined by the capacity value of the condenser and the total resistance value through which it discharges (the choke coil resistance + the load resistance).

The lower the ohmic value of the load, the lower is the total resistance through which the input filter condenser discharges; a low load resistance (corresponding to a large load) thus makes the input filter condenser discharge more completely in between peaks, as indicated by the solid-line curve in Fig. *14*. You can readily see that there is more a.c. ripple in this curve than there is in the dotted-line curve corresponding to a small load (high load resistance value). This explains why you obtained higher a.c. ripple voltage values for the 10,000-ohm load than you did for the 40,000-ohm load.

Since the choke coil and the output filter condenser are in series across the input filter condenser, these two parts really form an a.c. voltage divider connected across the input filter condenser. Therefore, according to Kirchhoff's Voltage Law, the voltage drop across each of the two parts will be proportional to the impedance of that part.

One requirement in the design of a filter circuit is a high choke coil impedance with respect to the output condenser impedance at the ripple frequency. When this condition is secured, most of the a.c. ripple voltage is dropped across the choke coil, and very little will be present across the output filter condenser and across the power pack load.

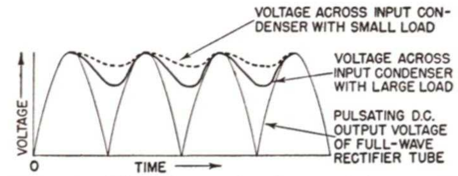


FIG. 14. Wave forms of voltages existing at different points in a power pack employing full-wave rectification and a condenser input filter.

Computation. We can readily compute the fraction of the ripple voltage which is dropped across each part of this a.c. voltage divider (across the choke coil and across the output filter condenser), assuming that the choke coil (L) has an inductance of 10 henrys, and the output filter condenser (C_O) has a capacity of 10 mfd. With the full-wave rectifier circuit employed in your power pack, the ripple frequency (f) is twice the power line frequency, or 120 cycles.

At the ripple frequency, the reactance of the output filter condenser will be:

$$X_C = 1{,}000{,}000 \div (6.28 \times f \times C_O)$$
$$X_C = 1{,}000{,}000 \div (6.28 \times 120 \times 10)$$
$$X_C = 1{,}000{,}000 \div 7{,}536 = 132 \text{ ohms}$$

Under the same conditions, the reactance of the choke coil will be:

$$X_L = 6.28 \times f \times L$$
$$X_L = 6.28 \times 120 \times 10 = 7{,}536 \text{ ohms}$$

These figures tell us that the reactance of the choke coil at the 120-cycle ripple frequency is about 57 times that of the output condenser (7,536 ÷ 132 = 57). This means that 56/57 of the total a.c. ripple voltage is dropped across the choke coil, and only 1/57 of the total (a negligible amount) is present across the output filter condenser and load. Since the a.c. ripple voltage at the filter input is rarely more than 7 volts even under full load, this means that the a.c. output voltage is negligibly small even when the load is increased to the maximum value which the power pack can safely handle.

We can compare reactances rather than impedances in this analysis simply because the d.c. resistance of the choke coil is negligibly small in comparison to its inductive reactance, and the condenser resistance is even smaller in comparison to its reactance.

Instructions for Report Statement No. 34. If you performed Experiment 34 slowly and carefully, so that you appreciated the full significance of each reading obtained, you will have no difficulty now in answering Report Statement No. 34 on the last page of this manual. In this report statement, you are simply asked to tell whether increasing the load on the d.c. output section of your power pack (by reducing the ohmic value of the load resistor) makes the a.c. ripple voltage across the input filter condenser decrease, increase or remain the same. Place a check mark after the answer you consider correct in the report statement.

EXPERIMENT 35

Purpose: **To prove that the inductance of the choke coil affects the a.c. ripple output voltage but does not affect the d.c. output voltage value, and to prove that the d.c. resistance of the choke coil affects the d.c. output voltage value.**

Step 1. To replace the choke coil in your power pack with a 200-ohm resistor, first unsolder the two wires which are on choke coil terminal *13*. Connect these two wires together with a temporary soldered hook joint, then bend the wires so that this joint does not touch terminal *13* or any other terminals. Now take your 200-ohm resistor (Part *3-4*) and connect one of its leads to choke coil terminal *14* with a temporary soldered lap joint. Connect the other resistor lead to the hook joint you just made, using either a soldered lap joint or a temporary soldered hook joint.

The change which you have just made is equivalent to removing the inductance of the choke coil while leaving its d.c. resistance in the circuit.

Step 2. To measure the d.c. output and the a.c. ripple voltages when the choke coil is replaced with a 200-ohm filter resistor and a 10,000-ohm load is connected to the d.c. output terminals, first take the group of four parallel-connected 40,000-ohm resistors left over from Experiment 34, and connect these to output terminals *4* and *5*.

With the power pack resting on its back side so that under-chassis connections are accessible, measure the d.c. output voltage between output terminals *4* and *5*, and record your result in Table *35* as the d.c. output voltage with a 200-ohm filter resistor and with a 10,000-ohm load.

Measure the a.c. voltage between terminals *4* and *5* for the same conditions, and record your result in Table *35* as the a.c. ripple voltage measured at the d.c. output terminals.

For comparison purposes, record in Table *35* the d.c. output voltage value which you measured in Experiment 32 for a 10,000-ohm load while the choke coil was still in the circuit (this is the first value which you recorded in Table *32*). Record also in Table *35* the a.c. ripple voltage in volts which you measured in Experiment 34 at the d.c. output terminals for a 10,000-ohm load and a 10-henry choke coil (the last reading you recorded in Table *34*).

Protecting N.R.I. Tester Against Surges. Always turn on the power pack before you turn on the N.R.I. Tester, and always turn off the N.R.I. Tester before you turn off the power pack. This prevents damage to the N.R.I. Tester by the voltage surges which exist at the instant of turning the power pack on or off. Be sure to turn off the power pack before touching the test clips with your fingers.

Step 3. To measure ripple and d.c. output voltages while the choke coil is replaced with a 200-ohm resistor and a 40,000-ohm load is connected to the d.c. output terminals, first remove three of the 40,000-ohm resistors from d.c. output terminals *4* and *5*, so as to leave only one 40,000-ohm resistor connected to these terminals. Now repeat each of the measurements made in Step 2; that is, measure the d.c. output voltage and the a.c. ripple voltage which is present at the d.c. output terminals, and record each measured value in Table *35*.

For comparison purposes, record also the d.c. and a.c. output voltages which you obtained in Experiments 32 and 34 respectively for a 40,000-ohm load and the original choke coil connection.

Discussion: A comparison of the two d.c. output voltage values which you recorded for Step 2 in Table *35* should prove definitely that the inductance of the choke coil has no effect upon the d.c. output voltage value. In other words, you should obtain essentially the same d.c. output voltage values when the 200-ohm resistor is in the circuit as when the choke coil was in the circuit during the 10,000-ohm load measurement in Experiment 32. Any difference between your values can be due to variations in line voltage or normal tolerances in radio part values.

A comparison of the d.c. output voltage values which you recorded in Step 3 of Table *35* for the 40,000-ohm load further verifies that the d.c. output voltage is independent of the amount of inductance in the choke coil.

When you study the a.c. output voltage values recorded for Step 2, however, you note an entirely different situation. When this was measured with a 10,000-ohm load and the choke coil in the circuit, in Step 2 of

STEP	CIRCUIT DATA	D.C. OUTPUT VOLTAGE IN VOLTS		A.C. VOLTAGE IN VOLTS AT D.C. OUTPUT TERM.	
		YOUR VALUE	N.R.I. VALUE	YOUR VALUE	N.R.I. VALUE
2	10,000Ω LOAD AND 200Ω FILTER RESISTOR		350		2.4
	10,000Ω LOAD AND 10H. CHOKE COIL		350		0
3	40,000Ω LOAD AND 200Ω FILTER RESISTOR		420		1.2
	40,000Ω LOAD AND 10H. CHOKE COIL		420		0

TABLE 35. Record your results here for Experiment 35. All power pack measurements in this table are for normal full-wave rectification and condenser input. Values on the first line in each step are obtained with a 200-ohm resistor connected in place of the 10-henry choke coil. Values in the second line of each step in the table are obtained from Tables 32 and 34.

Experiment 34, zero voltage was obtained. When the choke coil is replaced with the 200-ohm resistor, however, an appreciable a.c. voltage value is present at the d.c. output terminals. This is definite proof that it is essentially the inductance of the choke coil (not the resistance) which keeps down the a.c. ripple voltage at the d.c. output terminals.

Making the same comparison for the 40,000-ohm load value in Step 3 further emphasizes the importance of the inductance in keeping down a.c. ripple.

Since the entire load current must flow through the choke coil or filter resistor, it should be apparent that the d.c. resistance of the choke coil will affect the d.c. output voltage. The greater the resistance of this choke coil, the greater will be the voltage drop across this coil and the less d.c. voltage there will be available at the d.c. output terminals.

You learned in connection with a previous experiment that the reactance of the choke coil is about 57 times the reactance of the output condenser (the computed values were 7,536 ohms and 132 ohms respectively). When you replace the choke coil with a resistor, however, you have only 200 ohms at the choke coil position acting in series with the output condenser reactance of 132 ohms. Under this condition, almost half of the input condenser ripple voltage is present across the output filter condenser and the load. This explains why you obtained measurable a.c. output voltage values at the d.c. output terminals when the choke coil was replaced by the 200-ohm resistor.

It is permissible to use a resistor in place of a choke coil in a filter circuit only when the ohmic value of the resistor is many times the reactance of the output filter condenser. A resistance value high enough for adequate filtering can be used only when the load voltage requirements are low or the load resistance is considerably higher than the required filter resistor value.

Instructions for Report Statement No. 35. The discussion for this experiment indicates that the ohmic value of the equivalent filter resistor affects both the d.c. output voltage value and the a.c. ripple voltage value. For this report statement, you will make additional measurements to verify these statements experimentally.

Remove the 200-ohm resistor which you connected between choke coil terminal *14* and the leads formerly on terminal *13,* and connect in its place a 20,000-ohm resistor (two of your 40,000-ohm resistors connected in parallel).

With a 40,000-ohm load still connected to the d.c. output terminals, measure the d.c. output voltage across the load (between terminals *4* and *5*). Compare this measured value with the d.c. output voltage value you obtained in Step 3 of this experiment for the same 40,000-ohm load and a 200-ohm resistor in place of the choke coil. Now turn to the last page of this manual, and answer the first half of Report Statement No. 35, wherein you are asked whether the d.c. output voltage increased, decreased or remained the same when you increased the ohmic value of the filter resistor from 200 ohms to 20,000 ohms.

Next, measure the a.c. ripple voltage value at the d.c. output terminals of your power pack while the same 40,000-ohm load and 20,000-ohm filter resistor are connected. Compare your measured value for this set-up with the measured ripple voltage value recorded for Step 3 in Table *35* for the 200-ohm filter resistor and 40,000-ohm load, then answer the last part of Report Statement No. 35.

If you keep in mind that you now have a 20,000-ohm resistance acting in series with the 132-ohm reactance of the output filter condenser, you should have no difficulty in figuring out the reason for the result you obtained when you measured the a.c. ripple voltage at the output terminals.

EXPERIMENT 36

***Purpose:* To determine how the filter system of your power pack performs when the input filter condenser is removed to give a choke input filter.**

Step 1. To secure a choke input connection, first remove the 20,000-ohm filter resistor which you used in place of the choke coil in the last experiment. Replace on choke coil terminal *13* the two wires which were originally on this terminal, so as to restore your power pack to its original circuit. Now disconnect the input filter condenser by unsoldering the lead which is on condenser terminal *29* and bend up this lead so it cannot touch other parts or terminals. Remove the 40,000-ohm load resistor from the d.c. output terminals.

Step 2. To measure the d.c. output voltage, the a.c. ripple output voltage, and the a.c. filter input voltage with no load on your power pack and with a choke input connection (with the input filter condenser removed), measure the d.c. voltage across terminals *4* and *5*, and record your result in Table *36* as the no-load d.c. output voltage.

Measure the a.c. ripple voltage at the d.c. output terminals *4* and *5*, and record your result in Table *36* as the a.c. voltage in volts at the d.c. output terminals of your power pack.

Measure the a.c. voltage across the 50,000-ohm bleeder resistor under the chassis, and record your result in Table *36* as the a.c. filter input voltage in volts.

Since there is no load in this step, there is no d.c. load current to measure. Simply record zero for this no-load current measurement in Table *36*.

Step 3. To measure the d.c. output voltage, a.c. ripple output voltage, the a.c. filter input voltage and the d.c. load current with a 40,000-ohm load and a choke input filter circuit, first take one of your 40,000-ohm resistors (Part *3-6A*) and connect it to output terminal screws *4* and *5*.

Measure the d.c. output voltage as instructed in Step 2, and record your result in Table *36*.

Measure the a.c. ripple voltage at the d.c. output terminals as instructed in Step 2, and record your result in Table *36*.

Measure the a.c. voltage at the input of the filter as instructed in Step 2, and record your result in Table *36*.

Prepare the N.R.I. Tester for direct current measurements according to previous instructions. Measure the d.c. load current in milliamperes by disconnecting the 40,000-ohm resistor lead from output terminal screw *4*, placing the red test clip on this re-

STEP	LOAD IN OHMS	D.C. OUTPUT VOLTAGE IN VOLTS		A.C. VOLTAGE IN VOLTS AT OUTPUT TERMINALS		A.C. FILTER INPUT VOLTAGE IN VOLTS		D.C. LOAD CURRENT IN MILLIAMPERES	
		YOUR VALUE	N.R.I. VALUE	YOUR VALUE	N.R.I. VALUE	YOUR VALUE	N.R.I. VALUE	YOUR VALUE	N.R.I. VALUE
2	NO LOAD		400		1.0		63		0
3	40,000		350		1.8		114		7
4	20,000		310		2.3		135		15
5	10,000		270		3.4		147		27

TABLE 36. Record your results here for Experiment 36. All power pack measurements in this table are for normal full-wave rectification and choke input.

sistor lead, and placing the black test clip on output terminal *4*. Record your result in Table *36* as the d.c. load current in milliamperes for a 40,000-ohm load.

Step 4. To repeat your series of four measurements with a 20,000-ohm load connected to the power pack, remove the test clips and reconnect the load resistor lead to output terminal screw *4*, then connect another 40,000-ohm resistor in parallel with this first one by means of temporary soldered lap joints so as to secure a 20,000-ohm load.

Measure the d.c. output voltage in volts as instructed in Step 2, and record your result in Table *36*.

Measure the a.c. ripple output voltage in volts as instructed in Step 2, and record your result in Table *36*.

Measure the a.c. voltage at the input of the filter circuit as instructed in Step 2, and record your result in Table *36*.

Measure the d.c. load current in milliamperes as instructed in Step 3, and record your result in Table *36*.

Step 5. To repeat your series of four measurements with a 10,000-ohm load connected to the power pack, take your remaining two 40,000-ohm resistors and connect them in parallel with the two already on output terminals *4* and *5*, so that you have four parallel-connected 40,000-ohm resistors connected to these terminals to give a 10,000-ohm load. Now repeat each of the four measurements as instructed in Steps 2 and 3, and record your four results in Table *36*.

Step 6. To get a better picture of how load current varies with d.c. output voltage when the input filter condenser is disconnected, plot on Graph *32* the four sets of readings you just obtained for d.c. load current and d.c. output voltage. You received instructions in Experiment 32 for plotting values like these on a graph. Make heavy dots for each of your four points on the graph, then connect the dots together with a curve which passes through all four points. Label this as your curve for choke input, to distinguish it from the curve you previously drew for condenser input.

Discussion: Although it might be more convenient to start with a full load of 10,000 ohms and remove resistors one by one to reduce the load (as was done in Experiment 32), you follow normal laboratory procedure in this experiment by starting with no load and gradually increasing the load up to the maximum value. This procedure is preferred because there are occasions when you will not know whether some part in the circuit is capable of standing up under full-load conditions.

By starting with no load, you can at least get some of your readings before it is necessary to stop measurements because of overheating of a part. Sometimes the readings will indicate a tendency towards failure sufficiently in advance for you to stop the experiment and change the part or circuit to correct the condition. As far as actual values are concerned, you will secure the same readings regardless of whether you work from no load to full load or from full load to no load.

In this experiment, you remove the input filter condenser from your power pack circuit so as to duplicate the entirely possible condition whereby this condenser becomes defective during actual operation. When the input filter condenser is removed, the choke coil becomes the first part in the filter circuit through which the pulsating d.c. output of the rectifier tube passes. A filter circuit of this nature is commonly known as a *choke input filter*,

while the original filter circuit in the power pack is known as a *condenser input filter*. Familiarity with the performance of a filter system having a defective input filter condenser will help you to recognize trouble of this type when you encounter it in radio equipment.

This experiment is important for still another reason. Although a choke input filter is rarely used in radio receivers, it is used extensively in

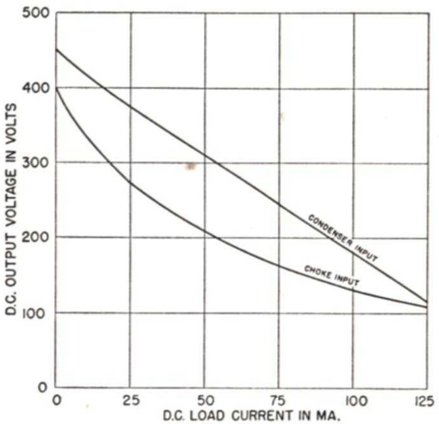


FIG. 15. Graph showing how the d.c. output voltages for condenser input and choke input in your power pack tend to become equal in value as the d.c. load current is increased up to the maximum safe current of 125 ma. which can be handled by the rectifier tube. Values for these curves can be obtained only by taking certain special precautions, because the power transformer and choke coil in your power pack are designed for maximum rated currents of only 25 ma. These current ratings are entirely ample for all experiments which you will perform with your power pack.

transmitter power packs and in the high-voltage power packs of special radio apparatus. By becoming familiar with the operating characteristics of this type of filter, you acquire valuable training in these branches of radio as well as in radio receiver servicing.

We can start our analysis of the results obtained in this experiment by considering the load current-d.c. output voltage curve which you plotted in Step 6. A comparison of this curve with that which you obtained in Experiment 32 shows immediately that the d.c. output voltage is lower for choke input than for condenser input. This is explained by the fact that with choke input, there is no input condenser to maintain the voltage in between the pulses of the rectifier tube output. The choke and output filter condenser merely serve to remove the a.c. component.

Voltage Regulation. To express how the output voltage of a power pack will drop when full load is applied, engineers often use a rating called *per cent voltage regulation.* This is obtained by taking the difference between the no-load and full-load voltages, dividing this difference by the no-load voltage value, then multiplying the result by 100.

There are certain special conditions in which choke input can give as good or even better voltage regulation than condenser input. For instance, the d.c. output voltage of the power pack was measured in the N.R.I. laboratory with various load values drawing up to 125 ma., using both choke input and condenser input, and the results plotted to give the curves shown in Fig. *15*. These curves show that with a 125-ma. load, the d.c. output voltages become very nearly equal for both curves.

Careful examination of the curves in the vicinity of 125 ma. shows that variations in load current in this region will cause less variation in the d.c. output voltage when choke input is used than when condenser input is used. In other words, the choke input curve is flatter than the condenser input curve at high load-current values. This verifies the statements made in your regular lessons regarding the advantages of choke input in power packs which must supply high d.c. output voltages to large varying loads, such as in the power packs of transmitters.

The curves in Fig. *15* give the voltage regulation of the entire power pack, including the power transformer. If a sufficiently large power transformer were used to eliminate the voltage regulation characteristics of the power transformer from these curves, the superiority of the choke input filter over the condenser input filter at high load current values would be much more evident.

Ripple Voltage. An examination of the a.c. voltage values which you recorded in Table *36* shows that both the input a.c. voltage to the filter and the a.c. ripple output voltage are much higher with choke input than they were for the corresponding measurements made in Experiment 34 with condenser input and recorded in Table *34*.

In the discussion of Experiment 34, we calculated that the ripple voltage was reduced about 57 times by the choke coil and output filter condenser. In the case of choke input, we can determine the ripple reduction factor for each load simply by dividing the filter input a.c. voltage by the filter output a.c. voltage.

The N.R.I. values of a.c. voltage and the resulting ripple reduction factors have been reproduced in Fig. *16* for your convenience in analyzing the results. Now we

LOAD IN OHMS	N.R.I. VALUE OF A.C. FILTER INPUT VOLTAGE IN VOLTS	N.R.I. VALUE OF A.C. FILTER OUTPUT VOLTAGE IN VOLTS	RIPPLE REDUCTION FACTOR
40,000	114	1.8	63
20,000	135	2.3	59
10,000	147	3.4	43

FIG. 16. N.R.I. values for the a.c. filter input and output voltages obtained in Experiment 36 have been repeated here for convenience in analyzing them, along with the computed ripple reduction factor values for each load resistance. The ripple reduction factor is obtained by dividing the a.c. filter input voltage for a given load by the a.c. filter output voltage obtained at that same load.

can see that for a 40,000-ohm load the ripple reduction is 63. With a 20,000-ohm load it drops slightly, down to 59, and with a 10,000-ohm load it drops down to 43. This change in the ripple reduction factor is due to the fact that the inductance of the choke coil drops as the direct current flowing through the choke coil increases.

The values in Fig. *16* show clearly that the a.c. input voltage to the filter goes up as load is applied, and the a.c. ripple voltage in the d.c. output likewise increases with load. This means that you should expect to secure increased hum when you increase the load acting on a power pack in a radio receiver. A common receiver defect illustrating this characteristic is that in which a partial short circuit is developed across the power pack by failure of some part in the receiver. The increased load pulls down the output voltage, thereby reducing the volume of the reproduced program, and at the same time the increased a.c. voltage in the output produces a hum in the loudspeaker.

A comparison of the results obtained in this choke input experiment with those obtained previously for condenser input tells you what symptoms can be expected if the input condenser in a radio receiver power pack becomes defective. First of all, hum will be noticeable, for the opening of the input condenser gives a choke input filter circuit, and this delivers a higher a.c. ripple voltage to the load. Furthermore, unless the power pack happens to be operating very near the current limit of the rectifier tube (a condition rarely encountered in radio receivers), the opening of the input condenser *will make the d-c. output voltage drop,* causing reduced volume and reduced receiver sensitivity.

Instructions for Report Statement No. 36. In this experiment, you demonstrated a number of important characteristics of radio receiver power packs. Among other things, you learned that the opening or removal of the input filter condenser changes your filter circuit from condenser input to choke input, with the result that both the d.c. output voltage and the a.c. ripple output change.

To test your understanding of what you measured and studied in the experiment, you are asked in Report Statement No. 36 to specify whether the d.c. output voltage increases, decreases or remains the same when the input filter condenser of your power pack opens up while connected to a 10,000-ohm load (equivalent to changing from condenser input to choke input). Place a check mark after the answer you consider correct.

EXPERIMENT 37

***Purpose:* To demonstrate that half-wave rectification gives a lower d.c. output voltage and a higher a.c. ripple output voltage than does full-wave rectification.**

Step 1. To convert your power pack circuit to a form which provides half-wave rectification, simply open the plate connection to one section of the rectifier tube by unsoldering the lead which is on socket terminal *4* and bending this lead up so that it cannot touch other terminals or parts. Leave other power pack connections as they were for the preceding experiment, so that you have a choke input filter (leave the lead still disconnected from condenser terminal *29*). Check the calibration of the N.R.I. Tester in the usual manner.

Step 2. To measure the d.c. and a.c. ripple output voltages for no load when the power pack is connected for choke input and half-wave rectification, measure the d.c. voltage between output terminals *4* and *5*, and record your result in Table *37* as the d.c. output voltage in volts for no load.

Measure the a.c. voltage between terminals *4* and *5*, and record your result in Table *37* as the a.c. ripple output voltage for no load.

Step 3. To measure the d.c. and a.c. ripple output voltages for a 40,000-ohm load when the power pack is connected for choke input and half-wave rectification, measure in turn the d.c. output voltage and the a.c. ripple output voltage of your power pack with a 40,000-ohm resistor connected to output terminals *4* and *5*. Follow exactly the same procedures specified in Step 2, and record your results in Table *37*.

Step 4. To measure the d.c. and a.c. ripple output voltages for a 10,000-ohm load when the power pack is connected for choke input and half-wave rectification, connect all four of your 40,000-ohm resistors in parallel to output terminals *4* and *5* in exactly the same manner you did for previous experiments, then measure in turn the d.c. output voltage and the a.c. ripple output voltage of your power pack by following the measuring procedures specified in Step 2, and record your results in Table *37*.

Discussion: Careful comparison of the results you obtained with corresponding load values recorded in Table *36* for choke input and *full-wave* rectification should show that half-wave rectification gives *lower d.c. output voltage* and *higher a.c. ripple output voltage* than does full-wave rectification. For example, with choke input and no load, the N.R.I. value of output voltage is 350 volts for half-

STEP	LOAD IN OHMS	D.C. OUTPUT VOLTAGE IN VOLTS		A.C. OUTPUT VOLTAGE IN VOLTS	
		YOUR VALUE	N.R.I.	YOUR VALUE	N.R.I.
2	NO LOAD		350		2.3
3	40,000		300		4.5
4	10,000		210		9.3

TABLE 37. Record your results here for Experiment 37. All power pack measurements in this table are for half-wave rectification and choke input.

wave rectification in Table *37*, and 400 volts for full-wave rectification in Table *36*. On no load, the a.c. ripple output voltage is 2.3 volts for half-wave rectification and only 1 volt for full-wave rectification.

The same factors which make the d.c. output voltage drop when half-wave rectification is employed also serve to make the a.c. output increase. First of all, with half-wave rectification only one alternation of each cycle of the a.c. secondary voltage of the power transformer is sending current through the rectifier tube. This is indicated by the filter input voltage wave shown in Fig. *17*. The filter input voltage is at zero for such a high proportion of the total time that the average d.c. voltage at the filter input is quite low for half-wave rectification.

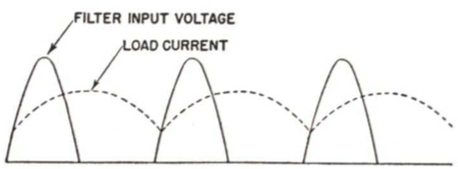


FIG. 17. Curves showing the wave form of the filter input voltage and the load current in an a.c. power pack employing half-wave rectification.

Fortunately, the choke coil prevents the load current from following too closely the fluctuations in the input voltage. The choke tends to oppose changes in the current passing through it, and consequently the load current has a wave form like that shown by the dash-dash load current curve in Fig. *17*. This is far from being a pure d.c. output, indicating that additional filtering would be needed in your power pack if it were permanently connected for choke input and half-wave rectification.

Another factor which makes half-wave rectification have a high a.c. ripple output is the fact that the fundamental ripple frequency for half-wave rectification is only 60 cycles, as compared to 120 cycles for full-wave rectification. Cutting the frequency in half cuts the reactance of the choke coil in half and doubles the reactance of the output filter condenser. As a result, the ripple reduction factor of the choke coil-output condenser combination is reduced 4 times. Dividing 57 by 4 gives only 14 as the ripple reduction factor when we have a 10-henry choke and 10-mfd. output condenser.

Instructions for Report Statement No. 37. So far, all of your measurements for half-wave rectification have been made with a choke input filter. To determine the effect of additional filtering upon the d.c. output voltage and the a.c. output voltage while using half-wave rectification, reconnect the input filter condenser lead to condenser terminal *29* to secure condenser input again, and repeat the series of two measurements which you made for a 10,000-ohm load in Step 4 of this experiment. Compare the d.c. output voltage value which you obtain for this condenser input measurement with that which you recorded in Table *37* for the 10,000-ohm load, then turn to the last page and answer the first half of Report Statement No. 37.

Next, compare the a.c. output voltage value which you just measured for condenser input with that which you obtained for choke input and a 10,000-ohm load in Step 4, and answer the last part of Report Statement No. 37.

Now, if you analyze your answers to this report statement, you should be able to figure out why a condenser input filter is always used in radio receiver power packs employing half-wave rectification.

Be sure to turn off the N.R.I. Tester and the power pack after completing these measurements. Leave the 10,000-ohm load connected to the power pack, since you will use this in the next experiment.

EXPERIMENT 38

***Purpose:* To demonstrate that the a.c. ripple output voltage can be reduced by tuning the choke coil with a suitable shunt condenser value.**

Step 1. To tune the choke coil in your power pack approximately to resonance, take the two .25-mfd. paper condensers (Parts *3-2A* and *3-2B*), connect one in parallel with the other by means of temporary soldered joints, then connect the combination in parallel with the choke coil (across terminals *13* and *14*) by means of temporary soldered lap joints. Now disconnect the lead from condenser terminal *29* so as to secure choke input again, and check output terminals *4* and *5* to be sure the 10,000-ohm load is still connected properly to these terminals. Leave the wire disconnected from socket terminal *4* to provide half-wave rectification.

A.C. RIPPLE VOLTAGE IN VOLTS AT D.C. OUTPUT TERMINALS	
YOUR VALUE	N.R.I. VALUE
	7.2

TABLE 38. Record your result here for Experiment 38. The measurement is made with half-wave rectification, choke input, a 10,000-ohm load, and a .5-mfd. condenser connected to tune the choke coil approximately to resonance.

Measure the a.c. ripple output voltage at d.c. output terminals *4* and *5*, and record your result in Table *38*.

Discussion: In an earlier experiment, you made measurements which showed that a .5-mfd. condenser will tune your 10-henry choke coil approximately to resonance at 60 cycles. Furthermore, you learned in your regular course that at resonance, a parallel resonant circuit has a much higher impedance than does the coil or condenser alone. You utilize all this information in a highly practical manner in this experiment by placing the .5-mfd. condenser across your choke coil, while the power pack is connected for half-wave rectification, choke input and a 10,000-ohm load.

As Table *38* indicates, an a.c. voltage value of 7.2 volts was obtained in the N.R.I. laboratory for this particular measurement. Comparing this value with the corresponding value obtained for a 10,000-ohm load, half-wave rectification and choke input in Table *37* (where the choke was not tuned), it is apparent that tuning the choke coil lowers the a.c. ripple output considerably.

Tuning of the filter choke coil is by no means a complete solution to the filtering problem in a half-wave rectifier, or even in a full-wave rectifier, but it does improve the filtering sufficiently to warrant its use in many radio receiver power packs. Whenever you encounter a receiver power pack in which a condenser is connected across the choke coil, you can be sure the condenser is there for the purpose of tuning the choke coil.

When tuning of the choke is incorporated in the power pack of a commercial radio receiver during design, the choke coil itself is designed to have a low a.c. resistance, so as to make its Q factor high. With a high Q factor, the impedance of the coil can be stepped up many times by tuning it to resonance, thus reducing the ripple output considerably. The 10-henry choke coil employed in your power pack has a relatively low Q factor, for it is designed primarily for use in ordinary condenser input filters where the Q factor is unimportant.

When excessive hum is encountered in a receiver which has a tuned choke coil in its power pack filter system, the condenser used across the choke coil should be checked carefully. If this condenser is open or is excessively leaky, there will be little or no impedance step-up, and the a.c. ripple or hum output will be high.

Sometimes a mechanical shock such as dropping a receiver will alter the positions of the laminations in the choke coil, thereby changing the inductance of the choke coil; in this case, a new choke or a different capacity value may be needed in order to produce resonance and eliminate hum.

Instructions for Report Statement No. 38. A .5-mfd. capacity gave a decided decrease in the hum output when connected across the choke coil; will an even greater reduction in hum be obtained with a .25-mfd. condenser,

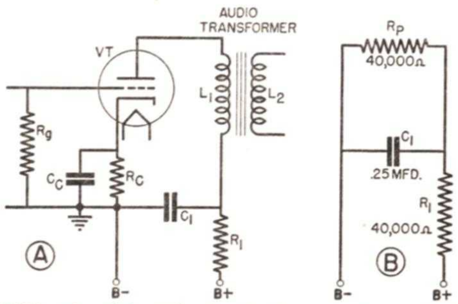


FIG. 18. Schematic circuit diagram of a typical audio amplifier stage (*A*), and the equivalent circuit diagram (*B*) which you set up to duplicate the loading effect of this stage upon a power pack to which it is connected.

will the hum remain the same, or will you get more hum than with the .5-mfd. capacity? This is the problem in Report Statement No. 38.

In order to answer this question, remove one of the .25-mfd. condensers which you connected across the choke coil, so that only .25 mfd. is in parallel with the choke, then repeat your measurement of the a.c. ripple voltage at the d.c. output terminals.

Compare your measured value with that which you recorded in Table *38* for the .5-mfd. condenser, then turn to the last page and place a check mark after the answer which describes your result. Finally, remove the .25-mfd. condenser which you placed across the choke coil.

EXPERIMENT 39

Purpose: **To demonstrate the effectiveness of a resistor-condenser filter in reducing a.c. ripple voltage.**

Preliminary Discussion: In Fig. *18A* is shown a typical audio amplifier circuit such as might be found connected to a power pack like yours in an actual radio receiver. The terminals marked *B*— and *B*+ in this circuit would go to the *B*— and *B*+ terminals respectively of the power pack.

As you have already demonstrated in previous experiments, a power pack may supply a small a.c. ripple voltage value along with its normal d.c. output voltage. If this ripple voltage is allowed to affect the plate circuit of a stage like this, it will produce a corresponding hum frequency in the signal output (across primary winding L_1 of the audio transformer).

Resistor R_1 and condenser C_1 in Fig. *18A* form a filter which effectively prevents power pack a.c. ripple from entering the plate circuit. The a.c. voltage between the *B*— and *B*+ terminals in Fig. *18A* is divided between C_1 and R_1, with most of the a.c. voltage being dropped across R_1. In designing a circuit like this, the reactance of C_1 is made very low in comparison to the resistance of R_1, so that only a negligibly small a.c. voltage is developed across C_1 for application to the plate circuit.

With your power pack, you can readily duplicate the conditions existing in the circuit of Fig. *18A*, and demonstrate to yourself the effectiveness of a resistor-condenser filter in reducing power pack hum or a.c. ripple. It is not necessary to use the entire vacuum tube circuit shown in Fig. *18A* for this experiment, because we can satisfactorily duplicate this circuit with two resistors and a condenser arranged as shown in Fig. *18B*. Here C_1 and R_1 are the same as in Fig. *18A*, but R_P is a 40,000-ohm resistor which essentially duplicates the total plate circuit resistance of a typical vacuum tube circuit (such as a circuit having a plate voltage of 250 volts and a plate current of 6.25 ma., corresponding to a total circuit resistance of 250 ÷ .00625, or 40,000 ohms).

By setting up the circuit shown in Fig. *18B*, connecting the *B*— and *B*+ terminals of the circuit to the corresponding terminals of your power pack, and measuring the a.c. ripple voltage first at the power pack output terminals (at the input of our resistor-condenser filter R_1-C_1), then across equivalent load resistor R_P (across the output of filter R_1-C_1), we can readily compute the ripple reduction factor of this filter combination.

Step 1. To set up the apparatus necessary for demonstrating the effectiveness of resistor-condenser filter R_1-C_1 in Fig. 18B, first connect a 20,000-ohm load to d.c. output terminals *4* and *5* by placing two of your 40,000-ohm resistors in parallel across these terminals in the manner shown in Fig. *19*. Arrange the resistors so that they rest on the table or bench top. Leave the power pack connected for half-wave rectification and choke input just as it was at the end of the preceding experiment, so that with this circuit combination and the 20,000-ohm load you are obtaining a fairly high a.c. ripple output along with the d.c. output.

Next, connect the remaining two 40,000-ohm resistors and a .25-mfd. condenser (Part *3-2A*) between output terminals *4* and *5* exactly as shown in Fig. *19*, allowing these resistors also to rest upon the table or bench top. Make temporary soldered joints in all cases.

Step 2. To measure the a.c. ripple voltage at the input of filter R_1-C_1, place the red test clip on any resistor lead going to output terminal *5*, place the black test clip on any resistor lead going to output terminal *4*, measure the a.c. voltage, and record your result in Table *39* as the a.c. ripple voltage in volts at the input of filter R_1-C_1.

To measure the a.c. ripple voltage at the output of filter R_1-C_1 (across C_1), simply move the red clip to the common junction of C_1, R_1 and R_P (Fig. *19*), leaving the black clip on a lead going to terminal *4*. Record your result in Table *39* as the a.c. ripple voltage in volts at the output of filter R_1-C_1.

A.C. RIPPLE VOLTAGE IN VOLTS AT INPUT OF FILTER R_1−C_1		A.C. RIPPLE VOLTAGE IN VOLTS AT OUTPUT OF FILTER R_1−C_1	
YOUR VALUE	N.R.I. VALUE	YOUR VALUE	N.R.I. VALUE
	6.9		1.1

TABLE 39. Record your results here for Experiment 39. The measurements are for half-wave rectification, choke input, and a 20,000-ohm load connected to the d.c. output terminals of the power pack.

Discussion: You can determine the ripple reduction factor of your resistor-condenser filter R_1-C_1 simply by dividing the a.c. filter input voltage by the a.c. filter output voltage.

If we do this with the N.R.I. values, we obtain a filter reduction factor of approximately 6. (6.9 ÷ 1.1 = 6.2). If you secure approximately this ripple reduction factor with your values, you have proved experimentally that a resistor-condenser filter of this type will definitely reduce hum voltages.

The theoretical ripple reduction factor of an R-C filter can very readily be computed. With half-wave rectification, the ripple frequency is 60 cycles. At this frequency, a .25-mfd. condenser will have a reactance of 10,600 ohms.*

With a value of 40,000 ohms for filter resistor R_1, the a.c. voltages will divide in the

$$*X_C = \frac{1{,}000{,}000}{6.28 \times .25 \times 60}$$

$$X_C = 10{,}600 \text{ ohms}$$

ratio of 40,000 to 10,600, which is approximately 3.77. This value will then be the theoretical ripple reduction factor. The shunting effect of 40,000-ohm resistor R_P on the condenser lowers the reactance between the condenser terminals, thus increasing the ripple reduction factor of the circuit. The measured N.R.I. value of 6 is, therefore, entirely acceptable.

A.F. Filtering Action. A resistor-condenser filter (usually called simply an R-C filter) in the plate circuit of a radio receiver also serves to prevent a.f. signals in the plate circuit from

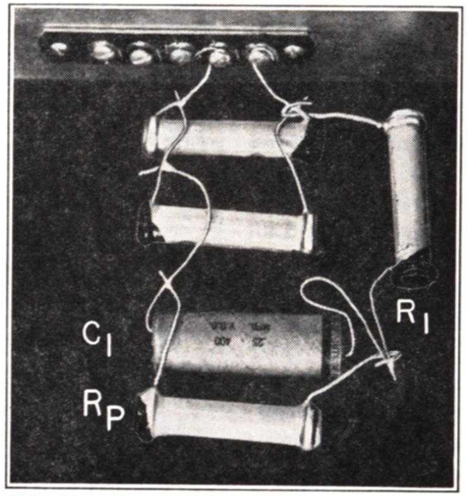


FIG. 19. Suggested method of connecting to the d.c. output terminals of your power pack a 20,000-ohm load and an arrangement of two resistors and a condenser (R_1, R_P and C_1) which duplicates the effect of a typical audio amplifier stage having an R-C filter and a total plate circuit resistance of 40,000 ohms.

entering the power pack and traveling from there to other circuits where undesirable regeneration or degeneration might be produced. Thus, filter condenser C_1 in the vacuum tube circuit of Fig. *18A* has a reactance which is low with respect to the total impedance of the signal path through vacuum tube *VT*, coil L_1 and the parallel combination of cathode resistor R_C and C_C, and hence only a small portion of the total available a.f. voltage exists across C_1 to feed back into the power pack.

R_1 in Fig. *18A* acts with the output filter condenser in the power pack as an R-C filter for a.f. signals heading in this opposite direction toward the power pack. The reactance of the output filter condenser is usually quite low at audio frequencies (is less than 200 ohms), while R_1 is generally higher than 10,000 ohms in value, so that the ripple reduction factor for a.f. signals heading toward the power pack is considerably higher than 50.

Instructions for Report Statement No. 39. Experiment 39 proved conclusively that an R-C filter connected between the power pack and a load will reduce the a.c. ripple filter voltage which reaches the load. One question still remains unanswered, however: Does the insertion of an R-C filter between source and load affect the value of the d.c. voltage applied to the load?

You will recall that resistor R_P in Fig. *18B* serves to duplicate the plate circuit resistance of an audio amplifier stage. Our question really asks,

then, whether the voltage across R_P is any different from the voltage between the *B—* and *B+* terminals in Fig. *18B*. This can be checked very easily by making two simple d.c. voltage measurements in your test circuit. Once you make these measurements and compare your readings, you will have no difficulty in answering Report Statement No. 39.

To measure the d.c. output voltage of your power pack, simply place the red clip on output terminal *5*, place the black clip on output terminal *4* (while leaving all four resistors and the condenser connected to these terminals in the manner shown in Fig. *19*), measure the d.c. voltage, and make a notation of your result in the margin of this page or elsewhere.

Next, measure the d.c. voltage across 40,000-ohm load resistor R_P by placing the red clip on the common junction of leads from R_P, C_1 and R_1 and leaving the black clip on output terminal *4*. Record this value also in the margin of this page. Compare your two measured values of d.c. voltage, then turn to the last page and place a check mark after the answer which best describes your conclusions regarding these measurements. Unsolder R_1, R_P and C_1 in Fig. *19*, but leave the other two 40,000-ohm resistors connected to the d.c. output terminals of the power pack.

EXPERIMENT 40

***Purpose:* To show that resistance in series with a filter condenser increases the amount of ripple voltage at the output of a power pack.**

Step 1. To connect your power pack for full-wave rectification with condenser input, with a 1,000-ohm resistance in series with the input filter condenser, and with a 10,000-ohm load connected to the d.c. output terminals of the power pack, first restore full-wave rectification by reconnecting the transformer secondary lead to socket terminal *4*. Next, take a 1,000-ohm resistor (Part *3-5A*), connect one of its leads to electrolytic condenser terminal *29* by means of a temporary soldered hook joint, and connect the other resistor lead to the wire from choke coil terminal *14* which formerly went to condenser terminal *29*, as indicated by the circuit diagram in Fig. *20A*. Adjust the position of the 1,000-ohm resistor so that none of its leads

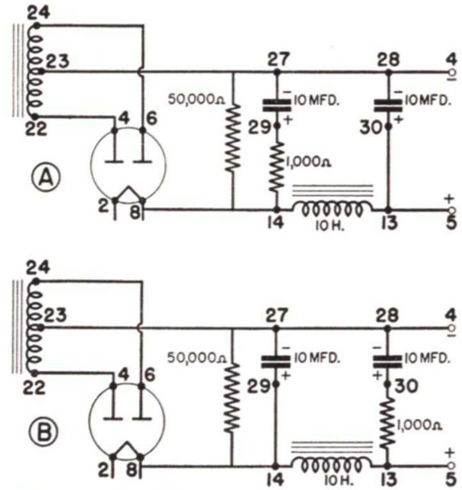


FIG. 20. Simplified schematic circuit diagrams of your a.c. power pack when connected normally for full-wave rectification and condenser input, showing how a 1,000-ohm resistor is to be inserted in series with each 10-mfd. electrolytic filter condenser in turn to duplicate the effect of a dried-out filter condenser.

are touching other uninsulated leads or terminals.

Place a 10,000-ohm load across output terminals *4* and *5* by soldering the remaining two 40,000-ohm resistors in parallel with the two 40,000-ohm resistors already connected to these terminals.

Step 2. To measure the input and output a.c. voltages of the filter system in your power pack when a 1,000-ohm resistor is in series with the input filter condenser, first measure the a.c. voltage across the 50,000-ohm bleeder resistor, and record your result in Table *40* as the a.c. ripple voltage in volts at the input of the filter when a 1,000-ohm resistance is in series with the input filter condenser.

Measure the a.c. voltage between output terminals *4* and *5* for the same conditions, and record your result in Table *40* as the a.c. ripple in volts at the output of the filter when you are using a 1,000-ohm resistor in series with the input filter condenser.

Measure the d.c. output voltage of the power pack, and record your measured d.c. output voltage value in Table *40*.

Step 3. To secure a.c. ripple voltage readings at the input and output of the filter when a 1,000-ohm resistor is in series with the output filter condenser, first remove the 1,000-ohm resistor from the power pack circuit and reconnect choke coil terminal *14* directly to condenser terminal *29*. Now unsolder the lead which is on condenser terminal *30*, connect one lead of the 1,000-ohm resistor to terminal *30*, and connect the other resistor lead to the lead which you just unsoldered from *30*. This places the 1,000-ohm resistor in series with the *output* filter condenser, as shown in Fig. *20B*.

Measure the a.c. voltage across the 50,000-ohm bleeder resistor, and record your result in Table *40* as the a.c. ripple in volts at the input of the filter when using a 1,000-ohm resistor in series with the output filter condenser.

Measure the a.c. voltage at output terminals *4* and *5*, and record your result in Table *40* as the a.c. ripple in volts at the filter output.

Measure the d.c. output voltage now, and record your result in Table *40*.

Discussion: It is entirely possible for an electrolytic condenser to dry out during use, so that it becomes equivalent to a condenser in series with a resistor. When this condition is sufficiently serious, hum becomes noticeable along with radio programs; in certain cases, the d.c. output voltage may drop, so that the receiver loses sensitivity (ability to reproduce programs of distant or weak stations satisfactorily), and the reproduced program becomes distorted due to low operating voltages.

In this experiment, you introduce in series with each electrolytic filter condenser in turn a 1,000-ohm resistor which duplicates the condition whereby the electrolytic condenser has dried out.

The N.R.I. values given in Table *40* for Step 2 indicates an a.c. filter input voltage of 33 volts, as compared to only 6.3 volts for the corresponding N.R.I. measurement in Step 2 of Table *34* when no resistor was in series with the input filter condenser. This is quite a large difference, but when we compare the N.R.I. values for the a.c. ripple output, the difference is very much less. Thus, the N.R.I. value is 1 volt in Table *40* and zero in Table *34*.

This indicates that a defective input filter condenser will increase the amount of a.c. input to the filter, but the output filter condenser and choke coil together will prevent most of this a.c. ripple from entering the load. The resistance acting in series with the input filter condenser prevents this condenser from charging and discharging fast enough to hold up the filter input voltage in between peaks of the rectified output.

The N.R.I. d.c. output voltage of 325 volts for Step 2 in Table *40* is comparable with the N.R.I. value of 350 volts for a 10,000-ohm load in Table *32*. This indicates that drying out of the *input* filter condenser will cause some decrease in the d.c. output

STEP	CIRCUIT DATA	A.C. RIPPLE IN VOLTS AT INPUT OF FILTER		A.C. RIPPLE IN VOLTS AT OUTPUT OF FILTER		D.C. OUTPUT VOLTAGE IN VOLTS	
		YOUR VALUE	N.R.I. VALUE	YOUR VALUE	N.R.I. VALUE	YOUR VALUE	N.R.I. VALUE
2	1000Ω IN SERIES WITH INPUT FILTER CONDENSER		33		1.0		325
3	1000Ω IN SERIES WITH OUTPUT FILTER CONDENSER		6.3		2.1		350

TABLE 40. Record your results here for Experiment 40. All power pack measurements in this table are for normal full-wave rectification and condenser input, with a 10,000-ohm load connected to the d.c. output terminals of the power pack.

voltage, resulting in lowered output volume, loss of sensitivity, and possibly also in distortion.

When the 1,000-ohm resistor is placed in series with the output filter condenser to simulate a defect in this condenser, the N.R.I. value of 6.3 volts in Step 3 of Table *40* is the same as the value of 6.3 volts for the corresponding condition without the 1,000-ohm resistor in Step 2 of Table *34*. The a.c. ripple output at the d.c. output terminals is quite high, however, when the resistor is present; it is 2.1 volts in Step 3 of Table *40*, but zero in Table *34*. This indicates that drying out of the output filter condenser will definitely cause appreciable hum in a radio receiver.

Considering the d.c. output values for Step 3 of Table *40* and for the 10,000-ohm load condition in Table *32*, we find that exactly the same values were obtained in both cases. This indicates that loss of capacity in the output filter condenser will have no effect upon the d.c. output voltage. Actually, you can disconnect the output filter condenser without affecting the d.c. output voltage.

Apparently it is the output filter condenser which has the most control upon the amount of ripple in the a.c. output. Let us consider why this is so. At 120 cycles (the ripple frequency in the full-wave rectifier circuit we are now employing), the reactance of a 10-mfd. condenser is about 132 ohms. The insertion of a 1,000-ohm resistor in series with 132 ohms will make the combination essentially resistive, having a total impedance only slightly higher than 1,000 ohms. The impedance of the output filter condenser is now much closer to the impedance of the choke coil, with the result that the ripple reduction factor is greatly reduced.

Drying out of the output filter condenser creates another serious condition in a practical radio circuit. As you will recall, this condenser acts with the series resistor in the plate supply lead of each vacuum tube stage as an R-C filter which prevents a.f. plate current from entering the power pack. A reduction in the capacity of the output filter condenser reduces considerably the effectiveness of this R-C filter, with the result that a.f. and r.f. currents may enter the power pack and travel from there to other circuits, causing serious regeneration or degeneration which is evident as howling, low volume or distortion.

Instructions for Report Statement No. 40. In the discussion, we pointed out that a reduction in the capacity of the output filter condenser has essentially no effect upon the value of the d.c. output voltage. This means that there will be essentially no change in the d.c. output if one lead of the output filter condenser in a radio receiver should accidentally break or open. But what will happen to the a.c. ripple voltage at the output of the filter when this occurs? By disconnecting one lead of the output filter condenser, then measuring this a.c. ripple voltage, you can answer this question for yourself and at the same time secure the information needed to answer Report Statement No. 40.

You should still have the 1,000-ohm resistor connected in series with the output filter condenser. Unsolder this resistor from the circuit, but leave this condenser still disconnected. Now measure the a.c. ripple output voltage at output terminals *4* and *5*, and record your result in Report Statement No. 40.

Now, for your own information, compare this measured value with that which you recorded in Step 2 of Table *34* for the corresponding conditions with the output filter condenser connected (your value will be under the column in Table *34* headed *A.C. VOLTAGE IN VOLTS AT D.C. OUTPUT TERMINALS*).

Important Instructions. Restore your power pack to its original circuit by reconnecting the lead from choke coil *13* back on condenser terminal *30*. Check the wiring of your power pack now against the semi-pictorial wiring diagram in Fig. *8*, to be sure that all connections are correct. If you desire, you can now convert all temporary hook joints to permanent hook joints by squeezing the hooks with long-nose pliers while keeping the solder molten on the joint with your soldering iron.

Finally, make a check of the no-load d.c. output voltage of your power pack to be sure it is operating properly. The voltage which you measure now should correspond to that which you recorded for Step 1 in Table *31*. Be sure to turn off the N.R.I. Tester and the power pack when you have finished your work.

NOTICE: Remember that during all work with your a.c. power pack, the short length of bare wire should be left between terminals *3* and *4*, exactly as instructed in this manual, and an external ground connection should always be made to terminal *3* or *4* whenever using the power pack.

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	4TR1	4-3	Power transformer, 60 cycle	3.10	
	4SO3	4-4	Octal socket (4RK-AC)	.07	
	4TU2	4-5	5Y3G Rectifier tube	.56	
	4SW1	4-6	Slide type power switch	.15	
	4ST7	4-7	5-terminal, screw type strip	.13	
	4SO4	4-8	Pilot lamp socket with grommet	.06	
	4LP1	4-9	6.3-volt pilot lamp	.09	
	4SC1	4-10A	Machine screw assortment (10)	.05	
	4NU1	4-10B	Hex nut assortment (10)	.05	
	4WI15	4-11	3-ohm resistance wire	.03	
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