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INSTRUCTIONS FOR PERFORMING RADIO EXPERIMENTS 41 TO 50

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NATIONAL RADIO INSTITUTE
ESTABLISHED 1914
WASHINGTON, D. C.

PIONEER HOME STUDY RADIO SCHOOL
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N.R.I. AGAIN PIONEERS

Among the most baffling of all measurements are those involving r.f. voltages. For this reason, the training of technicians has in the past been generally limited to d.c., a.c. and possibly a.f. measurements. This explains why radio men today look upon an r.f. measurement as something mysterious which gives unexplainable results unless made in a research laboratory with special instruments costing hundreds of dollars.

Actually, however, most of the r.f. measurements required in practical radio work can be made easily, with inexpensive test instruments, if a few basic rules are understood and followed.

A series of remarkably simple and effective r.f. measuring techniques for the N.R.I. Tester has been developed in the N.R.I. laboratory. We are proud to be among the first in this country to offer a thoroughly practical training in r.f. measuring techniques.

The experiments in this manual and the next manual have been planned to give valuable practical experience in making r.f. measurements successfully and with confidence. Perform each experiment slowly and carefully so you will understand its full significance, and use the Technical Consultation Service whenever questions arise.

J. E. SMITH.

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1950 Edition

A LESSON TEXT 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 Experiments 41 to 50

Introduction

YOU are now ready to begin work with audio and radio frequency circuits. You will set up typical practical circuits and make measurements of r.f. and a.f. signals in these circuits with your N.R.I. Tester. You will learn techniques which eliminate many of the difficulties usually encountered when making r.f. measurements, and will acquire a practical attitude toward r.f. signals which will be of great value in your work as a Radiotrician.

First of all, you will assemble an audio frequency oscillator and carry out experiments which demonstrate how it operates and how its frequency can be varied.

Next, you will assemble a resistance-capacitance coupled audio amplifier stage and analyze its characteristics. You will demonstrate the highly practical fact that while the theoretical maximum amplification of a stage depends upon the amplification factor of the tube, the actual over-all gain of the stage is less and depends upon the nature of the load circuit.

You will build an r.f. oscillator and an r.f. amplifier stage, and learn how resonant circuits can be used to increase the gain of an r.f. amplifier stage. The r.f. oscillator will serve as your signal source for r.f. amplifier experiments. You will learn how loading affects the gain of the stage.

Finally, you will assemble both an r.f. oscillator and an a.f. oscillator, and interconnect them so that the a.f. signal modulates the r.f. oscillator. Thus, you produce a modulated r.f. signal which simulates, for experimental purposes, the signal produced by a broadcasting station or by modern radio servicing instruments. You will leave this modulated r.f. oscillator set up for use in connection with later experiments.

Contents of this Radio Kit

The parts included in this Radio Kit are illustrated in Fig. *1* and listed in the caption underneath. Check off on this list the parts which you have received, to be sure you have all of them.

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

Information on Type 6F8G Tube

The type 6F8G tube which is supplied to you in this Radio Kit is really two vacuum tubes mounted in a single glass envelope. The filament is the only part which is common to both sections of the tube; since this is a heater-type tube with two independent cathodes, this filament is present merely for heating purposes, and need not be connected to the r.f. or a.f. circuit in which the tube is employed. According to the tube manufacturer, the type 6F8G tube is actually two type 6J5G tubes in a

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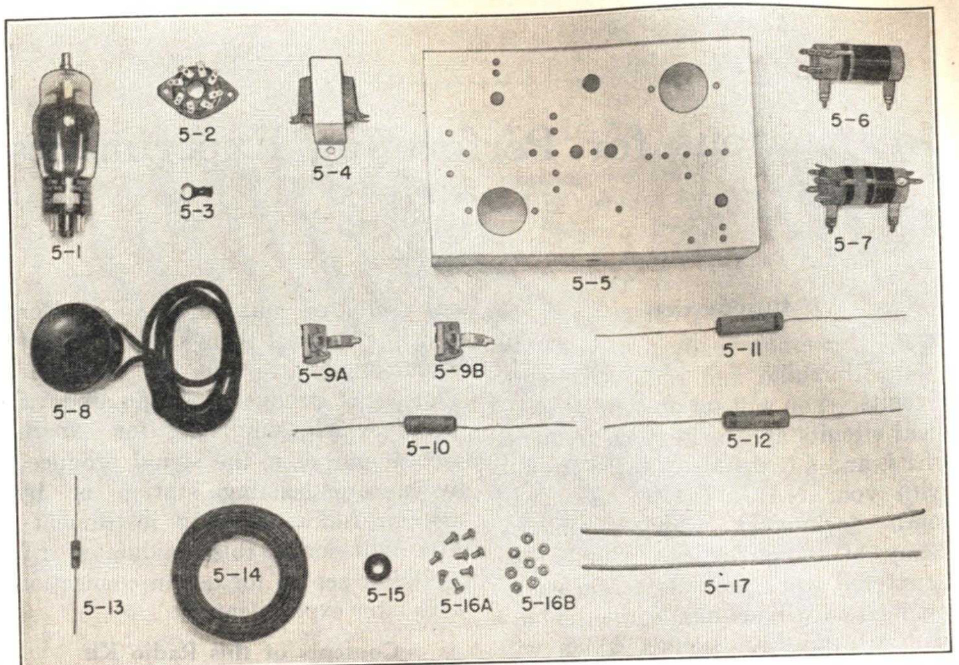

FIG. 1. The parts included in this Radio Kit are pictured above, and identified in the list below. Some resistors may have a better tolerance (lower percentage tolerance) than that indicated here.

Part No.	*Description*
5-1	One type 6F8G double-triode vacuum tube.
5-2	One octal-type tube socket with 8 terminal lugs.
5-3	One grid clip for octal-type tubes.
5-4	One audio transformer with 2½-to-1 turns ratio.
5-5	One cadmium-plated steel chassis bent to shape, with all holes already punched for parts used in 5RK.
5-6	One standard broadcast band antenna coil, with two mounting screws, four nuts and two wooden spacers.
5-7	One three-winding signal generator coil with two mounting screws, four nuts and two wooden spacers.
5-8	One 1,000-ohm headphone unit.
5-9A	One 370-mmfd. trimmer condenser with mounting bracket.
5-9B	One 370-mmfd. trimmer condenser with mounting bracket (same as Part *5-9A*).
5-10	One .001-mfd., 400-volt paper condenser.
5-11	One .01-mfd., 400-volt paper condenser.
5-12	One .05-mfd., 400-volt paper condenser.
5-13	One 100,000-ohm (.1-megohm), ½-watt resistor with 10% tolerance (color-coded brown, black, yellow, silver).
5-14	One 25-foot roll of push-back hook-up wire with red insulation.
5-15	One small rubber grommet.
5-16A	Eight ¼-inch long, 6-32 cadmium-plated binder-head machine screws.
5-16B	Eight cadmium-plated hexagonal nuts for 6-32 screws.
5-17	Two 8-inch lengths of No. 20 stranded tinned rubber and cotton insulated wire.
5-18	One 1000-ohm, ½-watt resistor of 10% tolerance. (Not shown above.)

The following parts which should be left over from previous radio kits will be needed in the next ten experiments.

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.
3-4	One 220-ohm, 1-watt resistor of 10% tolerance (color-coded red, red, brown, silver).
3-5A, B & C	Three 1,000-ohm, ½-watt resistors 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).
3-8	One 1,000-ohm wire-wound potentiometer.
3-12	One 6-lug terminal strip, with four of the lugs insulated.
4-21	One 10-megohm, ½-watt resistor with 10% tolerance (color-coded brown, black, blue, silver)
	One N.R.I. assembled Tester (Kit 2RK) and power pack (Kit 4RK).

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single envelope; if you examine the internal structure of your tube carefully, you may be able to see the two sets of tube elements.

The schematic symbol for a type 6F8G tube is shown in Fig. *2*. This diagram also identifies the terminals of this tube when looking at the bottom of the socket or when looking at the bottom of the tube base.

The glass inside your type 6F8G tube may have a black or silvery metallic deposit; this is the tube shield, and is connected internally to prong *1* on the tube base. The solid black dot at terminal *1* in the schematic symbol in Fig. *2* is a common means of indicating that there is an internal shield connection to this terminal.

The filament (heater) terminals are *2* and *7*. Terminals *8, 5* and *6* are the cathode, control grid and plate respectively of one triode section. Terminals *4*, the top cap and *3* are the cathode, control grid and plate terminals of the other triode section. Thus, the top cap of the tube goes to the control grid of one triode section.

Since this is an octal tube, the aligning key is in its standard position between terminals *1* and *8*. Any terminal on the tube socket can be readily located and indentified by reference to the position of this aligning key.

Your type 6F8G tube has a rated filament voltage of 6.3 volts, and draws .6 ampere of filament current when this filament voltage is applied. The tube will work satisfactorily, however, with a filament voltage anywhere between 5.5 volts and 7.5 volts.

When operated as an amplifier, the type 6F8G tube may have a plate voltage as high as 250 volts; with this voltage and with a C bias of —8 volts, the plate current will be about 9 ma.

The a.c. plate resistance of a type 6F8G tube is about 7,500 ohms, its mutual conductance is about 2,600 micromhos, and its amplification factor is about 20. Of course, the tube can be operated at other plate voltages, but such operation will give different values for the important ratings of the tube.

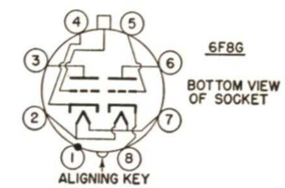

FIG. 2. Combination schematic and socket connection diagram for the type 6F8G double-triode tube supplied to you in this Radio Kit.

The grid-cathode inter-electrode capacity for each triode section is about 3 mmfd. The plate-cathode capacity for each triode section is about 3.5 mmfd. The grid-plate capacity for each triode section is about 4 mmfd.

The input capacity of a triode section is always higher than the grid-cathode capacity when the tube is in operation; actually, the input capacity is the sum of the grid-cathode capacity, the stray grid circuit capacities and a value equal to the grid-plate capacity multiplied by the true amplification of the stage.

A small capacity, less than .4 mmfd., exists between any electrode in one triode section and any electrode in the other triode section, but the effects of these capacities will be negligible in our experiments.

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 for that type of measurement in this manual or in the previous manuals.
3. Study the discussion of the experiment and analyze your results.
4. Answer the report statement for the experiment. It will always be on the last page of the manual.

EXPERIMENT 41

Purpose: **To build an a.f. oscillator and check its performance with the N.R.I. Tester and a headphone; to demonstrate that a condenser can be used to tune the a.f. oscillator circuit to a desired frequency.**

Preliminary Discussion: The schematic circuit diagram of the a.f. oscillator which you build for this experiment is shown in Fig. *3*. Observe that this circuit employs only one

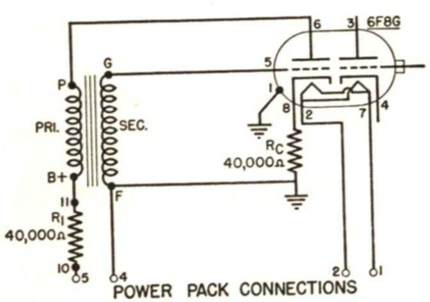

FIG. 3. Schematic circuit diagram of the a.f. oscillator which you build as a part of Experiment 41.

triode section of the type 6F8G tube. The iron-core transformer serves to couple the plate circuit to the grid circuit in the proper manner for oscillation. The filament and plate supply voltages for the tube are obtained from your power pack.

The schematic circuit diagram is presented for reference purposes and to help you understand how an audio oscillator of this type works. You will assemble the oscillator according to the detailed step-by-step instructions and semi-pictorial diagrams which will now be given.

Step 1. To mount on the chassis the parts needed for the a.f. oscillator, carry out the following instructions:

a. Place before you the following parts:

Type 6F8G vacuum tube (Part *5-1*).
Octal-type tube socket (Part *5-2*).
Audio transformer (Part *5-4*).
Cadmium-plated steel chassis (Part *5-5*).
Headphone unit (Part *5-8*).
.001-mfd. paper condenser (Part *5-10*).
.01-mfd. paper condenser (Part *5-11*).
.05-mfd. paper condenser (Part *5-12*).
Rubber grommet (Part *5-15*).
Machine screws and nuts (Parts *5-16A* and *5-16B*).
.25-mfd. paper condenser (Part *3-2A*).
Two 40,000-ohm resistors (Parts *3-6A* and *3-6B*).
Six-lug terminal strip (Part *3-12*).
Soldering iron, solder, hook-up wire, and all tools used in previous experiments.

b. To identify the chassis holes through which hook-up wire will be run, place your chassis bottom side up in the position shown in Fig. *4*, then locate holes *a, b, c, d, e, f, g, h, i, j* and *k* on your chassis and identify each with metal-marking crayon exactly as indicated in Fig. *4*.

Turn the chassis over, and identify these eleven holes on top of the chassis with metal-marking crayon in the same manner, being sure that your marking above the chassis for each hole is the same as the marking underneath the chassis (see Fig. *6*).

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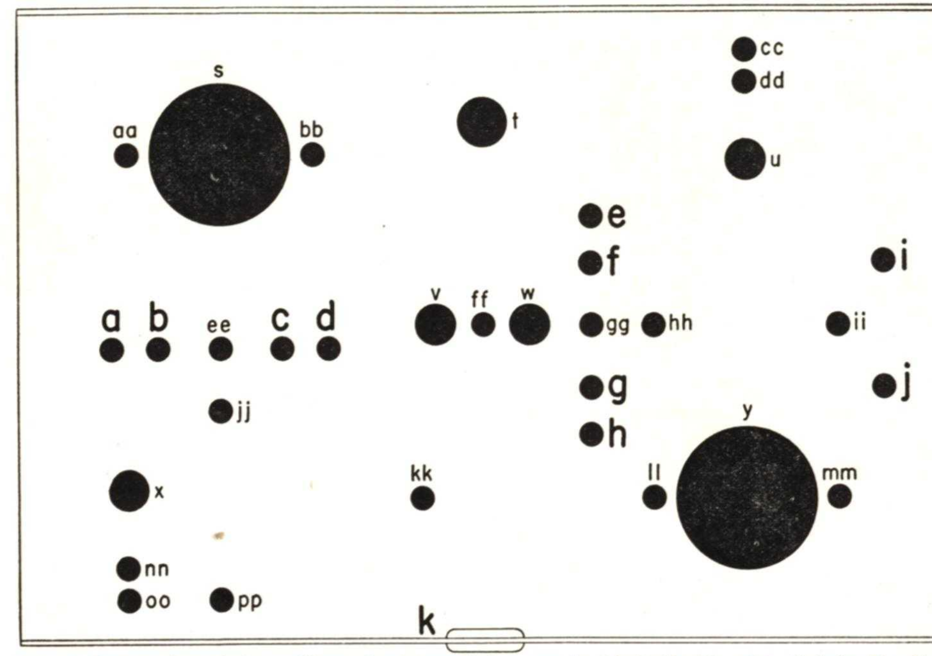


FIG 4. Bottom view of the oscillator chassis supplied to you in this Radio Kit, with all holes identified. Holes *a, b, c, d, e, f, g, h, i, j* and *k* should be identified on both sides of your own chassis with metal-marking crayon exactly as indicated here, but do not make any other marks on your chassis at this time.

Do not place any other markings on your chassis at the present time. The remaining holes are used for mounting parts, and Fig. *4* is an adequate guide for locating these holes.

c. Insert the rubber grommet (Part *5-15*) in hole *k*, after referring to Fig. *4* to locate this hole. It is on one side of the chassis.

d. Mount the 6-lug terminal strip underneath the chassis in holes *kk* and *ll*, by inserting the machine screws through these holes from the top of the chassis, placing the mounting holes of the strip over the projecting screws underneath the chassis in such a way that the lugs are farthest away from the rubber grommet, as shown in Fig. *5*, then placing nuts on the screws and tightening with pliers and a screwdriver.

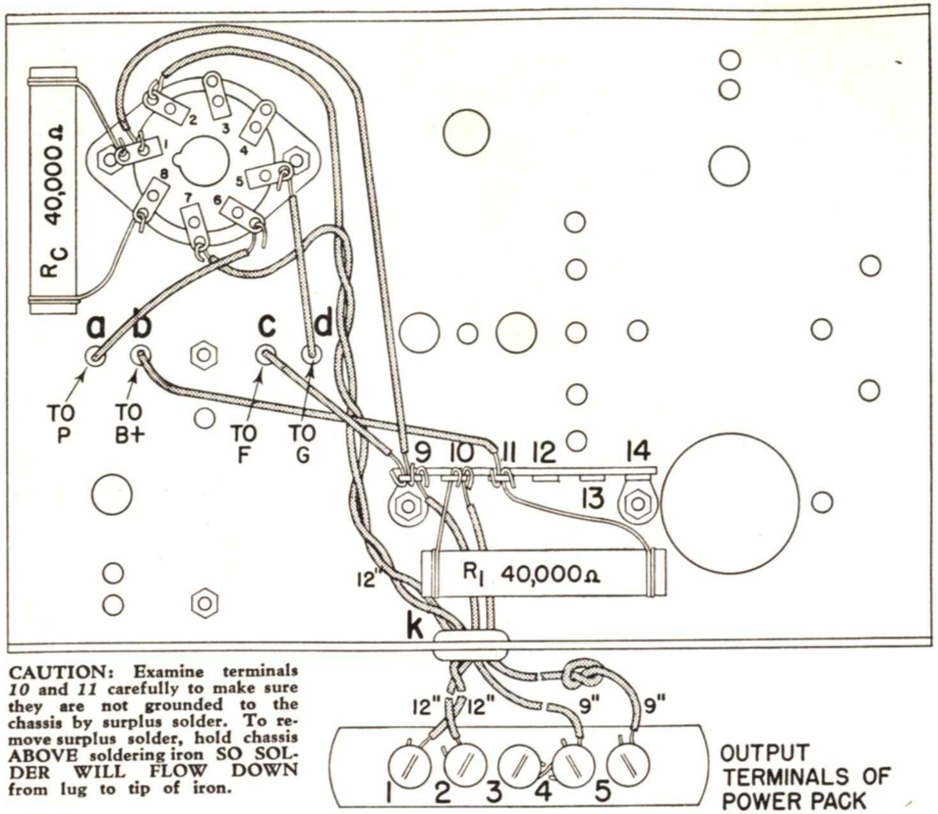
e. Mount the tube socket in hole *s* by inserting it in its hole from the bottom of the chassis in such a way that the aligning slot is next to hole *aa*, then fastening the socket to the chassis with machine screws and nuts.

f. Mount the audio transformer on top of the chassis in holes *ee* and *pp*, in a position such that the transformer lugs are approximately above holes *a, b, c* and *d*. The correct position of the transformer is shown in Fig. *6*.

Step 2. Complete the wiring of your a.f. oscillator in the following manner, making *temporary* soldered hook joints unless otherwise specified:

a. Identify the terminals of the 6-lug terminal strip by placing the numbers *9, 10, 11, 12, 13* and *14* on the chassis near these terminals with metal-marking crayon in exactly the manner shown in Fig. *5*.

Although tube socket terminal numbers are embossed on the bakelite portion of the socket already, you may find it easier to identify the socket lugs if you also mark these numbers on the chassis alongside the lugs with metal-marking crayon.



CAUTION: Examine terminals *10* and *11* carefully to make sure they are not grounded to the chassis by surplus solder. To remove surplus solder, hold chassis ABOVE soldering iron SO SOLDER WILL FLOW DOWN from lug to tip of iron.

FIG. 5. Semi-pictorial bottom view of the oscillator chassis, showing how parts and wires should be arranged for the a.f. oscillator which you construct for Experiment 41.

b. Cut two 12-inch lengths of red hook-up wire, connect one length to socket terminal *7*, with a *permanent* soldered hook joint, connect the other length to socket terminal *2*, with a *permanent* soldered hook joint, bend this length around the tube socket as shown in Fig. *5*, then twist the two wires together for the remainder of their length as indicated in Fig. *5*. A simple method of twisting wires together neatly with your fingers is shown in Fig. *7*. Bring the two twisted leads through the rubber grommet in hole *k*, as indicated in Fig. *5*.

c. Connect a 9-inch length of red hook-up wire to terminal *9* with a *permanent* hook joint but do not solder this joint yet. Run this wire out of the chassis through the rubber grommet in hole *k*.

d. Connect a 9-inch length of red hook-up wire to terminal *10* with a *permanent* hook joint, without soldering. Bring this lead out through the

IMPORTANT: Resistor and condenser leads which are more than two inches long should be cut to a length of approximately two inches. This applies to all remaining experiments in your Practical Demonstration Course. Resistor and condenser leads in semi-pictorial diagrams may sometimes appear to be shorter than two inches, but this effect occurs because the leads are at an angle to the chassis. From now on, all connections which you make in your Practical Demonstration Course should be ***temporary soldered joints.***

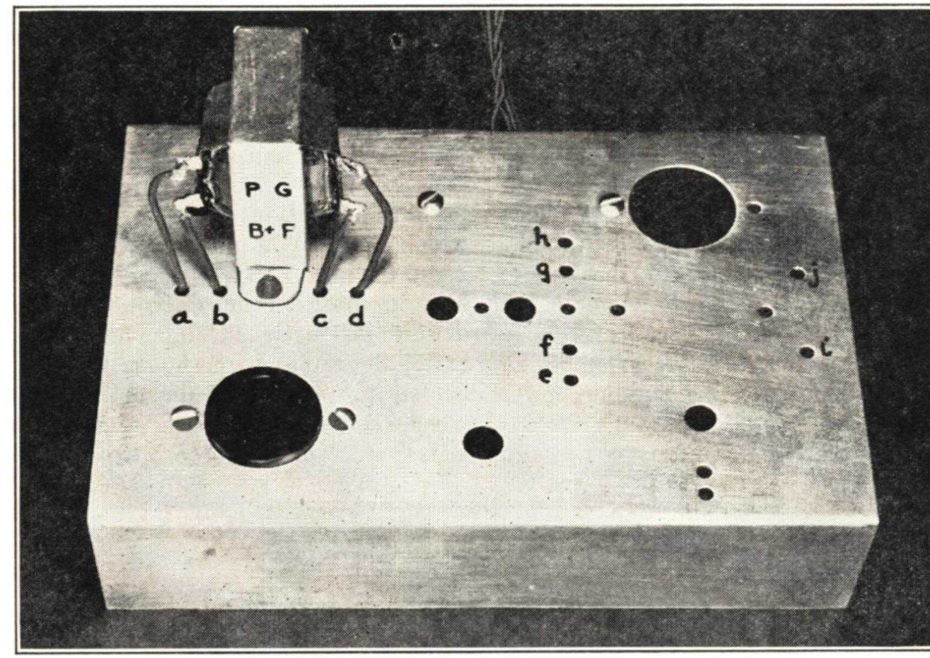


FIG. 6. Top view of the completed a.f. oscillator used in Experiment 41.

rubber grommet, and tie a simple knot about 2 inches from the end of the lead as indicated in Fig. *5*, to identify it as the B+ lead which is always to go on power pack output terminal *5*.

e. Connect a 40,000-ohm resistor (Part *3-6A*) between terminals *10* and *11* with temporary hook joints, soldering only terminal *10*. Adjust so neither the resistor nor its leads touch the chassis or other terminals.

f. Connect audio transformer terminal *F* (above the chassis) to terminal *9*. This connection is shown in Figs. *5* and *6*. Run the wire through chassis hole *c*, make temporary hook joints, and solder only at terminal *F*. The professional technique for making connections of this type involves straightening out several feet of wire from your roll of red hook-up wire, bringing the end of this wire through chassis hole *c* from the top of the chassis and connecting the wire to terminal *9*, then holding the wire alongside terminal *F*, cutting the wire enough above terminal *F* to permit forming a hook, then connecting to terminal *F*. This can be done much more rapidly than cutting the wire first to a specified dimension, hence lengths of leads will not be specified in future steps unless there is some special reason for having a particular length of wire.

g. Connect the *B+* terminal of the audio transformer to terminal *11* under the chassis, running the wire through chassis hole *b* and soldering both terminals. (Sometimes this terminal on an audio transformer is simply marked *B*.) Run this wire over the twisted filament leads but under the single wire going from hole *c* to *9*.

h. Connect audio transformer terminal *P* to socket terminal *6*, running the wire through chassis hole *a* and soldering both terminals.

i. Connect audio transformer terminal *G* to socket terminal *5*, running the wire through chassis hole *d* and soldering both terminals.

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j. Connect socket terminal *1* to terminal *9,* running the wire around the socket as shown in Fig. *5* and soldering both terminals. Place the wire in the lower hole of terminal lug *1.*

k. Connect a 40,000-ohm resistor (Part *3-6B*) between socket terminals *1* and *8,* soldering both terminals. Place the resistor lead in the upper hole of terminal lug *1,* as indicated in Fig. *5.*

Step 3. Complete the assembly of the a.f. oscillator by making power pack connections as follows:

a. Connect the two twisted wires to output terminals *1* and *2* respectively of your power pack. These are filament supply wires, and their polarity is unimportant.

b. Connect to output terminal *5* on your power pack the a.f. oscillator lead in which you previously tied a knot. This is the *B+* lead.

c. Connect the remaining a.f. oscillator wire to output terminal *4* on your power pack. This is the *B—* lead.

d. Insert the type 6F8G tube in its socket on the a.f. oscillator chassis. The power pack and a.f. oscillator unit should now appear as shown in Fig. *8,* if you have an a.c. power pack. Power pack connections are made in exactly the same manner for the d.c. power pack. (The wire which connects together output terminals *2, 3* and *4* on the d.c. power pack should be left in position; likewise, the wire which connects output terminals *3* and *4* on the a.c. power pack should be left in position until you receive definite instructions to remove it. The external ground wire should be connected to terminal *3* in both cases whenever the power pack is used.)

Step 4. To check the operation of your assembled a.f. oscillator, use your N.R.I. Tester and the headphone unit (Part *5-8*) to listen to the a.f. signal between the chassis and the *G* terminal of the audio transformer, by following the instructions given in this manual for "LISTENING TO AUDIO SIGNALS." The red clip should go on terminal *G,* and the black clip should go on the chassis, as shown in Fig. *8.* Now turn on the power pack and the N.R.I. Tester. If you have assembled the a.f. oscillator correctly, you should hear a distinctly audible tone in the headphone after the tubes have warmed up.

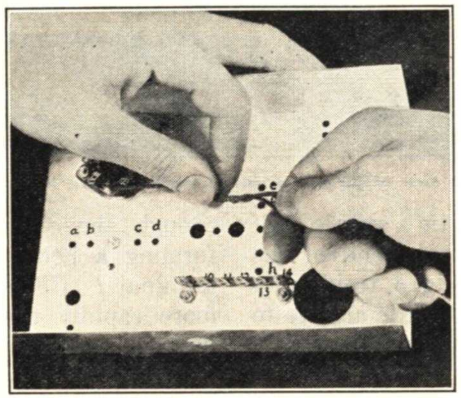

FIG. 7. Method of twisting the wires together to serve as filament leads for the a.f. oscillator. These leads will be left connected to socket terminals 2 and 7 for all ten of the experiments in this manual.

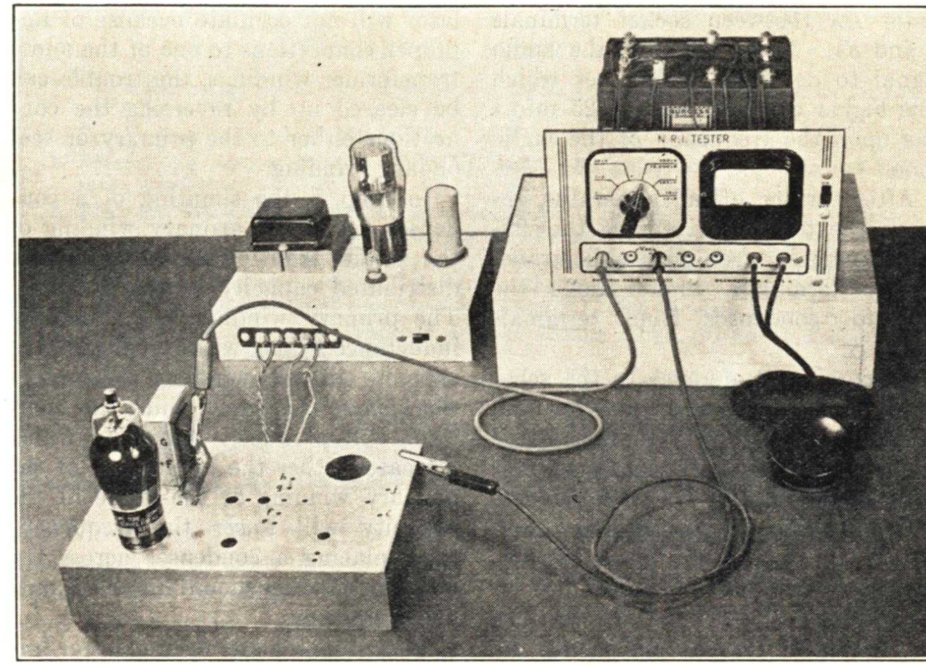

FIG. 8. This view shows how the a.f. oscillator is connected to the power pack, and how the N.R.I. Tester is used for listening to the audio output of the oscillator.

While the power pack and the N.R.I. Tester are still turned on, switch to the *30 × V* range and note the effect upon volume. Disregard meter readings for the present. Switch momentarily to lower voltage ranges, but do not leave the selector switch at a lower range for more than a few seconds if it causes overloading of the meter.

Turn off the N.R.I. Tester, then turn off the power pack. Leave the test clips in position.

Step 5. To determine the effect which various condenser values connected between P and B+ have upon the frequency of the audio signal, first connect a .001-mfd. condenser (Part *5-10*) between the *P* and *B+* terminals of the audio transformer by means of temporary soldered lap joints. Listen to the signal again with the headphone and N.R.I. Tester (red clip on *G,* black clip on chassis, and selector switch at *100 × V*). Try to decide whether the frequency (the musical pitch) of the signal is now higher or lower than it was without the condenser. If you leave one condenser lead disconnected, and make this connection momentarily several times while listening (by pushing on the body of the condenser with your fingers), the change in frequency will be easier to recognize.

Remove the .001-mfd. condenser from the audio transformer terminals (always be sure to turn off all power before making any circuit changes), connect a .05-mfd. condenser (Part *5-12*) to audio transformer terminals *P* and *B+* in its place, listen to the audio signal again, and note the effect which this higher capacity has upon the frequency of the audio signal.

Remove the .05-mfd. condenser from the audio transformer terminals, and connect in its place a .25-mfd. condenser (Part *3-2A*). Connect the .05-mfd. condenser across cathode re-

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sistor R_C (between socket terminals *1* and *8*). Again listen to the audio signal to determine the effect which this higher capacity value (.25 mfd.) has upon the frequency of the audio tone.

After turning off all apparatus, remove the test clips, remove the .25-mfd. condenser from the audio transformer terminals, and remove the .05-mfd. condenser from terminals *1* and *8*.

Discussion: Reference to the schematic circuit diagram for your a.f. oscillator (Fig. *3*) will show that the conventional by-pass condenser for cathode resistor R_C has been omitted, and no plate supply by-pass condenser has been used. These two by-pass condensers have been left out for the purpose of reducing the amount of feed-back, thereby improving the wave form of the a.f. signal produced by the oscillator. In other words, omission of these by-pass condensers makes the a.f. voltage of the oscillator have more nearly the desired perfect sine wave form.

This circuit produces oscillations at an audio frequency simply because each voltage change or surge in the plate circuit passes through the primary winding of the audio transformer and is transferred to the secondary or grid circuit, with the phase relationship being such that this feed-back voltage *reenforces* the grid voltage. Since the audio transformer reverses the phase of a voltage 180°, this means that the plate-cathode a.f. voltage of the tube must be about 180° out of phase with the grid-cathode a.f. voltage, if oscillation is to be secured.

Audio transformer connections must therefore be made exactly as specified in the instructions in order to make your a.f. oscillator work. In practical radio work, when an audio oscillator will not oscillate because of improper connections to one of the audio transformer windings, the trouble can be cleared up by reversing the connections either to the primary or secondary winding.

In Step 5, the shunting of a condenser across the primary winding of the audio transformer adds to the distributed capacity of this winding. The primary winding has a definite inductance which, with the distributed capacity of the winding, determines the *highest* frequency which the oscillator will produce. Anything which increases either the inductance of the primary winding or the value of the capacity will *lower* the frequency; thus, placing a condenser across the primary winding should lower the output frequency.

Theoretically, any desired lower frequency can be obtained by shunting the correct capacity value across the coil. Actually, however, this statement holds true only within limits; if the capacity across the coil is made too large, the circuit stops oscillating. When this occurs, the coil inductance must be increased before the capacity is further increased.

Instructions for Report Statement No. 41. In the discussion, it was pointed out that in order for oscillation to occur, the a.f. plate voltage in your a.f. oscillator must be about 180° out of phase with the a.f. grid voltage. Since the audio transformer reverses the phase of a voltage (changes it 180°), this means that during normal oscillator operation the a.f. voltage which is fed back into the grid circuit is *in phase* with the a.f. grid voltage, and therefore reenforces the grid voltage.

For this report statement, you are to reverse the connections to the primary winding of the audio transformer, thereby reversing the phase of the a.f. voltage which is fed back into the grid circuit. You probably know already what to expect when this is done, but by actually carrying out this change, you will impress its effect indelibly upon your mind.

To reverse the primary winding connections, first unsolder the lead which is on the *P* terminal of the audio transformer. Now disconnect the lead from the *B+* terminal of the audio transformer, extend this lead about 1 inch with a short piece of hook-up wire, and connect it to the *P* terminal. Finally, connect to the *B+* terminal the lead which you removed from the *P* terminal. No condenser will be used across the primary winding for this test. Place your test clips on the *G* terminal and the chassis, and listen for the audio tone just as before, after turning on your apparatus. You can now answer Report Statement No. 41, which merely asks you to check what you heard after making this test.

Finally, restore the original connections to the audio transformer, make a final listening check to be sure your oscillator is operating normally, and turn off the N.R.I. Tester and the power pack.

LISTENING TO AUDIO SIGNALS

1. **Place the red probe in the left-hand V_{AC} jack, and place the black probe in the $-V_{AC}$ jack.**
2. **Set the selector switch to *100 × V*.**
3. **Remove the jumper from the *PHONE* jacks, and plug the headphone tips into these two jacks.**
4. **Place the black clip on the a.f. terminal which is closest to or actually at chassis potential for a.f. signals, and place the red clip on the other a.f. terminal.**
5. **Turn on the apparatus (the power pack in your case), then turn on the N.R.I. Tester and listen to the signal. Remember that with apparatus employing heater-type tubes, you must wait about half a minute for tubes to warm up.**
6. **To increase the volume, switch to a lower voltage range, providing it does not make the meter swing off scale.**
7. **When through, turn off the N.R.I. Tester first, then turn off the apparatus, remove the test clips from the a.f. terminals, pull out the test probes, remove the phone tips from the *PHONE* jacks, and replace the U-shaped jumper in the *PHONE* jacks. Accurate measurements cannot be made while the headphone is plugged in.**

EXPERIMENT 42

***Purpose:* To assemble an a.f. amplifier stage and connect it to amplify the output signal of your a.f. oscillator; to show that the gain provided by the a.f. amplifier stage increases as the resistance of its plate load is increased.**

Step 1. To assemble an a.f. amplifier stage on your chassis and connect it to the a.f. oscillator stage already on that chassis so as to secure the circuit shown in Fig. 9A, carry out the following step-by-step procedure:

a. Place before you the following parts:

Two .25-mfd. condensers (Parts *3-2A* and *3-2B*).
1,000-ohm resistor (Part *3-5A*).
Two 40,000-ohm resistors (Parts *3-6C* and *3-6D*).
18,000-ohm resistor (Part *1-16*).
1,000-ohm potentiometer (Part *3-8*).
Grid clip (Part *5-3*).

b. After removing the 6F8G tube from its socket, mount the 1,000-ohm potentiometer (Part *3-8*) in hole *t* on the chassis (see Fig. *4*) by removing the nut, inserting the potentiometer shaft in this hole from the bottom, then replacing the nut on the shaft projecting above the chassis and tightening with ordinary pliers while hold-

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ing the potentiometer in such a position that its lugs are pointing toward the rubber grommet underneath the chassis. Identify the three potentiometer terminals by placing the numbers *15*, *16* and *17* on the chassis near the lugs with metal-marking crayon in the manner shown in Fig. *10*.

To ground the control arm of the potentiometer, solder a wire to the center terminal *(16)*, fasten the other end to ground lug *9*, and solder lug *9* after placing the other leads.

There is no need to disconnect the four wires from the power pack during this procedure, for the wires will bend readily when you turn the oscillator chassis over.

c. Connect a 1,000-ohm resistor (Part *3-5A*) between socket terminals *1* and *4*, arranging the leads so the resistor does not touch the chassis.

d. Connect a .25-mfd. condenser (Part *3-2A*) between socket terminal *4* and terminal *14*. The body of the condenser can touch the chassis, but the leads should be well away from other leads and terminals. This condenser (C_2) is now in parallel with 1,000-ohm resistor R_3, as called for in the circuit diagram of Fig. *9A*, for socket terminal *1* is connected to terminal *9*, and *9* is connected to *14* through the chassis.

e. Connect a .25-mfd. condenser (Part *3-2B*) between potentiometer terminal *17* and terminal *11*.

f. Connect a 6½-inch length of red hook-up wire to potentiometer terminal *17* after first inserting the wire through chassis hole *e* from the top of the chassis. To the other end of this wire (projecting above the chassis), connect the grid clip (Part *5-3*) by pushing the insulation back from the end of the wire, bending the end of the wire at right angles about ¼ inch, inserting the end of the wire into the hole in the clip from underneath, bending the wire back along the top of the clip, pushing the insulation back over the wire up to the hole, bending the pointed tabs of the clip around the insulation, then soldering the exposed end of the wire. Details of this grid clip connection are shown in Fig. *11*.

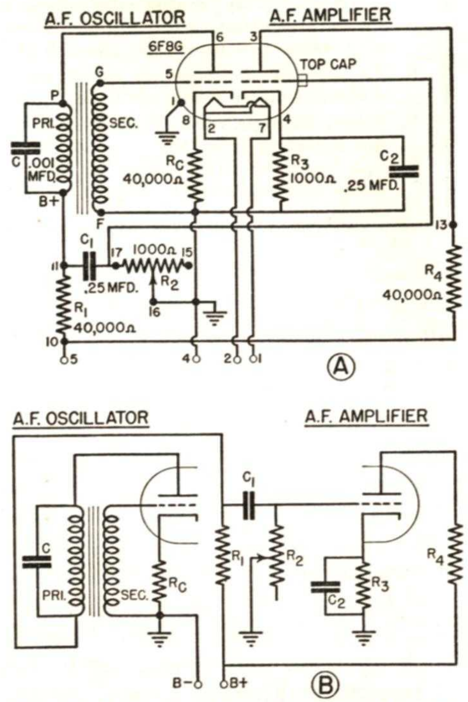

FIG. 9. Schematic circuit diagram (*A*) for the combination a.f. oscillator and a.f. amplifier which you assemble for Experiment 42. The left-hand triode section of the 6F8G tube serves the a.f. oscillator, while the right-hand triode section serves the a.f. amplifier. At *B* is a simplified schematic diagram of this same circuit, with the two triode sections separated just as if they were two individual triode tubes; in this spread-out form, the circuits are easier to recognize.

g. Connect socket terminal *3* to terminal *13*.

h. Connect a 40,000-ohm resistor (Part *3-6C*) between terminals *10* and *13* by means of temporary soldered *lap* joints. The bottom of your chassis should now appear as shown in Fig. *10*.

i. Connect a .001-mfd. condenser (Part *5-10*) between the *P* and *B+* terminals of the audio transformer.

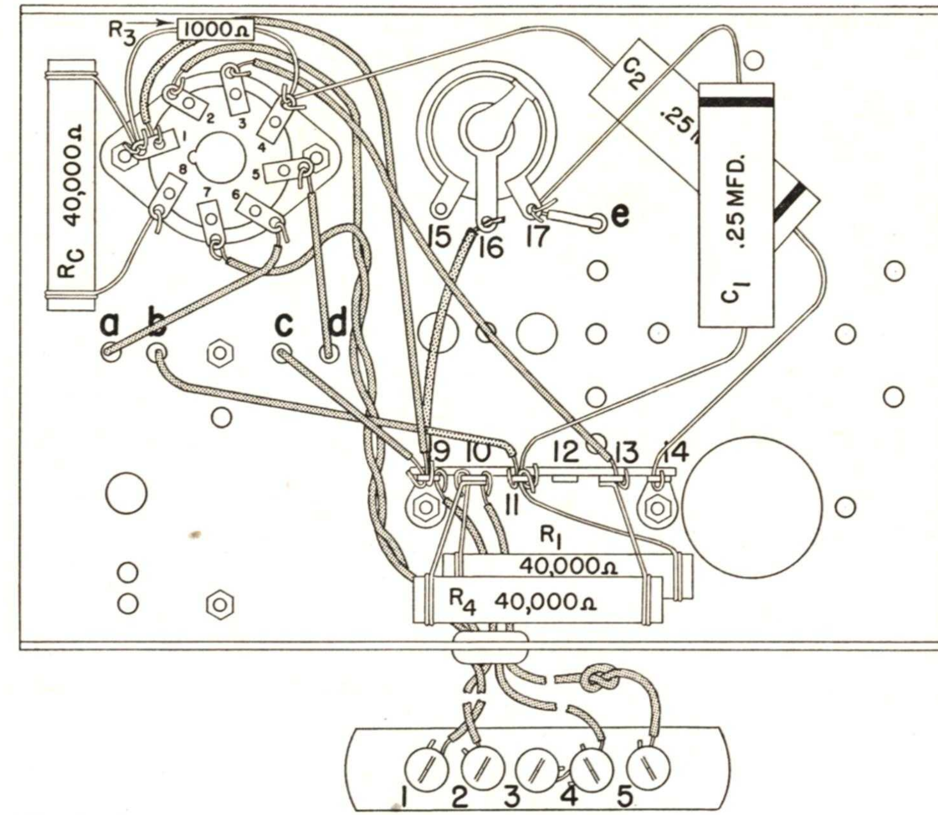

FIG. 10. Semi-pictorial bottom view of the chassis, showing how all parts and wires are arranged for the combination a.f. oscillator and a.f. amplifier circuit employed in Experiment 42. On this and future semi-pictorial diagrams of this type, terminal numbers may be in different positions than the numbers on your chassis, but this is done merely for clearness in the diagram. Once you place a number on your chassis, do not remove it.

With this condenser, your a.f. oscillator will have a frequency of about 800 cycles.

j. Replace the 6F8G tube in its socket and push the grid clip over the top cap of the tube. If necessary, the clip may be opened up slightly so it will fit over the top cap.

Step 2. To measure the a.f. output voltage of your audio amplifier stage for various plate load resistance values when the a.f. input voltage is 1 volt, first check the calibration of your N.R.I. Tester in the usual manner. Be sure to remove the headphone tips and replace the U-shaped jumper in the *PHONE* jacks when checking the calibration. Now read carefully the instructions given in this manual for "A.F. VOLTAGE MEASUREMENTS." You are expected to follow these instructions in the future whenever making a.f. measurements, for detailed instructions will not always be given in the experiments.

Since you now have the circuit shown in Figs. *9A* and *9B*, in which there is a 40,000-ohm plate load resistance (R_4) in the audio amplifier stage, your first a.f. measurement will be for this plate load value.

Place the red clip on the grid clip of your 6F8G tube, place the black clip on the a.f. oscillator chassis, leave the selector switch at *100 × V*, check the four power pack leads to be sure

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OPERATING INSTRUCTIONS FOR N.R.I. TESTER

A.F. VOLTAGE MEASUREMENTS

1. Check the calibration of the N.R.I. Tester in the usual manner, as instructed in previous manuals. Be sure the U-shaped jumper is in the *PHONE* jacks during calibration. Tap the meter lightly with your finger during calibration to minimize bearing friction. Place the test probes in the V_{AC} jacks (black in $-V_{AC}$).
2. Practically all a.f. measurements in these experiments will be made with the *V* or *3* × *V* range. Always try both ranges, and use whichever range gives the *higher result in volts* (not the higher scale reading).

   Important: Always start an a.f. measurement with the *100* × *V range*, and switch to a lower range only after you are certain that all tubes have reached normal operating conditions. This is necessary because the high d.c. voltages which are sometimes present at a.f. terminals during the initial warming-up period might overload the meter on a lower range, temporarily destroying the tester calibration. If you accidentally make the meter swing off-scale through forgetting to switch initially to *100* × *V*, be sure to correct the calibration by moving the calibrating clip temporarily to —4½C, then replace the clip on —9C.
3. Read a.f. voltages on the *AC* scale in exactly the same manner as for a.c. measurements.
4. If a scale reading above 5.5 is obtained with the *3* × *V* range, you can: 1. Estimate the value as being a few volts higher than 16.5 volts; 2. Switch to the *30* × *V* range and read as best you can, though it will be very difficult to get an accurate reading because the pointer is below *1* on the scale; 3. Insert a 10-megohm voltage multiplier resistor in series with the tester leads while using the *3* × *V* range, to convert this to a *6* × *V* range and thus secure an easy-to-read on-scale reading. (Detailed instructions for increasing a voltage range in this manner were given in the previous manual.)

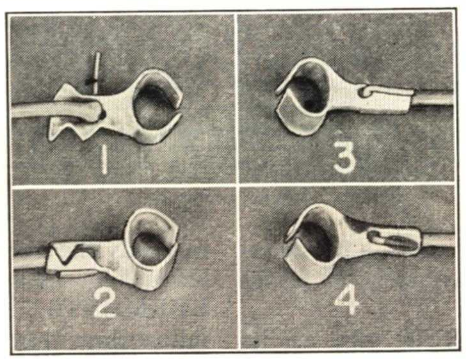

FIG. 11. The four important steps in connecting the grid clip for the type 6F8G tube to the end of a length of hook-up wire are shown here.

all connections are still secure and no leads are shorting at the power pack terminal strip, then turn on the power pack and the N.R.I. Tester. Half a minute later switch to the *V* range and rotate the potentiometer on the a.f. oscillator chassis with a screw-driver while watching the meter reading. The pointer should move from zero at one extreme position of the potentiometer to about 2 volts for the other extreme position.

To set the potentiometer accurately to an a.f. input voltage of exactly 1 volt, first rotate the potentiometer in a counter-clockwise direction as far as it will go, so as to bring the meter to *0*. If the pointer does not move exactly to *0* on the *AC* scale now when the meter is tapped lightly, adjust the knob at the back of the meter to secure this condition; this slight change in the knob setting will make measurement of low a.c. voltages more accurate without appreciably affecting the general calibration of the tester. Now rotate the potentiometer on the a.f. oscillator chassis in a clockwise direction until the meter reads exactly 1 volt on the *AC* scale. Do not change the setting either of this potentiometer or of the tester adjustments for the remainder of this experiment.

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Step 3. To measure the a.f. load voltage for a 40,000-ohm plate load resistor, set the a.f. oscillator chassis on its back side so that under-chassis terminals are accessible, set the selector switch at *100* × *V*, place the red clip on socket terminal *3*, leave the black clip still on the chassis, turn on the power pack and the N.R.I. Tester, switch to the *3* × *V* range half a minute later, read the meter on the *AC* scale, multiply the reading by 3 and record your result in Table *42* as **the a.f. load voltage for a 40,000-ohm** plate load. Return the selector switch to *100* × *V*, turn off the N.R.I. Tester, and turn off the power pack without **changing anything else.**

Step 4. To measure the a.f. load voltage for a 20,000-ohm load, first connect another 40,000-ohm resistor (Part *3-6D*) in parallel with the 40,000-ohm resistor already connected to terminals *10* and *13*, using soldered lap joints. Turn on the power pack, turn on the N.R.I. Tester, half a minute later set the selector switch at *3* × *V*, read the meter on the *AC* scale, multiply your reading by 3, and record your result in Table *42* as the **a.f. load voltage for a 20,000-ohm** load. Set the selector switch back to *100* × *V*, turn off the N.R.I. Tester, and turn off the power pack.

Step 5. To measure the a.f. load voltage for approximately a 10,000-ohm plate load resistance, first connect an 18,000-ohm resistor (Part *1-16*) in parallel with the two 40,000-ohm resistors already connected to terminals *10* and *13*. Turn on the power pack, turn on the N.R.I. Tester, half a minute later set the selector switch to *3* × *V*, read the meter on the *AC* scale, multiply the reading by 3, and record your result in Table *42* as the a.f. load voltage for a 10,000-ohm load. Set the selector switch back to *100* × *V*, turn off the N.R.I. Tester, and turn off the power pack.

Step 6. To measure the a.f. load voltage for an 80,000-ohm load, first **remove the two 40,000-ohm resistors and the 18,000-ohm resistor which are** connected to terminals *10* and *13*. Now connect the two 40,000-ohm resistors in series between terminals *10* and *13* by using terminal *12* as an anchor point. In other words, connect one 40,000-ohm resistor between terminals *10* and *12* with soldered lap joints, and connect the other 40,000-ohm resistor between terminals *12* and *13* **with soldered lap joints. Adjust** the resistors carefully so neither of them touches the chassis. Turn on the power pack, turn on the N.R.I. Tester, half a minute later set the selector switch to *3* × *V*, read the meter on the *AC* scale, multiply the reading by 3, and record your result in Table *42* as the a.f. load voltage in volts for an 80,000-ohm plate load. Set the selector switch back to *100* × *V*, turn off the N.R.I. Tester, and turn off the power pack.

Step 7. Make a graph of load resistance plotted against the gain of your amplifier stage, by using your a.f. voltage values as gain values (you will learn in the discussion that the gain is the same as your measured value of a.f. load voltage). **Use the** same procedure employed for making graphs in previous experiments; in other words, put a dot on Graph *42* for each of your four measured values, then draw a smooth curve through or near these four dots and through the zero point on Graph *42*.

Discussion: Reference to the schematic circuit diagram in Fig. *9B* will give you a better understanding of the circuit you are now using. The 800-cycle a.f. plate current of the a.f. oscillator section flows through 40,000-ohm resistor R_1, developing across this resistor a corresponding a.f. voltage. Condenser C_1 and potentiometer R_2 provide a shunt path to ground, and signals taking this path develop across R_2 an a.f. voltage which is applied between the grid and cathode of the a.f. amplifier stage. The potentiometer is used as a rheostat; by adjusting it, the a.f. voltage drop across the potentiometer can be made exactly 1 volt, so that the a.f. input voltage of the audio amplifier stage is 1 volt.

This a.f. input voltage produces a corresponding a.f. plate current in the amplifier section of the 6F8G tube. This a.f. plate current flows through plate load resistor R_4, developing across this resistor the a.f. output voltage which we measure in this experiment for four different values of R_4 (we actually measure the voltage between plate terminal *3* and the chassis, but this is equivalent to measuring across the plate load resistor because the 10-mfd. output filter condenser in the power pack connects the chassis to the plate supply end of R_4 insofar as a.f. signals are concerned).

The actual gain or amplification provided by an a.f. amplifier stage is equal to the a.f. output voltage divided by the a.f. input voltage. Since we have adjusted the a.f. input voltage to exactly 1 volt, the a.f. output voltage value in volts will also be the gain of the stage. The values which you recorded in Table *42* thus represent the gain of your a.f. amplifier stage under the various conditions.

Your results for this experiment can be analyzed most readily by examining the curve which you obtained on Graph *42* for your values. This curve should have the same general shape as the N.R.I. curve plotted for comparison on this graph, but need not have the same values. Observe that the gain is low for low plate load resistance values, and increases rather rapidly at first with increases in plate load resistance. As load resistance is increased, however, the curve tends to flatten out and approach the theoretical amplification factor of the tube itself.

The rated amplification factor of each triode section in the 6F8G tube is 20, but we cannot expect to make experimental results check with rated values because of normal manufacturing tolerances and because of the difficulty encountered in reading low values accurately on the *AC* scale of the meter. Keep in mind that during the remaining experiments in your Practical Demonstration Course, the important thing is to obtain a *change* in value *in the correct direction,* rather than to obtain any specific measured value.

Now let us consider the reasons why the actual amplification or gain of a stage is less than the rated amplification factor of the tube. First of all, we know that if an a.c. voltage of 1 volt is applied to the grid of the tube, it will be equivalent to a plate circuit a.c. voltage of 1 volt multipled by the amplification factor (μ) of the tube. If we could utilize all of this a.c. plate voltage, the gain of the tube would be equal to the rated amplification factor of the tube. This a.c. plate voltage must send current through the a.c. plate resistance and the plate load resistance, however, and the voltage drop across the a.c. plate resistance

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reduces the amount of a.c. voltage available across the load.

Under the conditions of this experiment, the a.c. plate resistance of the tube is approximately 7,000 ohms. The 20-volt a.f. plate circuit voltage (1 volt multiplied by the rated amplification factor of 20) is therefore divided between the 7,000-ohm a.c. plate resistance and whatever load resistance value we are using.

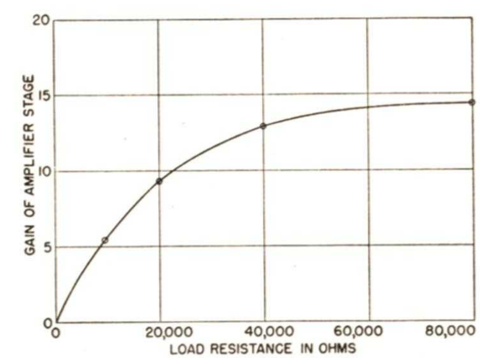
For a 10,000-ohm load, the total plate circuit resistance is 7,000 plus 10,000, or 17,000 ohms. The proportion of the total 20 volts available

STEP	PLATE LOAD IN OHMS	YOUR VALUE OF A.F. LOAD VOLTAGE IN VOLTS	N.R.I. VALUE OF A.F. LOAD VOLTAGE IN VOLTS
3	40,000		12.6
4	20,000		9.3
5	10,000		5.7
6	80,000		14.4

TABLE 42. Record your results here for Experiment 42. If a meter reading higher than 5.5 is obtained for Step 3 or Step 6 while using the *3* × *V* range, corresponding to a voltage higher than 16.5 volts, you can either estimate the voltage as being slightly higher than 16.5, switch to the *30* × *V* range, or use a 10-megohm multiplier resistor in series with one test lead.

across the 10,000-ohm load will therefore be in the ratio of 10,000 to 17,000, and we can expect to get only about 11.7 volts across a 10,000-ohm load. For the reasons given in the next paragraph, however, your a.f. output voltage value for a 10,000-ohm load may be considerably lower than this value, just as is the N.R.I. value in Table *42*. The actual computation is: $(10{,}000 \div 17{,}000) \times 20 = 11.7$.

For an 80,000-ohm load, the total plate circuit resistance is 7,000 + 80,000, or 87,000 ohms. For this load, the computed a.f. plate load voltage is 18.4 volts: $(80{,}000 \div 87{,}000) \times 20 = 18.4$. Your value for an 80,000-ohm load need not be anywhere near this value, as long as it is definitely higher than your value for a 10,000-ohm load, because your type 6F8G tube may have an amplification factor considerably different from the rated value of 20 due to normal manufacturing tolerances. Furthermore, the 7,000-ohm value which we estimated roughly as being the a.c. plate resistance may actually be at least 20% different from this assumed value, making the computations inaccurate. Actually, the a.c. plate resistance for this experiment is considerably higher



GRAPH 42. When you plot on this graph your own results for Experiment 42, you should obtain a curve having the same general appearance as the N.R.I. curve already drawn here, but you need not necessarily obtain the same curve.

than 7,000 ohms, because we are using a lower plate voltage than the normal 250-volt value for this tube.

Observe that 1,000-ohm cathode resistor R_3 for your amplifier stage is shunted by .25-mfd. condenser C_2. Ordinarily we expect that a by-pass condenser has considerably lower reactance than its shunt resistors, but the reactance of this condenser is only about 800 ohms at the 800-cycle frequency being used. This means that some a.f. voltage is developed across the cathode resistor and its by-pass condenser when the a.f. plate current is fairly high, such as for low plate load resistance values. This a.f. voltage causes degeneration, making the amplification of the stage lower than the normal value for that plate load resistance. (At N.R.I., when this cathode resistor was shunted with an 8-mfd. condenser while using an 80,000-ohm plate load resistance, the gain jumped to 17.)

The important thing to remember in connection with this experiment is that in a resistance-capacity coupled a.f. amplifier stage, a high plate load resistance value is necessary if approximately the full amplification capability of the tube is to be obtained.

Instructions for Report Statement No. 42. With an 80,000-ohm plate load resistance and with your apparatus connected exactly as it was for Step 6, remove the .25-mfd. cathode by-pass condenser by unsoldering one lead of the condenser which is connected between socket terminal *4* and terminal *14* underneath your a.f. oscillator chassis, and measure the a.f. plate voltage with this condenser removed.

Compare your result with that which you recorded in Step 6 of Table *42* for the corresponding condition with the condenser in place; if you are not entirely sure that a change has occurred, reconnect and disconnect the condenser momentarily while watching the meter, either by pushing on the condenser lead with a piece of wood or by holding the paper body of the condenser with your fingers while power is on. Do not touch any leads or terminals with your fingers while doing this.

After you are certain you know how the a.f. plate voltage changes when the cathode by-pass condenser is removed, answer Report Statement No. 42. Turn off all apparatus now, and remove the test probes from the N.R.I. Tester, but leave all other circuit connections as they are.

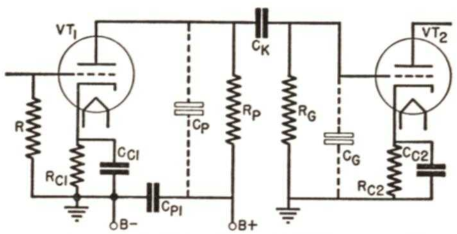


FIG. 12. Schematic circuit diagram of a typical resistance-capacity coupled audio amplifier circuit such as is widely used in radio receivers. In Experiment 43, you work with the electrical equivalent of this circuit.

EXPERIMENT 43

Purpose: **To show that reducing the capacity of the coupling condenser in an a.f. amplifier stage reduces the over-all gain of the stage at low audio frequencies; to show that shunt capacities in the output circuit of an a.f. amplifier stage reduce the over-all gain of the stage at high audio frequencies.**

Preliminary Discussion: A typical resistance-capacity coupled amplifier circuit is shown in Fig. *12*. In this circuit, R_P is the plate load resistor for the stage employing tube VT_1, C_K is the plate-to-grid coupling condenser, and R_G is the grid return resistor for the stage employing tube VT_2.

In this experiment, you will set up with your apparatus a circuit which is equivalent to that shown in Fig. *12*, and make measurements which tell how the circuit will behave under various conditions. To do this, you add to your audio amplifier stage a coupling condenser equivalent to C_K and a grid resistor equivalent to R_G, and first determine what effect the value of C_K has upon the a.f. voltage developed across R_G.

In another step, you introduce a capacity which essentially duplicates the effect of stray circuit capacities C_P and C_G, to determine what effect these stray capacities have upon the over-all gain of the stage.

Step 1. To check the over-all gain of your audio amplifier stage for two different coupling condenser values at a frequency of about 180 cycles, first place before you the a.f. oscillator which you assembled according to the schematic diagram in Fig. *9A* and modified according to the instructions in Step 6 of Experiment 42 so as to change R_4 from 40,000 ohms to 80,000 ohms.

To change this oscillator so it will produce a frequency of about 180 cycles, remove the condenser from audio transformer terminals *P* and *B*+, and connect instead to these terminals a .05-mfd. condenser.

Remove from your audio amplifier circuit (Fig. *9A*) the .25-mfd. cathode by-pass condenser which is connected between terminal *14* and socket terminal *4*. Connect one lead of this .25-mfd. condenser to socket terminal *3*, connect the other condenser lead to one lead of your 100,000-ohm resistor (Part *5-13*) by means of a temporary soldered lap or hook joint, then connect the other resistor lead to terminal *14*, so that the a.f. amplifier portion of your set-up has the circuit shown in Fig. *13*. Adjust these two parts so that their leads do not touch the chassis or other parts.

Note: A 100,000-ohm resistor is sometimes marked 100M or .1 MEG. by resistor manufacturers or on circuit diagrams.

Adjust the a.f. input voltage of your a.f. amplifier stage to 1 volt just as you did in the previous experiment (with the red clip on the grid clip, with the black clip on the oscillator chassis, and with the selector switch first at *100* × *V* and then at *V*, adjust the potentiometer on the oscillator chassis until the meter reads exactly 1 volt on the *AC* scale).

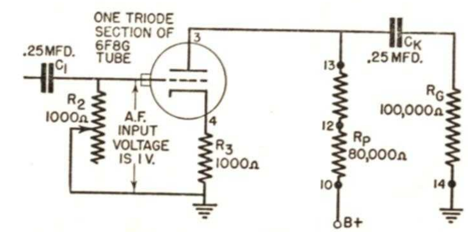


FIG. 13. Schematic circuit diagram of the a.f. amplifier set-up which you employ in Experiment 43 to duplicate a resistance-capacity coupled audio amplifier circuit.

Measure the a.f. output voltage across the 100,000-ohm resistor you just added to your amplifier circuit by moving the red clip to the common junction of the .25-mfd. condenser and 100,000-ohm resistor, leaving the black clip on the chassis, and setting the selector switch to the *3* × *V* range. Be sure the red clip does not touch other leads or terminals. Record your measured value of a.f. voltage in Table *43*.

To measure the a.f. output voltage when the value of the coupling condenser is .001 mfd., first remove the .25-mfd. condenser which was connected between socket terminal *3* and the 100,000-ohm resistor lead, and

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connect in its place a .001-mfd. condenser. Without changing any other connections, measure the a.f. output voltage across the 100,000-ohm resistor as previously instructed, using the *V* range, and record your result in Table *43* as the a.f. output voltage value for the condition wherein C_K is .001 mfd.

Step 2. To determine the effect of a shunt capacity upon the over-all gain of your audio amplifier stage at a frequency of about 800 cycles when using a .25-mfd. coupling condenser, first remove the .001-mfd. condenser which is connected between socket terminal *3* and the 100,000-ohm resistor lead, and connect in its place again the .25-mfd. condenser. Now remove the .05-mfd. condenser (added in Step 1 of this experiment) from the *P* and *B+* terminals of the audio transformer, and connect the .001-mfd. condenser to these terminals so as to restore the circuit of Fig. *9A* and make the a.f. oscillator deliver a frequency of about 800 cycles.

To check the gain at 800 cycles first without any shunt capacity in the amplifier circuit, adjust exactly to 1 volt the a.f. input voltage to the amplifier stage as previously instructed, then measure the a.f. output voltage across the 100,000-ohm resistor while using the *3* × *V* range of the N.R.I. Tester, and record your result in Table 43, as the a.f. output voltage in volts when the frequency is 800 cycles and there is no shunt capacity.

Connect a .01-mfd. condenser between terminals *9* and *13* so as to provide a shunt capacity between the amplifier triode plate and ground, measure the a.f. output voltage again across the 100,000-ohm resistor while using the *3* × *V* range, and record your result in Table *43* as the a.f. output voltage in volts when the frequency is 800 cycles and the shunt capacity (C_S) is .01 mfd.

Discussion: The N.R.I. values for Step 1 show that lowering the value of coupling condenser C_K from .25 mfd. to .001 mfd. makes the a.f. output voltage drop considerably; your own values for these two measurements should show the same thing. At 180 cycles, the .25-mfd. coupling condenser has a reactance of about 3,500 ohms, which is quite small in comparison with the 100,000-ohm value of the grid resistor. As a result, very little a.f. voltage appears across the coupling condenser, and most of the voltage is developed across the grid resistor. A .25-mfd. coupling condenser thus gives very nearly the maximum over-all gain which could be obtained from the amplifier tube when using the 80,000-ohm plate load resistor.

With a .001-mfd. coupling condenser, the condenser reactance at 180 cycles is about 880,000 ohms, much higher than the 100,000-ohm value of the grid resistor. Now most of the a.f. voltage is dropped across the coupling condenser, where it is of no use, and only a small portion is dropped across the grid resistor. This explains why the N.R.I. values of a.f. output voltage drop from 15.0 for the .25-mfd. condenser to 1.7 volts for the .001-mfd. coupling condenser.

The N.R.I. values for Step 2 show clearly that a shunt capacity connected between the amplifier triode plate and ground to duplicate the effects of inter-electrode and stray shunt capacities makes the a.f. output voltage drop. At higher frequencies than 800 cycles, there would be an even greater drop in a.f. output voltage when the shunt condenser is used.

Note that even though the circuits are identical for the first measurements in Steps 1 and 2, there is some difference in the N.R.I. values of output voltage. This is due simply to the fact that the wave form of the 180-cycle a.f. voltage used in Step 1 is different from the wave form of the 800-cycle voltage used in Step 2. Actually, the wave form at 180 cycles is an almost pure sine wave, while at 800 cycles it is distorted considerably from a sine wave (the peak in one direction is short and broad, and in the other direction is narrow and long).

Instructions for Report Statement No. 43. According to Kirchhoff's Voltage Law for d.c. circuits, the sum of the three d.c. voltages in the plate circuit of your amplifier stage (the d.c. voltage drop across plate load resistor R_P, the voltage drop across the d.c. plate resistance of the triode tube section, and the d.c. voltage drop across 1,000-ohm cathode resistor R_3 (in Fig. *13*) should equal the d.c. output voltage of your power pack. You can measure all four of these d.c. voltages with the N.R.I. Tester and verify Kirchhoff's Law if you like, but you will only have to measure two of these d.c. voltages in order to answer Report Statement No. 43.

With your apparatus connected exactly as for the last measurement in Step 2 of this experiment, prepare the N.R.I. Tester for d.c. voltage measurements according to previous instructions, then measure the d.c. output voltage provided by your power pack. You can do this either by measuring between terminals *4* and *5* of the power pack or by placing the black clip on terminal *9* and the red clip on terminal *10* under the chassis of your oscillator. Remember that all apparatus must be turned off before you move the test clips.

Next, measure the d.c. plate voltage of the amplifier triode section (the plate-cathode voltage) by placing the red clip on socket terminal *3* and placing the black clip on socket terminal *4*. Compare the two d.c. voltage values you just measured, then answer Report Statement No. 43.

STEP	CIRCUIT DATA	YOUR VALUE OF A.F. OUTPUT VOLTAGE IN VOLTS	N.R.I. VALUE OF A.F. OUTPUT VOLTAGE IN VOLTS
1	C_K = .25 MFD. f IS 180 CYCLES		15.0
	C_K = .001 MFD. f IS 180 CYCLES		1.7
2	NO SHUNT CAPACITY f IS 800 CYCLES		11.7
	SHUNT CAPACITY C_S IS .01 MFD. f IS 800 CYCLES		8.1

TABLE 43. Record your results here for Experiment 43.

EXPERIMENT 44

***Purpose:* To prepare and calibrate the N.R.I. Tester for r.f. measurements; to assemble an r.f. oscillator; to show that increasing the d.c. plate supply voltage of an r.f. oscillator causes increases in the r.f. voltage across the resonant circuit, the d.c. bias voltage across the grid resistor, and the d.c. plate current.**

Preliminary Discussion: Even under ideal laboratory conditions, radio fre-

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quency measurements are usually only approximate, for many factors tend to make r.f. measurements inaccurate and difficult. Fortunately, however, extremely accurate r.f. measurements are seldom required; experienced technicians who realize this fact and realize the limitations of their equipment do not expect too much precision.

In the circuit employed in the N.R.I. Tester, we have normal variations with frequency such as are encountered in all vacuum tube circuits of this type. The circuit has either regeneration or degeneration, depending upon the nature of the plate load. At audio frequencies, the .05-mfd. condenser which is shunted across the meter provides adequate compensation.

At radio frequencies, however, degeneration is sufficient to make the meter readings somewhat low. We have found from experience that meter readings beyond 4.5 on the *AC* scale correspond to r.f. input voltages high enough to swing the grid of the tube in the tester positive on peaks. The resulting grid current flow through the grid resistor increases the C bias and upsets the calibration of the tester, hence we must not allow the grid to swing positive. This is why you are instructed to switch to a higher voltage range during r.f. measurements whenever the pointer swings beyond 4.5 on the *AC* scale. You will learn, however, that this limitation does not prevent you from obtaining satisfactory results.

Here is the important general rule which you must keep in mind when making r.f. measurements: Try all three of the lowest voltage ranges (V, $3 \times V$ and $30 \times V$), and use the one which gives the highest *voltage* value (not necessarily the highest scale reading). You cannot damage the instrument in this particular measurement by switching to too low a range, for grid current will develop a negative C bias which prevents overloading of the meter.

At radio frequencies, the grid-cathode inter-electrode capacity of the type 1C5GT tube in the N.R.I. Tester has such a low reactance in ohms that it becomes an appreciable shunt reactance across a portion of the voltage divider in the tester; this capacity is indicated as C_{GK} in Fig. *14A*, which shows the input circuit of the tester in simplified form as it is during r.f. and a.f. measurements when using the $3 \times V$ range.

Capacity C_{GK} upsets the division of r.f. voltages in the tester, so that voltage V acting upon the grid and cathode of the type 1C5GT tube is no longer exactly ⅓ of the voltage being measured when the selector switch is set at $3 \times V$. However, by placing across the 6.7-megohm resistor an added capacity C_1 having a capacitive reactance which is one-half the capacitive reactance of grid-cathode capacity C_{GK}, we obtain a condenser voltage divider which divides the voltages in the ratio of 1 to 3 and thus corrects this r.f. condition without affecting the accuracy of other types of measurements.

You will receive instructions later in this manual for introducing this capacity and adjusting it to the correct value. With this correction, r.f. voltages up to 3 × 4.5 volts, or 13.5 volts, can be measured. (Remember that *AC* scale readings above 4.5 are not to be trusted during r.f. measurements, because of grid current.)

There will be a few occasions in which r.f. voltages higher than 13.5 volts will require measurement, but these r.f. values will rarely if ever be higher than 30 × 4.5, or 135 volts We must therefore be sure that voltage division is correct also for the $30 \times V$ range of the N.R.I. Tester.

When the selector switch of the N.R.I. Tester is set to $30 \times V$, the simplified schematic diagram of the tester takes the form shown in Fig. *14B*. We still have grid-cathode capacity C_{GK} shunting a portion of the voltage divider, and a definite capacity value C_1 shunting the 6.7-megohm portion of the voltage divider. To secure correct voltage division on the $30 \times V$ range, the capacity across the 6.7-megohm and 3-megohm resistors must be 1/29 the capacity value of C_{GK}. This means that there must be a capacity across the 3-megohm resistor. It so happens that the capacities between the switch terminals and between the leads connected to the terminals are equivalent to a capacity C_2 which is just about the required value.

Thus, by the addition of a single capacity across the 6.7-megohm resistor, you can make your N.R.I. Tester provide satisfactory comparisons of r.f. voltage values on the three lowest voltage ranges. The only limitation to remember is that you must use the range which gives the highest voltage value. To help you in this connection, the range used to obtain the N.R.I. values given in the tables will usually be specified in the instructions.

Step 1. To prepare for the assembly of an r.f. oscillator, carry out the following steps in exactly the order indicated.

a. Remove the type 6F8G tube from its socket on the chassis, and disconnect the four leads from the power pack output terminals.

b. Remove the .001-mfd. condenser from the *P* and *B+* terminals of the a.f. transformer, unsolder the leads from all four a.f. transformer terminals, then remove the a.f. transformer from the chassis.

c. Turn the chassis over, and unsolder all of the connections which are on tube socket terminals *1, 3, 4, 5, 6* and *8*. This removes the 1,000-ohm resistor and the 40,000-ohm resistor; set these aside for future use. Do not remove the filament leads from socket terminals *2* and *7*.

d. Remove all leads from terminals *9, 10, 11, 12, 13* and *14* except those on terminals *9* and *10* which go to the power pack and potentiometer.

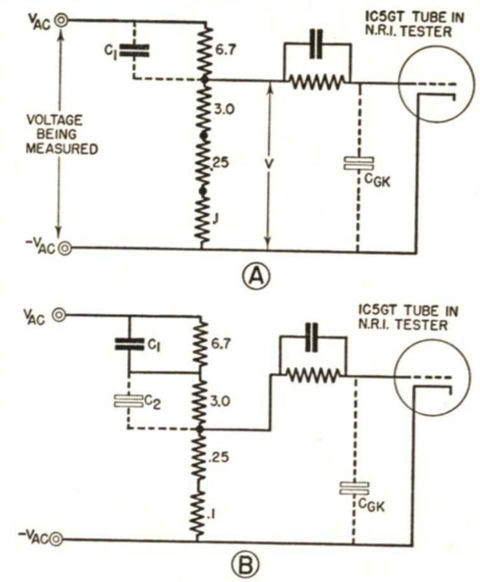

FIG. 14. Simplified schematic circuit diagram of the N.R.I. Tester as it is when used for a.c. voltage measurements on the $3 \times V$ range (*A*) and on the $30 \times V$ range (*B*).

e. Remove all leads from potentiometer terminal *17*. Finally, remove surplus solder from all terminals and leads. The only leads now left underneath the chassis should be the four power supply leads and the one on terminals *9* and *16*.

f. Place before you the following additional parts:

Three-winding s.g. (signal generator) coil (Part *5-7*).

370-mmfd. trimmer condenser (Part *5-9A*).

.001-mfd. paper condenser (Part *5-10*).

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.01-mfd. paper condenser (Part *5-11*).

Machine screws and nuts (Parts *5-16A* and *5-16B*).

Grid clip with attached lead.

Four 40,000-ohm resistors (Parts *3-6A*, *3-6B*, *3-6C* and *3-6D*).

1000-ohm resistor (Part *5-18*).

Step 2. To assemble an r.f. oscillator according to the schematic circuit diagram shown in Fig. 15, carry out the following instructions for mounting and wiring the parts, using the semi-pictorial diagrams in Figs. *16* and *17* as your guides.

a. Mount the s.g. coil (signal generator coil) on top of the chassis by removing one nut from each of its mounting screws, inserting the screws through holes *hh* and *ii* in such a way that the *yellow* and *gray* terminals will be above holes *i* and *j*, as shown in Fig. *16*, then replace the nuts on the screws underneath the chassis and tighten with pliers. (Colored dots of paint on the coil terminals serve to identify these terminals.)

b. Mount the 370-mmfd. trimmer condenser C_A underneath the chassis by pushing a binder-head machine screw through hole *dd* from the top of the chassis, placing the trimmer condenser over this screw underneath the chassis exactly as shown in Fig. *17*, then placing a nut on the screw and tightening with pliers and screwdriver. Place the notation C_A near this condenser both above and below the chassis, and place the numbers *18* and *19* on the bottom of the chassis near the condenser terminals with metal-marking crayon, as shown in Figs. *16* and *17*.

c. With the chassis upside down, connect socket terminal *1* to terminal *9* with a suitable length of red hook-up wire.

From now on, you are expected to use your own judgment as to the best time for soldering each joint. Use the semi-pictorial wiring diagram as your guide; if more than one wire is shown on a particular terminal, do not solder the terminal until you have placed on it all of the wires which are called for on the diagram.

d. Connect a 1000-ohm resistor between socket terminals *1* and *4*.

e. Cut a 6-inch length of red hook-up wire, connect one end to socket terminal *3*, bring the wire around the potentiometer and up through chassis hole *f* as indicated in Fig. *17*, and connect the other end of this wire to the *blue* terminal lug of the s.g. coil.

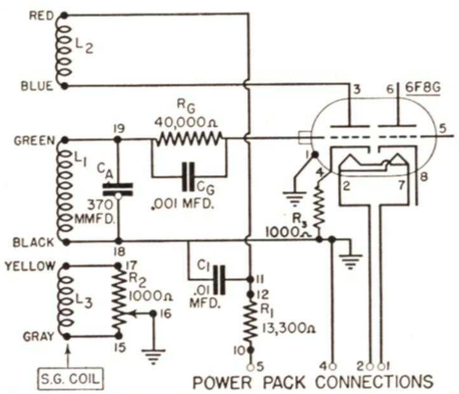

FIG. 15. Schematic circuit diagram of the r.f. oscillator which you assemble as a part of Experiment 44. R_1 is made up of three 40,000-ohm resistors connected in parallel between terminals *10* and *12*.

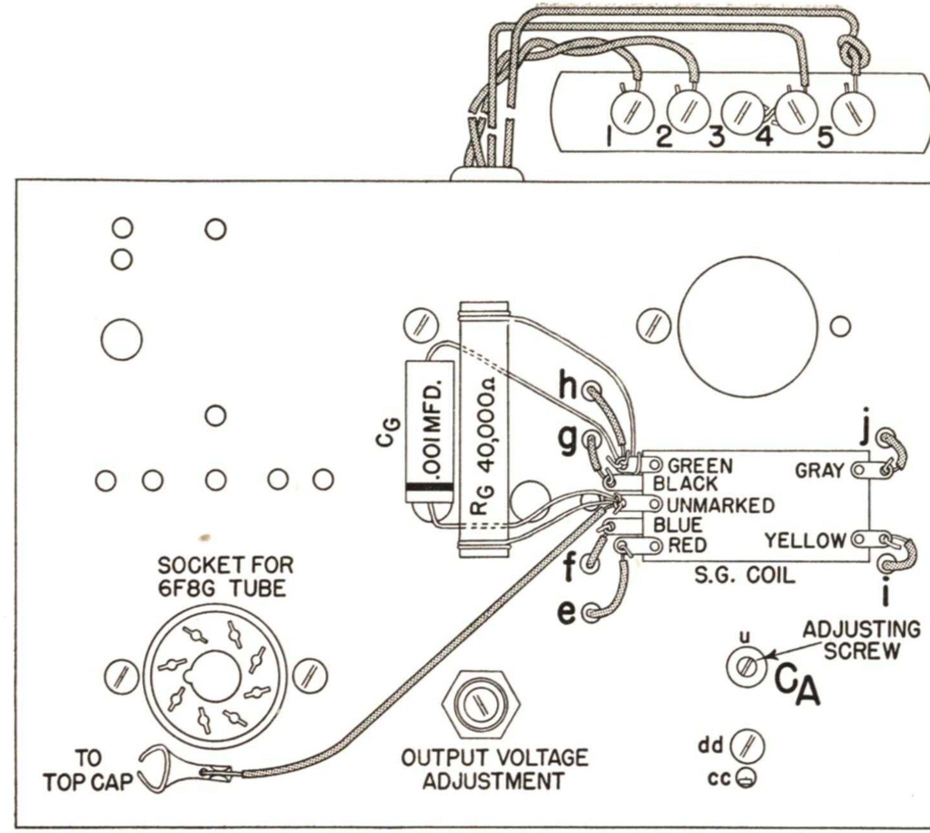

FIG. 16. Top view of the r.f. oscillator chassis furnished to you in Radio Kit 5RK-1, showing parts and connections as they should be made for the r.f. oscillator which you assemble in Experiment 44.

f. Connect terminal *11* to the *red* terminal lug of the s.g. coil, bringing the wire through chassis hole *e*.

g. Connect terminal *14* to the *black* terminal lug of the s.g. coil, bringing the wire through hole *g*.

h. Connect trimmer condenser terminal *19* to the *green* lug of the s.g. coil, bringing the wire through hole *h*.

i. Connect trimmer condenser terminal *18* to terminal *14* with hook-up wire.

j. Connect the .01-mfd. condenser between terminals *9* and *11*, with the outside foil lead of the condenser going to terminal *9*.

k. Connect potentiometer terminal *15* to the *gray* lug of the s.g. coil, bringing the hook-up wire through chassis hole *j*.

l. Connect potentiometer terminal *17* to the *yellow* lug of the s.g. coil, bringing the hook-up wire through hole *i*.

m. Connect a 40,000-ohm resistor between terminals *10* and *12* by means of temporary soldered hook joints, arranging the resistor so that it has the same position as resistor R_1 in Fig. *17*.

Cut two 1-inch lengths of bare hook-up wire, connect one of these to terminal *12* by means of a temporary soldered hook joint, connect the other 1-inch length to terminal *11* by means of a temporary soldered hook joint,

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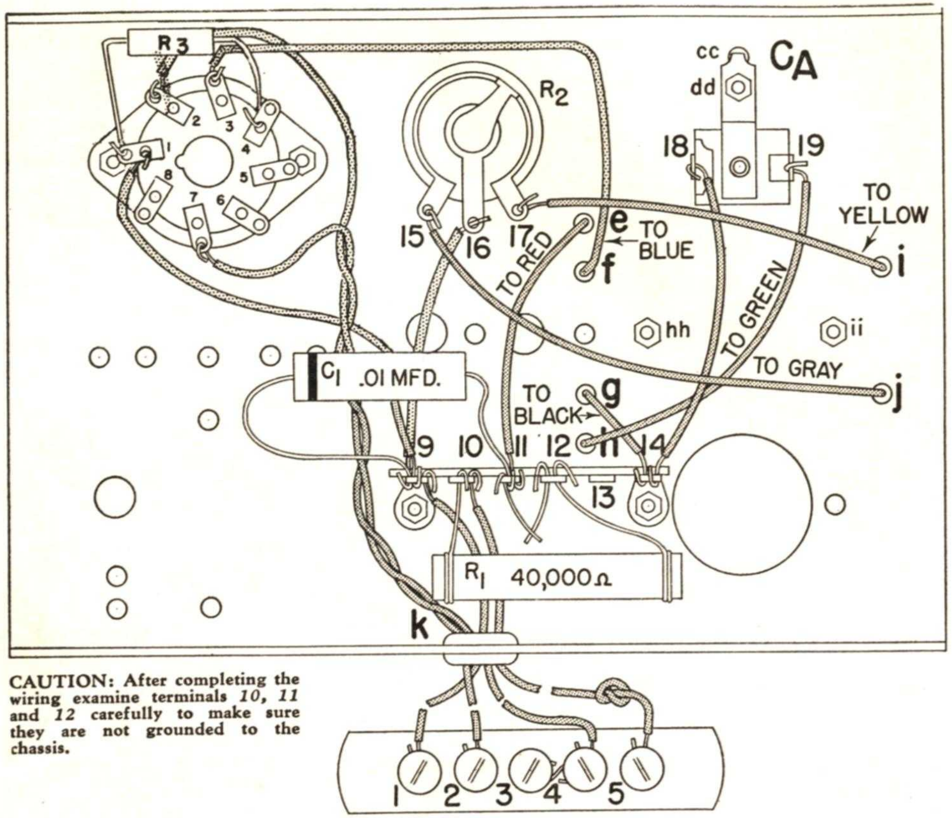

CAUTION: After completing the wiring examine terminals *10, 11* and *12* carefully to make sure they are not grounded to the chassis.

FIG. 17. Bottom view of the oscillator chassis, showing all connections as they should be made for the r.f. oscillator which you assemble in Experiment 44. For the first measurement in this experiment, R_1 must be 13,300 ohms; this is obtained by connecting three 40,000-ohm resistors in parallel to terminals *10* and *12* in the manner shown in Fig. *18*.

then cross over the other ends of these two bare wires and solder them together by means of a lap joint, as indicated in Fig. *17*.

Now connect two other 40,000-ohm resistors in parallel with that already on terminals *10* and *12*, in the following manner:

Connect one of these 40,000-ohm resistors to the opposite sides of terminals *10* and *12* by means of temporary soldered lap joints, as shown in Fig. *18*. Bend the leads of this resistor so that the resistor body is in contact with the body of the .01-mfd. condenser (this will not do any harm). Now take another 40,000-ohm resistor and connect it to the leads of the first resistor (R_1) with temporary soldered lap joints, after first folding the resistor leads inward as shown in Fig. *18*, so that the lap joints will be well away from terminals *10* and *12*.

n. Turn the chassis over, and connect the remaining 40,000-ohm resistor between the *green* lug and the *unmarked* extra lug on the s.g. coil. (This unmarked lug is provided as an anchor point, and is not connected to any of the coil windings).

o. Connect the .001-mfd. condenser between the *green* lug and the *unmarked* lug on the s.g. coil, so that this

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condenser is in parallel with the 40,000-ohm resistor.

p. Locate the length of hook-up wire which has the grid clip attached to one end, connect it to the *unmarked* lug on the s.g. coil, insert the type 6F8G tube in its socket and place the grid clip on the top cap of this tube.

q. You have now assembled the r.f. oscillator according to the schematic circuit diagram shown in Fig. *15*. Check all of your connections carefully against the semi-pictorial diagrams in Figs. *16* and *17*, then make connections to the power pack exactly as you did for the a.f. oscillator (twisted wires go to power pack output terminals *1* and *2*, knotted wire goes to *5*, and the other wire goes to *4*).

Step 3. To determine whether your r.f. oscillator is operating properly, prepare the N.R.I. Tester for d.c. voltage measurements by setting the selector switch to $100 \times V$ and plugging the probes into the V_{DC} jacks, then place the black clip on the *unmarked* s.g. coil terminal, and place the red clip on the *green* terminal.

Set trimmer condenser C_A for maximum capacity by inserting your screwdriver through chassis hole *u* from the top of the chassis and rotating the adjusting screw as far as it will go in a clockwise direction. This tightens the trimmer condenser plates. Now rotate the screwdriver 1½ turns in a counter-clockwise direction, so as to set your circuit to oscillate at about 900 kilocycles.

Turn on the power pack, turn on the N.R.I. Tester, wait about one half a minute, then switch to the $30 \times V$ range. If a deflection of the meter pointer is observed, you know that the oscillator is operating. With this test, you are merely measuring the d.c. voltage drop produced across the 40,000-ohm grid resistor by the flow of grid current.

For an additional check of operation, turn off all apparatus, move the probes to the V_{AC} jacks, move the red clip to the *yellow* s.g. coil terminal, and attach the black clip to the chassis. Set the N.R.I. Tester to the *V* range, then turn on the power pack and the N.R.I. Tester. After about half a minute, you should note

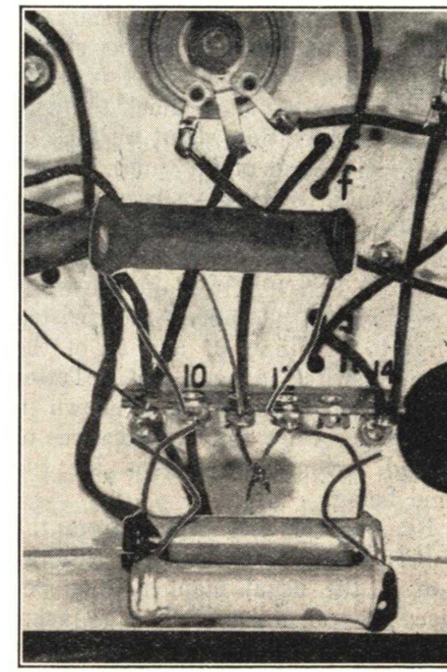

FIG. 18. Method of connecting three 40,000-ohm resistors in parallel to terminals *10* and *12* so as to secure a 13,300-ohm plate supply resistance.

a deflection of the meter pointer if the potentiometer R_2 is approximately in a mid-position. Rotate the potentiometer on the oscillator chassis with your screwdriver to see how it controls the r.f. output voltage value, but do not attempt to read the meter or record any values during these preliminary tests.

Always turn off the power pack and the N.R.I. Tester when through with a test or measurement, even though instructions are not specifically given.

Step 4. To adapt the N.R.I. Tester for r.f. measurements, first secure the **two 8-inch lengths of insulated wire** which are supplied in Radio Kit 5RK as Part *5-17*, remove the insulation for about 3/8 inch from one end of each wire, and tin the exposed wire. Hold the bare ends side by side with the thumb and forefinger of your left hand, and twist the wires together with the thumb and forefinger of your right hand in the manner shown in Fig. *19A*. As you do this, keep moving your left hand along the wire so that it is within about an inch of your right hand at all times.

When the wires have been twisted together, pull the ends of the twisted length with two pairs of pliers as shown in Fig. *19B* to make the wires stay twisted. Connect the twisted wires to terminals *21* and *22* of the selector switch in your N.R.I. Tester with soldered lap joints, as shown in Fig. *19C*. Allow the twisted wires to extend beyond the chassis for the time being.

Remove the test probes from the N.R.I. Tester and check the calibration in the usual manner, then replace the test probes in the V_{AC} jacks. Leave the test clips still connected to the *yellow* s.g. coil terminal and the chassis. Set the selector switch at *V*, turn on the power pack and the N.R.I. Tester, wait about half a minute for tubes to warm up, then adjust the potentiometer (R_2) on the oscillator chassis until the meter reading on the *AC* scale is exactly 4.5 (corresponding to an r.f. voltage of 4.5 volts).

Without turning off the apparatus or changing any adjustments, move the selector switch to the $3 \times V$ setting and note the meter reading on the *AC* scale. If the reading is higher than 1.5, cut off with side-cutting pliers about half an inch from the end **of the twisted pair of wires without** turning off the apparatus, then take your hands away from the wires and tap the meter lightly to overcome bearing friction. If the reading is still higher than 1.5, cut another half-inch **from the twisted wires and again** tap the meter to get the reading accurately. Continue shortening these wires until the meter reads 1.5 on the *AC* scale. It should not be necessary to cut more than about 2 inches of wire at the most to secure this calibration, and sometimes it may not be necessary to cut any wire.

Switch to the *V* range to make sure that the reading is still exactly 4.5 volts on the *AC* scale for this range. You have now made a calibration which insures that readings on the $3 \times V$ range will be exactly three times the readings on the *V* range at radio frequencies.

Arrange the remaining length of twisted wire in a neat loop, as shown in Fig. *19D*, being sure that the exposed bare ends of the wire are not touching each other or any nearby parts. This twisted wire is to be left in this position permanently, for it serves to correct r.f. measurements and does not interfere with other types of measurements.

Step 5. To measure voltage and current values in your r.f. oscillator circuit when a plate supply resistance value of 13,300 ohms is employed and there is no r.f. load, remove the lead which runs between potentiometer terminal *17* and the *yellow* terminal of the s.g. coil, then remove the lead which runs between potentiometer terminal *15* and the *gray* terminal of the s.g. coil.

Now measure the d.c. plate voltage of the oscillator tube with the N.R.I. Tester by placing the red clip on the *red* s.g. coil terminal and placing

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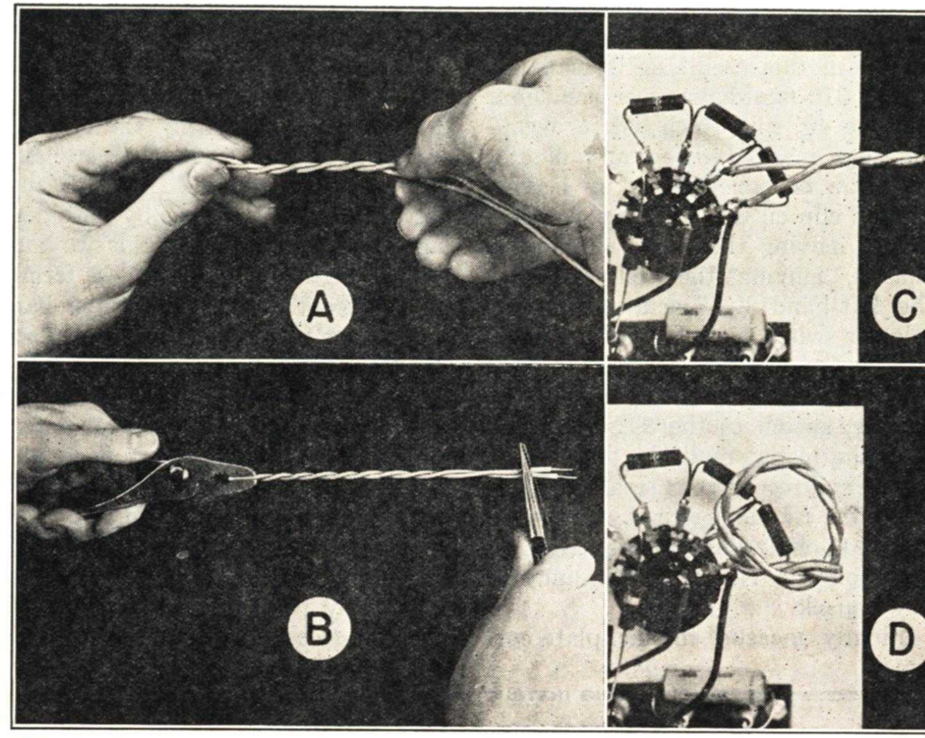

FIG. 19. Steps in connecting to terminals *21* and *22* of the N.R.I. Tester an additional capacity which consists of two insulated leads twisted together.

the black clip on the chassis, after preparing the tester for d.c. voltage measurements. Set the selector switch at $100 \times V$, turn on the power pack, turn on the N.R.I. Tester, wait about half a minute for the tubes to warm up, read the meter on the *DC* scale, multiply the reading by 100, and record your result in Table *44* as the d.c. plate voltage for a 13,300-ohm plate supply resistor. Turn off the N.R.I. Tester and the power pack. (The measurement is made to the plate supply end of the coil instead of to the plate, so as to prevent the capacity of the tester from affecting operation of the oscillator.)

Next, measure the d.c. C bias voltage value which is developed across the 40,000-ohm grid resistor by the flow of rectified grid current through this resistor. To make this measurement, place the test clips across this 40,000-ohm resistor which is above the chassis, with the red clip going to that resistor terminal which is on the *green* terminal of the s.g. coil. With the selector switch still at $100 \times V$, turn on the power pack and the N.R.I. Tester, wait about half a minute, then switch to the lowest range which does not overload the meter, read the meter, and record your result in Table *44* as the C bias voltage in volts for a 13,300-ohm plate supply resistance. Turn off the N.R.I. Tester and the power pack.

Do not touch the chassis or panel of the N.R.I. Tester when measuring the C bias voltage; the capacity of your body would have the effect of grounding the grid of the oscillator tube, thereby upsetting circuit conditions and giving erroneous voltage readings. Keep the test leads away from the s.g. coil as much as possible.

Now measure the r.f. voltage existing across the tank circuit (the tank circuit in this oscillator is made up of the 370-mmfd. trimmer condenser and the s.g. coil which has its terminal lugs marked *green* and *black*). This can be done simply by leaving the red clip on the *green* s.g. coil terminal, moving the black clip to the chassis, moving the red probe to the left-hand V_{AC} jack, setting the selector switch back to *100* × *V*, then turning on the power pack and the N.R.I. Tester. After waiting half a minute, switch to the *30* × *V* range, read the meter, multiply the reading by 30, and record your result in Table *44* as the r.f. tank circuit voltage for a 13,300-ohm plate supply resistor. Turn off the N.R.I. Tester and the power pack.

Finally, measure the d.c. plate current of the oscillator tube in the following manner. Prepare the N.R.I. Tester for direct current measurements by moving the test probes to the *I* jacks and setting the selector switch to *10* × *I*. Open the plate circuit between terminals *11* and *12* under the oscillator chassis by unsoldering the lap joint between the two bare 1-inch lengths of wire on these terminals, place the red clip on the bare wire going to terminal *12*, and place the black clip on the bare wire going to terminal *11*. After making sure that the clips do not touch other terminals, turn on the power pack and the N.R.I. Tester while leaving the oscillator chassis upside down, wait about half a minute, then read the meter on the *DC* scale, multiply the reading by 10, and record your result in Table *44* as the d.c. plate current in ma. for a 13,300-ohm plate supply resistor. Turn off the N.R.I. Tester and power pack.

Warning: During this current measurement, the tester chassis is at a high d.c. potential with respect to the other chassis units and to ground, because the current measurement is being made at a point which is highly positive with respect to ground. Therefore, do not touch the oscillator chassis, the power pack chassis, or any other grounded object while turning on, turning off or adjusting the tester for this and similar *current* measurements.

OPERATING INSTRUCTING FOR N.R.I. TESTER

R.F. VOLTAGE MEASUREMENTS

1. Check the calibration of the N.R.I. Tester in the usual manner, as instructed in previous manuals. Be sure the U-shaped jumper is in the *PHONE* jacks during calibration. Tap the meter lightly with your finger during calibration to minimize bearing friction.
Special Note: These instructions assume that you have already added the twisted wire to the N.R.I. Tester, according to the instructions given in Step 2 of Experiment 44.

2. Place the red probe in the left-hand V_{AC} jack, and place the black probe in the $-V_{AC}$ jack.

3. Start with the selector switch set at the *30* × *V* range. Switch to a lower range only after all tubes in the circuit have warmed up and reached normal operating conditions. The *100* × *V* range is never used for r.f. measurements.
Choose for your final reading the range which gives the *highest result in volts* (not the highest scale reading).
Do not under any condition use a scale reading higher than *4.5* on the *AC* scale; switch to the next higher range whenever the pointer is above *4.5* on this scale. This is necessary because scale readings above *4.5* are inaccurate for r.f. measurements.
***Important:* Whenever you obtain an off-scale reading through accident or otherwise, be sure to correct the calibration immediately by moving the calibrating clip temporarily to the —4½C terminal, then returning the clip to the —9C terminal.**

4. Read r.f. voltages on the *AC* scale in exactly the same manner as for a.c. measurements.

5. If a scale reading above *4.5* is obtained with the *3* × *V* range, you can: *1.* Estimate the value as being a few volts higher than 13.5 volts; *2.* Switch to the *30* × *V* range and read as best you can, although it will be difficult to secure an accurate reading because the pointer is below 1 on the scale. (The 10-megohm resistor cannot be used as a multiplier for doubling a voltage range during r.f. measurements, because we now have a capacity voltage divider.)

STEP	PLATE SUPPLY RESISTANCE IN OHMS	D.C. PLATE VOLTAGE IN VOLTS		C BIAS VOLTAGE IN VOLTS		R.F. TANK CIRCUIT VOLTAGE IN VOLTS		D.C. PLATE CURRENT IN MA	
		YOUR VALUE	N.R.I.	YOUR VALUE	N.R.I.	YOUR VALUE	N.R.I.	YOUR VALUE	N.R.I.
5	13,300		160		66		72		15
6	20,000		130		48		54		10
7	40,000		110		30		30		5

TABLE 44. Record your results here for Experiment 44.

Step 6. To measure voltage and current values in your r.f. oscillator when a plate supply resistance value of 20,000 ohms is used, first remove the last 40,000-ohm resistor which you connected to terminals *10* and *12* (this leaves only two 40,000-ohm resistors connected to terminals *10* and *12*). Since the N.R.I. Tester and its clips are still set for d.c. plate current measurements, make this measurement first exactly as instructed in Step 5, and record your result in the right-hand column of Table *44* as the d.c. plate current in ma. for a 20,000-ohm plate supply resistance.

Remove the test clips and solder together again the two bare leads on terminals *11* and *12*. Measure the *d.c. voltage* now between the *red* s.g. coil terminal and the chassis exactly as instructed in Step 5, and record your result in Table *44* as the d.c. plate voltage in volts for a 20,000-ohm plate supply resistor.

Measure the d.c. voltage drop across the 40,000-ohm grid resistor exactly as instructed in Step 5, and record your result in Table *44* as the C bias voltage in volts for a 20,000-ohm plate supply resistor.

Measure the r.f. voltage across the tank circuit as instructed in Step 5, and record your result in Table *44* as the r.f. tank circuit voltage in volts for a 20,000-ohm plate supply resistor.

Step 7. To measure voltage and current values in your r.f. oscillator circuit when a plate supply resistor value of 40,000 ohms is used, first unsolder and remove one of the two 40,000-ohm resistors which are still connected to terminals *10* and *12*. This leaves only a single 40,000-ohm resistor in the plate supply circuit of the oscillator.

Measure the d.c. voltage between the *red* s.g. coil terminal and the chassis, and record your result in Table *44* as the d.c. plate voltage in volts for a 40,000-ohm plate supply resistor. If necessary, switch to the *30* × *V* range to obtain a more accurate reading.

Measure the d.c. voltage across the 40,000-ohm grid resistor and record your result in Table *44* as the C bias voltage in volts for a 40,000-ohm plate supply resistor. Switch to the lowest range which does not overload the meter, to obtain as accurate a reading as possible for this measurement.

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Measure the r.f. voltage between the *green* s.g. coil terminal and the chassis, and record your result in Table *44* as the r.f. tank circuit voltage in volts for a 40,000-ohm plate supply resistor. You will probably have to use the *30* × *V* range for this measurement.

Measure the d.c. plate current by unsoldering the joint between the two bare wires on terminals *11* and *12*, placing the red clip on the wire going to *12*, placing the black clip on the wire going to *11*, then measuring the current as instructed in Step 5 and recording your result in Table *44* as the d.c. plate current in ma. for a 40,000-ohm plate supply resistor. Be sure to turn off the N.R.I. Tester and the power pack after completing this final measurement.

Discussion: The N.R.I. values in Table *44* indicate definitely that as the d.c. plate voltage is lowered (by increasing the value of the plate supply resistance), the C bias voltage, the r.f. tank circuit voltage and the d.c. plate current will all drop correspondingly. Your value should show this same drop with d.c. plate voltage even though the values themselves may be entirely different from corresponding N.R.I. values.

Oscillator Circuit Theory. When a vacuum tube oscillator like that which you set up in this experiment reaches normal operating conditions, the grid is being driven sufficiently positive to produce a grid current flow and this develops a definite C bias voltage across the grid resistor. The a.c. voltage which is developed across the tank circuit makes the grid swing alternately positive and negative with respect to the fixed C bias voltage value.

If the oscillator tube had an E_G-I_P characteristic curve like that shown in Fig. *20A*, the a.c. tank voltage e_g might swing sufficiently positive to place the C bias voltage E_C beyond cut-off, as indicated in the diagram. Under this condition, plate current can flow only when e_g is swinging more positive than the cut-off bias value, and the plate current i_p becomes a pulse having an operating angle less than 180° (so that plate current flows for less than half of each grid voltage cycle).

The plate current pulse i_p in Fig. *20A* represents the power required to maintain oscillation, for it is the power in this plate current pulse which is fed back into the tank circuit for the purpose of setting this resonant circuit into natural oscillation.

The area of the plate current pulse i_p (the shaded portion in Fig. *20A*), when considered as a graph, is proportional to the amount of power drawn by the oscillator from its d.c. supply source. The greater the area of this pulse, the more power the oscillator will be able to deliver. Theoretically, the area of this current pulse can be increased by increasing the peak value of the pulse, by increasing the operating angle, and by making the pulse flatter at the top so that its sides will be steeper; all three of these factors will thus tend to increase the amount of power which the oscillator is capable of delivering.

The d.c. power drawn by the oscillator has a number of functions to perform. In addition to supplying the r.f. power which is drawn from the oscillator by its load circuit or by associated equipment, this d.c. power must overcome the losses in the tank circuit, the power dissipated in the grid resistor, the power dissipated in the grid-cathode resistance of the oscillator tube, the power dissipated in the plate-cathode resistance of the oscillator tube, and incidental circuit losses such as that due to the resistance of the wiring.

Now let us consider how the a.c. tank voltage e_g is maintained at a definite level for a given set of operating voltages. Suppose there is a tendency for this a.c. tank voltage to *increase;* this makes the positive pulse of e_g swing more positive, so that grid current increases and the voltage drop E_C across the grid resistor increases correspondingly. This increased negative C bias moves the operating point further beyond cut-off, so that the operating angle of the plate current pulse i_p is reduced even though the peak value of this pulse may tend to increase. With the area of the current pulse reduced in this manner, less power is available for oscillation, and consequently, a braking action occurs which makes the a.c. tank voltage return to its normal value.

If the a.c. tank voltage tends to *drop*, the C bias voltage decreases, making the operating angle of the plate current pulse greater. More power is then drawn from the d.c. supply source, making the a.c. tank voltage return to its normal value at which the d.c. power drawn by the oscillator is just enough to take care of oscillator circuit losses and the r.f. power being drawn from the oscillator.

The plate supply resistance changes made in this experiment change the d.c. plate voltage on the oscillator tube, so let us consider how the d.c. plate voltage changes can affect the C bias voltage, the r.f. tank voltage and the average value of the plate current pulse i_p.

First of all, we must realize that increasing the d.c. plate voltage gives a different E_G-I_P curve for the oscillator tube, as shown in Fig. *20B*. The cut-off bias voltage value is now more negative than before, and the plate current for any grid voltage value more positive than cut-off is much higher than before. Since the a.c. tank voltage must still swing the grid positive in order to produce the automatic C bias voltage required as a condition for oscillation, the a.c. tank voltage becomes much higher for the higher plate voltage value. Furthermore, the area of the plate current pulse i_p becomes larger, and its average d.c. value as measured by the N.R.I. Tester becomes correspondingly higher than before. Finally, since the fixed C bias must be more negative than cut-off under this condition, the C bias voltage developed across the grid resistor is also higher than before. The measurements which you made for this experiment are thus all confirmed by this theoretical analysis.

One fact which is worth remember-

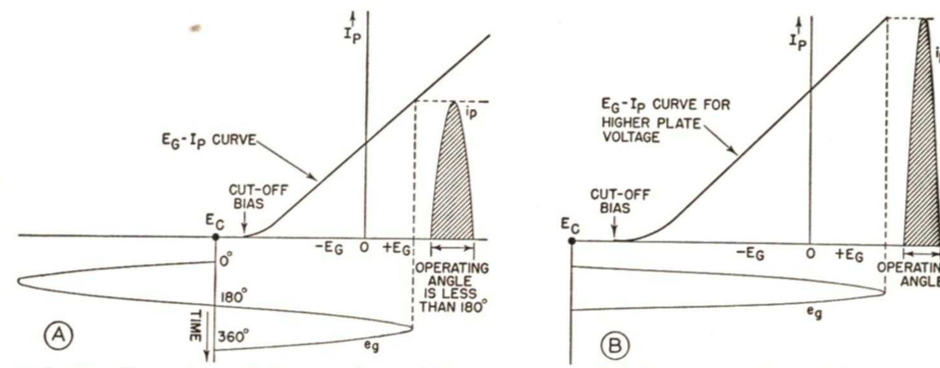

FIG. 20. These characteristic curves for a triode vacuum tube will help you to understand how your r.f. oscillator functions.

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ing in connection with this oscillator experiment is that an increase in the a.c. tank voltage is always accompanied by an increase in the C bias voltage developed across the grid resistor. From a practical standpoint, this means that you can tell if the oscillator is working and determine how the r.f. tank voltage value is varying simply by measurng the d.c. voltage across the grid resistor with an ordinary high-sensitivity d.c. voltmeter such as the N.R.I. Tester.

The purpose of the 1000-ohm resistor in the cathode circuit is to introduce a sufficient amount of degeneration to stabilize the circuit. The voltage drop across this resistor acts as a variable bias that opposes changes in the grid circuit. This resistor must not be by-passed.

Instructions for Report Statement No. 44. On the basis of the measurements you have already made, you should now be able to predict what happens to the oscillator circuit values when the d.c. plate voltage is reduced still more by using an 80,000-ohm plate supply resistance. You can verify your prediction very easily, simply by inserting the 80,000-ohm resistance in the plate circuit and measuring the C bias voltage.

For this report statement, break the connection between terminals *11* and *12*, then connect another 40,000-ohm resistor between terminals *11* and *12*, so that you now have two 40,000-ohm resistors in series between terminals *10* and *11* to give an 80,000-ohm plate supply resistance.

Turn the chassis over, and measure the d.c. voltage across the 40,000-ohm resistor to secure the C bias voltage for an 80,000-ohm plate supply resistance. Compare this measured C bias voltage value with that which you recorded for a 40,000-ohm plate supply resistance in Table *44*, then answer Report Statement No. 44.

Be sure that you turn off the N.R.I. Tester and the power pack, and remove the test leads both from the N.R.I. Tester and the oscillator after making the final measurement for Experiment 44.

EXPERIMENT 45

***Purpose:* To show that there is a minimum value of feed-back coupling below which oscillation cannot be maintained in an r.f. oscillator circuit; to show that increasing the feed-back coupling beyond the minimum value increases the r.f. tank voltage, the C bias voltage and the d.c. plate current of the oscillator tube.**

Preliminary Discussion: The signal generator coil which you use in your r.f. oscillator has two windings in addition to the main tuning coil across which the 370-mmfd. trimmer condenser is connected. One of these additional windings (the one at the end of the coil form) has twenty-two turns, while the other winding (near the center of the coil form) has sixteen turns. Connecting these two coils in series gives a total of thirty-eight turns, while connecting them in opposition gives six turns. Thus, by varying coil connections we can secure four different values of feed-back coupling: six turns; sixteen turns; twenty-two turns; thirty-eight turns.

Step 1. To make oscillator circuit measurements with twenty-two turns of feed-back coupling, first insert a 40,000-ohm plate supply resistance by removing the 40,000-ohm resistor which you connected between terminals *11* and *12* in the previous experiment, then connecting together terminals *11* and *12* by means of the short bare lengths of wire so that a single 40,000-ohm resistor is connected between terminals *10* and *12*.

Measure the d.c. voltage between

STEP	FEED-BACK COUPLING TURNS	D.C. PLATE VOLTAGE IN VOLTS		C BIAS VOLTAGE IN VOLTS		R.F. TANK VOLTAGE IN VOLTS		D.C. PLATE CURRENT IN MA.	
		YOUR VALUE	N.R.I.	YOUR VALUE	N.R.I.	YOUR VALUE	N.R.I.	YOUR VALUE	N.R.I.
2	6		150		0		0		5
4	16		110		27		30		7
1	22		110		30		33		7
3	38		84		66		69		9

TABLE 45. Record your results here for Experiment 45.

the *red* s.g. coil terminal and the chassis, and record your result in Table *45* as the d.c. plate voltage when the feed-back coupling is twenty-two turns. Note that your readings for this step are to be recorded in the third horizontal line of Table *45;* this is done so that you can secure the various coupling arrangements in the easiest possible manner and yet still have your values arranged in the order of increasing coupling. This procedure is common practice in laboratory work.

Measure the d.c. voltage across the 40,000-ohm resistor (red clip on *green* terminal) and record your result in Table *45* as the C bias voltage in volts for a feed-back coupling of twenty-two turns.

Turn the chassis on its side, measure the r.f. voltage across the 370-mmfd. trimmer condenser with the *30 × V* range (black clip on grounded lead, which goes to terminal *14*) and record your result in Table *45* as the r.f. tank circuit voltage in volts for a feed-back coupling of twenty-two turns.

Measure the current flowing between terminals *11* and *12* by breaking the connections between these terminals and inserting your measuring instrument, then record your result in Table *45* as the d.c. plate current in ma. for a feed-back coupling of twenty-two turns. Be sure to connect terminals *11* and *12* together again after completing this current measurement.

Step 2. To make oscillator circuit measurements for a feed-back coupling of six turns, change the feed-back coupling to six turns in the following manner: unsolder the lead from the *blue* s.g. coil terminal, connect a 3-inch length of hook-up wire to this *lead* by means of a temporary soldered hook joint, and connect this wire to the *yellow* terminal of the s.g. coil. Now connect the *gray* and *blue* terminals of the s.g. coil together with a suitable length of hook-up wire.

Measure the d.c. voltage between the *red* s.g. coil terminal and the chassis, and record your result in Table *45* as the d.c. plate voltage in volts for a feed-back coupling of six turns. Note that all readings for this step are to go in the first horizontal line of Table *45*.

Measure the d.c. voltage across the 40,000-ohm resistor, and record your result in Table *45* as the C bias voltage in volts for a feed-back coupling of six turns.

Measure the r.f. voltage across the 370-mmfd. trimmer condenser by using the *V* range of the N.R.I. Tester, and record your result in Table *45* as the r.f. tank voltage in volts for a feed-back coupling of six turns.

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Measure the direct current flowing between terminals *11* and *12* and record your result in Table *45* as the d.c. plate current in ma. for a feed-back coupling of six turns.

Step 3. To make oscillator circuit measurements for a feed-back coupling of thirty-eight turns, first change the feed-back coupling to thirty-eight turns by reversing the connections which you made in the previous step to the *gray* and *yellow* terminals of the s.g. coil. In other words, remove from the *gray* terminal the wire which goes to the *blue* terminal, and place this instead on the *yellow* terminal. Remove from the *yellow* terminal the wire which goes through chassis hole *f*, and connect this wire instead to the *gray* terminal.

Measure the d.c. voltage between the *red* s.g. terminal and the chassis and record your result in Table *45* as the d.c. plate voltage in volts for a feed-back coupling of thirty-eight turns. Note that all readings for this step go on the last horizontal line of Table *45*.

Measure the d.c. voltage across the 40,000-ohm grid resistor, and record your result in Table *45* as the C bias voltage in volts for a feed-back coupling of thirty-eight turns.

Measure the r.f. voltage across the 370-mmfd. trimmer condenser, using the *30* × *V* range of the N.R.I. Tester, and record your result in Table *45* as the r.f. tank voltage in volts for a feed-back coupling of thirty-eight turns.

Measure the direct current flowing between terminals *11* and *12*, and record your result in Table *45* as the d.c. plate current in ma. for a feed-back couping of thirty-eight turns.

Step 4. To make oscillator circuit measurements for a feed-back coupling of sixteen turns, first unsolder the lead which is on the *blue* lug, unsolder the lead which is on the *red* lug, and connect these two unsoldered leads together by means of a temporary soldered hook joint so as to secure a feed-back coupling of sixteen turns.

Measure the d.c. voltage between the chassis and the soldered joint which you just made, and record your result in Table *45* as the d.c. plate voltage in volts for a feed-back coupling of sixteen turns. Note that your results for this step go on the second horizontal line of Table *45*.

Measure the d.c. voltage across the 40,000-ohm grid resistor, and record your result in Table *45* as the C bias voltage in volts for a feed-back coupling of sixteen turns.

Measure the r.f. voltage across the 370-mmfd. trimmer condenser, and record your result in Table *45* as the r.f. tank voltage in volts for a feed-back coupling of sixteen turns. Use the *3* × *V* range if the pointer stays below 4.5 on the *AC* scale; otherwise, use the *30* × *V* range for this measurement.

Measure the direct current flowing between terminals *11* and *12*, and record your result in Table *45* as the d.c. plate current in ma. for a feed-back coupling of sixteen turns.

Discussion: An analysis of the N.R.I. values obtained for this experiment will serve as a guide for you in analyzing your own results.

First of all, the zero C bias and zero r.f. tank voltage values obtained for a feed-back coupling of six turns indicate that this lowest number of turns is not sufficient to produce oscillation. The d.c. plate current value of 5 ma. obtained with this six-turn coupling simply corresponds to the plate current for zero C bias and a d.c. plate voltage of 150 volts. Any disturbances which might exist in the plate circuit cannot feed a sufficiently strong pulse of energy into the tank circuit to set that circuit into natural oscillation and keep it oscillating.

Oscillation could be secured even with only six turns of coupling, however, if the plate voltage were increased. For example, we increased the plate voltage in the N.R.I. laboratory by shorting out the 40,000-ohm plate load resistor; this made the d.c. plate voltage go up to 370 volts, and we then measured an r.f. tank voltage of 7.8 volts, proving that the circuit was oscillating. The d.c. plate current under this condition was 30 ma., indicating that when coupling is weak both the d.c. plate voltage and the d.c. plate current must be high in order to secure even a low value of r.f. tank voltage. It is not advisable for you to try this experiment yourself, since the measurement must be made quickly in order to prevent damage to the 6F8G tube by the high plate current which flows when the plate load resistor is shorted.

A feed-back coupling of sixteen turns was obviously sufficient to produce oscillation, as the r.f. tank voltage value for this coupling was 30 volts. Note that as the feed-back coupling is increased, both the r.f. tank voltage and the C bias voltage increase. Increasing the coupling raises the mutual inductance existing between the coils, so that more of the a.c. plate circuit energy can be transferred through this mutual inductance to the tank circuit. With more energy fed into it, the tank circuit develops a greater r.f. voltage, and this in turn sends a higher rectified grid current through the grid resistor to produce across this resistor a higher C bias voltage value.

Although N.R.I. values are recorded for d.c. plate current, it must be admitted that these were obtained under extremely difficult conditions and are therefore far from accurate. To obtain these values, it was necessary to use the *10* × *I* range of the N.R.I. Tester, and this range gave readings so close to zero that variations of 1 or 2 milliamperes could hardly be detected.

Computations: We do not have to rely upon measured plate current values, however, for we can readily compute the true plate current through its relationship with the d.c. plate voltage. Since our measured values indicate that the d.c. plate current is not changing appreciably, we can safely assume that the power pack d.c. output voltage remains constant throughout the experiment.

The computations require measurement of this power pack d.c. output voltage, it being 430 volts for the N.R.I. values. With a 40,000-ohm plate supply resistor being used to limit the d.c. plate voltage acting upon the tube, the difference between the d.c. supply voltage and the d.c. plate voltage will be the d.c. voltage drop across the plate supply resistor. This voltage drop divided by the 40,000-ohm resistance value then gives us the true d.c. plate current value.

For example, with a coupling of twenty-two turns in Step 1, the voltage drop across the resistor would be 430 volts minus 110 volts, which is 320 volts; dividing 320 volts by 40,000 ohms gives 8 ma. Just as we expected, this true computed value is somewhat different from the measured value of 7 ma. Computations for the other three experiments would show just about this same discrepancy between measured N.R.I. values and true current values.

It is not necessary for you to make these calculations of plate current, however, for in this experiment we are interested simply in knowing whether the plate current goes up or down, and the measured plate voltage values give this information. The lower the plate current, the lower will be the voltage drop produced across the 40,000-ohm plate supply resistor by this plate current, and the higher will be the resulting d.c. plate voltage. Thus, for a high value of plate current, the drop across the resistor will be high, giving only a low d.c. voltage for the plate.

Examination of the N.R.I. d.c. plate voltage values shows that the d.c. plate voltage is lowest for thirty-eight

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turns of coupling; the d.c. plate current must therefore be the highest for this coupling. Furthermore, the d.c. plate voltage is the highest for six turns, and therefore the d.c. plate current must be lowest for this coupling.

In any oscillator circuit, the d.c. plate voltage multiplied by the d.c. plate current gives the oscillator input power. This holds true for your oscillator circuit as well; we can neglect the power lost in the plate supply resistor because in a practical high-efficiency oscillator circuit the power pack would be designed to supply exactly the correct voltage, and consequently no voltage-reducing plate supply resistor would be employed. The power required to heat the filament is likewise neglected, as it remains the same for a particular tube regardless of how that tube is employed.

Optimum coupling occurs when the maximum r.f. tank voltage per watt of oscillator power input is obtained. Although we cannot draw any definite conclusion as to optimum coupling from the values obtained in this experiment, additional measurements in the N.R.I. laboratory indicated that about thirty turns gave optimum coupling. The number of turns which gives optimum coupling varies with the d.c. plate voltage, the load, the d.c. grid voltage, etc. In an oscillator circuit where some means is provided for varying the coupling, it will be found that for a given plate voltage and fixed circuit constants, optimum coupling will exist when the ratio of r.f. tank voltage to d.c. plate current is a maximum.

It is possible to increase the coupling to the point where the oscillator operates intermittently even though normal grid leak values are used. Technically, we say that the oscillator *blocks* due to over-coupling. This over-coupling tends to produce such a high r.f. tank voltage that it makes the grid drive the oscillator tube up to plate current saturation, with the tank circuit capable of supplying still more excitation. This causes a large negative C bias voltage, making the operating angle too small to supply the energy required for oscillation, with the result that oscillation stops.

It takes a number of cycles before this condition takes place, so the circuit will oscillate normally for a short time before it stops or blocks. When the C bias is reduced by normal leakage through the circuit, the oscillator will start again and the cycle will repeat itself. With the apparatus available for these experiments, we are not able to produce sufficient coupling to give intermittent blocking while using the low grid resistance value which we have in this particular circuit. This blocking action will be demonstrated with a different circuit in the next experiment.

When two coils are connected in series aiding as is done in Step 3, the total effective number of turns is the sum of the individual turns. The current then flows in the same direction through both of the coils. When two coils are connected in series bucking, so that current flows in different directions through the two coils, the effective number of turns is the difference between those on the individual coils; this is how we secure six turns in Step 2.

Instructions for Report Statement No. 45. To determine the effect which reversal of feed-back coil connections has upon oscillation, replace the twenty-two-turn feed-back coil just as it was for Step 1 in this experiment, measure the C bias voltage again for this condition, then reverse the connections to the twenty-two-turn coil and measure the C bias voltage again.

Remember that the C bias voltage is produced by the r.f. tank voltage.

To accomplish all this, first remove entirely the short wire which connects the *gray* coil terminal to the lead coming out of hole *f*. Remove the short wire which connects the *yellow* coil terminal to the wire coming out of hole *e*. Connect to the *blue* coil terminal the wire which comes out of chassis hole *f*. Connect to the *red* coil terminal the wire which comes out of chassis hole *e*.

Measure the C bias voltage across the 40,000-ohm resistor now to make sure it is essentially the same as the value which you recorded for Step 1 in Table *45*, then reverse the connections to the *blue* and *red* coil terminals and again measure the C bias voltage. The lead coming out of hole *f* must be lengthened temporarily to make this reversal of connections possible. Now answer Report Statement No. 45.

EXPERIMENT 46

Purpose: **To show that increasing the ohmic value of the grid resistor in an oscillator circuit makes the automatic C bias voltage and the r.f. tank voltage both increase up to a certain point, after which the circuit begins blocking to produce intermittent oscillation resulting in audio frequency modulation of the r.f. signal; to show that when a load is placed on the tank circuit, the C bias voltage and the r.f. tank voltage will be lower but will increase in the same manner as before when the grid resistance value is increased.**

Step 1. To make the measurements called for in this experiment, first restore the original connections for the twenty-two-turn feed-back coil by reversing the positions of the leads on the *red* and *blue* s.g. coil terminals. (The lead from hole *f* should now go to the *blue* terminal, and the lead from hole *e* should go to the *red* terminal). The plate supply resistance is still 40,000 ohms.

In this experiment you will use five different values of grid resistance. For each value you will make three meter measurements and one phone test without any load connected across the tank circuit, then make three more meter measurements with a 40,000-ohm load connected across the tank circuit, so as to secure at one time all of the readings required for the two purposes of this experiment.

The six meter measurements and the phone test for each grid resistor value are to be made in the following manner:

Connect the grid resistor of the specified value between the *green* terminal and the *unmarked* terminal of the s.g. coil in place of the 40,000-ohm resistor previously on these terminals, while leaving the .001-mfd. condenser connected to these terminals just as before. The five grid resistor values which you are to use are 1,000 ohms, 40,000 ohms, 100,000 ohms, 140,000 ohms (obtained by placing the 40,000 and 100,000-ohm resistors in series between the *green* and *unmarked* terminals), and 10 megohms (Part 4-21). Make temporary soldered hook or lap joints being careful not to place excessive strain on the coil terminals while making a joint or removing leads.

With the grid resistor connected properly, first measure the d.c. voltage between the *red* s.g. coil terminal (red clip) and the chassis, and record your result in Table *46* as the d.c. plate voltage for the grid resistance being used, with no load on the tank circuit.

Measure the d.c. voltage between the leads of the grid resistor (red clip on *green* s.g. coil terminal) and record your result in Table *46* as C bias volt-

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age for the grid resistance being used, with no load on the tank circuit.

Measure the r.f. voltage between the *green* s.g. coil terminal (red clip) and the chassis while using the voltage range specified at the top of the box in which the measurement is to be recorded in Table *46*, then record your result as the r.f. tank voltage in volts for the grid resistance being used, with no load on the tank circuit. Turn off all apparatus.

With the tester still connected as for the r.f. voltage measurement, remove the U-shaped jumper from the phone jacks and insert the metal tips of your headphone leads in these jacks. Set the selector switch at *V*. Listen for an audio tone after all apparatus is turned on again; if no tone is heard, record your result as *zero* for the frequency of oscillation with the grid resistance being used and with no load on the tank circuit. If a high-pitched tone is heard, corresponding to a high frequency, record your result as *HIGH;* if the tone is more of a rasping or buzzing sound, corresponding to a low frequency, record your result as *LOW*. Remove the phone tips and replace the U-shaped jumper in the phone jacks after making this test.

Connect a 40,000-ohm resistor temporarily between terminals *18* and *19* of trimmer condenser C_A under the chassis, then repeat your d.c. plate voltage measurement, your C bias voltage measurement, and your r.f. tank voltage measurement, and record your results in the spaces provided for this purpose in Table *46* for the specified grid resistance value and a 40,000-ohm load on the tank circuit. When the three measurements have been completed, remove the 40,000-ohm resistor from terminals *18* and *19*, then change to the next grid resistance value and repeat the entire series of measurements again.

Discussion: An analysis of the N.R.I. values for this experiment shows that both the C bias voltage and the r.f. tank voltage go up as the ohmic value of the grid resistor is increased, regardless of whether or not there is a load across the tank circuit.

The larger the ohmic value of the grid resistor, the greater is the d.c. voltage developed across this resistor by a definite grid current value. The increased negative C bias resulting from increased grid current makes it necessary for the r.f. tank voltage to increase in order to swing the grid sufficiently positive to maintain oscillation. The combination of the more negative operating point and increased r.f. tank voltage means a smaller operating angle for the plate current, and consequently the average d.c. plate current drops. The resulting lower voltage drop across the plate resistance leaves more voltage for the tube itself, with the result that the d.c. plate voltage goes up. The N.R.I. values verify this analysis, for they show that the d.c. plate voltage goes up as the ohmic value of the grid resistor is increased.

The N.R.I. results in the *FREQUENCY* column of Table *46* indicate that intermittent oscillation occurs only when the grid resistance value is increased to 10 megohms, but you may also hear a tone in the headphone for the 140,000-ohm grid resistance value (blocking started in the N.R.I. laboratory at a grid resistance value only slightly higher than 140,000 ohms, and with some tubes and parts we actually did hear a *HIGH* frequency tone for this value).

The C bias voltage is high at high grid resistance values, but the r.f. tank voltage has not increased suffi-

GRID RESISTANCE IN OHMS	NO LOAD ON TANK CIRCUIT: D.C. PLATE VOLTAGE IN VOLTS	C BIAS VOLTAGE IN VOLTS	R.F. TANK VOLTAGE IN VOLTS	FREQUENCY (PHONE TEST)	40,000Ω LOAD ON TANK CIRCUIT: D.C. PLATE VOLTAGE IN VOLTS	C BIAS VOLTAGE IN VOLTS	R.F. TANK VOLTAGE IN VOLTS
1,000	75	1	4.8 (3 x V)	0	78	6	4.5 (V)
40,000	117	30	36 (30 x V)	0	135	15	14 (3 x V)
100,000	150	54	63 (30 x V)	0	160	21	18 (30 x V)
140,000	160	64	54 (30 x V)	0	180	24	21 (30 x V)
10 MEG.	430	101	0 (V)	LOW	430	72	0 (V)

TABLE 46. Record your results here for Experiment 46. In this particular table, the N.R.I. value is placed in the triangular area at one corner of the box in which you are to write your own value. The voltage range which you should use for each of the r.f. tank voltage measurements is indicated at the top of each of the boxes provided for these measurements.

ciently to offset this increase in negative bias. As a result, the grid is driven so far negative that for a few r.f. cycles no plate current is drawn, and oscillation ceases. The charge on the grid condenser then leaks off through the grid resistor, lowering the C bias and permitting the circuit to return to its normal oscillating condition. Oscillation again builds up the negative C bias, causing the circuit to block and repeat the entire cycle. This process continues indefinitely, and when it is within the audio frequency spectrum, a tone can be heard in the headphone. Actually, we have a self-modulating circuit in which the r.f. signal is modulated at an audio rate.

Commercial test oscillators often employ this self-modulating r.f. circuit so that a tone can be heard when the r.f. oscillator is connected to the input of a receiver.

When the grid resistance value is increased to the very high value of 10 megohms, oscillation occurs for such a short interval of time in between the blocking intervals that little or no r.f. voltage can be measured, even though it actually is present. Furthermore, increasing the grid resistance value increases the time required for the grid condenser to discharge and lower the C bias to the point where oscillation can continue, with the result that we hear a lower audio frequency note.

If the grid resistor value in megohms (140,000 ohms corresponds to .14 megohms) is multiplied by the capacity of the grid condenser in microfarads (.001 mfd.) we secure a value of .00014 seconds for the time constant of these two parts. This means that theoretically the circuit will block at intervals of about .00014 second. Dividing the number 1 by this time in seconds gives about 7,100 cycles as the frequency of blocking ($1 \div .00014 = 7{,}100$). The actual frequency will be somewhat lower than this theoretical value, however, for it takes a little time for the circuit to recover again after the blocking condition has cleared up.

With a 10-megohm grid resistor, the time constant becomes $10 \times .001$, or .01 second; this corresponds to 100 cycles, explaining why we hear a low-

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frequency note when the 10-megohm grid resistor is used. This is a buzz rather than a pure tone, because the modulation is not a pure sine wave in form.

In a normal r.f. oscillator circuit, the grid resistor value must be such that high r.f. output is obtained, if this is desired, without self-modulation or blocking.

The N.R.I. values show that loading of the tank circuit reduces both the r.f. tank voltage and the C bias voltage. Loading of a tank circuit reduces its Q factor, with the result that for a given amount of feed-back energy less r.f. voltage is developed. Since the r.f. voltage produces the C bias, this C bias lowers also.

Although loading increases the operating angle of the plate current, the peak plate current value is reduced due to the lowered r.f. voltage, and consequently the d.c. plate current is less. As previously explained, a lowered d.c. plate current results in a higher d.c. plate voltage just as was found by actual measurement in this experiment.

Instructions for Report Statement No. 46. In a practical oscillator circuit, it is entirely possible to encounter the condition in which the grid resistor opens up, giving infinity as the grid resistance value. The grid condenser is still in the circuit, but ordinarily the resistance of a small paper condenser like this is somewhere between 5,000 and 25,000 megohms, and for practical purposes this may be considered infinite. For this report statement, you will duplicate this open grid resistor condition and note its effect.

Remove the 10-megohm grid resistor from the *green* and *unmarked* s.g. coil terminals. Be sure that the 40,000-ohm resistor has been removed from trimmer condenser terminals *18* and *19*. Insert the phone tips in place of the U-shaped jumper wire in the phone jacks, connect the tester for r.f. tank voltage measurements, set the selector switch at the *V* range, then turn on the power pack and the N.R.I. Tester and listen to the phone for several minutes. Turn off your apparatus, then answer Report Statement No. *46*.

EXPERIMENT 47

Purpose: **To show that an r.f. amplifier stage having a coil in the plate circuit will provide r.f. gain; to show that the gain of an r.f. amplifier stage can be increased by tuning the secondary winding of the r.f. transformer in the plate circuit; to show that weak output coupling reduces the r.f. output voltage and the gain.**

Preliminary Discussion: First of all, we require for this experiment an unmodulated variable r.f. voltage source, so that we can feed a definite r.f. voltage value into the grid of the r.f. amplifier stage which is built as a part of this experiment.

The tuned grid r.f. oscillator which you constructed and used in the previous experiment gives a suitable variable-frequency r.f. voltage source; to vary its r.f. output voltage, we simply connect the 1,000-ohm potentiometer across the third winding (*gray* and *yellow* terminals) of the signal generator coil. Since the movable (center) terminal of the potentiometer is grounded to the chassis through the lead to terminal *9*, we can obtain the r.f. voltage between the chassis and either of the outer potentiometer terminals.

The complete schematic circuit diagram for the r.f. oscillator and r.f. amplifier used in this experiment is given in Figs. *21A* and *21B*. The second triode section of the type 6F8G tube serves as the r.f. amplifier stage.

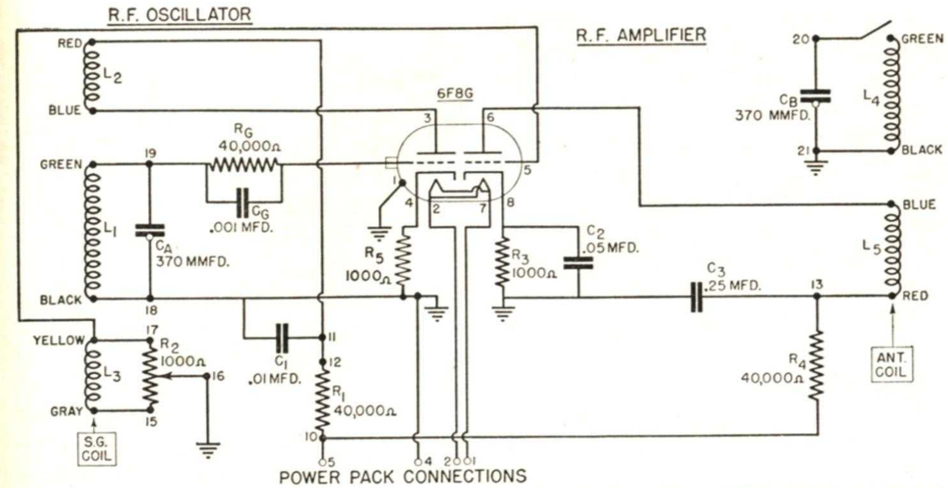

FIG. 21A. Schematic circuit diagram for the r.f. oscillator and r.f. amplifier which you build in Experiment 47. The connection from trimmer condenser terminal *20* to the *green* terminal of the antenna coil is not made until after you complete the first measurement for this experiment. If you desire, you can redraw this diagram in the spread-out form of Fig. *9B*, to secure valuable practice in reading and drawing schematic diagrams. Start out by drawing the two separate triode sections, placing them about four inches apart and making them about three times the size of the symbols shown here. Coils can be rearranged, but coil terminal markings must be kept the same. One method of redrawing this circuit is shown in Fig. *21B*; use this as a guide only if you encounter difficulties.

A 1,000-ohm resistor (R_3) in the cathode lead provides automatic C bias, and a .05-mfd. condenser (C_2) across this resistor by-passes r.f. signals so as to reduce degeneration. The antenna coil furnished you in Radio Kit *5RK* serves as the load for this r.f. amplifier stage, with the smaller of its two coils (L_5) being connected into the plate circuit. For one series of measurements, you use this coil alone as an untuned load. In another series of measurements, you will tune the secondary winding (L_4) of this r.f. output transformer with the 370-mmfd. trimmer condenser so as to secure a tuned load.

Step 1. To assemble the r.f. amplifier stage required for this experiment, first place before you the following parts:

.25-mfd. paper condenser (Part *3-2A*).
Three 40,000-ohm resistors (Parts *3-6B, C* and *D*).
1,000-ohm resistor (Part *3-5A*).
Standard broadcast band antenna coil (Part *5-6*).
370-mmfd. trimmer condenser (Part *5-9B*).
.05-mfd. paper condenser (Part *5-12*).

Connect a 40,000-ohm resistor between the *green* and *unmarked* terminals of the s.g. coil, to serve as the grid resistor for your r.f. oscillator. This will now be in parallel with the .001-mfd. condenser also connected to these terminals. Connect potentiometer terminal *17* to the *yellow* terminal of the s.g. coil, bringing the wire through chassis hole *i*. Connect potentiometer terminal *15* to the *gray* terminal of the s.g. coil, bringing the wire through chassis hole *j*. This places the potentiometer across the third winding of your s.g. coil, thereby providing variable r.f. output for your r.f. oscillator.

Mount the antenna coil in holes *jj* and *pp*, in a position such that the four terminal lugs of this coil will be above chassis holes *a*, *b*, *c* and *d*.

Mount the 370-mmfd. trimmer condenser in chassis hole *nn* in such a way that the tab of this condenser will be in hole *oo* and the adjusting screw will be adjustable from the top of the chassis through hole *x*. Identify this condenser as C_B on both sides of

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the chassis with metal-marking crayon and identify the terminals under the chassis by marking the number *20* alongside the condenser terminal nearest the edge of the chassis, and marking *21* alongside the other terminal. (These numbers can have the same positions as are indicated for trimmer condenser C_B in Fig. *25*.) You will now have two r.f. coils mounted above the chassis and two 370-mmfd. trimmer condensers mounted underneath the chassis.

Connect potentiometer terminal *17* to socket terminal *5* with hook-up wire.

Connect the .05-mfd. paper condenser between socket terminals *1* and *8*, then place a 1,000-ohm resistor in parallel with this condenser by connecting the resistor leads also to socket terminals *1* and *8*.

Connect socket terminal *6* to the *blue* terminal of the antenna coil, bringing the hook-up wire through chassis hole *d*.

Connect terminal *13* under the chassis to the *red* terminal of the antenna coil, bringing the hook-up wire through chassis hole *c*.

Connect a .25-mfd. condenser between terminals *13* and *14* under the chassis.

Connect a 40,000-ohm resistor between terminals *13* and *10* under the chassis. Bend the leads of all parts so that the parts are within the limits of the chassis. Make sure that leads do not accidentally touch adjacent bare leads or terminals.

Connect the *green* terminal of the antenna coil to terminal *20* of trimmer condenser C_B, bringing the hook-up wire through chassis hole *a*.

Connect the *black* terminal of the antenna coil to terminal *21* of C_B, bringing the hook-up wire through chassis hole *b*.

Ground terminal *21* of C_B to the chassis by connecting it to terminal *9* with hook-up wire.

Unsolder temporarily the lead which is on the *green* terminal of the antenna coil, since your first measurements will be made with an untuned secondary winding on this coil. Connections underneath the chassis should now be as shown in Fig. *22*.

Step 2. To measure the r.f. output voltage before and after the secondary of the plate coil for the r.f. amplifier stage is tuned, first set your r.f. oscillator to a low radio frequency (about 600 kc.) by rotating trimmer condenser C_A as far as it will go in a clockwise direction, then turning it back one-fourth turn in a counter-clockwise direction. (This trimmer condenser can be adjusted with a screwdriver inserted through chassis hole **u**.)

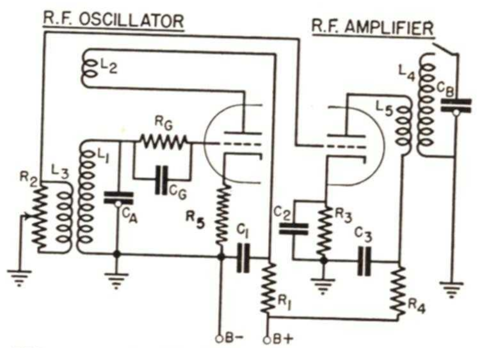

FIG. 21B. Spread-out version of the schematic diagram given in Fig. *21A*. Any circuit employing double-function tubes can be redrawn with the tube sections separated in this manner, if desired.

Prepare the N.R.I. Tester for r.f. voltage measurements by checking its calibration according to previous instructions, then place the black clip on the chassis, and place the red clip on the *yellow* terminal of the s.g. coil. Keep the test leads well apart from each other, and keep your hands and other parts of your body well away from these leads during measurement to avoid effects of body capacity.

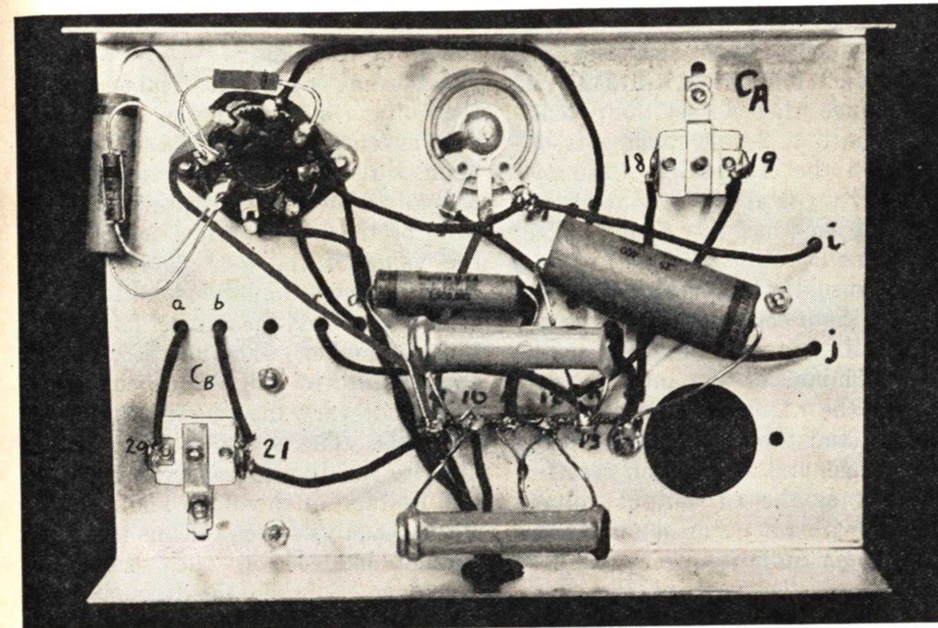

FIG. 22. The bottom of your r.f. chassis should appear like this after you have completed the assembly instructions given in Step 1 of Experiment 47.

Set the N.R.I. Tester to its *V* range, turn on the power pack and the N.R.I. Tester, wait half a minute, then rotate the potentiometer on the r.f. chassis with a screwdriver while watching the meter, to note how much control this potentiometer has upon the r.f. output voltage of your r.f. oscillator. Now set the potentiometer for an r.f. output of 2 volts by adjusting it until the meter reads 2 on the *AC* scale.

Without turning off the power pack or the N.R.I. Tester, move the red clip to the *green* terminal of the antenna coil (the coil marked *ANT*). Since there is only a 2-volt potential on the clip in both cases here, it is safe to touch it without turning off the power in this particular case. Read the meter on the *AC* scale, and record your result in Table *47* as the r.f. output voltage for an untuned load when using a *low* radio frequency.

Turn off the power pack, then reconnect to the *green* terminal of the antenna coil the lead which comes up through chassis hole *a*. Move the red clip to this *green* terminal, set the selector switch to $3 \times V$, and adjust trimmer condenser C_B for maximum meter deflection. If this adjustment gives a voltage higher than 13.5 volts, switch to the $30 \times V$ range and continue adjusting C_B for a maximum meter deflection. Record your result in Table *47* as the r.f. output voltage in volts with a tuned load when using a *LOW* radio frequency.

If your r.f. output voltage value with tuned load is considerably less than the N.R.I. value, there is a possibility that the grid circuit wiring of the r.f. oscillator is picking up the signal of a strong local broadcast station at the oscillator frequency, thereby giving modulation. The remedy involves adjusting C_A about ¼ turn in either direction, then retuning C_B for a maximum meter deflection, so as to make the oscillator frequency different from that of the broadcast station.

Turn off the power pack, then move the red clip to the *yellow* terminal of the s.g. coil. Turn on all apparatus, increase the frequency (to about 800 kc.) by rotating trimmer condenser C_A one turn more in the counter-clockwise direction (so that it is now 1¼

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turns counter-clockwise from its maximum-capacity position), set the selector switch of the N.R.I. Tester to the *V* range, then adjust the potentiometer until a 2-volt reading is obtained on the *AC* scale. (Trimmer condenser C_A is chiefly a control over frequency, and has only a small effect upon the r.f. output voltage.)

Now unsolder temporarily the lead going to the *green* terminal of the antenna coil. Move the red clip to the *green* terminal of the antenna coil, measure the r.f. voltage between this terminal and the chassis while using the *V* range, and record your result in Table *47* as the r.f. output voltage in volts with an untuned load when using a *high* radio frequency.

Reconnect the lead to the *green* terminal of the antenna coil, tune trimmer condenser C_B for maximum output voltage while using the *30* × *V* range, read the meter, and record your result as the r.f. voltage in volts with a tuned load when using a *high* radio frequency.

Discussion: When an r.f. voltage of 2 volts was fed into the input of the r.f. amplifier stage while the load was untuned and the low radio frequency (about 600 kc.) was used, only .5 volt r.f. was obtained across the secondary terminals. The reason we get less voltage out of this r.f. amplifier stage than we put into it is that the coupling between the primary and secondary coils of the output transformer (the antenna coil) is very weak. It would be necessary to increase the coupling considerably in order to obtain amplification from this stage without tuning.

When the frequency of the r.f. oscillator was increased, a slightly higher N.R.I. output voltage value was obtained for the untuned load condition when the input was 2 volts r.f., but still the output voltage was less than the input voltage.

According to mathematical analysis, the voltage induced in the secondary of the output transformer depends upon three factors: *frequency*, the *mutual inductance* between the two coils of the output transformer, and the value of the *a.c. plate current*. (The voltage is actually equal to these three factors and the number 6.28 multiplied together.) The mutual inductance is fixed in this experiment since we do not vary the coupling between the coils. The a.c. plate current is likewise fixed since we fixed the a.c. grid voltage at 2 volts. The mathematical analysis thus tells us that the voltage induced in the secondary should go up when the frequency is increased. The experimental results confirmed this, because the N.R.I. value of r.f. output voltage increased from .5 volt to 1.2 volts when the frequency was raised.

Q Factor. When you place a 370-mmfd. trimmer condenser across the secondary of the output transformer, you have a series resonant circuit, for the voltage induced in the secondary acts *in series* with the inductance of the secondary coil and the capacity of the trimmer condenser. In regular N.R.I. lesson texts, you learned that the voltage across the coil (or the condenser) at resonance in a series resonant circuit is equal to Q times the a.c. supply voltage for the circuit, with Q being the reactance of the coil divided by the circuit resistance.

In this experiment, the source voltage value for your series resonant circuit is the voltage which you measured across the secondary terminals for the untuned condition. The Q factor of your secondary circuit is therefore equal to the r.f. output voltage you measured with tuned load divided by the r.f. output voltage measured with

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untuned load. For the low-frequency case, the N.R.I. Q factor value will be 15 ÷ .5, which is 30. For the high-frequency case, the N.R.I. Q factor value will be 63 ÷ 1.2, or about 52. We thus see that the Q factor of the series resonant circuit is considerably higher at the higher frequency.

Now let us consider why Q factor should increase with frequency. First of all, increasing the frequency raises the reactance of the coil in our resonant circuit, and this naturally raises the Q factor of the circuit because this Q is basically equal to coil reactance divided by circuit resistance. At the same time, however, the coil and circuit losses increase when frequency is increased, preventing us from securing as high a Q factor as might otherwise be possible. In practical resonant circuits, we often encounter the condition where the increased losses more than offset the increase in coil reactance, with the result that circuit Q factor and gain actually drop when frequency is increased.

N.R.I. lesson texts also pointed out that loading a resonant circuit with resistance reduces the Q factor of the resonant circuit, thereby reducing the over-all gain of the stage. When high-gain r.f. amplifier stages are desired, loading of resonant circuit is definitely to be avoided. This loading need not necessarily be in the form of a shunt resistor; serious loading can result from improper inductive coupling between the secondary and another circuit, from moisture in the coil, from leakage resistance in circuit parts, from improper placement of the coil in a metal shield, or from coupling the coil to the grid-cathode of a tube which draws grid current (such as a grid leak-condenser detector or a diode detector.)

Instructions for Report Statement No. 47. The effect which loading has upon the Q factor of a resonant circuit and the over-all gain of the r.f. amplifier stage which includes the resonant circuit can very readily be demonstrated. The over-all gain of the r.f. amplifier stage is simply the measured value of r.f. output voltage divided by the r.f. input voltage. (We fixed the r.f. input voltage at 2 volts in every case.) Thus, when using the higher radio frequency and a tuned load, the N.R.I. value of over-all gain for the r.f. amplifier stage becomes 63 ÷ 2, or 31.5; this indicates that our 2-volt input r.f. signal is amplified 31.5 times.

For this report statement, you are asked to give the over-all gain of your own r.f. amplifier stage before and after the tuned output circuit is loaded

FREQUENCY	R.F. OUTPUT VOLTAGE IN VOLTS WITH UNTUNED LOAD		R.F. OUTPUT VOLTAGE IN VOLTS WITH TUNED LOAD	
	YOUR VALUE	N.R.I.	YOUR VALUE	N.R.I.
LOW		.5		15
HIGH		1.2		63

TABLE 47. Record your results here for Experiment 47.

with a 40,000-ohm resistor. You can secure these values in the following manner.

First obtain your value of over-all gain for the higher frequency and tuned load, by dividing the last value which you recorded in Table *47* (that for the r.f. voltage in volts with tuned load and high frequency) by the number 2 and record your result in Report Statement No. 47. Next, with your circuit connected exactly as it was for the last measurement in this experiment, place a 40,000-ohm resistor across your series resonant circuit by connecting it between terminals *20* and *21* of trimmer condenser C_B.

With this resistor connected, check the r.f. input voltage again (red clip on *yellow* terminal of s.g. coil, black clip on chassis, and selector switch at *V*) to make sure it is still 2 volts r.f., then measure the r.f. output voltage across the coil in the resonant circuit by moving the red clip to the *green* terminal of the antenna coil, setting the selector switch to *3* × *V*, and retuning trimmer condenser C_B for a maximum meter deflection. (If this gives a voltage higher than 13.5 volts, switch to the *30* × *V* range and readjust C_B for a maximum reading.)

Divide your measured value of r.f. output voltage by 2, and record your result in Report Statement No. 47 as the over-all gain of your r.f. amplifier stage when the tuned output circuit is loaded with a 40,000-ohm resistor.

EXPERIMENT 48

Purpose: **To show that the gain of an r.f. amplifier increases when the plate load impedance is increased.**

Preliminary Discussion: The r.f. amplifier stage used in the previous experiment employed transformer coupling to transfer energy from the plate circuit to the output circuit. Another widely used type of r.f. amplifier is that using either an r.f. choke coil or a parallel resonant circuit as the plate load, with a d.c. blocking condenser being used to couple the plate circuit to the input of the next stage. In this case, the input of the next stage must be shunted by a high resistance, so that the C bias voltage is applied to the stage without appreciably affecting the plate load impedance of the preceding stage.

The higher the impedance of the plate load being used in an r.f. amplifier stage, the higher will be the over-all gain of the stage. When a choke coil alone is being used as the plate load, its impedance will be a definite value which depends upon the inductance of the coil and the frequency of the signal. Any stray circuit capacity which acts in parallel with this plate load serves to reduce the plate load impedance and thus reduce the over-all stage gain. To secure maximum gain and at the same time counteract stray circuit capacities, the plate load inductance is often tuned to resonance by a shunt condenser so as to secure a parallel resonant circuit which has a high resistance at resonance. Stray circuit capacities then become a part of the tuning capacity, so that their presence is no longer objectionable.

There are two windings on the antenna coil form supplied you in Radio Kit 5RK-1, with one having more turns than the other. Since the winding having a higher number of turns will have the highest inductance and reactance, we can use each winding in turn as the plate load of our r.f. amplifier stage, and thus secure measurements of over-all gain for two different plate load inductance values. By feeding exactly 2 volts r.f. into the input of the r.f. amplifier and measuring the r.f. voltage developed across the load inductance, we can determine the over-all gain, just as was done in the previous experiment. The r.f. output voltage across the coil divided by the r.f. input voltage value of 2 will give the over-all stage gain.

After measuring the over-all gain when using low-reactance and high-reactance plate loads, we will tune the high-reactance load to resonance with a trimmer condenser and again determine the over-all gain. Since the resistance of the parallel resonant circuit at resonance is very much higher than the reactance of the coil alone, we should get the highest over-all gain with the tuned load.

Step 1. To measure the over-all gain of your r.f. amplifier stage while using a low-reactance coil as plate load, first unsolder the lead from the *green* terminal of the antenna coil, so

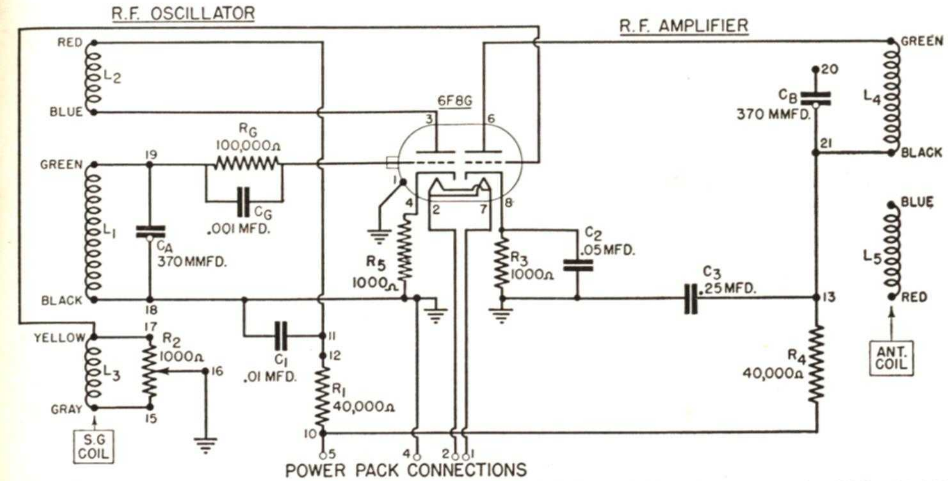

FIG. 23. This is the circuit which you use in Step 2 of Experiment 48. Resistor R_g should be 40,000 ohms instead of 100,000 ohms as shown.

that only the low-reactance primary winding will be effective in the plate circuit. Leave the rest of the circuit exactly as it was for the report statement measurement in the previous experiment. Trimmer condenser C_A should still be 1¼ turns off from its maximum clockwise setting.

Adjust the r.f. input voltage of your r.f. amplifier stage to 2 volts exactly as you did in the previous experiment (red clip on *yellow* s.g. coil terminal, black clip on chassis, selector switch at *V* and adjust the potentiometer to a meter reading of 2 volts on the *AC* scale).

Measure the r.f. voltage across the plate load by moving the red clip to the *blue* terminal of the antenna coil and leaving the selector switch set at *V*. Record your result in Table *48* as the r.f. voltage in volts across the plate load when the load is a low-reactance coil.

Divide your measured value of r.f. output voltage by the input voltage value of 2 to secure the over-all gain under this condition, and record your result in Table *48* as the over-all gain when the plate load is a low-reactance coil.

Step 2. To measure the over-all gain when using a high-reactance coil as the plate load, first make the following changes so as to secure the circuit arrangement shown in Fig. *23*.

Unsolder the lead from the *blue* terminal of the antenna coil, and push this lead entirely down through chassis hole *d*.

Unsolder the lead from the *red* terminal of the antenna coil, and push this lead entirely down through chassis hole *c*.

Unsolder the 40,000-ohm resistor from the terminals of trimmer condenser C_B.

Remove completely the lead which connects terminal *9* to trimmer condenser terminal *21*.

Unsolder the lead which is on trimmer condenser terminal *20*, and connect this lead to the free end of the lead which is on socket terminal *6*.

Connect to trimmer condenser terminal *21* the free end of the lead which is on terminal *13*.

Connect to the *green* terminal of the antenna coil the lead which comes out of hole ***a***.

Adjust the r.f. input voltage of your r.f. amplifier stage to 2 volts (red clip

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on *yellow* terminal of s.g. coil, black clip on chassis).

Move the red clip to the *green* terminal of the antenna coil, set the selector switch to the *3* × *V* position, turn on your apparatus, and measure the r.f. plate load voltage for this connection. Record your result in Table *48* as the r.f. voltage in volts across the plate load when this load is a high-reactance coil.

Divide your measured r.f. output voltage value by the input voltage value of 2, and record your result also in Table *48* as the over-all gain for this same condition.

Step 3. To measure the over-all gain of your r.f. amplifier stage when voltage value by the input value of 2, and record your result in Table *48* as the over-all gain for this condition.

Discussion: The N.R.I. value for this experiment shows that as the plate load reactance or impedance is increased, the r.f. voltage goes up, and the over-all gain of the r.f. amplifier stage likewise increases. Note that an over-all gain value of 28.5 was obtained for Step 3 in the N.R.I. laboratory; this is higher than the rated amplification factor of 20 for each section of this 6F8G tube, so some explanation is required. Of course, we can always blame a disagreement like this upon normal inaccuracies in our measurements, but a more likely

STEP	NATURE OF PLATE LOAD	R.F. VOLTAGE IN VOLTS ACROSS PLATE LOAD		OVER-ALL GAIN	
		YOUR VALUE	N.R.I. VALUE	YOUR VALUE	N.R.I. VALUE
1	LOW-REACTANCE COIL		2.0		1
2	HIGH-REACTANCE COIL		10.8		5.4
3	TUNED HIGH REACTANCE COIL		57		28.5

TABLE 48. Record your results here for Experiment 48.

using a tuned high-reactance coil as a plate load, first locate the common junction of the leads coming from chassis hole *a* and socket terminal *6*, and connect this junction to trimmer condenser terminal *20*. This connects C_B across L_4 in Fig. *23*.

With the red clip still on the *green* terminal of the antenna coil and the black clip on the chassis, set the selector switch to *30* × *V* and adjust trimmer condenser C_B for a maximum meter reading so as to secure resonance. Measure the voltage under this condition, and record your result in Table *48* as the r.f. voltage in volts across the plate load when this load is a tuned high-reactance coil.

Divide your measured r.f. output explanation is the fact that a certain amount of regeneration exists in this r.f. amplifier stage due to the unneutralized inter-electrode capacity between the plate and grid of the triode section. This regeneration raises the over-all gain of the stage.

Instructions for Report Statement No. 48. A by-pass condenser is commonly placed across a cathode resistor to prevent degeneration due to an a.c. voltage drop across this resistor. We should therefore be able to introduce degeneration into our r.f. amplifier circuit by removing the .05-mfd. by-pass condenser which is shunting the 1,000-ohm cathode resistor.

The purpose of this report statement is to prove that removal of the

by-pass condenser actually causes degeneration and a reduction in over-all gain.

Unsolder from terminal *8* the lead of the .05-mfd. condenser, while leaving the rest of your circuit exactly as it was for the last measurement in Step 3. The test clips should still be in position to measure the r.f. voltage between the *green* antenna coil terminal and the chassis. Use the *30* × *V* range. When you obtain the r.f. output voltage value for this condition, divide it by 2 to get the over-all gain

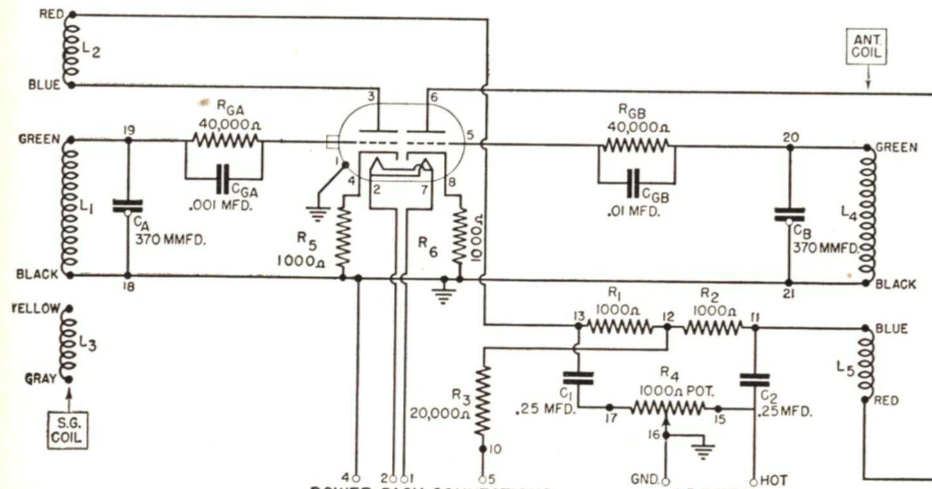

FIG. 24. Schematic circuit diagram of the beat frequency r.f. oscillator which you build as a part of Experiment 49.

of the stage, and record your result in Report Statement No. 48. After this, answer the last half of this report statement, in which you compare this measured value of over-all gain with that which you recorded for Step 3.

EXPERIMENT 49

***Purpose:* To build a beat frequency oscillator and adjust it to zero beat; to show that changing the value of the grid leak resistance, changing the value of the grid condenser, changing the amount of loading on the tank circuit, or the presence of body capacity near the tank circuit of one of the r.f. oscillator circuits will change the beat frequency.**

Preliminary Discussion: In this experiment, you will build two r.f. oscillators, feed their outputs into a common mixing circuit, and use the N.R.I. Tester as a detector to rectify the resulting signal and give an audio tone which you can hear in the headphone. Each r.f. oscillator will have its own trimmer condenser, so that by adjusting one trimmer condenser you can make the two r.f. oscillators very nearly equal in frequency. Then, by means of the potentiometer which is connected to give a vernier control over frequency, you can adjust the system more accurately until both r.f. oscillators are very nearly the same in frequency. You then have the condition known as *zero beat.*

The schematic circuit diagram for this beat frequency oscillator is given in Fig. *24* for reference purposes, but you will use the semi-pictorial bottom and top views of the chassis in Figs. *25* and *26* respectively as your guides for assembling this oscillator.

Step 1. To assemble a beat frequency r.f. oscillator, first disconnect

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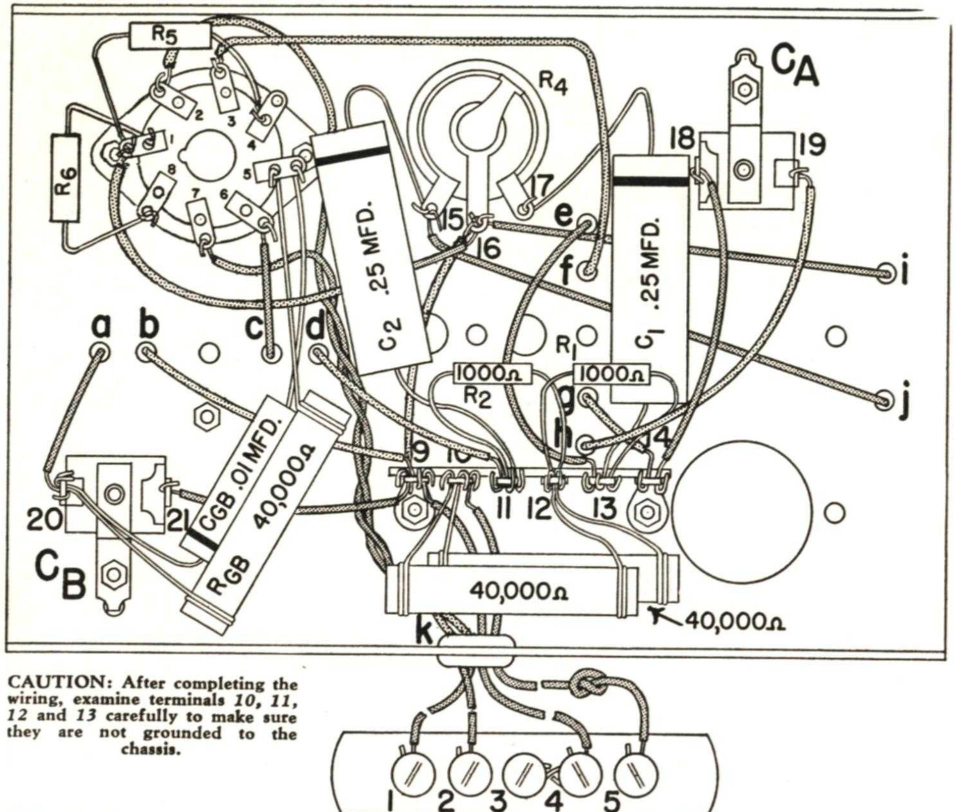

CAUTION: After completing the wiring, examine terminals *10, 11, 12* and *13* carefully to make sure they are not grounded to the chassis.

FIG. 25. Bottom view of the r.f. chassis, showing how parts and wiring should appear after you have built your beat frequency r.f. oscillator according to the instructions given in Step 1 of Experiment 49.

the four leads from the power pack output terminals. Remove the type 6F8G tube from its socket, as a safety precaution during assembly.

Unsolder from the various terminals above and below the r.f. chassis all of the fixed condensers, resistors and wires except the power supply leads on terminals *2, 7, 9, 10,* and the potentiometer ground lead.

When the chassis is placed upside down for this work, it is resting directly on the two coils. Excessive pressure on the chassis, or sliding the chassis around on a rough-surfaced workbench may damage the coils, so it is a good idea to place several thicknesses of cloth between the coils and the bench, or prop up the chassis on small boxes.

Remove surplus solder from the lugs on the tube sockets, the terminal strip and the other parts both above and below the chassis. Save all lengths of wire, and use these lengths as much as possible for the beat oscillator connections now to be described.

You should now have the signal generator coil and the antenna coil mounted above the chassis; below the chassis there should be the 6-lug terminal strip, trimmer condensers C_A and C_B, the 1,000-ohm potentiometer and the tube socket, with the four power supply wires still in position and going out of the chassis through the rubber grommet.

a. Connect two 1000-ohm resistors to socket terminals *1, 4,* and *8* just as shown in Fig. *25.* (Use Figs. *25* and

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26 as guides to determine the best time for soldering each joint.)

b. Connect socket terminal *1* to grounded center terminal *16* of the potentiometer.

c. Connect a 7-inch length of hook-up wire to potentiometer terminal *16,* bringing the other end of this wire through chassis hole *i,* and leave this wire projecting above the chassis to serve as the grounded r.f. output lead of this beat frequency oscillator.

d. Connect terminal *9* to trimmer condenser terminal *21.*

e. Connect terminal *9* to the *black* terminal of the antenna coil, running the wire through chassis hole *b.*

f. Connect trimmer condenser terminal *20* to the *green* terminal of the antenna coil, running the wire through chassis hole *a.*

g. Connect socket terminal *6* to the *red* terminal of the antenna coil, running the wire through chassis hole *c.*

h. Connect terminal *11* to the *blue* terminal of the antenna coil, running the wire through chassis hole *d.* This completes the four connections to the antenna coil.

i. Connect socket terminal *3* to the *blue* terminal of the s.g. coil, running the wire through chassis hole *f.*

j. Connect a .01-mfd. paper condenser between socket terminal *5* and trimmer condenser terminal *20.*

k. Connect a 40,000-ohm resistor between socket terminal *5* and trimmer condenser terminal *20,* so that this resistor is in parallel with the .01-mfd. condenser.

l. Connect terminal *13* to the *red* terminal of the s.g. coil, running the wire through chassis hole *e.*

m. Connect terminal *14* to the *black* terminal of the s.g. coil, running the wire through chassis hole *g.*

n. Connect terminal *14* to trimmer condenser terminal *18.*

o. Connect trimmer condenser terminal *19* to the *green* terminal of the

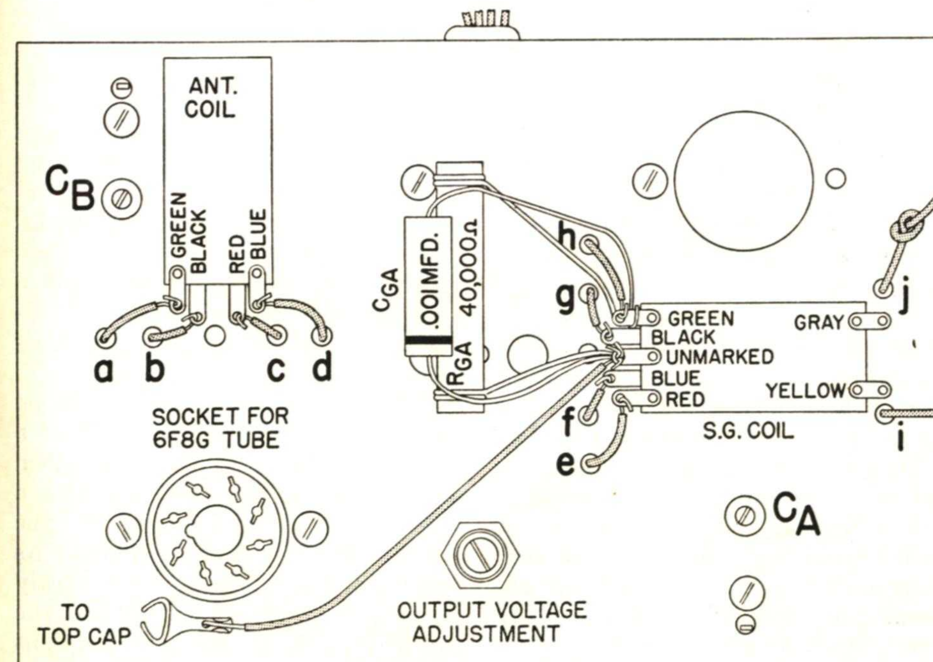

FIG. 26. Top view of the r.f. chassis, showing how parts and wiring should appear after construction of the beat frequency r.f. oscillator in Experiment 49.

s.g. coil, running the wire through chassis hole *h*.

p. Connect a .25-mfd. paper condenser between terminal *13* and potentiometer terminal *17*. Outside foil connections for paper condensers are unimportant in this beat oscillator and can be disregarded.

q. Connect a .25-mfd. paper condenser between terminal *11* and potentiometer terminal *15*.

r. Connect an 8-inch length of hook-up wire to potentiometer terminal *15*. Bring the wire up through chassis hole *j*, and leave this wire projecting above the chassis to serve as the hot output lead of this beat frequency oscillator. Tie a simple knot about 1½ inches from the free end of this lead for identifying purposes.

s. Connect two 40,000-ohm resistors in parallel between terminals *10* and *12*. Adjust the positions of the resistors so that they are within the limits of the chassis but do not touch either the chassis or other terminals.

t. Connect a 1,000-ohm resistor between terminals *11* and *12*.

u. Connect a 1,000-ohm resistor between terminals *12* and *13*.

v. Connect the top cap lead to the *unmarked* lug on the s.g. coil, insert the type 6F8G tube in its socket, and place the grid clip on the top cap of this tube.

w. Connect a .001-mfd. condenser between the *green* terminal and the *unmarked* terminal of the s.g. coil.

x. Connect a 40,000-ohm resistor between the *green* and *unmarked* terminals of the s.g. coil, so that this resistor is in parallel with the .001-mfd. condenser.

This completes the wiring of your beat frequency oscillator. Before proceeding any further, check your work carefully against the semi-pictorial diagrams in Figs. *25* and *26* to be sure you have made every connection correctly. By now, you should be able to make this check against a diagram without detailed instructions.

Step 2. To adjust your beat frequency oscillator for zero beat, first provide power for your oscillator by connecting the two twisted power supply wires to power pack output terminals *1* and *2*, connecting to output terminal *5* the single wire which comes through the grommet and has a knot, and connecting the remaining single grommet wire to output terminal *4*.

Adjust the potentiometer on the r.f. chassis to its mid-position, so that the movable arm underneath the chassis is in line with the center terminal lug of the potentiometer.

Set each trimmer condenser in turn to maximum capacity by rotating in a clockwise direction with a screwdriver inserted through the adjusting hole on top of the chassis, then turn each adjusting screw back *one complete turn* in a counter-clockwise direction.

To listen to the audio beat note produced by your beat frequency oscillator, insert the headphone cord tips in the *PHONE* jacks of the tester, set the selector switch to the *V* range, insert the test probes in the V_{AC} jacks, place the black clip on the output lead which comes through chassis hole *i*, and place the red clip on the hot output lead which comes through chassis hole *j*.

Turn on the power pack, turn on the N.R.I. Tester, wait about half a minute for tubes to warm up, then adjust trimmer condenser C_A with a screwdriver while listening to the phone, until you hear a squeal. As you rotate the adjusting screw slowly through the position which gives the squeal, you will note two positions close together at which the high-frequency squeal is heard, with a mid-

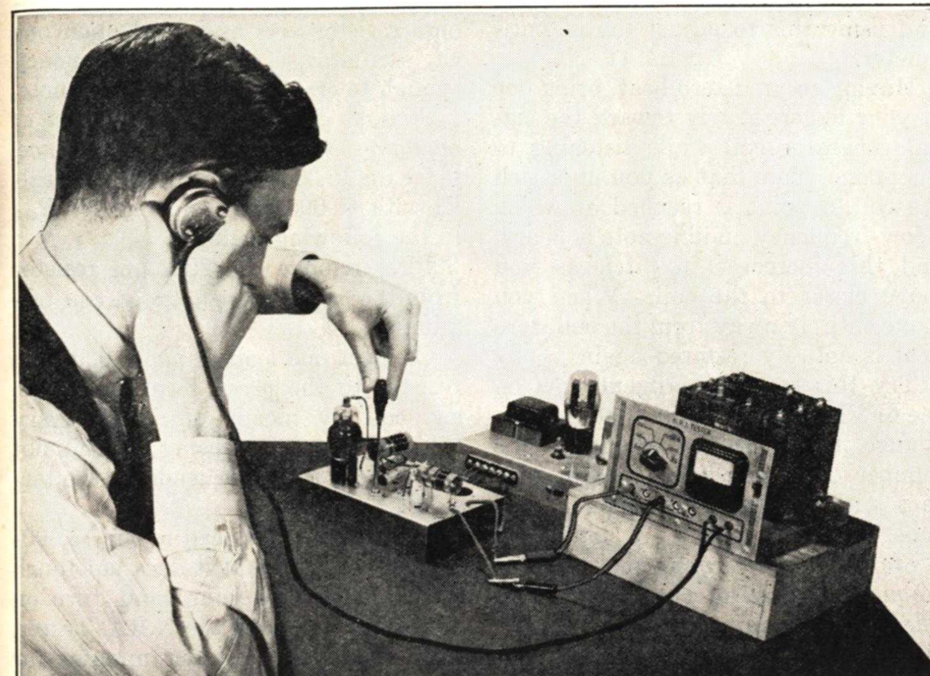

FIG. 27. If you arrange your beat frequency r.f. oscillator, power pack and N.R.I. Tester on your workbench in the manner shown here, there will be little chance for your hands and tester leads to affect the frequency of either of the r.f. oscillator circuits.

position between these points where the squeal is very low or there is no sound at all; this is the *zero beat* position. You may have some difficulty in adjusting exactly to zero beat, so set the trimmer condenser at the lowest possible pitch in between the squeals, then adjust the 1,000-ohm potentiometer on the r.f. chassis until you obtain zero beat. At this position of the potentiometer, no sound will be heard in the headphone, but a slight adjustment of the potentiometer in either direction will result in an audible sound. The potentiometer permits a more accurate adjustment to zero beat than is possible with the trimmer condenser.

Whenever adjusting your beat frequency oscillator for zero beat, keep your hand as far away from the type 6F8G tube as possible, and keep the test leads and the phone cord also away from this tube. If you arrange your apparatus in the manner shown in Fig. *27*, you should have no difficulty in keeping these parts away from the highly critical 6F8G tube.

Step 3. To determine the effect of body capacity upon your beat frequency oscillator, first adjust the potentiometer so that zero beat will be obtained when your hand and the adjusting screwdriver are well away from the oscillator chassis. This may take considerable patience; you will have to find the potentiometer position which, even though it causes a squeal while your hand and the screwdriver are in position, gives zero beat when the screwdriver and hand are removed. If you wish, you can make an anti-capacity screwdriver from a piece of wood about 12 inches long and ¼ inch in diameter (such as wood dowel rod) by carving one end of the rod to

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the shape of your screwdriver blade and using this to adjust the potentiometer.

Having secured zero beat, bring one of your fingers slowly toward the signal generator coil while listening to the phone. Note that as you approach the coil, a point is reached at which a low-frequency audible note is heard, and this increases in pitch as you move closer to the coil. When you move entirely away from the coil, zero beat is entirely restored again.

Try this same experiment now on the 6F8G tube. Observe that you can change the pitch by changing the number of fingers which are in contact with the glass envelope of the tube.

Step 4. To determine how the beat frequency output of your oscillator is affected by loading of the tank circuit, turn off all apparatus and connect one lead of a 220-ohm resistor to the *gray* terminal of the s.g. coil by means of a temporary soldered hook joint. Adjust the other resistor lead so that it will make contact with the *yellow* s.g. coil terminal when the lead is pressed with a stick of wood (such as a ruler).

With the other resistor lead still unconnected, remove your hands from the chassis, turn on the power pack and the N.R.I. Tester, wait three or four minutes for all parts to assume normal operating conditions, then listen for zero beat again. Readjust the potentiometer if necessary in order to obtain zero beat.

Without turning off your apparatus, connect the 220-ohm resistor across winding L_3 of the s.g. coil by pressing the free lead of this resistor against the *yellow* s.g. coil terminal with a wooden rod, keeping your hand well away from the 6F8G tube; listen to the phone while doing this. You should now hear an audible tone having a fairly high pitch for the 220-ohm resistor acts as a load upon one r.f. oscillator, changing its frequency enough to create an audible beat note.

Step 5. To determine the effect of changing the grid leak resistance, place an 18,000-ohm resistor in parallel with 40,000-ohm grid resistor R_{GA} in the following manner:

First remove the 220-ohm resistor from the *gray* and *yellow* s.g. coil terminals.

Connect one lead of an 18,000-ohm resistor to the *green* terminal of the s.g. coil by means of a temporary soldered lap joint, being careful not to unsolder the other leads on the terminal.

Adjust the other lead of the 18,000-ohm resistor so that it does not touch anything, remove your hand, turn on the power pack and the N.R.I. Tester, wait about three or four minutes for operating conditions to be reached, then listen to the beat note and readjust the potentiometer for zero beat if necessary.

Without turning off any apparatus and while still listening to the phone, press the free lead of the 18,000-ohm resistor against the *unmarked* terminal of the s.g. coil with a wooden rod. A distinctly audible note having a fairly high pitch should now be heard, proving that lowering of the grid resistor value affects the frequency of one r.f. oscillator.

Step 6. To determine how the beat frequency output of your oscillator is affected by an increase in the capacity of the condenser across the grid leak, first turn off all apparatus and disconnect the 18,000-ohm resistor from the s.g. coil terminal. Connect one lead of a .05-mfd. condenser to the *green* s.g coil terminal by means of a temporary soldered lap joint, adjust the other lead so that it is near but not touching the *unmarked* s.g. coil terminal,

then turn on your apparatus, wait about four minutes, then readjust the potentiometer if necessary to secure exactly zero beat again. Now press the free lead of the .05-mfd. condenser on the *unmarked* terminal with your wooden rod. You should be able to hear in the phone an audible beat note having a fairly high frequency. Placing this condenser in parallel with the .001-mfd. condenser gave a combined capacity of .051-mfd., since the capacity of condensers in parallel add. Turn off your apparatus and remove the .05-mfd. condenser.

Discussion: When two r.f. signals having slightly different frequencies are combined, the amplitude of the resulting signal varies in a manner corresponding to the difference between the frequencies of the two original r.f. signals. If this resulting signal is passed through a rectifier circuit such as that used in the N.R.I. Tester, a signal having this difference frequency will be obtained. If this rectified signal is fed into a sound-reproducing unit such as your headphone and if the difference frequency is in the audio spectrum, an audible tone will be heard. When both r.f. signals have exactly the same frequency, the difference frequency is zero and consequently there is no audible tone. As was already pointed out, this condition is known as *zero beat.*

Theoretically, it should be possible to obtain an extremely low-frequency audio signal by making the two r.f. signals only slightly different in frequency, but you probably observed that the audio signal disappears suddenly as you lower the beat frequency by bringing the r.f. oscillators closer together in frequency. When the r.f. signal from one oscillator enters the other oscillator, and the difference between the frequencies is quite small, an inter-action occurs which causes the oscillators to synchronize or lock in step with each other, so that both oscillate at the same frequency. In other words, as the difference frequency is lowered slowly, a low audio frequency is reached at which there is a sudden transition to zero beat.

This automatic synchronization between oscillators occurs due to the coupling existing between the parts and leads of the two r.f. oscillator circuits (the plate-to-plate inter-electrode capacity between the two triode sections of the tube, and the common coupling provided by the two .25-mfd. condensers and the 1,000-ohm potentiometer in the mixing circuit). At low frequency difference values, only a small amount of mutual coupling is required to cause this locking action.

In a practical beat frequency oscillator circuit, separate oscillator tubes are employed. Each r.f. circuit, including its tube, is placed in its own shielded compartment to reduce coupling to a minimum. Furthermore, the outputs of the individual oscillators are very weakly coupled to the common output circuit, so as to minimize inter-action through this channel.

Oscillator stability is a highly important radio problem, particularly in selective superheterodyne receivers. In these receivers, any drifting in the frequency of the oscillator destroys the accuracy of the receiver alignment, destroys the calibration of the receiver tuning dial, causes distortion, and even causes a reduction in signal strength in certain cases where highly selective i.f. amplifier stages are being used.

We normally associate a change in oscillator frequency with a change in either the inductance or capacity of the oscillator tank circuit. You demonstrated this fact in this experiment

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by adding your body capacity to the tank circuit capacity when you brought a finger near the signal generator coil. This changed the frequency of the r.f. oscillator using this coil, with the result that you heard a beat note.

The frequency of an r.f. oscillator can change even though the inductance or capacity values in the tank circuit are not altered directly. For example, any circuit change which affects the over-all gain of the oscillator stage will affect the input capacity of the oscillator stage and thereby change the resonant frequency, because this input capacity is in parallel with the tank circuit capacity. A more detailed analysis will show why this is true.

As was previously explained, the input capacity of a tube is the sum of four individual capacity values: *1. The grid-cathode inter-electrode capacity; 2. The grid-plate inter-electrode capacity; 3. A value equal to the grid-plate capacity multiplied by the true gain of the tube; 4. Stray grid circuit capacities,* such as that between the grid and cathode leads and terminals. Since the gain of the circuit affects the third of these individual capacities, it also affects the input capacity.

The input capacity of an oscillator tube can be considered as acting in parallel with the tank circuit capacity simply because the grid leak and grid condenser act essentially as a short-circuit path for r.f. current (reference to the schematic circuit diagram in Fig. *24* will help you to understand this). Any capacity in parallel with the tank capacity naturally increases the total tank circuit capacity, thereby lowering the resonant frequency.

Having shown how any change in the gain of an oscillator stage will affect the frequency of the oscillator, let us now consider how the application of a load to the tank circuit affects the gain. (Placing a 220-ohm load resistor between the *yellow* and *gray* terminals of the s.g. coil in Step 4 loads the tank circuit indirectly, giving exactly the same effect as if you placed a resistor across the tank circuit).

You will recall that when you placed a 40,000-ohm resistor across a tank circuit in a previous experiment, the measured value of C bias voltage changed. The C bias voltage therefore changed in Step 4 also, moving the operating point of the tube to a different region on the characteristic curve, and this changed the true amplification of the circuit (the true amplification varies with the slope of the characteristic curve).

Changing the value of the C bias resistor from 40,000 ohms in Step 5 affects the C bias voltage directly, for the rectified grid current flows through a lower resistance value and thus develops a lower voltage across the grid resistor for C bias purposes. As we just found out, a change in C bias changes the operating point and thus changes the true amplification of the circuit.

When you changed the grid condenser value from .001 mfd. to a value slightly larger than .05 mfd. in Step 6, you again changed the C bias voltage; the higher the capacity of this grid condenser, the closer to the peak value of the rectified grid current will be the voltage developed across the grid resistor.

Thus, every change which you made in this experiment affected the *C bias voltage,* the *amplification* of the oscillator circuit, the *input capacity,* the total effective *tank circuit capacity,* the *resonant frequency* of the tank circuit, the *output frequency* of the

r.f. oscillator stage, and consequently *the frequency of the audio beat note.*

Temperature is another factor which can affect the frequency of an individual r.f. oscillator stage and thereby affect the frequency of the audio beat note produced by a beat frequency oscillator. Changes in temperature affect the physical dimensions of all parts in an oscillator circuit, with the changes in the tank circuit coil and condenser being the most important. In practical beat frequency oscillator circuits, identical parts are used in both r.f. oscillator circuits so that changes in temperature will affect each circuit identically, and even then the oscillators are allowed to operate for some time before an attempt is made to adjust for zero beat.

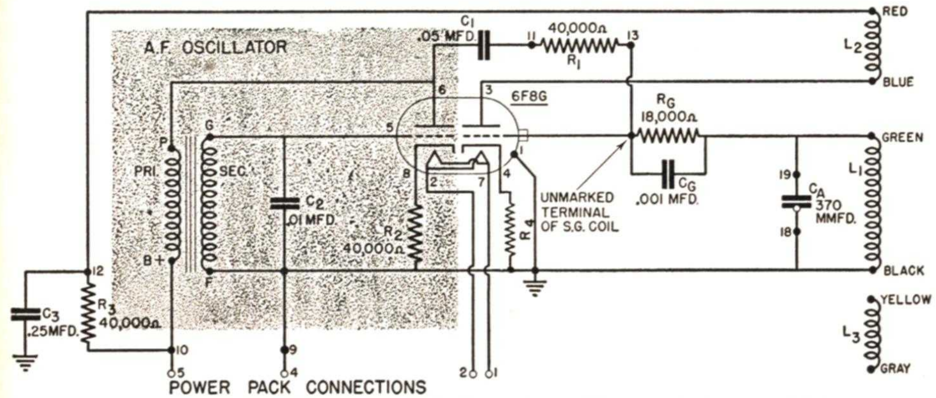

FIG. 28. Schematic circuit diagram for the grid-modulated r.f. oscillator which you build in Step 1 of Experiment 50.

Instructions for Report Statement No. 49. So far, we have only assumed that both r.f. oscillator circuits were operating and producing the audio beat note. For this report statement, you will prove this to be true by stopping one of the r.f. oscillators; if this stops the audio beat note, you will know that both r.f. oscillators must be working in order to produce the beat note.

With your beat frequency oscillator connected just as it was after completing Step 6, turn on your apparatus and adjust for an audible beat note (not for zero beat). It is highly important that a ground wire be connected to **output terminal *3* of the** power pack during this test. This ground wire should always be connected to this terminal. Now remove the clip from the top cap of the type 6F8G tube so as to stop the r.f. oscillator circuit which employs this top cap as its grid terminal, note the effect upon the beat note, and answer Report Statement No. 49. Be sure to turn off all apparatus when you have completed this test.

EXPERIMENT 50

***Purpose:* To build an r.f. oscillator which is grid-modulated by an a.f. oscillator; to build an r.f. oscillator which is cathode-modulated by an a.f. oscillator; to build an r.f. oscillator which is plate-modulated by an a.f. oscillator.**

Step 1. To build an r.f. oscillator which is grid-modulated by an a.f. oscillator, as shown in the schematic circuit diagram in Fig. 28, carry out the following steps while using the semi-pictorial diagrams in Figs. *29* and *30* as your guides.

a. Remove the 6F8G tube from its socket, then remove from your oscillator chassis all leads except the four power leads on terminals *2, 7, 9, 10,*

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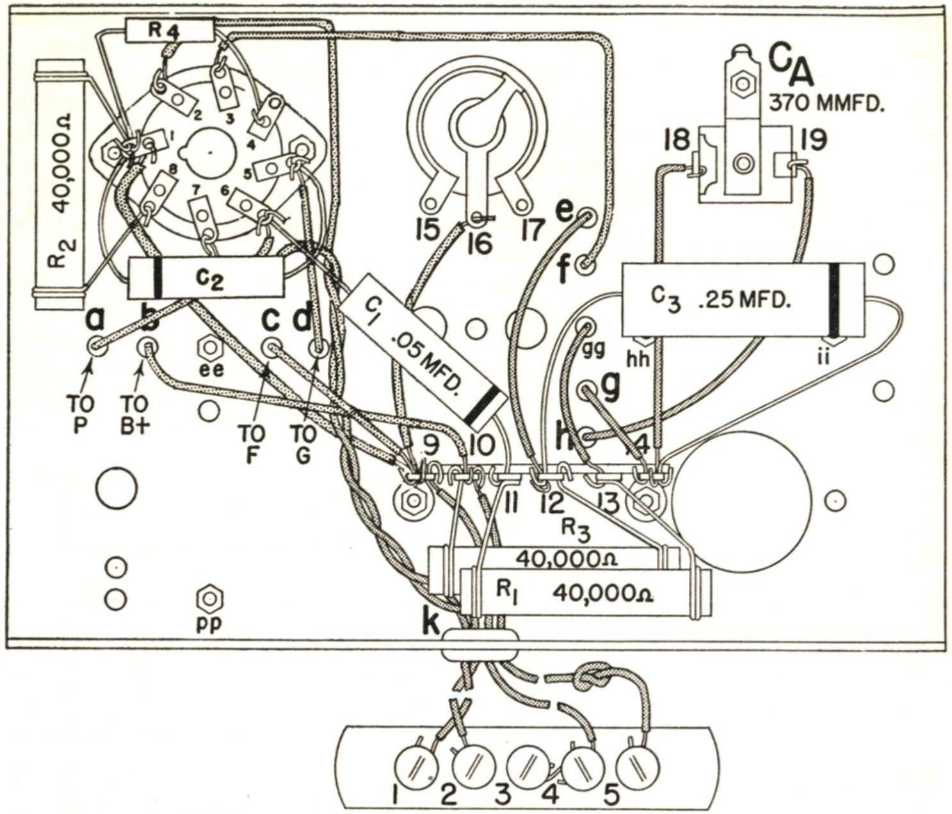

FIG. 29. Bottom view of the r.f. chassis, showing how it should appear after you have assembled the grid-modulated r.f. oscillator according to the instructions given in Step 1 of Experiment 50.

and on potentiometer terminal *16*. Remove all fixed resistors and paper condensers. Remove the antenna coil and its associated trimmer condenser C_B, but leave the remaining parts on the chassis. Remove surplus solder from the lugs of the parts still on the chassis.

b. Mount the audio transformer on top of the chassis in holes *ee* and *pp*, in such a position that the transformer lugs will be above chassis holes *a*, *b*, *c* and *d*.

c. Connect a 1000-ohm resistor to socket terminals *1* and *4*.

d. Connect a 40,000-ohm resistor between socket terminals *1* and *8*.

e. Connect socket terminal *1* to terminal *9*.

f. Connect a .01-mfd. condenser between socket terminals *1* and *5*.

g. Connect socket terminal *5* to terminal *G* of the audio transformer, running the wire through chassis hole *d*.

h. Connect a .05-mfd. condenser between socket terminal *6* and terminal *11*.

i. Connect socket terminal *6* to terminal *P* of the audio transformer, running the wire through chassis hole *a*.

j. Connect socket terminal *3* to the *blue* terminal of the s.g. coil, running the wire through chassis hole *f*.

k. Connect terminal *10* to the *B+* terminal of the audio transformer, running the wire through chassis hole *b*.

l. Connect terminal *9* to the *F* terminal of the audio transformer, running the wire through chassis hole *c*.

m. Connect terminal *14* to terminal *18* of trimmer condenser C_A.

n. Connect trimmer condenser terminal *19* to the *green* terminal of the s.g. coil, running the wire through chassis hole *h*.

o. Connect terminal 12 to the *red* terminal of the s.g. coil, running the wire through chassis hole *e*.

p. Connect terminal *13* to the *unmarked* terminal of the s.g. coil, running the wire through chassis hole *gg* (this is the unmarked hole located between marked holes *f* and *g*).

q. Connect terminal *14* to the *black* terminal of the s.g. coil, running the wire through chassis hole *g*.

r. Connect a .25-mfd. condenser between terminals *12* and *14*.

s. Connect a 40,000-ohm resistor between terminals *10* and *12*.

t. Connect a 40,000-ohm resistor between terminals *11* and *13*.

u. Connect the grid clip lead to the *unmarked* terminal of the s.g. coil.

v. Connect an 18,000-ohm resistor between the *green* and *unmarked* terminals of the s.g. coil.

w. Connect a .001-mfd. condenser between the *green* and *unmarked* terminals of the s.g. coil, in parallel with the 18,000-ohm resistor.

x. Connect your completed oscillator to the power pack by placing the two twisted leads on output terminals *1* and *2*, the knotted lead on terminal *5*, and the remaining lead on output terminal *4*.

y. Insert the type 6F8G tube in its socket, and place the grid clip on the top cap of this tube.

Testing Instructions. To listen to the audio signal at the output of your modulated r.f. oscillator, first prepare your N.R.I. Tester for audio listening tests as previously instructed (probes in V_{AC} jacks, selector switch at *V* and

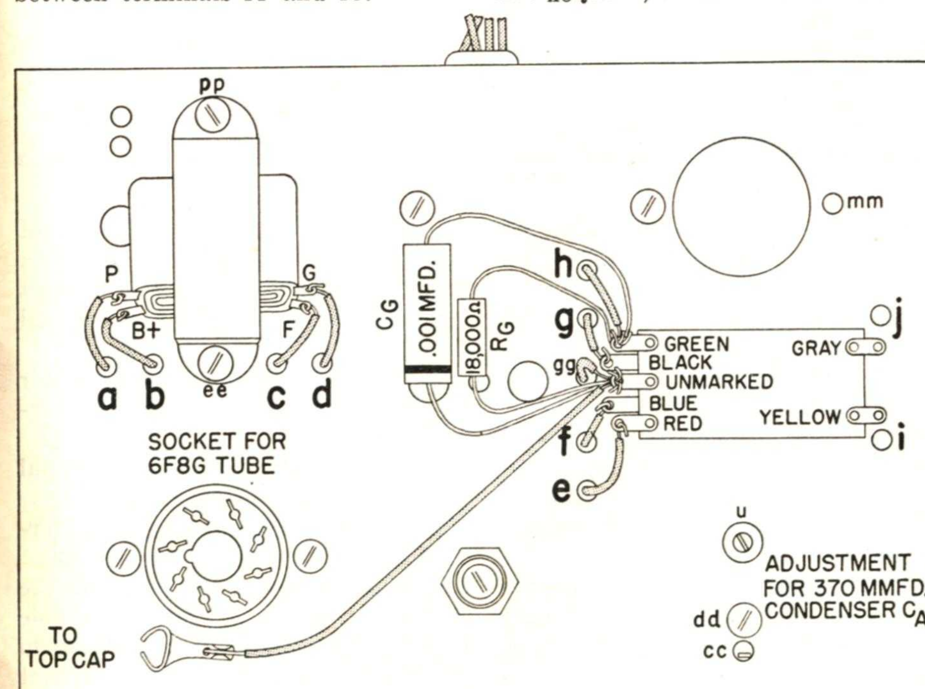

FIG. 30. Top view of the completed grid-modulated r.f. oscillator.

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phone tips in *PHONE* jacks). Place one test clip on the *gray* terminal of the s.g. coil, and place the other test clip on the *yellow* terminal; polarity of connections does not matter.

Turn on the power pack, turn on the N.R.I. Tester, and listen to the phone after the tubes have warmed up. You should hear a clear audio tone if you have followed these instructions correctly. Turn off all apparatus now.

Step 2. To build an r.f. oscillator which is cathode-modulated by an a.f. oscillator, make the following changes in your grid-modulated oscillator so condenser C_2 remain on terminal *1* as this is the ground return point for the audio oscillator as well as for the r.f. oscillator.

c. Remove the 18,000-ohm resistor from the *green* and *unmarked* terminals of the s.g. coil, and connect in its place a 100,000-ohm resistor. Leave the .001-mfd. condenser connected to the *green* and *unmarked* terminals so that it is now in parallel with the 100,000-ohm resistor.

d. Disconnect from the *unmarked* terminal of the s.g. coil the lead which comes up through chassis hole *gg,* push this lead back down through the

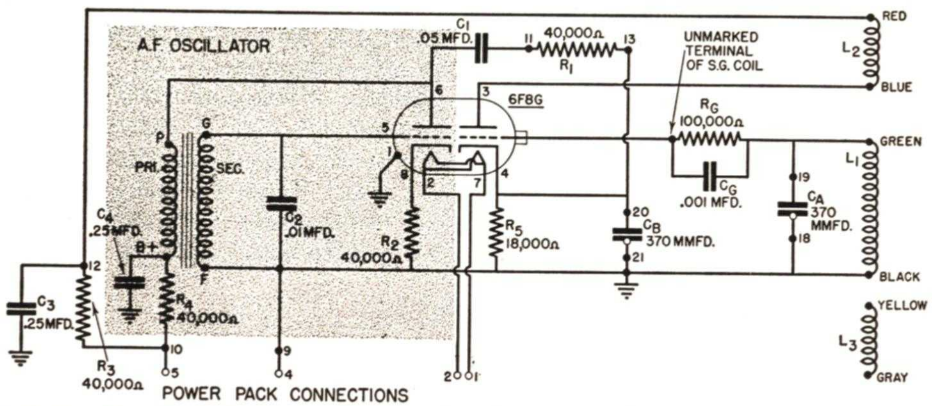

FIG. 31. Schematic circuit diagram of the cathode-modulated r.f. oscillator which you build for Step 2 of Experiment 50.

as to secure the cathode-modulated oscillator circuit shown in schematic form in Fig. *31*.

a. Mount your remaining 370-mmfd. trimmer condenser underneath the chassis in mounting hole *nn,* then adjust this condenser (identified as C_B) for maximum capacity by rotating the adjusting screw as far as it will go in a clockwise direction with a screwdriver inserted through chassis hole *x*.

b. Remove the 1000-ohm resistor from terminals *1* and *4* of the 6F8G tube socket. Make sure, however, that the ground lead (from terminal *9*), cathode resistor R_2, and by-pass chassis hole, add a 2-inch length of hook-up wire to it by means of a temporary soldered joint, and connect this extended lead to socket terminal *4*.

e. Connect the 18,000-ohm resistor between socket terminal *4* and terminal *9*.

f. Connect terminal *9* to terminal *21* of trimmer condenser C_B.

g. Connect socket terminal *4* to terminal *20* of trimmer condenser C_B.

h. Remove from terminal *10* the lead which goes through chassis hole *b,* connect one lead of a 40,000-ohm resistor to terminal *10,* and connect the other lead of this resistor to the

wire which you just disconnected from terminal *10*.

i. Connect a .25-mfd. condenser between trimmer condenser terminal *21* and the last joint made in the previous step (this is equivalent to connecting the condenser between terminal *21* and the *B+* terminal of the audio transformer).

j. Arrange all parts now so that the leads do not touch each other when the parts are within the limits of the chassis, so as to permit turning the chassis over.

Testing Instructions. Adjust trim- the power pack, remove the tube, then unsolder all wires and leads above and below the chassis except the power supply leads on terminals *2, 7, 9, 10,* and potentiometer terminal *16*.

b. Remove trimmer condenser C_B. The only parts which you should now have left on the chassis are the audio transformer and signal generator coil above the chassis, and the tube socket, 1,000-ohm potentiometer, 370-mmfd. trimmer condenser C_A, the six-lug terminal strip, and the four power pack leads under the chassis.

c. Connect terminal *9* to the *F* ter-

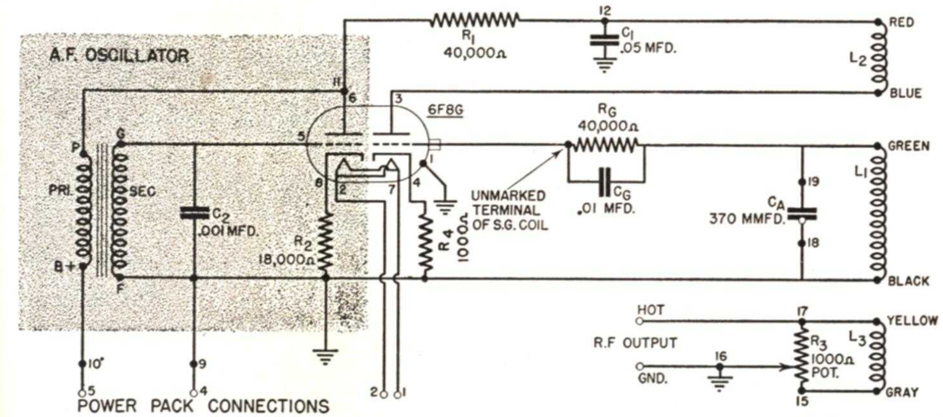

FIG. 32. Schematic circuit diagram of the plate-modulated r.f. oscillator which you build for Step 3 of Experiment 50. You are to leave this oscillator set up for use in connection with experiments in the next manual.

mer condenser C_A to one turn less than maximum capacity by rotating the adjusting screw as far as it will go in a clockwise direction, then turning back counter-clockwise one full turn. Listen to the output signal with the N.R.I. Tester by placing the test clips on the *gray* and *yellow* terminals of the s.g. coil. Turn off all apparatus.

Step 3. To build an r.f. oscillator which is plate-modulated by an a.f. oscillator, according to the schematic circuit diagram in Fig. *32*, carry out the following steps while using the semi-pictorial diagram in Fig. *33* and the top view in Fig. *34* as your guides.

a. Disconnect the experiment from minal of the audio transformer, running the wire through chassis hole *c*.

d. Connect terminal *9* to socket terminal *1*.

e. Connect a 1000-ohm resistor between socket terminals *4* and *1*.

f. Connect an 18,000-ohm resistor between socket terminals *1* and *8*.

g. Connect terminal *5* to the *G* terminal of the audio transformer, running the wire through chassis hole *d*.

h. Connect a .001-mfd. condenser between socket terminals *1* and *5*.

i. Connect terminal *6* to the *P* terminal of the audio transformer, running the wire through chassis hole *a*.

j. Connect terminal *10* to the *B+*

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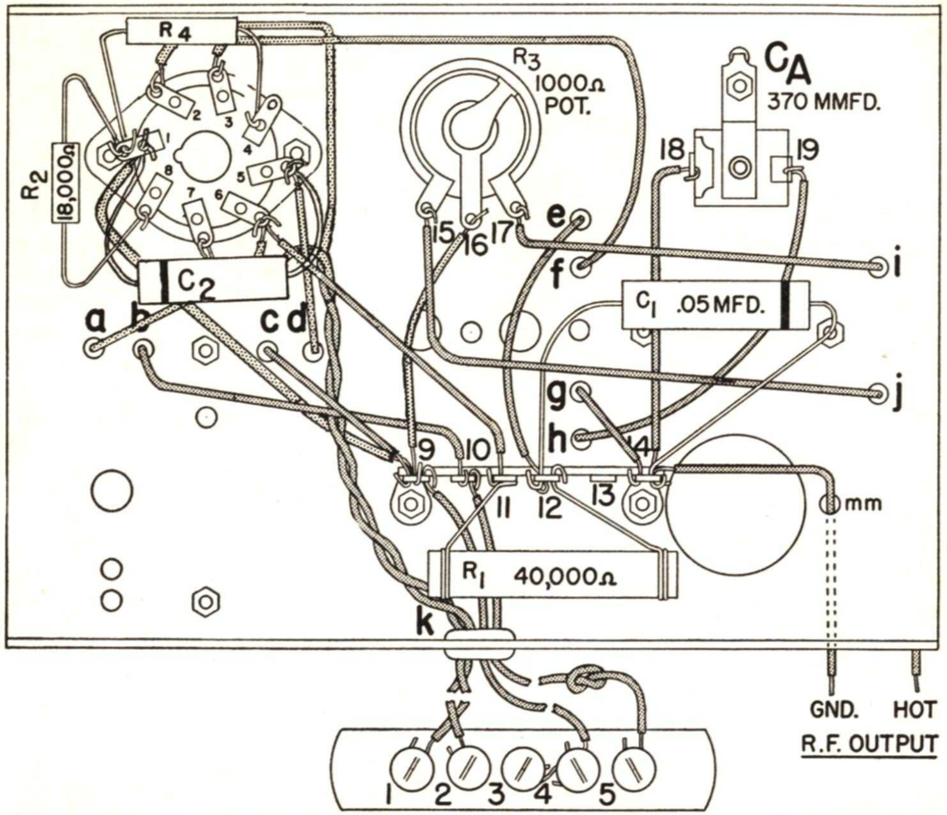

FIG. 33. Bottom view of the r.f. chassis, showing how the completed plate-modulated r.f. oscillator should appear after assembly has been completed. Connections on top of the chassis for this plate-modulated oscillator are the same as for the grid-modulated oscillator except for the r.f. output leads, and consequently the top view in Fig. *30* can be used as a guide for building this plate-modulated r.f. oscillator, if desired.

terminal of the audio transformer, running the wire through chassis hole *b*.

k. Connect terminal *19* to the *green* terminal of the s.g. coil, running the wire through hole *h*.

l. Connect terminal *14* to terminal *18* of trimmer condenser C_A.

m. Connect terminal *14* to the *black* terminal of the s.g. coil, running the wire through hole *g*.

n. Connect terminal *3* to the *blue* terminal of the s.g. coil, running the wire through hole *f*.

o. Connect terminal *12* to the *red* terminal of the s.g. coil, running the wire through hole *e*.

p. Connect socket terminal *6* to terminal *11*.

q. Connect a 40,000-ohm resistor between terminals *11* and *12*.

r. Connect a .05-mfd. condenser between terminals *12* and *14*.

s. Connect terminal *15* to the *gray* terminal of the s.g. coil, running the wire through hole *j*.

t. Connect terminal *17* to the *yellow* terminal of the s.g. coil, running the wire through hole *i*.

u. Connect an 8-inch length of hook-up wire to terminal *14*, bring this wire up through chassis hole *mm*, and leave the wire projecting above the chassis to serve as the grounded r.f. output terminal (terminal lug *14* is grounded to the chassis through its mounting screw).

v. Connect a 6-inch length of hook-

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up wire to the *yellow* terminal of the s.g. coil, to serve as the hot r.f. output lead. Tie a knot in this lead.

w. Connect a 40,000-ohm resistor between the *green* and *unmarked* terminals of the s.g. coil.

x. Connect a .01-mfd. condenser between the *green* and *unmarked* terminals of the s.g. coil, so that it is in parallel with the 40,000-ohm resistor.

y. Connect the grid clip lead to the *unmarked* terminal of the s.g. coil. Insert the 6F8G tube in its socket, then place the grid clip on the top cap of the tube.

z. Connect your completed plate-modulated r.f. oscillator to the power pack output terminals (twisted leads on output terminals *1* and *2*, knotted lead on terminal *5* and the other lead on terminal *4*).

Testing Instructions. Prepare your N.R.I. Tester for use as an aural indicator (for listening to audio signals), and connect its clips to the r.f. output leads of your plate-modulated r.f. oscillator as shown in Fig. *35* (polarity does not matter). Turn on the power pack and the N.R.I. Tester, and listen for the modulation tone in the headphone after the apparatus has warmed up.

Adjust the position of the 1,000-ohm potentiometer over its entire range, and note the effect of the potentiometer setting upon the level (signal strength) of the audio modulation.

Adjust trimmer condenser C_A and note that changing the frequency of the r.f. signal in this manner has some effect upon the level of the audio modulation, but that the modulation exists for all settings.

Discussion: In this experiment, we use essentially the same type of r.f. oscillator circuit and the same type of a.f. oscillator circuit in all three steps, and introduce the a.f. signal into the r.f. oscillator circuit at three

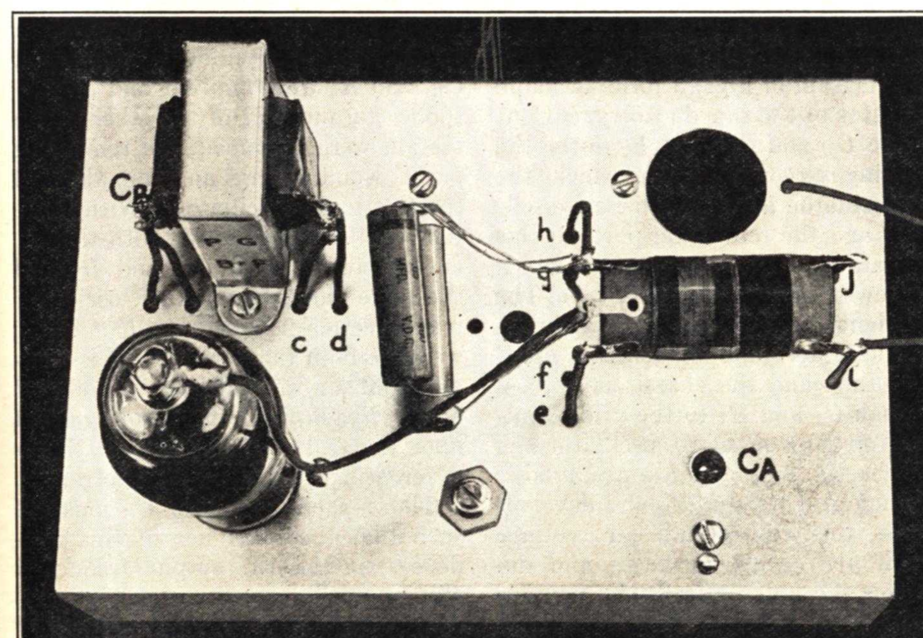

FIG. 34. Top view of completed plate-modulated r.f. oscillator, as assembled for Experiment 50 and for future experiments.

different points: *in the grid circuit; in the cathode lead; in the plate circuit.* In each case, we used the N.R.I. Tester as an aural indicator; the tube in the tester rectifies the modulated r.f. signal so that the r.f. and a.f. signals can be separated, and the phone unit then makes the a.f. signal audible.

The fact that we obtain the output or test signal from the third winding of the signal generator coil is definite proof that we are producing an audio-modulated r.f. signal rather than an audio signal alone. This third winding is inductively coupled to the other windings through an air core, and we know that only a negligible amount of a.f. signal can be transferred from one winding to another through an air core. This means that r.f. energy is being transferred to this third winding. The fact that we hear an audio tone proves that this r.f. energy is modulated with the audio signal.

With the grid-modulated circuit employed in Step 1, the parts within the shaded area in the schematic circuit diagram in Fig. *28* form an audio oscillator of the tuned grid type. Condenser C_1 and resistor R_1 form the coupling circuit through which the a.f. oscillator feeds into the r.f. oscillator, and the remaining parts in this diagram form an r.f. oscillator which is likewise of the tuned grid type. The a.f. signal voltage developed between the plate terminal of the a.f. oscillator tube and the chassis is applied through C_1 and R_1 to the grid terminal (top cap) of the r.f. oscillator and the chassis, so that a.f. current flows through grid resistor R_G and develops across this resistor an a.f. voltage which alternately increases and decreases the automatic C bias voltage across this resistor. As a result, we have both r.f. and a.f. voltages acting upon the grid of the r.f. oscillator triode section, and the signal current flowing through the plate coil is an r.f. signal with audio modulation. This induces in the third winding of the signal generator coil the modulated r.f. signal which you listen to with the aural indicator.

Both C_1 and R_1 in the coupling circuit limit the flow of a.f. current along this path. The larger the capacity value of C_1 and the smaller the ohmic value of R_1, the more a.f. voltage there will be applied to the grid circuit of the r.f. oscillator. On the other hand, increasing the capacity of C_1 or reducing the resistance of R_1 loads both the r.f. and a.f. oscillators, reducing their output voltages. If this loading acts unequally upon the two oscillators, excessive loading may make it impossible to secure the desired percentage of modulation, and may even make one oscillator stop functioning.

With the cathode-modulated circuit used in Step 2 and shown in Fig. *31* the parts within the shaded area again form the audio oscillator. If C_1, R_1, C_B, and R_5 were omitted and the cathode (terminal *4*) of the other triode section were grounded, the remaining parts would form an unmodulated tuned grid r.f. oscillator. With these four parts in the circuit, both the a.f. current fed through C_1 and R_1 and the plate current of the r.f. oscillator triode section flow through R_5. Thus, we have both the normal C bias voltage and an a.f. voltage developed across R_5; both of these voltages act upon the grid of the r.f. section, thereby creating a modulated r.f. signal.

The capacity value of C_B must be such that the reactance of this condenser at the r.f. output frequency will be negligible with respect to the ohmic value of R_5. We also have the requirement that at audio frequencies the reactance of this condenser must be as large as possible; this is the reason for using only a 370-mmfd. condenser for C_B.

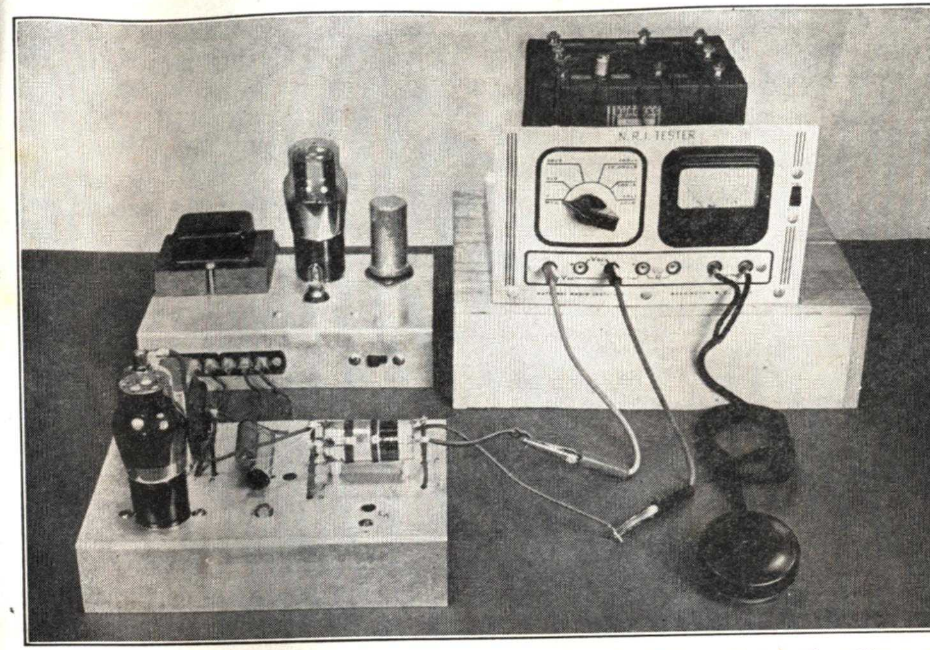

FIG. 35. In this view, all connections have been made between the plate-modulated r.f. oscillator, the power pack and the N.R.I. Tester in preparation for an audio listening test.

With this cathode-modulated circuit C_1, R_1 and R_5 control the percentage of modulation and at the same time affect the output of each oscillator circuit through their loading effects.

With the plate-modulated r.f. oscillator circuit used in Step 3 and shown in Fig. *32*, parts within the shaded area again represent the audio oscillator, and all other parts form the r.f. oscillator. Note that the plate voltage of the r.f. oscillator tube is applied through the primary winding of the audio transformer and through 40,000-ohm resistor R_1. Condenser C_1 is high enough in value (.05 mfd.) to by-pass all r.f. signals to the chassis and thus prevent r.f. from entering the audio circuit. At the same time R_1 and C_1 together act as a resistance-capacity filter for audio signals, allowing the desired fundamental audio frequency to pass through but suppressing the higher audio harmonics which might otherwise distort the modulation.

When the plate-modulated r.f. oscillator circuit is in operation, both the normal d.c. supply voltage and the a.f. signal developed across the primary of the audio transformer act in series upon the plate of the r.f. oscillator triode section. The resulting increases and decreases in the d.c. plate voltage at an audio rate cause the amplitude of the r.f. plate current to rise and fall at an audio rate, thereby giving the desired amplitude modulation.

In this plate-modulated circuit, lowering the resistance of R_1 makes the r.f. oscillator give higher r.f. output, because this raises the d.c. plate voltage of the oscillator tube. At the same time, lowering R_1 places a greater load upon the audio oscillator, for R_1 acts through the plate-cathode

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path of the r.f. tube to shunt the a.f. oscillator output circuit. An excessively low value for R_1 would make the audio voltage so low that the percentage of modulation would be very nearly zero and no audio signal would be heard with an aural indicator.

Instructions for Report Statement No. 50. The r.f. output voltage value of your modulated r.f. oscillator can readily be measured with the N.R.I. Tester. Furthermore, since this value will tell us whether you have assembled this final project in this manual correctly, you are asked in Report Statement No. 50 to give the r.f. output voltage value you measured between the two r.f. output leads while using the *V* range of the N.R.I. Tester, with the 1,000-ohm potentiometer on the oscillator chassis adjusted for maximum r.f. output, and with trimmer condenser C_A set one turn off from maximum capacity. The headphone should be removed from the *PHONE* jacks for this measurement. For your information, the N.R.I. value for this measurement was 3 volts; your own value should be within 1 volt of this, but need not necessarily be the same.

Important: After completing all measurements for this experiment, turn off the power pack and the N.R.I. Tester, remove the test probes from the N.R.I. Tester, then set aside all apparatus carefully in a safe place until you receive the next manual in your Practical Demonstration Course and are ready to start the next group of ten experiments. Do not discard any parts or wires whatsoever until you have completed the entire N.R.I. Course.

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	5-6	Antenna coil	.52		
	5-7	Signal generator coil	.59		
	5-8	Headphone	.95		
	5-9A	370-mmfd. trimmer condenser	.20		
	5-10	Condenser, .001-mfd., 400-volt	.12		
	5-11	Condenser, .01-mfd., 400-volt	.12		
	5-12	Condenser, .05-mfd., 400-volt	.12		
	5-13	Resistor, .1-megohm, 10% tolerance	.07		
	5-14	Hookup wire, 25' roll	.25		
	5-15	Rubber grommet	.02		
	5-16A	Machine screw assortment (8)	.04		
	5-16B	Hex. nut assortment (8)	.04		
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