THE USE OF ARITHMETIC IN RADIO

36X

REFERENCE BOOK

NATIONAL RADIO INSTITUTE
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WASHINGTON, D.C.

FOOD FOR THOUGHT

Every man must submit to be slow before he is quick, and insignificant before he is important. The too early struggle against the pain of obscurity corrupts no small share of understandings.

Well and happily has that man conducted his understanding who has learned to derive from the exercise of it regular occupation and rational delight; who, after having overcome the first pain of application, and having acquired a habit of looking inwardly upon his own mind, perceives that every day is multiplying the relations confirming the accuracy, and augmenting the number of his ideas; who feels that he is rising in the scale of intellectual beings, gathering new strength with every new difficulty which he subdues, and enjoying today as his pleasure that which yesterday he labored at as his toil.

SIDNEY SMITH.

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

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A LESSON TEXT OF THE N. R. I. COURSE
WHICH TRAINS YOU TO BECOME A
RADIOTRICIAN & TELETRICIAN
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The Use of Arithmetic in Radio

INTRODUCTION

Anyone who has read magazine articles dealing with Radio—anyone who has studied even the first lesson of a radio course—realizes to what extent a knowledge of mathematics will help him. Take for example Ohm's law. Without a knowledge of simple multiplication and division, we could not put Ohm's law to any practical use. But with this knowledge, Ohm's law becomes the most useful of the fundamental principles of Radio and electricity.

Then when we come to the design of power packs, the design of coils, and the calculation of the resonant frequency of a circuit, etc., we must use formulas that are not always as simple as Ohm's law—and yet if we know our "math" they won't be "Chinese puzzles" to us, but "tools" which we will use in our every-day work.

Mathematics is used so continually in Radio that certain short cuts have been developed. These will be included here, not only to show you how radio calculations are made, but so that you may develop a system of rapid calculation which you can put to practical uses as you progress in your radio studies.

We mentioned Ohm's law as if it were the only use for a knowledge of numbers. The more expert radio technician uses a large variety of radio formulas which will be given in another reference text. You will be told how to use formulas, including: what is a formula, uses for radio formulas, expressing formulas graphically, how to solve a practical problem with a formula, how to rearrange a formula, and how to design by means of formulas. Rarely will you have to develop your own formula, a task that you should leave to expert research technicians.

But before you can acquire this remarkable ability you must develop ability to compute. You must review or learn to add, subtract, multiply, divide; learn how to work with fractions and decimals, find roots and powers of numbers. If your work requires lots of arithmetic, you should learn how to use logarithms and the slide rule. This text is devoted to this.

ADDITION

As none of us ever has any trouble in the addition of a few numbers, let us start immediately with a long column of large numbers. Let us say we have a nine section voltage divider and that the individual resistance sections were measured in a very accurate bridge. The first section was found to be 4826 ohms, the second 2958 ohms, and so on. We want to check the resistance of the entire unit.

We set down the figures in a column, then proceed to add them.

4826		
2958		
8277		
3936		
5729		
9127		
6344		
7413		
1662		
	Check	
52		45
32		49
49		32
45		52
50272		50272

So that our minds can work with a minimum of exertion as we add up the individual columns, we say only the totals in our mind. We don't say 6 plus 8 are 14, 14 plus 7 are 21, 21 plus 6 are 27, etc.—we merely say 14, 21, 27, 36, etc. We find that the right-hand column totals up to be 52. In school we most likely learned to write down the 2 and carry 5 over to the next column. However, it is best not to carry over the figures from one column to another, but put down the totals for the columns as shown.

To check your results, follow the same procedure but start with the left-hand column as shown.

There are several columns of figures below for you to practice on. Strive for speed and accuracy. Check your results as you go along.

53296	4257	4139
19387	9316	3146
23845	8297	9357
72981	5489	2879
68346	2568	5764
71291	4697	3192
36572	3963	8653

Where a great amount of column addition must be done, the time required to do it can be reduced materially by considering three or four figures of a single column at a time. For example, in the problem just worked out, instead of adding $6 + 8 + 7 + 6$, etc., add $14 + 13 + 9 + 11$, etc. Column addition may also be often simplified by watching for figures that total up to 10 as you go down the column. That is, if there is a 7 and a 3, a 6 and a 4, an 8 and a 2, etc., even though separated by 1 or 2 numbers, we can immediately add 10 to our total and then add the intermediate numbers. Or if there are several similar numbers, it is often easier to determine the number of times this number appears and multiply it out, later adding the odd numbers together, then adding the two totals for the total of the entire column.

One important thing in connection with the use of addition in Radio—and for that matter, the same is true of subtraction—we can deal only with like terms. By this we mean that we can't add ohms and farads, any more than we can add feet and pounds. Likewise, we can't add amperes and milliamperes directly, we must first convert all quantities to similar terms. Thus to add 100 milliamperes to 1 ampere, we would convert the ampere to 1000 milliamperes and then our total would be 1100 ma.

SUBTRACTION

Very few of us have difficulty in subtracting even the most complicated numbers. However, for the sake of completeness let us work out a problem, and follow through the various steps involved.

$$\begin{array}{r} {\scriptstyle 7\quad\; 5\,2\,10} \\ 7{,}849{,}630 \\ \underline{4{,}291{,}375} \\ 3{,}558{,}255 \end{array}$$

Starting at the extreme right, we see immediately that we can't subtract 5 from 0—we can't take away something from nothing. Therefore, we must borrow 10 from the next number (3), leaving 2. Taking 5 from 10 we get 5. Then moving one place to the left we find we can't subtract 7 from 2 so we borrow again, making the 2, 12. As 7 from 12 is 5 we write this down in the answer. Again moving one place to the left we subtract 3 from 5—not 6—because we have borrowed 1 from 6. $5 - 3 = 2$, which we write down. Then 1 from 9 is 8. The next step requires borrowing again as we can't subtract 9 from 4. We take one from the 8 and subtract 9 from 14 which gives us 5. The next is simple—2 from $7 = 5$ and 4 from $7 = 3$.

Answers to problems of this kind are easily checked—all we have to do is to add the answer to the smaller number and if we have subtracted properly, the total will be the larger number of the problem. Thus:

$$\begin{array}{r} 4,291,375 \\ +3,558,255 \\ \hline 7,849,630 \end{array}$$

MULTIPLICATION IN RADIO

Multiplication is nothing more than a short-cut method of addition. This can be easily seen if we consider a simple problem such as 6×9. If we were to add 6 nines together we would get 54, but this would be a rather laborious process.

The development of mathematics was due largely to the search for short-cuts, and the multiplication table was evolved early in the history of mathematics to make unnecessary a great deal of cumbersome addition. We learned the multiplication table early in our school life—and now when we see 6×9 we know instantly that 6 nines are 54. Refer to Table 1 which is the familiar multiplication table in a shortened form.

In a problem of multiplication such as 6×9, the 6 is the *multiplier* and the 9 is the *multiplicand*. The answer, 54, is the *product*.

Now let us consider a problem in which the multiplicand is a large number. Suppose we want to multiply 9,437 by 7. The proper method of solving the problem is as shown below.

$$\begin{array}{r} {\scriptstyle 3\ \ 2\,4} \\ 9,437 \\ 7 \\ \hline 66,059 \end{array}$$

Stated in words, the operation is as follows: $7 \times 7 = 49$. Set the 9 down as part of the product and carry over the 4, writing it above the next number to be multiplied. $7 \times 3 = 21$ and adding the carried 4 we get 25. Set down the 5 in the product and carry the 2. $7 \times 4 = 28$ and adding the carried 2 we get 30. Set down the 0 and carry 3. $7 \times 9 = 63$ and adding the carried 3 we get 66 all of which we set down in the product to get the entire product 66,059.

As a point of interest it might be stated here that the number 9,437 is the same as $9000 + 400 + 30 + 7$. If we multiplied each of these by 7 and added the products we would get 66,059 as shown by the following:

$$
\begin{aligned}
7\times 9{,}000 &= 63{,}000\\
7\times 400 &= 2{,}800\\
7\times 30 &= 210\\
7\times 7 &= 49\\
\hline
7\times 9{,}437 &= 66{,}059
\end{aligned}
$$

From this we can see if we multiply the sum of several

	1	2	3	4	5	6	7	8	9	10
1	1	2	3	4	5	6	7	8	9	10
2	2	4	6	8	10	12	14	16	18	20
3	3	6	9	12	15	18	21	24	27	30
4	4	8	12	16	20	24	28	32	36	40
5	5	10	15	20	25	30	35	40	45	50
6	6	12	18	24	30	36	42	48	54	60
7	7	14	21	28	35	42	49	56	63	70
8	8	16	24	32	40	48	56	64	72	80
9	9	18	27	36	45	54	63	72	81	90
10	10	20	30	40	50	60	70	80	90	100

Table No. 1

numbers by a number, the product will be equal to the sum of the products of all the multiplicands and the multiplier.

The same can be said in the case where the multiplicand is the difference between two numbers, as for example, $20-8$. Suppose we have the problem $4 \times (20-8)$. Of course this is equivalent to 4×12, the product of which is 48. We would arrive at the same answer if we worked it out this way: $(4 \times 20)-(4 \times 8)$ in which case we would get $80-32$ or 48.

Now let us consider a problem in which both multiplier and multiplicand are numbers of several places, as for example, $8{,}468 \times 241$. This problem is worked out as follows:

```
      8,468
        241
      8 468
    338 72
  1 693 6
  2,040,788
```

From this we can see that we multiply first by 1, then by 4, then by 2, in each case off-setting the product one place to the left, for it must be remembered that although we multiply by 4, what we are really doing is multiplying by 40. In the same way, when we multiply by 2, we are really multiplying by 200. Then the various products are added and we have the solution to the entire problem.

Another multiplication problem, in which both multiplier and multiplicand are four place numbers, is worked out below so that you can fix the process firmly in mind. Follow through each step carefully.

```
       3,947
       5,126
      23 682
      78 94
     394 7
  19 735
  20,232,322
```

In order to gain speed and accuracy in multiplying, work out the following problems several times.

```
4,157     9,208     7,546
2,631     6,452     3,158
```

For the purpose of illustrating the use of multiplication, involving numbers of several places, let us take the formula for capacity in a resonant circuit, either series or parallel resonance, $C = \frac{10}{394f^2L}$ where C is the capacity in farads, f is the frequency in cycles per second and L is the inductance in henries. Let us forget for the time being the fact that we have to divide $394f^2L$ into 10 and deal only with the lower term. Later when we study division we shall see how a large number is divided into a smaller one or into some multiple of 1.

Now let us say that the frequency is 120 cycles and the inductance is 30 henries. Then instead of $394f^2L$ we would have:

$$394 \times 120 \times 120 \times 30$$

You notice that f^2, which is read "f squared," means that 120 (in this case) must be multiplied by itself. In working out the problem it will be easiest to multiply out all the simple terms first—as follows:

$$\begin{array}{r}
120 \\
\times 120 \\
\hline
2\ 400 \\
12\ 0 \\
\hline
14\ 400 \\
\times 30 \\
\hline
432\ 000 \\
\times 394 \\
\hline
1\ 728\ 000 \\
38\ 880\ 00 \\
129\ 600\ 0 \\
\hline
170{,}208{,}000
\end{array}$$

If this final product is divided into 10 we find that C is approximately .00000006 farads.* But we are not interested in the particular value of C in this case, all we wanted to do was to get the value of $394f^2L$ which involves nothing but multiplication.

Before we leave the subject of multiplication of whole numbers there are two points you should memorize. First: When either the multiplier or the multiplicand is zero, the product will be zero. Thus 100×0 or $0 \times 100 = 0$. Second, when either term is 1, the product will be equal to the other term. Thus 1×150 or $150 \times 1 = 150$. These points are emphasized here because, while to many people they are obvious, it often happens that we become confused momentarily when confronted with them in our practical work.

DECIMALS IN ADDITION, SUBTRACTION AND MULTIPLICATION

In practically all radio work involving the use of arithmetic, fractions are converted to decimals for purposes of calculation. For example, we have .0005 mfd. condensers. No one would ever write this $\frac{5}{10{,}000}$ mfd. It is true we have 1/2 megohm resistors, but even here, when calculations are involved, we convert the 1/2 megohm to .5 megohm or 500,000 ohms.

The decimal system is nothing more or less than a means of expressing numbers less than 1 in terms of tenths.

Simple decimals of this sort will not be difficult for us, as we use them every day in handling money. When we say 50 cents meaning a half dollar, we are really saying 50/100th or

* To find the value in microfarads move the decimal point six places to the right (multiply by 1,000,000). This gives .06 microfarad.

5/10th of a dollar. A quarter is 25 cents, or 25/100th of a dollar; 75 cents is three-quarters of a dollar or 75/100th of a dollar. We write .50, .25, and .75 using the decimal point to show that what follows is really less than 1.

In Radio we deal with decimals to many places, such as .0008, .0025, etc. The table below will show you how these are to be read and includes the fractional equivalents.

.1	= 1/10	= one-tenth.
.01	= 1/100	= one-hundredth.
.001	= 1/1000	= one-thousandth.
.0001	= 1/10,000	= one ten-thousandth.
.00001	= 1/100,000	= one hundred-thousandth.
.000001	= 1/1,000,000	= one millionth.

As a short cut, when reading decimals of a large number of places such as .0008, instead of reading eight ten-thousandths, we aften read "point 0-0-0 eight," "three zeros eight," or even "triple-0 eight." Sometimes even decimals of one place are read in this way. Thus .5 may be read "point five," or "one-half" instead of "five-tenths."

If you should hear someone say that a certain quantity is "5 zeros three," you will know that he means "three-millionths." If you hear "double 0 two five," you will immediately see in your mind .0025 which you know to be 25 ten-thousandths.

In adding or subtracting decimals, all that is necessary is that the decimal points of the various numbers used be in a line vertically. To illustrate:

$$\begin{array}{r@{.}l} 1 & 008 \\ & 0005 \\ 126 & 1 \\ 21 & 004 \\ \hline 148 & 1125 \end{array}$$

Of course the decimal point in the result will be directly below the decimal points in the numbers added.

The same is true when we subtract decimals. For example:

$$\begin{array}{r@{.}l} 298 & 3760 \\ -19 & 0422 \\ \hline 279 & 3338 \end{array}$$

When we multiply decimals, the position of the decimal in the set-up of the problem is unimportant. Suppose we repeat one of the problems worked out in the chapter on multiplication, (8468 $\times$ 241), but let us make it 8.468 $\times$ 24.1. We would multiply this out exactly as though there were no decimals and we would get 2,040,788. Now where would we put our decimal point? Add up the number of decimal places in both the multiplier and the multiplicand, 3 + 1, then place the decimal point 4 places to the left in the product and the final result is 204.0788.

DIVISION OF WHOLE NUMBERS

Division is the process of arithmetic which can well be considered as being opposite to multiplication. We use division when we want to find out how many times a certain number will "go into" another number, or in other words, what number we would have to multiply by to get that number.

For example, we all know that $3 \times 9 = 27$. We also know that 3 "goes into 27" 9 times and that 9 "goes into 27" three times.

The sign for division is "÷" or the problem can be set down as a fraction—thus $9 \div 3$ and $\frac{9}{3}$ mean exactly the same thing. In this case the number 9 is called the *dividend*, the number 3 is the *divisor* and the answer is the *quotient.*

A brief reference to Table 1 at this point will do two things —it will refresh your mind on the division of single numbers, and it will show you why division may be considered as being the opposite of multiplication. Now, instead of locating our multiplier and multiplicand on the top and left-side of the Table respectively and reading the product at the point where the two columns intersect, locate the divisor on the left-side column and the dividend in the body of the table, then read the quotient in the top horizontal column.

Whenever the divisor is a number less than 13 it is common practice to use the process known as short division. A practical short division problem is worked out below:

$$\begin{array}{r} 4\,1\,5\,6\,3 \\ 9\overline{)3\,7\,{}^{1}4\,{}^{5}0\,{}^{5}6\,{}^{2}7} \end{array}$$

Reviewing the process in words: 9 won't go into 3 so we start by dividing 9 into 37. The closest we can get is 4 times. We set the number 4 down in the quotient. But $4 \times 9 = 36$. Therefore we have 1 left over. Write this above the next number in the dividend. Then 9 goes into 14 once with 5 left over. Set the 1 down in the quotient and write 5 above the next number in the dividend, in this case 0. Now 9 goes into 50 five times with 5 left over, etc. The quotient is 41,563.

Where the divisor is a number larger than 12, the "long division" process is used, as illustrated in the following example in which 31 is our divisor and 969,401 is our dividend.

```
     31271
  31)969401
     93
      39
      31
       84
       62
       220
       217
         31
         31
```

You will notice that the process is essentially the same as for short division, but in this case we set our individual products down for convenience. Notice, too, that in each step we carried down the following number in the dividend.

In both the problems worked out here the answer came out even. But suppose the last number in the dividend in the second example had been something other than 1. Let us say for purposes of illustration that the dividend were 969,409. In the final step, then, we would have had 8 left over. We might say that our quotient in this case were 31271 and 8/31, but the more common procedure is to continue dividing and to get the fraction in decimal form. In the dividend place a decimal point after the 9 and after this write down two zeros. Then our dividend will be 969,409.00. We also place a decimal point in the quotient when we begin to carry down the zeros to the right of the decimal point in the dividend. Worked out in this manner, the problem becomes:

```
      31,271.26
  31)969,409.00
     93
      39
      31
       84
       62
       220
       217
         39
         31
          80
          62
          180
          186
```

Notice that in the first step, when we divide 31 into 96, the quotient 3 is written directly above the 6 in the dividend. Then the decimal point in the quotient is placed directly above the decimal point in the dividend.

Where the dividend contains a decimal the procedure is the same as that just illustrated. In the process of dividing, place a decimal in the quotient at the point where the first number to the right of the decimal in the dividend is carried down. If the quotient is set down carefully, this decimal will be directly above the decimal in the dividend.

Where the divisor contains a decimal, the simplest procedure is to make a whole number of it and move the decimal in the dividend the same number of places to the right as it must be moved in the divisor to make it a whole number. For example, let us say we have the problem $974.63 \div 1.3$. We simplify this by making it $9746.3 \div 13$. A slightly more difficult problem would be $1.41 \div .0025$. To make of the divisor a whole number, we have to move the decimal four places to the right and our problem becomes $14100 \div 25$ or $\frac{14100}{25}$.

On the other hand, suppose we have to divide a whole number into a decimal, as for example: $.0007 \div 45$ or $\frac{.0007}{45}$ We would work this out as follows:

$$\begin{array}{r}
.0000155 \\
45\overline{).0007000} \\
45 \\
\overline{250} \\
225 \\
\overline{250} \\
225 \\
\hline
\end{array}$$

Notice that we set down in the quotient the three zeros in the dividend. Then because 45 won't go into 7, we set down another zero. Now 45 goes into 70 once and we set down the number 1 in the quotient. 45 from 70 leaves 25. Bring down a zero from the dividend and divide 45 into 250. It goes 5 times with 25 left over. Bring down another zero and divide 45 into 250. It goes 5 times and we set the 5 down in the quotient. We could continue adding zeros to the dividend all we wanted to, but for most purposes we are satisfied with three significant numbers in the quotient. In this case our quotient is 155 ten-millionths.

Now you will be able to see how we obtained .00000006 farads when we divided 170,208,000 into 10 in a previous chapter. We set the problem down as below, adding the required number of zeros to the dividend.

```
              00.000000058
170,208,000)10.000000000
             8 51040000
             1 489600000
             1 361664000
```

You will notice we had to add 9 zeros to the dividend. Therefore, there will be nine places in the quotient and the answer would be read 58 thousand-millionths. But the answer is in farads so we convert it to microfarads by multiplying by 1 million and we get .058 or .06 mfd.

In radio work we frequently have to divide a whole number into 1 in order to obtain the reciprocal. The procedure is exactly the same as outlined above. Suppose we want to find the conductance $\frac{1}{R}$ when R is 2500 ohms. We proceed as follows:

```
      0.0004
2500)1.0000
     1 0000
```

Notice that the quotient has as many places as the dividend. The conductance in this case would be 4 ten-thousandths of a mho.

To check the correctness of a quotient, multiply it by the divisor. The result should be the same as the dividend.

SHORT CUTS IN MULTIPLICATION AND DIVISION

Many short cuts have been devised to aid in the rather tedious task of multiplying large numbers. One of the simplest short cuts has to do with the multiplication of numbers containing several zeros.

As an example, $24{,}000 \times 4{,}000 = 96{,}000{,}000$. Multiply the numbers together, exclusive of the zeros, and add to the answer as many zeros as appear in both multiplicand and multiplier. In our problem we multiply $24 \times 4 = 96$. There are three zeros in both terms of our example, therefore, there will be six zeros in the product.

Considerable time is also saved by the proper choice of multiplier. In multiplication it doesn't make any difference which term we use as the multiplier. It is always good policy to make the smaller term the multiplier. For example, we are to multiply 5134 and 2100. With 5,134 as the multiplier our problem would be set up thus:

```
      2 100
      5 134
      -----
      8 400
     63 00
    210 0
 10 500
 ----------
 10,781,400
```

Using 2100 as the multiplier would be much simpler as shown below:

```
    513 4
      2 100
    -------
    513 4
 10 268
 ----------
 10,781,400
```

In this set-up, we followed our rule about numbers containing zeros, adding two zeros to the product of 5,134 $\times$ 21.

A short cut can be used where a number is multiplied by ½ (.5), ¼ (.25), and ¾ (.75).

(A) To multiply by .5—

In order to multiply a number by .5, divide the number by 2. This is self-evident, as .5 is the same as 5/10, which is equal to ½. If the number is 15, we see that 15 $\times$ .5 is the same as 15 $\times$ ½, which becomes 7.5.

(B) To multiply by .05—

In order to multiply a number by .05, move the decimal point of the number one place to the left and divide by 2. Take the case where 5 per cent of a number is required. Now 5 per cent is 5/100 of a number, which becomes in decimals .05. If the number is 15, move the decimal point of the number one place to the left, which gives 1.5 and divide by 2, obtaining .75.

(C) To multiply by .25—

In order to multiply any number by .25, divide by 4. Thus, if the number 264 is to be multiplied by .25, it is seen that considerable figuring would be necessary to multiply it out. But by dividing by 4, we quickly obtain the answer 66.

We can use this same method whether our multiplier is 2.5, 25, 250, or 25 million, simply by adding to the multiplicand as many zeros as there are whole numbers in the multiplier. Mul-

N	0	1	2	3	4	5	6	7	8	9	P. P. 1 2 3 4 5
10	0000	0043	0086	0128	0170	0212	0253	0294	0334	0374	4 8 12 17 21
11	0414	0453	0492	0531	0569	0607	0645	0682	0719	0755	4 8 11 15 19
12	0792	0828	0864	0899	0934	0969	1004	1038	1072	1106	3 7 10 14 17
13	1139	1173	1206	1239	1271	1303	1335	1367	1399	1430	3 6 10 13 16
14	1461	1492	1523	1553	1584	1614	1644	1673	1703	1732	3 6 9 12 15
15	1761	1790	1818	1847	1875	1903	1931	1959	1987	2014	3 6 8 11 14
16	2041	2068	2095	2122	2148	2175	2201	2227	2253	2279	3 5 8 11 13
17	2304	2330	2355	2380	2405	2430	2455	2480	2504	2529	2 5 7 10 12
18	2553	2577	2601	2625	2648	2672	2695	2718	2742	2765	2 5 7 9 12
19	2788	2810	2833	2856	2878	2900	2923	2945	2967	2989	2 4 7 9 11
20	3010	3032	3054	3075	3096	3118	3139	3160	3181	3201	2 4 6 8 11
21	3222	3243	3263	3284	3304	3324	3345	3365	3385	3404	2 4 6 8 10
22	3424	3444	3464	3483	3502	3522	3541	3560	3579	3598	2 4 6 8 10
23	3617	3636	3655	3674	3692	3711	3729	3747	3766	3784	2 4 5 7 9
24	3802	3820	3838	3856	3874	3892	3909	3927	3945	3962	2 4 5 7 9
25	3979	3997	4014	4031	4048	4065	4082	4099	4116	4133	2 3 5 7 9
26	4150	4166	4183	4200	4216	4232	4249	4265	4281	4298	2 3 5 7 8
27	4314	4330	4346	4362	4378	4393	4409	4425	4440	4456	2 3 5 6 8
28	4472	4487	4502	4518	4533	4548	4564	4579	4594	4609	2 3 5 6 8
29	4624	4639	4654	4669	4683	4698	4713	4728	4742	4757	1 3 4 6 7
30	4771	4786	4800	4814	4829	4843	4857	4871	4886	4900	1 3 4 6 7
31	4914	4928	4942	4955	4969	4983	4997	5011	5024	5038	1 3 4 6 7
32	5051	5065	5079	5092	5105	5119	5132	5145	5159	5172	1 3 4 5 7
33	5185	5198	5211	5224	5237	5250	5263	5276	5289	5302	1 3 4 5 6
34	5315	5328	5340	5353	5366	5378	5391	5403	5416	5428	1 3 4 5 6
35	5441	5453	5465	5478	5490	5502	5514	5527	5539	5551	1 2 4 5 6
36	5563	5575	5587	5599	5611	5623	5635	5647	5658	5670	1 2 4 5 6
37	5682	5694	5705	5717	5729	5740	5752	5763	5775	5786	1 2 3 5 6
38	5798	5809	5821	5832	5843	5855	5866	5877	5888	5899	1 2 3 5 6
39	5911	5922	5933	5944	5955	5966	5977	5988	5999	6010	1 2 3 4 6
40	6021	6031	6042	6053	6064	6075	6085	6096	6107	6117	1 2 3 4 5
41	6128	6138	6149	6160	6170	6180	6191	6201	6212	6222	1 2 3 4 5
42	6232	6243	6253	6263	6274	6284	6294	6304	6314	6325	1 2 3 4 5
43	6335	6345	6355	6365	6375	6385	6395	6405	6415	6425	1 2 3 4 5
44	6435	6444	6454	6464	6474	6484	6493	6503	6513	6522	1 2 3 4 5
45	6532	6542	6551	6561	6571	6580	6590	6599	6609	6618	1 2 3 4 5
46	6628	6637	6646	6656	6665	6675	6684	6693	6702	6712	1 2 3 4 5
47	6721	6730	6739	6749	6758	6767	6776	6785	6794	6803	1 2 3 4 5
48	6812	6821	6830	6839	6848	6857	6866	6875	6884	6893	1 2 3 4 4
49	6902	6911	6920	6928	6937	6946	6955	6964	6972	6981	1 2 3 4 4
50	6990	6998	7007	7016	7024	7033	7042	7050	7059	7067	1 2 3 3 4
51	7076	7084	7093	7101	7110	7118	7126	7135	7143	7152	1 2 3 3 4
52	7160	7168	7177	7185	7193	7202	7210	7218	7226	7235	1 2 2 3 4
53	7243	7251	7259	7267	7275	7284	7292	7300	7308	7316	1 2 2 3 4
54	7324	7332	7340	7348	7356	7364	7372	7380	7388	7396	1 2 2 3 4

N	0	1	2	3	4	5	6	7	8	9	P. P. 1. 2. 3. 4. 5
55	7404	7412	7419	7427	7435	7443	7451	7459	7466	7474	1. 2. 2. 3. 4
56	7482	7490	7497	7505	7513	7520	7528	7536	7543	7551	1. 2. 2. 3. 4
57	7559	7566	7574	7582	7589	7597	7604	7612	7619	7627	1. 2. 2. 3. 4
58	7634	7642	7649	7657	7664	7672	7679	7686	7694	7701	1. 1. 2. 3. 4
59	7709	7716	7723	7731	7738	7745	7752	7760	7767	7774	1. 1. 2. 3. 4
60	7782	7789	7796	7803	7810	7818	7825	7832	7839	7846	1. 1. 2. 3. 4
61	7853	7860	7868	7875	7882	7889	7896	7903	7910	7917	1. 1. 2. 3. 4
62	7924	7931	7938	7945	7952	7959	7966	7973	7980	7987	1. 1. 2. 3. 3
63	7993	8000	8007	8014	8021	8028	8035	8041	8048	8055	1. 1. 2. 3. 3
64	8062	8069	8075	8082	8089	8096	8102	8109	8116	8122	1. 1. 2. 3. 3
65	8129	8136	8142	8149	8156	8162	8169	8176	8182	8189	1. 1. 2. 3. 3
66	8195	8202	8209	8215	8222	8228	8235	8241	8248	8254	1. 1. 2. 3. 3
67	8261	8267	8274	8280	8287	8293	8299	8306	8312	8319	1. 1. 2. 3. 3
68	8325	8331	8338	8344	8351	8357	8363	8370	8376	8382	1. 1. 2. 3. 3
69	8388	8395	8401	8407	8414	8420	8426	8432	8439	8445	1. 1. 2. 3. 3
70	8451	8457	8463	8470	8476	8482	8488	8494	8500	8506	1. 1. 2. 2. 3
71	8513	8519	8525	8531	8537	8543	8549	8555	8561	8567	1. 1. 2. 2. 3
72	8573	8579	8585	8591	8597	8603	8609	8615	8621	8627	1. 1. 2. 2. 3
73	8633	8639	8645	8651	8657	8663	8669	8675	8681	8686	1. 1. 2. 2. 3
74	8692	8698	8704	8710	8716	8722	8727	8733	8739	8745	1. 1. 2. 2. 3
75	8751	8756	8762	8768	8774	8779	8785	8791	8797	8802	1. 1. 2. 2. 3
76	8808	8814	8820	8825	8831	8837	8842	8848	8854	8859	1. 1. 2. 2. 3
77	8865	8871	8876	8882	8887	8893	8899	8904	8910	8915	1. 1. 2. 2. 3
78	8921	8927	8932	8938	8943	8949	8954	8960	8965	8971	1. 1. 2. 2. 3
79	8976	8982	8987	8993	8998	9004	9009	9015	9020	9025	1. 1. 2. 2. 3
80	9031	9036	9042	9047	9053	9058	9063	9069	9074	9079	1. 1. 2. 2. 3
81	9085	9090	9096	9101	9106	9112	9117	9122	9128	9133	1. 1. 2. 2. 3
82	9138	9143	9149	9154	9159	9165	9170	9175	9180	9186	1. 1. 2. 2. 3
83	9191	9196	9201	9206	9212	9217	9222	9227	9232	9238	1. 1. 2. 2. 3
84	9243	9248	9253	9258	9263	9269	9274	9279	9284	9289	1. 1. 2. 2. 3
85	9294	9299	9304	9309	9315	9320	9325	9330	9335	9340	1. 1. 2. 2. 3
86	9345	9350	9355	9360	9365	9370	9375	9380	9385	9390	1. 1. 2. 2. 3
87	9395	9400	9405	9410	9415	9420	9425	9430	9435	9440	0. 1. 1. 2. 2
88	9445	9450	9455	9460	9465	9469	9474	9479	9484	9489	0. 1. 1. 2. 2
89	9494	9499	9504	9509	9513	9518	9523	9528	9533	9538	0. 1. 1. 2. 2
90	9542	9547	9552	9557	9562	9566	9571	9576	9581	9586	0. 1. 1. 2. 2
91	9590	9595	9600	9605	9609	9614	9619	9624	9628	9633	0. 1. 1. 2. 2
92	9638	9643	9647	9652	9657	9661	9666	9671	9675	9680	0. 1. 1. 2. 2
93	9685	9689	9694	9699	9703	9708	9713	9717	9722	9727	0. 1. 1. 2. 2
94	9731	9736	9741	9745	9750	9754	9759	9763	9768	9773	0. 1. 1. 2. 2
95	9777	9782	9786	9791	9795	9800	9805	9809	9814	9818	0. 1. 1. 2. 2
96	9823	9827	9832	9836	9841	9845	9850	9854	9859	9863	0. 1. 1. 2. 2
97	9868	9872	9877	9881	9886	9890	9894	9899	9903	9908	0. 1. 1. 2. 2
98	9912	9917	9921	9926	9930	9934	9939	9943	9948	9952	0. 1. 1. 2. 2
99	9956	9961	9965	9969	9974	9978	9983	9987	9991	9996	0. 1. 1. 2. 2

tiplying by 2.5 we would add one zero and divide by 4. Multiplying by 25 we would add 2 zeros and divide by 4, etc.

(D) To multiply by .75—

In order to multiply any number by .75, divide by 4 and then multiply the result by 3. Take the number 264 to be multiplied by .75. Applying the rule, we have 264 divided by 4 equals 66 and when multiplied by 3 we get 198.

To multiply by 7.5, 75, 750, etc., add zeros to the multiplicand as when multiplying by variations of .25.

(E) To divide any number by 25—

In order to divide any number by 25, move the decimal point two places to the left, and multiply by 4. Taking the number 2640, we move the decimal two places to the left and we have $26.40 \times 4 = 105.6$.

To divide by 250, move the decimal 3 places to the left and multiply by 4. To divide by 2500, move the decimal 4 places, etc.

In the same way, to divide 50, 500, 5000, etc., move the decimal point in the dividend to the left as many places as there are whole numbers in the divisor, then multiply by 2. To divide by .5, multiply by 2 without moving the decimal. To divide by .05, move the decimal one place to the right. If there is no decimal in the dividend, add a zero, then multiply by 2.

LOGARITHMS

In this lesson on arithmetic we are not going to consider the longhand methods of finding the square root, the cube root, etc., or of raising a number to a certain "power," such as squaring it or cubing it. Instead we are going to learn how to use logarithms—the short cut method of multiplying, dividing, extracting roots and raising numbers to the required powers. After all, what we are interested in learning is how practical radio men calculate—and they use logarithms whenever possible as a convenient short cut method.

Let us begin our study of logarithms with a consideration of the simple number 10. If we multiply 10 by itself, which is the same as *squaring* it, we get 100. That is, 10×10 or $10^2 = 100$. In the same way $10 \times 10 \times 10$ or $10^3 = 1000$ and $10 \times 10 \times 10 \times 10$ or $10^4 = 10{,}000$.

In the expressions 10^2, 10^3 and 10^4, the small number to the right is the power, or the *exponent*. And from the figures given it is clear that if we wrote the number 10 with an exponent, it would be 10^1.

Conversely, if we had the number 100, the square root ($\sqrt{100}$) would be 10 for $10 \times 10 = 100$. Likewise the cube root of 1000 ($\sqrt[3]{1000}$) would be 10 and the fourth root of 10,000 ($\sqrt[4]{10{,}000}$) would be 10 for 10^4 or $10 \times 10 \times 10 \times 10 = 10{,}000$.

Of course, all this is very simple, but it is not quite as easy to realize that *any number* can be expressed in terms of 10 raised to a certain power. Take for example, the number 2. This could be expressed as $10^{.301}$ which is to say that if it were possible to multiply the number 10 by itself .301 times, the product would be 2. In this case, the exponent .301 is called the *logarithm* of the *number* 2.

Then let us take another example. The number 44 can be expressed as $10^{1.6435}$. The logarithm of the number 44 is 1.6435. Notice now that the logarithm is divided in two parts—one part to the left of the decimal, the other to the right of the decimal. The part to the left is called the *characteristic* and the part to the right is the *mantissa* of the logarithm (or log).

The characteristic of a log tells us how many whole numbers there are in the *number*. Thus, a characteristic of 1 means that there are two whole numbers in the *number*. If it were 2, there would be 3 whole numbers in the *number*, that is, the *number* would be between 100 and 999. Stated differently, the characteristic is always 1 less than there are whole numbers in the original *number*.

The following table will help to make this clear.

For numbers from:	*Characteristic*
1 to 9	0.
10 to 99	1.
100 to 999	2.
1,000 to 9,999	3.
10,000 to 99,999	4.
100,000 to 999,999	5.

From this we are led naturally to the question of what the characteristic will be if the *number* is less than 1, such as .4321. The rule in this case is that the characteristic will always be 1 more than the number of zeros immediately following the decimal point, *but it will be preceded by a minus sign.* In the example given, the characteristic will be —1 for there is no zero after the decimal and nothing plus one equals 1. Here is another table showing the various characteristics of *numbers* less than 1.

For numbers from:	*Characteristic*
.9 to .1	−1.
.09 to .01	−2.
.009 to .001	−3.
.0009 to .0001	−4.
.00009 to .00001	−5.

Having well in mind the use and meaning of the characteristics of logs, we are now ready to work with mantissae. To obtain the mantissa of any number we shall have to have a log table available such as the short table in the center of this book. You will notice that only mantissae are given.

Let us start with the number 39. We know that the characteristic will be 1. The mantissa we find to be 5911 from our log table. Therefore, the log of 39 is 1.5911. If the number had been 3.9, our log would have been .5911. If .39, it would be −1.5911. If .0039, the log would be −3.5911, etc.

If we have a three-place number such as 599 we first set down the characteristic 2, then in the N column we locate 59. Then we move over to the 9 column and we obtain the mantissa 7774. Our complete log is now 2.7774.

MULTIPLICATION AND DIVISION BY LOG METHOD

Right here we are going to see to what extent long multiplication and division problems can be simplified by the use of logarithms. *To multiply, add the logs of the numbers—to divide, subtract the logs of the numbers.*

Suppose we want to multiply 599 by 39. We have already found the logs, 2.7774 and 1.5911 respectively. Adding 2.7774 and 1.5911 we get 4.3685. Now all we have to do is to convert the log 4.3685 to a number and we will have our product.

We know that our product is going to be between 10,000 and 99,999 because the characteristic is 4. Now we try to locate the mantissa 3685 in the log table. We can't find it directly, but we can locate 3674 and 3692. As 3685 is nearer the latter, let us take that one and our number is 23,400. Notice we have to add 2 zeros because our number must be between 10,000 and 99,999. If we multiplied this out by the long method we would get 23,361.

For most practical work in Radio 23,400 would be close enough, but under some circumstances it might be desired to have four significant terms in the answer.

If we wanted to have our answer correct to four places we would use the last column (P.P.—proportional parts) of the log table. We would locate the mantissa nearest to 3685, in this case the larger one, 3692. This is larger than 3685 by 7. Now in the last column look up 7. The proportional part for 7 is 4—reading at the top of the column. Subtracting 4 from 2340 we get 2336, and our number is 23,360—with 4 significant terms.

For purposes of additional illustration let us solve the problem 965.43×83.97.

The log of 965.43 is 2.9847. Notice that we disregard the last number 3. The log of 965 is 9845. In the last column (P.P.) we locate the next significant figure 4 at the top. Reading down the column, opposite 96, we find the number 2 which we add to the mantissa making it 9847.

The log of 83.97 is 1.9241. First find the mantissa for 840 (because the final number 7 is larger than 5, we work backwards from 84.00). This is 9243. The difference between 8400 and 8397 is 3 which we look up in the last column. The proportional part for 3 is 2 and so we subtract 2 from 9243 and our log is 1.9241.

Now we are ready to add the logs and $2.9847 + 1.9241 = 4.9088$. Converting this to a number, we get 81,070. We do this by locating the mantissa nearest to 9088 which is 9090. The number is 81,100. But 9088 is 2 less than 9090. To get the final result we get the number for the proportional part 2, which is 3. Subtracting from the fourth term of 81,100, we get the final answer 81,070.

If we were to work out our problem by arithmetic, we would get as our product, 81,067.1571. However, except where computations involving money are made, four significant figures are sufficient so that our product 81,070 is close enough for all practical purposes.

At this point you are urged to work out a number of multiplication problems, both by arithmetic and by logarithms. After going through the procedure a few times, checking your work as you go along, you will begin to appreciate how easy and convenient it is to use logs.

Division by the use of logarithms is just as simple as multiplication. As an example, let us take a problem we worked out by long division in a previous chapter, i. e., $969{,}409 \div 31$. Disregarding the last two figures (09) in the dividend as being insignificant, the log is 5.9865. The log of 31 is 1.4914. Subtracting these we get 4.4951 which is the log of our quotient.

Converting this to a number we get 31,270 which for practical purposes is as good as our other quotient 31,271.26.

A slightly more difficult problem would be to divide .000375 by, let us say, 17. The log of .000375 is —4.5740 and the log of 17 is 1.2304. Our next step is to subtract the logs but the problem (—4.5740) — 1.2304 presents difficulties. To make the first log a plus value so we can subtract from it we make use of a subterfuge. We write the problem down as follows:

$$\begin{array}{r} 6.5740-10 \\ -1.2304 \\ \hline +5.3436-10 \end{array}$$

This, of course, is equivalent to —5.3436. Notice that our subterfuge consisted of replacing the —4 with $6-10$ which is exactly the same. But we got a plus value which is essential before we can take something away from it. It is obvious that we can't take something away from nothing—and it is just as impossible to take something away from a negative value which is less than nothing.

Converting —5.3436 to a number, we find it is .00002206.

POWERS AND ROOTS

The squaring of large numbers and finding the square roots of large numbers are by no means simple tasks if ordinary methods of arithmetic are used. And when powers and roots other than 2 are involved, the arithmetical procedures are extremely complicated.

Of course you know that 25^2 is another way of writing 25×25. It is to be read "25 squared." Similarly 25^3 means that 25 is to be raised to the 3rd power, and 25^4 means that 25 is to be raised to the 4th power, that is, $25 \times 25 \times 25 \times 25$.

The radical sign $\sqrt{}$ over a number indicates that the square root of that number is to be taken. The sign $\sqrt[3]{}$ means that the cube root is to be taken, and $\sqrt[4]{}$ means that the number is to be reduced to the 4th root.

By the use of logarithms, any problems involving the raising of a number to any power, or the reduction of a number to any root is extremely simple.

To square a number, multiply its log by 2. To cube, multiply its log by 3. To raise a number to the 17th power, multiply its log by 17, etc. To find the square root of a number, divide its log by 2. To find the cube root, divide the log by 3. To find the 17th root, divide the log by 17, etc.

The practical problems worked out below will serve as illustrations. Study over them carefully—check the logs against the log table—and the processes involved will be very clear to you.

(1) $393^2 = 393 \times 393$

$$\begin{array}{r} \log 393 = 2.5944 \\ 2 \\ \hline 5.1888 \end{array}$$

N = 154500

(3) $25^3 = 25 \times 25 \times 25$

$$\begin{array}{r} \log 25 = 1.3979 \\ 3 \\ \hline 4.1937 \end{array}$$

N = 15620

(2) $\sqrt{53000}$

$\log 53000 = 4.7243$

$4.7243 \div 2 = 2.3621$

N = 230

(4) $\sqrt[3]{15620}$

$\log 15620 = 4.1937$

$4.1937 \div 3 = 1.3979$

N = 25

THE PRINCIPLE OF THE SLIDE RULE

The slide rule is the most commonly used labor saving device for mathematical computations involving multiplication and division. The underlying principle of the slide rule is the logarithm and the operation of a slide rule involves merely the changing of the position of one logarithmic scale with respect to another logarithmic scale.

You are familiar to some extent with logarithmic scales for you have seen characteristic curves of receivers plotted logarithmically. You will have noted too that on a logarithmic scale, the divisions become smaller from 1 to 10. That is, from 1 to 2 is a larger division than from 2 to 3, while the division between 9 and 10 is the smallest of them all.

Two logarithmic scales are shown in Fig. 1. They can be considered as replicas of two logarithmic scales on a typical slide rule. Now, since it is possible to multiply two numbers by adding their logs it is obvious that if we set the slide rule so that the logarithmic scales are placed as shown in Fig. 2, we can multiply any number up to 5 by 2 and obtain the product simply by referring to the multiplicand in the upper scale and reading the product on the lower scale.

If we wanted to multiply numbers larger than 5 by 2 we would place the scales as shown in Fig. 3 and follow the same procedure.

Suppose we wanted to multiply 3 by 2. On the upper scale in Fig. 2 we would locate the number 3 and the product would be indicated directly below it on the lower scale. Likewise if we wanted to multiply 2×9 we would place the scales as shown in Fig. 3. Locating the 9 on the top scale we would read 18 on the bottom scale.

Stated very briefly, the process of multiplication with a slide rule is as follows: Set the number 1 of the upper scale over the multiplier on the lower scale, locate the multiplicand on the upper scale and read the product directly on the lower scale, below the multiplicand.

We can move the upper scale either to the right or the left, using the left hand 1 or the right hand 1 (10) as the index, depending on which is the more convenient.

By using the various subdivisions we can multiply larger numbers. Suppose we want to multiply 78 by 23. We move the upper scale to the left until the right-hand 1 is over 23 on the lower scale as shown in Fig. 4. Then locating 78 on the upper scale we read the product on the lower scale and we find it to be 1795. If we multiplied this out by longhand we would get the product as 1794. In practice, 1790 would be close enough as accuracy to three places, that is, to within 2 per cent, is sufficient.

Of course the slide rule does not tell us how many places there are going to be in the product, or if we are dealing with decimals it does not tell us where the decimal should be placed in the product. We must determine the number of places or the position of the decimal by inspection. When multiplying 23 by 78 for example, we can see at a glance that the product will be above 1000 and below 10,000 for $20 \times 70 = 1400$. In a later chapter we shall learn more about decimal location, etc., by inspection.

Division by means of a slide rule is just as simple as multiplication. The process is essentially one of subtracting. We use the same scales as in multiplication.

In dividing we position the upper scale so that the divisor is directly above the dividend and read the quotient on the lower scale directly under the index 1.

Suppose we want to divide 3 into 6. We place the 3 of the upper scale directly above the 6 of the lower scale. Then under the index 1 we read the quotient on the lower scale which is 2. We would divide 300 into 600 or 3,000,000 into 6,000,000 in exactly the same way. Or we could divide 30 into 6,000,000 in which case we would have to determine the number of zeros in the quotient by inspection.

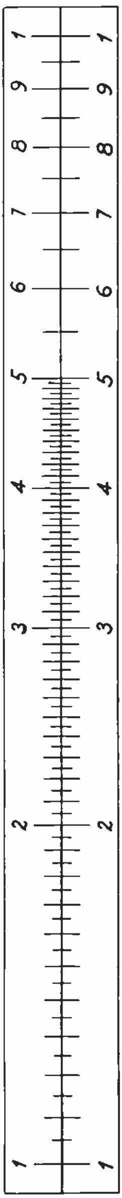


FIG. 1

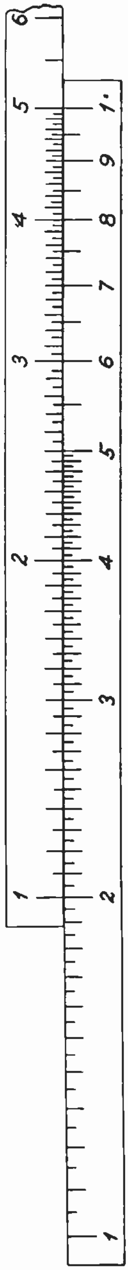


FIG. 2

FIG. 3

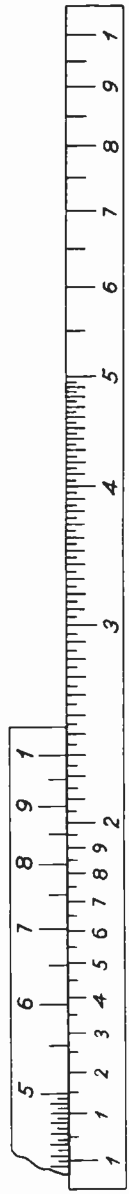


FIG. 4

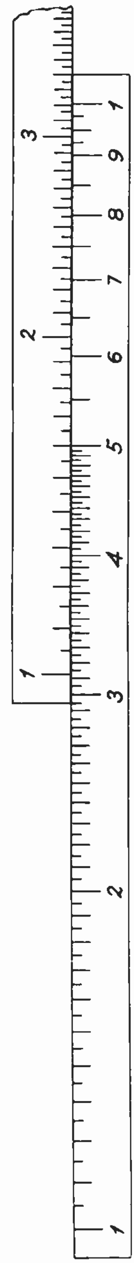


FIG. 5

Let us take a slightly more difficult problem such as the one we worked out by long division in a previous chapter. The problem is to divide 969,409 by 31. We locate the divisor 31 on the upper scale and move it directly above 969 on the lower scale as in Fig. 5. Notice that we disregard the last three figures as insignificant. We now read the quotient directly below the index 1, on the lower scale, and we find it to be slightly less than 313. By inspection we know that the quotient must be between 10,000 and 100,000, therefore we add two zeros to 313 to get 31,300. If we were dealing with money, of course this would be too inaccurate. There would be too much difference between $31,300 and $31,271.26, but in Radio and for most practical purposes, the answer as given by the slide rule will be close enough.

LOCATION OF DECIMALS BY INSPECTION

When using a slide rule, the only way of finding out how many places there will be in the answer, or where the decimal point belongs, is by inspection. We shall consider briefly inspection in multiplication and division.

Inspection in multiplication. Consider 3856×4.414: Inspection will show that the answer will contain five whole figures, for the answer will be a little more than 4×3856. Thus, 3856×4.414 gives 17,030.

Consider 3856×441.4: Think of the number as being multiplied by 4 with the decimal moved two places to the right. Then, the number multiplied by 4 will give five figures, plus two ciphers which will give the answer in 7 places. Thus, 3856×441.4 gives 1,703,000.

Consider $3856 \times .0004414$: Think of the number as being multiplied by 4 with the decimal point moved 4 places to the left. Then the number multiplied by 4 will give five figures but with the decimal moved 4 places to the left. Thus $3856 \times .0004414$ equals 1.703.

Inspection in division. Consider the fraction .3856/4414: Think of the denominator 4414 as having the decimal after the first figure. Then, move the decimal point in the numerator the same number of places in the same direction. Making the above mental operations we think of the denominator as having the decimal after the first figure, thus 4.414, and then moving the decimal point in the numerator three places in the same direction, we have .0003856/4.414, where we see that 4 will go into the numerator about .00009. The correct answer is .0000874.

Consider the fraction 38.56/.0004414: We have, by placing the decimal mentally in its proper place 385600/4.414, where we see that 4 will go into the numerator about 90,000 times. The correct answer is 87,400.

SIGNIFICANT FIGURES

In the previous chapters we frequently mentioned significant figures and it was stated several times that a result that was accurate to 3 or 4 places was sufficiently accurate for most practical purposes.

It must not be thought from this that radio engineers and engineers of all other kinds are careless or are willing to sacrifice accuracy for convenience.

The true justification of this simplified method of computation is to be found in the fact that beyond a certain point the numbers represent such small values that they are insignificant. There is a very homely example which will serve to illustrate this nicely—suppose you had $10 and you wanted to divide it into 3 parts. Let us say you wanted first to calculate the value of each part. You would divide 3 into 10 and get $3.33. You could keep on dividing and get 3.333—and an infinite series of 3's if you wanted to but there would be no point to it for any number of 3's you might add to $3.33 would not affect the $3.33.

In this case the significant numbers are limited to those which have their counterpart in dollars and cents, that is, they are limited by the practical consideration of our system of money.

In Radio our limitations are still greater for they are imposed by the accuracy of electrical instruments which are seldom accurate to more than 5 per cent. Suppose we had a 45.7 ohm resistor as measured by a high grade ohmmeter and with a precision ammeter we discover that 3.16 amperes of current were flowing through the resistor. To find the voltage we will multiply 45.7 by 3.16. If we worked this out arithmetically we would get 144.412 volts. But no voltmeter designed to read more than 100 volts would indicate differences of thousandths of volts. In fact, it would take a very good voltmeter to read 144.4 volts. Therefore, the last two figures are insignificant and for practical purposes 144.4 is as correct as 144.412 volts.

Let us take another example—suppose we used a Wheatstone bridge to measure the resistance of a resistor and found it to be 45.72 ohms. Then suppose that the current through the resistor fluctuates but we read an average value of 3.2 amperes. The voltage will be 3.2 $\times$ 45.72 or 146.304 volts—if we worked it out the long way. But 146 volts would be just as accurate—first because any voltmeter we might use to check our calculations would not give a reading containing six significant figures and second because the voltmeter reading would not be constant as the current is not constant. The chances are the voltmeter reading would vary between 145 and 147.

A general rule that it is always safe to follow is that if two numbers are multiplied or divided or added, the answer should contain as many significant figures as the least accurate number. In the example just given, 3.2 amperes is rather inaccurate so that even though the value of the resistance is known quite accurately, our result can't be entirely accurate and 3 or 4 significant figures will be as close as we need ever come.

In general radio calculations only three significant figures are considered. Thus in calculating, we would substitute 39600 for 39607; .217 for .21653, etc.

PRACTICAL SLIDE RULE CALCULATION

A typical commercial slide rule is shown in Fig. 6. It is known as the Polyphase (Manheim) Slide Rule and is manufactured by Keuffel & Esser, 127 Fulton Street, New York City.

You will note two upper logarithmic scales, A on the rule and B on the slider; also two lower scales, C on the slider and D on the rule. The glass with a vertical engraved line through the center is known as the runner. A little later we shall see how it is used. Between the B and C scales on the slide there is a "CI" scale, known as the inverted C scale. Below the D scale we find another scale marked K, used with the D scale to find cubes and cube roots. The slider has three scales on the reverse side which may be observed in the actual rule by pulling out the slider. These scales are marked S, L, and T. They are used with the top scales for calculations involving sines, logarithms and tangents.

Suppose we wish to multiply 78 by 23. We shall use the C and D scales. Set 1 on the right-hand* end of the C scale above 78 on the D scale; move the runner so that the cross hair

* If the left-hand 1 of scale C is used, as would appear natural at first, reading under 23 on the D scale would be impossible. By using the right-hand 1 of the C scale, we are in actuality placing a second D scale after the first.

is at 23 on the C scale, the answer is read on the D scale, 1,795.

To simplify multiplication the CI scale is used. Again multiply 78 × 23. Set the runner on 78 of the D scale, move the slider until 23 on CI scale is on the engraved line of the runner. Read the answer below 1 on the C scale—either the right or left hand will indicate the answer. It makes little difference whether 78 or 23 is used on the D scale.

Squares and square roots may be found by use of the runner alone. To find the square of a number, locate the number on the D scale with the cross hair and read the answer directly on the A scale. For example, setting the cross hair on 4 of the D scale, we find that the square is 16. Again, the square of 8 is 64. Note that the numbers mentioned here might be 8, 80, 800, etc., and the squares would be 64, 6,400, 640,000.

Note that the A scale is really two log scales exactly alike and we may call the left scale A1 and the right scale A2. In finding the square root of a number, arithmetically, we divide the number into groups of two figures each from the left and

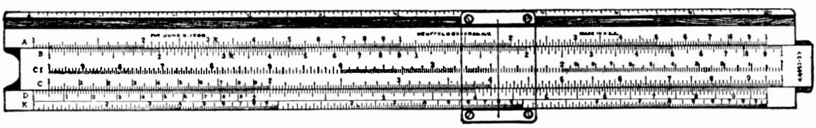


FIG. 6

right of the decimal point. For example 25′00, 6′72, 97′40, 5. In determining whether the A1 or A2 scale is to be used, we only consider the number in the first group, that is, 25, 6, 97, 5. When there are two figures, use A2—when only one, use A1, thus 25 (A2)—6 (A1)—97 (A2)—5 (A1).

To find the square root of 25′00, set the cross hair on 25, on the A2 scale, locate the answer 5 on the D scale. The actual answer is 50.

If we wanted to find the square root of a decimal, we would proceed as before, to divide our number into groups of figures from the right of the decimal point, thus .00′36. Rule: If the first group containing digits, after the ciphers, contains one or two such digits, we use A1 or A2, respectively.

Our number contains 2 digits in the group after the zeros and therefore we locate 36 on the A2 scale. The answer 6 is found on the D scale, directly underneath. Our problem was the square root of .0036, therefore the answer is .06.

To find the cube of a number, set the cross hair at the number on D, and read the cube directly on K. The cube of 4 is 64; again the cube of 8 is 512.

Note that the K scale consists of three identical log scales, referred to as K1, K2, K3, reading from left to right. Again we will use a rule to determine which to use when finding cube roots. Rule: For numbers greater than 1 begin at the decimal point and mark off the number into groups of three figures. If the last group contains one, two, or three figures, we use K1, K2, or K3 respectively. To illustrate, let us take the number '216. This number contains 3 figures, so we use K3. Setting the runner and cross hair on 216 of K3, we read 6, directly above it.

If the number is a decimal we group the numbers in threes, beginning from the decimal point and working toward the right, thus, .008'. Rule: If the first group containing digits after the ciphers contains one, two, or three such digits, use K1, K2, or K3. Our number contains one digit, 8, after the ciphers so we use K1, and find the cube root on the D scale is .2.

THE LANGUAGE OF RADIOTRICIANS

2X

REFERENCE BOOK

NATIONAL RADIO INSTITUTE
EST. 1914
WASHINGTON, D.C.

MENTAL COURAGE

People fear most the things about which they know the least; in ancient times an eclipse of the sun was often an occasion for great panic, for nothing was then known about the paths of the sun, moon and earth through space. Mental courage—that hard-to-define characteristic which makes a person forget his fears, is one of the most valuable assets you can have.

A lad of eight was overheard discussing arithmetic with a friend. Said Johnny: "Teacher's gonna start us on subtraction tomorrow; wish I could stay home." But Harry answered: "Aw, I've had that and it's easy; what I'm worrying about is multiplication!"

Each time you open a new lesson, call upon *your* mental courage; start that lesson with the firm conviction that it will be interesting, valuable and easy to master. Do not allow yourself to become discouraged by new subjects, and do not worry about little difficulties which come up when you read through the lesson for the first time. Lessons in this Course each contain so much material that it is practically impossible to know everything after a single reading; if you have the mental courage to read through a lesson that first time without fear, you, too, will soon be saying, "Aw, that was easy!"

J. E. Smith.

WASHINGTON, D.C.

1941 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)

JD6M1240

Printed in U.S.A.

AN IMPORTANT MESSAGE FOR THE READERS OF THIS REFERENCE BOOK

Of course, you want to talk the language of radio men. Yet, I feel sure, you do not expect to be a trained Radiotrician until you have mastered more than half of this Course.

But most of my students are anxious to learn early in their training the special means employed by radio men to express radio ideas. They want it in a condensed form, just as it is given in this reference book.

If you try to master the contents of this book the first time you read it, you may be disappointed. Some of the ideas are elementary, some are advanced. Yet, if you follow my recommendation of reading this book early in the Course, that is with the first five lessons, and again when you study lessons 10, 15 and 20, the facts that were not understood the first time will become clearer the second or third or fourth reading.

When you finish the fundamental Course a final reading of this reference lesson will surprise you. Then you will understand and talk the language of radio men, as presented in a condensed form in this reference text.

J. E. SMITH.

The Language of Radiotricians

RADIO HAS A SPECIAL LANGUAGE, TOO

Like the doctor, the plumber, the mechanical engineer, radio men have a special language, which is a great aid in explaining and discussing problems pertaining to their field. And what does a radio technician talk about—radio apparatus and radio devices, particularly their appearance, their action or behavior, and how they work with other radio parts, that is, how radio circuits behave.

If you or I happen to see a piece of radio apparatus or a new radio set for the first time, and are fortunate enough to be with some one who is thoroughly familiar with its construction, it is perfectly possible for him to point to this or that section and tell us what it is called and what is its purpose. He could explain in words or in gestures how this or that device works. Should the action be a little complex, he would naturally draw or sketch the various sections schematically (in suggestive form) with a pencil and paper; and with this sketch he could explain in a better way how it works. All this is rather common, and no doubt the actual operation of many new things has been explained to you in this way.

If one of the actions is of a common nature, the person describing the new piece of apparatus will refer to it by the commonly accepted name. Let us consider an example that you are no doubt familiar with—a carpenter's or claw hammer. As you know, it has a striking head, a claw and a handle. In referring to the action of a hammer, I could say that a nail is driven in by the *impact* of the head; that a nail is drawn out of a piece of wood by the *leverage* afforded by the claw and handle. To one not familiar with the meaning of the word "impact," perhaps the explanation that it is the *blow* of the hammer will help explain what is meant. But that is not a thorough technical explanation. I must resort to the use of other explanatory words, namely to the *mass* (weight) of the hammer head, the ability of the head to resist a change in shape under force (called its *elasticity*), and the speed (or velocity) imparted to the hammer head by its user. It is both the velocity and the mass that determine the impact of the hammer. However, in comparing the effectiveness of various hammers, I am compelled to resort to a little arithmetic to express their mass (or weight) and the speed imparted to this solid mass as numbers. By comparing the mass (or weight) we are able to understand which hammer is best for driving large or small nails. Of course, you know that hammers are selected as to weight—a 9 ounce hammer head being a medium sized hammer. With this simple example in mind, let us turn to our own needs in teaching and learning radio.

In teaching radio to you, it will be a considerable help to refer to a reproduced photograph (an *illustration*) of the part you are studying. This will give you a general idea of its appearance. But in many radio parts, the important sections are concealed (out of sight) and a special *sketch* or drawing will make it easier for you to learn what actually exists. Rarely in radio is a part by itself of any great use—for many pieces of radio apparatus are electrically connected together to give a working unit, a radio circuit. If you and I had to draw detailed sketches of the parts used and then show how they were electrically wired, the task of teaching, explaining or even studying would be made extremely cumbersome and difficult. So to make it easier, we represent this and that radio part by a simplified sketch (or *symbol* as it is called) which can be quickly and easily drawn, and which has the power to make us imagine the real piece of apparatus that it represents. A drawing of a radio circuit using symbols to suggest the parts, and lines to represent the electrical connections, is called a *schematic circuit diagram,* or briefly the circuit diagram or schematic diagram.

Indeed, from a radio technician's point of view the circuit diagram is one of the most important aids in understanding radio. We may trace the flow of an electric current, the location of the effective voltages, or the behavior of the electron as influenced by the parts. In addition to symbols and lines to represent electrical connections, little arrows, letters and numbers are used, so that it may be explained that "electrons at point *A*" are doing this or that, rather than some expression as "the electrons existing in the circuit near the surface of the plate."

But when we come to analyze the action of a circuit or a radio part, we immediately want to know *how much* of the action, or *how much of the action in comparison to some other condition* exists. Then we must turn to arithmetic, which you know deals with numbers. In this lesson I want to review a few simple facts regarding this idea of "how much," facts which I feel sure you are already familiar with; for I want you to get my "slant" on the subject. When we compare and study actions we will find the *table,* the *graph* and the *formula* of considerable help.

One more tool (aid) in studying radio is *time*—an important matter, because radio and signal currents are really varying currents, meaning of course, varying from instant to instant. This action may be represented as a *curve,* which is easily obtained in a laboratory with a circuit eye, called an oscillograph. As the shape of the curve is important, we must understand how it is drawn. The curve obtained is called a wave form.

You have already studied two lessons of the course, and many of these "aids" or "tools" have been used. No doubt you have noticed how the use of the "Language of Radiotricians" gives you a definite, clear mental picture of some part or its action. Remember this, *you* do not have to use all of these aids in practical work, but I am including them here and there in the course to help you round out your training. Even "figuring" can be eliminated from practical work, for I will show methods whereby computation may be eliminated entirely.

Of course, you want to learn rapidly and thoroughly; also I want to make this course as easy for you as I can. We can do this if you learn the "Language of Radiotricians." Read the remainder of this book carefully, as I am going to explain these important subjects. After lessons 5, 10, 15 and 20 read this text-book again. Gradually its purpose will have the desired effect, and the "Language of Radiotricians" will become your language. You should not expect to thoroughly understand all that is in this reference book, until you have almost finished your fundamental course.

ILLUSTRATIONS, SKETCHES, SYMBOLS

Most radio men get their first contact and impressions of new radio apparatus from illustrations in radio magazines, and in jobbers' or manufacturers' catalogs. From constant inspection of radio receivers and transmitters they are quite familiar with existing equipment, and by tying the two together they clearly see the changes or improvements in the new parts. As a matter of fact, I study the advertisement sections of radio magazines, and every catalog or piece of descriptive literature on radio equipment that comes to my desk. I go "window shopping" along radio row and inspect all new apparatus as it appears in the window display. Thus I keep abreast of radio developments. You too should do likewise. Perhaps because of your location only the local radio store will be your contact with new apparatus, but the radio magazine, and the radio mail order catalog will do wonders in acquainting you with modern equipment. Your lessons with the many illustrations will have the same purpose; your home experiments will bring you in working contact with the more important radio devices and circuits. Study carefully the radio receiver in your home, so the various standard parts are easily identified.

Of course, the reproduced photograph (the illustration) of a radio part only gives you a general idea of its construction; in fact, only the outside appearance of the part. Perhaps the illustration is not as clear as it should be. To help members of the radio profession (the buyer) get a better idea, the maker often makes a line drawing of the part. Let us take a typical example, the metal radio tube.

Figure *1A* is an illustration of a metal radio tube, one in which the glass has been replaced with a special steel alloy shell and painted black. Clearly it presents the general appearance of the tube. With this illustration alone, you would have no difficulty in recognizing other metal tubes. Other than allowing you to see what its general appearance happens to be, it gives no useful information—tells you nothing of what is inside or how it is assembled. You are not even told how large it is, but a line drawing, as shown in Fig. *1B*, will give this additional information. The important dimensions are given;

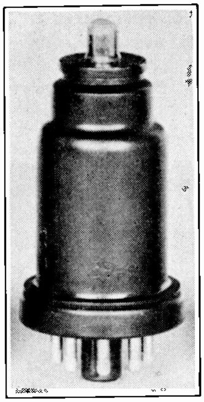


FIG. 1A

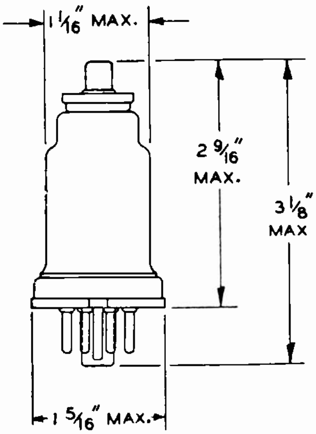
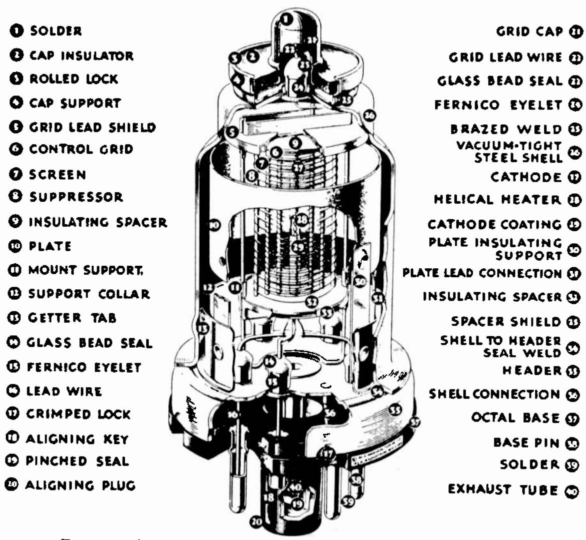


FIG. 1B

for example, the fact that the longest dimension is $3\frac{1}{8}$ inches maximum, and the largest width or diameter is $1\frac{5}{16}$ inches maximum, etc. So if you were to design a radio receiver you would know how much space must be allowed for this tube. You learn at once, how much larger or smaller it is in comparison to other tubes with which you are familiar. You recognize that this metal tube, like other tubes, has a top (cap) connection and a number of pin or prong (bottom) connections. They are the terminals of the working parts inside the tube.

But what is inside? Many manufacturers cut their products through the center or some other section and take a photograph for purposes of illustration. Unfortunately, such illustrations are not as instructive as the "exploded sketch" shown in Fig. *1C*. Notice how much detail can be presented by a skilled artist—the tube manufacturer in this case went to a lot of trouble and expense to show the internal construction of his metal tube. Each part is clearly shown and numbered. And for those not familiar with this tube a special list for reference is given. After you master the basic principles of the vacuum tube, given later in the course, this reference list will be of great help.

The radio vacuum tube is a very important device in a radio circuit, and when drawing radio circuits, it would be cumbersome and even confusing to draw a sketch of the tube as in Fig. *1C*. Very few of us, even if we were able, would care to draw it in this manner. After you understand how the vacuum tube is constructed, and how it works, a simpler sketch will do just as well. You will learn, for example, that in a simple amplifying radio tube, the *filament* which heats the



Internal structure of an all-metal radio tube.
(Courtesy RCA Manufacturing Company)

FIG. 1C

cathode, the *plate* which attracts the electrons emitted from the heated cathode, and the *grid* which controls the flow of electrons are the important parts of a vacuum tube. In fact, radio tubes consist essentially of one or more filaments, cathodes, grids and plates; and, in presenting a simple sketch (in a symbolic manner) only those parts are drawn.

Figure *2A* represents a simple amplifying tube in a *symbolic* manner. Observe how the various elements are drawn. In this sketch I have identified each of the tube elements, but remember that in a practical drawing this procedure is often omitted. In some cases the terminals are lettered; *H* for heater or filament, *K* for cathode, *G* for grid, and *P* for plate. Usually even these indicating letters are omitted, and without any confusion, if you learn to recognize the significance of each part of the symbol. The tube shown in Figs. *1A, 1B* and *1C* is shown in Fig. *2B* in a symbolic manner. Quite obviously it is much simpler a presentation, and more readily understood. This tube as shown in Fig. *2B* has three grids marked G_1, G_2 and G_3. One of the grids is connected to the top connection (see Fig. *1A*) and this is shown in the symbolic sketch by the little rectangle at G_1. Furthermore, the metal envelope has a terminal marked *S*, and as you will later learn, the metal envelope acts as a blocking device (shield) for electrical interference, as well as a shell (or envelope) to keep out the air.

Now all tube symbols are not drawn in the orderly manner that characterizes the symbols shown in Figs. *2A* and *2B*. These are rather recent standard procedures. Figures *2C, 2D, 2E* and *2F* show alternate methods of drawing the tube indicated in Fig. *2A*. Notice particularly that in Fig. *2F* the envelope is omitted. Sometimes symbols are drawn the way shown in Figs. *2C* to *2F*, because it simplifies a circuit diagram, other times because the engineer or draftsman has gotten into the

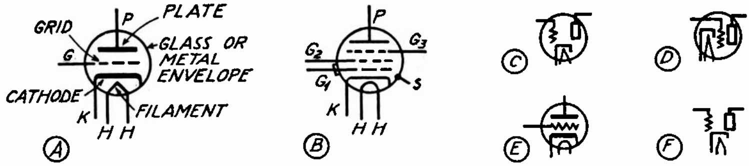


Fig. 2

habit of drawing them this way and has not bothered to change. As you must be familiar with all forms, I will use all of them in the following lessons.

One more example of the power of a symbol to represent a radio part. Figure *3A* is an artists' sketch of an amplifying transformer giving a general idea of its appearance. To give you more information of the inside of the device, an exploded view of this transformer is shown in Fig. *3B*. This sketch shows the core, the primary and secondary windings. But, see how Fig. *3C* simplifies the transformer insofar as electrical details are concerned. One curl represents the primary (*P*), one the secondary (*S*) and the parallel separating lines represent the steel core. Special connecting instructions may be indicated on the symbol; for example, to indicate the proper connections for each terminal, letters may be used as in Fig. *3D;* also to indicate that it is a step-up transformer the secondary is represented with more curls than the primary. As a rule the letters are omitted from the symbol, but are marked on the transformer, so the latter may be properly connected.* The reason for this is not difficult to understand. A circuit diagram shows the proper connection but to execute it in a wiring job requires some identification on the device.

In this lesson I cannot enumerate the symbols for all the devices used in radio. As we study the various apparatus used in radio, their

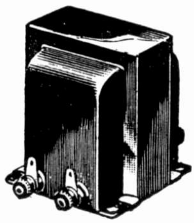


Fig. 3A

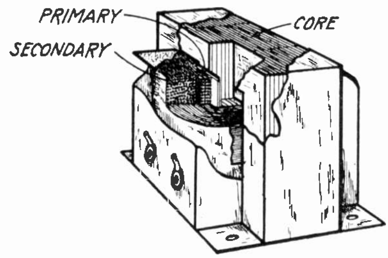


Fig. 3B

symbols will be introduced. In a previous reference text, "Common Radio Terms, Symbols and Abbreviations," scores of symbols are shown. At this time it is important for you to realize that you must master the value and purpose of the symbol; each one suggesting to your mind a real tube, or transformer, or coil, or resistor, or condenser, as the case may be. When you face the practical radio world, a busy

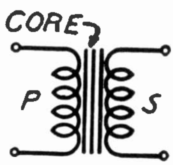


Fig. 3C

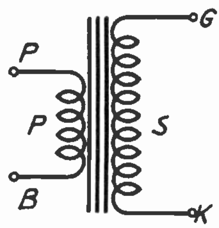


Fig. 3D

radio man is not going to draw picture diagrams for you, nor should you expect them. Realize that set makers are not going to draw picture diagrams for you—so learn this part of your profession.

A CIRCUIT DIAGRAM IN SYMBOLIC FORM

A practical example of how a circuit diagram in symbolic form makes for clarity and greater simplicity is worthy of special attention at this time. As every A.C. operated radio receiver must have a power

* In some cases the leads from a radio device are colored to help identify them.

converting system which will change 110 volt alternating current (A.C.) socket power to high voltage direct current (D.C.), I will use this section of a receiver for purposes of explanation. Without going into the electrical means of accomplishing this conversion of electric power, I am simply going to state that the apparatus needed is shown in Fig. *4A*. Each part is clearly shown, a letter with or without a subscript being included for purposes of abbreviation and reference. Thus *T* denotes a rectifier tube; C_F is used to indicate a special kind of condenser, a filter condenser. Although, either letters or numbers may be used for identification, they are more often omitted. In Fig. *4A,* the lines indicate connecting wires. Note especially how *a connection* and *no connection* are shown. This is the customary practice. Observe that the reference letters and the subscript are chosen so they suggest the name of the part. This is done to quickly suggest the name of the part indicated.

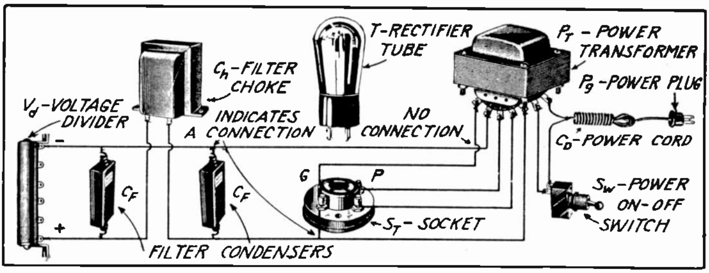


FIG. 4A

Clearly if you were to assemble the radio parts shown in this power converting system you would have no trouble in connecting them. After all, everything is presented in picture form and what could be more obvious? But, as a practical radio man, you will not get picture diagrams, except in very rare cases. Only manufacturers who make parts specifically for beginners go to this trouble. They do so to simplify showing you the exact connections to the parts, and not the circuit for purposes of analysis. In practically all other cases you will receive a symbolic circuit diagram.

Figure *4B* shows the same circuit in symbolic form. By means of the reference letters it is possible to compare the symbol of each part with the picture of the part shown in Fig. *4A*. Observe how simple the schematic (symbol) diagram becomes. I can, and I feel sure you will be able to, draw the symbol diagram in a few minutes; but the picture diagram is beyond my ability, in fact it took an artist many hours to draw it. Radio men live in a world of schematic diagrams—

no wonder they object to drawing picture diagrams. Why should they, when the schematic means just as much or even more to them? * And it will to you, if every symbol produces in your mind a mental picture of the real part, and it may be any one of many different makes and designs.

Learn to appreciate the importance of the schematic circuit diagram; learn to read it as you would a book written in the English language. Your course has this as one of its major purposes.

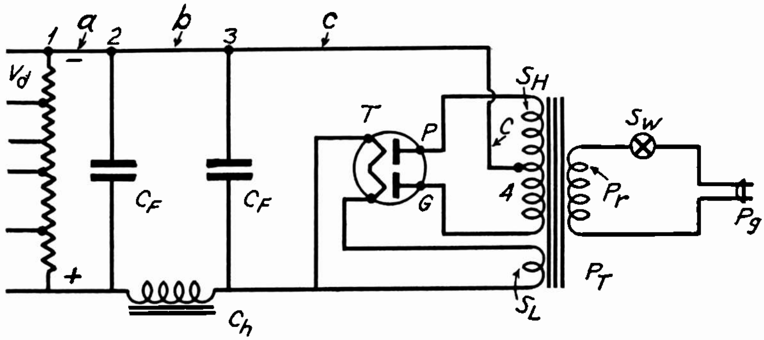


Fig. 4B

A VACUUM TUBE EXPERIMENT

Now, I want to explain how the *behavior* of radio circuits is best presented for a clear understanding. In particular I want to show the use of the *table*, the *graph*, and the special value of simple *arithmetic*. To do this in a practical way, I want you to consider with me a simple vacuum tube experiment, one that you could easily duplicate if you wanted to. Figure *5A* expresses in a schematic or symbolic manner an experiment intended to show how a simple radio tube behaves when the voltages required to make it work as a useful radio device are changed. You are familiar with some of the symbols, the new ones are explained in Fig. *5B*. Notice particularly that an electron generator (a source of voltage) is represented by short and long parallel lines. Batteries are electron generators, or a voltage supply. Usually no attempt is made to indicate how much voltage exists by the number of short and long lines, for the voltage is generally written

---

* Although the schematic diagram shows connecting wires *a, b* and *c* for the purpose of conecting points *1, 2, 3* and *4*, in an actual set-up these wires would not necessarily be used. Any arrangement which would connect points *1, 2, 3* and *4* would be employed regardless of the arrangement of connecting leads. If the apparatus shown in Figs. *4A* and *4B* were mounted on a metal chassis, points *1, 2 3* and *4* would be connected to the chassis, eliminating the need for connecting wires.

in on the diagram. However, the polarity (+ or —) is indicated. The symbol indicated by I_p represents an electric meter which will measure electron or current flow; a similar meter V_L can be obtained to measure voltage. Just now we need not concern ourselves with how they work, but rather realize that they are electrical measuring devices. The lead (or line) with a little arrow indicates that the connection

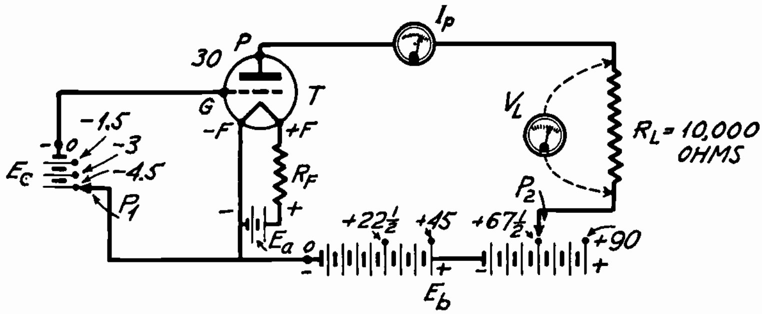


FIG. 5A

can be changed, and in this simple experiment the connections to batteries E_c and E_b may be changed. Dotted lines ending in arrows usually indicate that the connection is only temporary, or in this case for the purpose of measuring voltage only when desired.

In this experiment the filament of the tube is heated by battery E_a, the resistor R_F used so that the current flowing in the filament will be of a desired value (which we could measure with a meter like I_p).

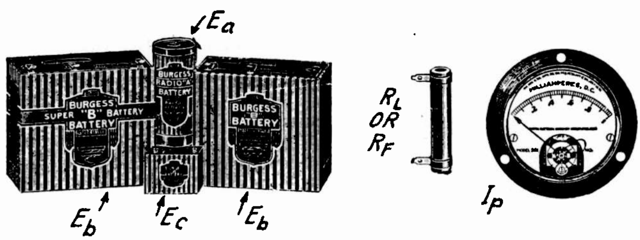
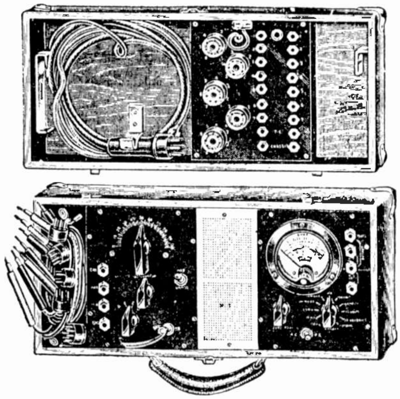


FIG. 5B

When this circuit is connected, electrons are emitted from the filament and are drawn to the plate by the positive charge placed on *P*, the plate, by the battery E_b. Battery E_c places a negative charge on the grid, *G*, and reduces the electron flow from the filament to the plate. As all of the electrons reaching the plate must circulate from the plate through the measuring device I_p, through the resistor R_L, through the battery E_b and back to the filament, the meter I_p measures the plate circuit electron flow (or current). Suppose we were to place variable contact P_1 on the point marked *o*. The grid is then connected directly to the —*F* terminal of the filament; and we connect variable contact P_2 to +*90* of E_b, making the plate 90 volts positive with respect to the —F filament terminal. And with this experiment set up we would probably find that the plate current meter I_p indicated that about 3.5 milliamperes * of current was flowing.



Tool or aid for Servicemen. This tester consists of an all-wave signal generator, a multimeter and a plug-in system. Your course will show and explain how these service tools are used.

TABULATING RESULTS; THE TABLE OF FACTS

If you were doing this experiment, wouldn't you naturally want to know how much plate current would flow if the plate voltage were varied from this initial value of 90 volts? Obviously an answer is quickly obtained by varying the position of P_2 and reading the results on the current meter I_p. In the circuit that I set up for a type 30 tube which I had on hand, I got the following results:

With grid still connected to —F, I found that when:

P_2 was set at +90, I obtained a plate current of 3.5 milliamperes; when

P_2 was set at +67½ volts, I obtained a plate current of 2.4 milliamperes; with

P_2 set to 45 volts, 1.4 milliamperes was obtained; with

P_2 set to 22½ volts only .5 milliampere existed; and when the plate was connected to the —F terminal no perceptible current existed.

---

* An ampere is a unit of measuring electric current. When we deal with small current flows, the unit milliampere is used. One milliampere is one ampere divided by 1,000; or there are 1,000 milliamperes in one ampere. A 110 volt, 50 watt light bulb such as you use in your home draws about one-half ampere when turned on. This is equivalent to 500 milliamperes.

You must admit that this is a rather cumbersome way of presenting the results. You might ask—is there a simpler way of presenting these facts? Why not list them in two columns so we can readily visualize the conditions. For example thus:

E_b (volts)	I_p (ma.)	
90	3.5	
67.5	2.4	
45	1.4	
22½	.5	
0	0	When $E_c = 0$

To make this presentation complete, I have written E_b (volts) above the voltage column so any one would know that I was measuring the battery electron generator in units of volts; I_p (ma.) on the other column to show that the current was measured in milliamperes (ma. is the abbreviation for milliamperes); and somewhere on the list I place the information that the grid was at zero potential ($E_c = 0$) with respect to the —F terminal; for perhaps if it were some other value these facts would not be obtained.

Such a presentation is referred to as tabulating the facts, and this listing is simply called a *table.* See how much easier it is to visualize what has taken place, as the plate voltage is varied. Tabulating facts is a very common means of expression and we see tabulated facts constantly in our daily newspapers.

A GRAPHICAL PICTURE OF THE FACTS

But there is a better way of presenting the facts given in a table—a graphical or picture presentation. There are several ways of showing these facts in a graphical manner, but in radio, as in any engineering field, there is a very definite procedure. Therefore, I will only show you the method that is important to you as a radio man.

Let us get down to "brass tacks" and master this procedure with the least possible explanation. Suppose we were to have a rectangular field or lot as shown in Fig. *6*. Suppose you were standing in the lower left corner, position *a,* and I were to say: "Walk 3½ paces east and then 3 paces north." Obviously you would have no trouble in carrying out my request, and you would be located at position *b*. On the other hand, assume that a creek passed through point *b;* and *a* was the position of a small dam. Clearly I could tell you the way the creek ran with respect to east and north by pacing off various points of the creek with respect to point *a*, the dam. For example, location *c* on the creek is 2 paces east and 2 paces north with respect to *a*.

In presenting radio or engineering facts in a pictorial manner, we use the same procedure, except the information is put on paper. Technicians usually procure a sheet of paper called rectangular field or plotting paper, as shown in Fig. 7.* With this special ruled paper the paces or distances to the east (or direction *o* to *x*) and the paces north (direction *o* to *y*) are on the paper. Instead of representing paces, suppose we say that each marked off distance from *o* to *x* represents

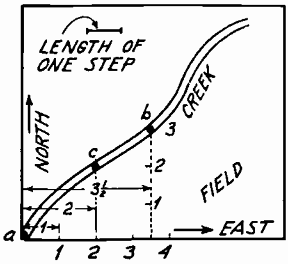


FIG. 6

20 volts; that each measured space from *o* to *y* represents 1 milliampere. Hence each distance between a solid line and a dotted line in the direction from *o* to *x* represents 10 volts; and of course we can easily see that this space may be divided into 10 parts so each very small distance will represent 1 volt. Usually the latter step is not taken as with a little experience you can imagine the division. Suppose each large division from *o* to *y* represents 1 milliampere, hence each subdivision (the distance between a dotted line and a solid line) will represent .5 or ½ a milliampere.

With the special plotting paper shown in Fig. 7 it is a simple matter to express the information given in the previous table in a graphical manner. For each test or set of conditions a dot or a cross is placed on the plotting paper. For example, dot *a* represents the condition for 90 volts on the plate and 3.5 milliamperes of plate current; dot *b* represents the condition for a plate voltage of 45 volts and a plate

* In making graphs for the lessons in this course, the artist draws this plotting paper.

current of 1.4 ma. Each point is located in a manner similar to the following one. With your pencil move from *o* to *x*, a distance representing 90 volts (position *Z*); then go vertically up for a distance representing 3.5 ma., and point *a* represents graphically this condition.

Then the points are connected by a smooth, regular line or rather a curved line passing as near as possible through all these points. Line $o \rightarrow b \rightarrow a$ is such a curve. Points *o*, *b* and *a* represent only definite conditions, the curve represents any number of conditions. From the curve it is possible to tell how much current will flow if some voltage other than the one used in the experiment is employed. For example, what current will flow if a voltage of 60 is used? Locate point *s* directly above 60 (meaning a distance representing 60 volts), and estimate by means of the special ruler or scale on the left how many milliamperes

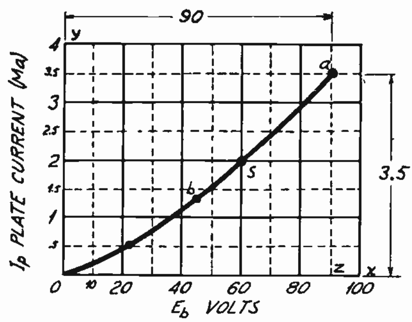


Fig. 7

this distance represents. Clearly it is about 2 milliamperes. This can be repeated for any other voltage; or you could use this graph, as it is called, to determine how much plate voltage would be required to get 3 milliamperes to flow. From the graph I get 80 volts approximately.

THE FAMILY OF CURVES

Let us return to our vacuum tube experiment. The behavior of the tube was determined for a condition of no voltage on the grid. Again we might ask what would we find if the grid were charged —1.5, —3.0 or —4.5 volts with respect to the —F filament terminal. If the apparatus is set up it is a simple matter to set P_1 to position —1.5 and repeat the test, that is vary the plate voltage and record the corresponding currents. Then the experiment is repeated with P_1 on —3.0, and finally on —4.5. Again we record the information in tabular form.

To have a complete presentation for all values of grid voltage let us prepare a composite table thus:

	I_p in milliamperes when:			
E_b	$E_c = 0$	$E_c = 1.5$	$E_c = 3.0$	$E_c = 4.5$
90	3.5	2.8	2.1	1.4
67.5	2.4	1.7	1.1	.5
45	1.4	.8	.3	0
22.5	.5	.1	0	0
0	0	0	0	0

Observe that considerable information has been tabulated in a compact and concise form. Again this information, indicating what exists under definite conditions, may be presented in graphical form, enabling us to visualize conditions to a greater degree. Rather than plot the information on four separate graph papers, why not show them on a single graph sheet, as I have done in Fig. *8?* Notice how I identify the various curves, so there will be no confusion. This sort of presentation is extremely useful, more for the designer than the service man. He can determine any condition for the tube even if he did not make measurements at the condition in which he happens to be interested.

Suppose you want to reproduce the condition presented by point *A* in this group of curves, a condition where 60 volts is applied to the plate, and 1.7 milliamperes flows. This condition can only exist if the grid is properly charged. Apparently point *A* is about one-half way between the curves marked $E_c = 0$ and $E_c = 1.5$; so *A* must be for a mid-value grid charge, about —.75 volts. In fact we could predetermine what set of conditions would exist if the grid were charged to —.75 volts by drawing an imaginary curve (dotted curve) half way between $E_c = 0$ and $E_c = 1.5$ curves. We could do this for any value of E_c from 0 to —4.5. Clearly, this *family of curves* as they are called, allows us the widest possible analysis of the behavior of the tube, more than we could determine from a table or an experimental set-up. Graphical analysis or study of electrical and radio conditions is a powerful language for the radio man—no wonder he uses it so much.

Let me make this point clear. As a radio service man you are not expected to draw or plot curves. They are not necessary. But to help me explain various radio actions, curves are mighty useful. Many testing instruments like signal generators used by service men are supplied with a family of curves for purposes of adjustment, so the ability to read curves is important. Of course, if you plan to design radio equipment, curves and graphical charts are indispensable. In this course a number of curves will be shown, but only to allow me to make it easier for you to study and learn.

ARITHMETIC AS AN AID IN RADIO—FORMULAS

Let us return to the schematic or symbol circuit diagram shown in Fig. *5A*. There are many things about this circuit that can be deter-

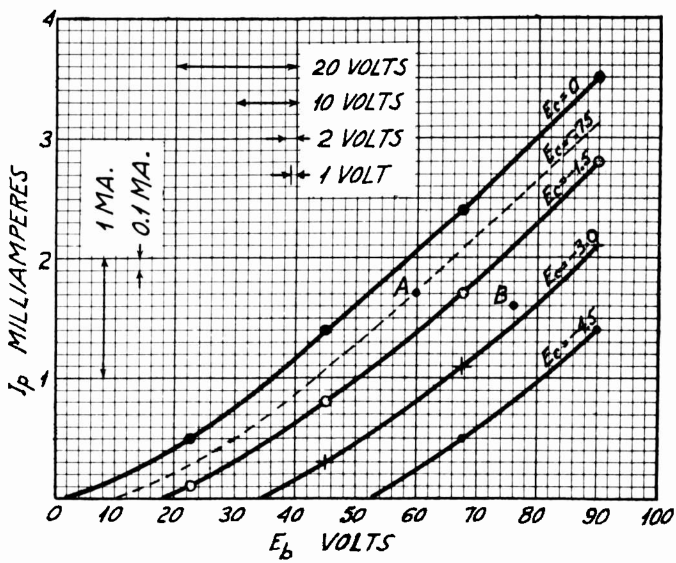


FIG. 8

mined from this figure and the family of curves given in Fig. *8*, if we are willing to employ a little elementary arithmetic, such as is taught in the primary and grade schools. Although you will rarely have to compute anything when servicing a radio receiver, I will have to make simple calculations in these lessons in order to make clear certain ideas that I want you to understand.

For example, in Fig. *5A* we might ask ourselves this question. If the tube is used as an amplifier, how much will the voltage across resistor R_L vary if we were to change the grid voltage, let us say 1.5 volts, or to be exact, from —1.5 to —3.0 volts? Here is how you would solve this problem, using a little of the radio theory that you will learn in a later lesson, and a little arithmetic.

First, from the fact that current, I_p flows through resistor R_L we know that part of the plate supply voltage is used to overcome the resisting effect of R_L, and part to pull the electrons out of the filament of the tube to the plate. The opposition to the current flow through the tube is called the plate resistance of the tube. If we know the value of the plate current in *ampere* units, and the resistance of R_L in *ohms* (a unit of electrical resistance), then by multiplying the two we could get the voltage required across R_L, namely V_L, to allow the current I_p to flow. We could express this idea in the following two simple ways.

*(1)

$$\underbrace{\textit{Voltage lost in } R_L}\ \underbrace{\textit{equals}}\ \underbrace{\textit{current through } R_L}\ \underbrace{\textit{times}}\ \underbrace{\textit{resistance of } R_L,}$$

or,

(2) $V_L \quad = \quad I_p \quad \times \quad R_L$

Both of the above expressions are called formulas, which are nothing more than "expressions" which permit us to calculate some unknown factor from known factors. These formulas are developed by advanced scientists and you and I must accept them as correct. As you use them, you find that they give the desired results and gradually you accept them as being true. Expression (2) is merely a shorter way of stating expression (1), and is used by experts more often than the longer expression. Quite often experts omit the symbol "$\times$," meaning times, and write the formula as follows:

(3) $V_L = I_p R_L$

for it is understood that two factors (such as I_p and R_L) when placed next to each other are to be multiplied together. [Expression (3) is read thus: *V* sub *L* equals *I* sub *P* times *R* sub *L*.]

Returning now to our original problem, we know that if we find the voltage drop across R_L when —1.5 volts are applied to the grid, and again when —3.0 volts are applied to the grid; the difference in voltage will be the change produced by the change in grid voltage. Now we can convert these ideas into real values. Return to the formula given by the expressions (1), (2) and (3).

When $E_c = -1.5$ and the terminal P_2 is connected to +90 volts, the curve marked $E_c = -1.5$ shown in Fig. *8* tells us that the plate current

* In the course most of the formulas will be written this way, so the average student will have little difficulty in reading them.

is 2.8 milliamperes. But we want the current in amperes, so we divide 2.8 by 1,000; as it takes 1,000 milliamperes to make one ampere. From elementary arithmetic $2.8 \div 1{,}000$ may be expressed as $\frac{2.8}{1{,}000}$, which is equal to .0028.* Now the voltage drop across R_L for this condition is from the formula:

$$V_L = .0028 \times 10{,}000$$

as the resistance of R_L is 10,000 ohms. Observe that when we want to show that two *numbers* are to be multiplied together we must use the "$\times$" symbol, otherwise the process would be confusing. Now multiplying .0028 by 10,000 we get:

$$V_L = 28 \text{ volts (when } E_c = -1.5)$$

What will be the voltage drop when $E_c = -3.0$? Again Fig. *8* tells us that in this case $I_p = 2.1$ milliamperes. Dividing this by 1,000 to change the value to amperes we get $I_p = .0021$ amperes. Going one step further—

$$V_L = .0021 \times 10{,}000 = 21 \text{ volts (when } E_c = -3.0)$$

Clearly by changing the grid voltage 1.5 volts (from —1.5 to —3.0 volts) a voltage change of 7 volts is produced across R_L (difference between 28 and 21 volts). From the previous facts, we may say that this tube circuit has amplified the change by a value equal to 7 divided by 1.5. Again expressed as a formula we would write this fact as follows:

(4) *Voltage amplification equals voltage change across the plate load divided by the grid voltage change.*

This can be further expressed in simpler manner if we use a symbol for difference or change. The symbol "Δ" is very often used for this purpose. You would read it as "difference in." Hence expression (4) may be expressed in symbolic form as follows:

(5) $A_v = \Delta V_L \div \Delta E_c$

where: A_v is used to represent voltage amplification and "$\div$" to indicate division.

* Recall from elementary arithmetic to divide by 10 move the decimal point one place to the left; divide by 100 move it two places to the left and so forth. To multiply by 10 add a zero (0) or move the decimal place one place to the right; to multiply by 10,000 add four zeros or move the decimal point four places to the right.

Or we may write this expression in this form:

$$(6) \quad A_v = \frac{\Delta V_L}{\Delta E_c}$$

which is then read: voltage amplification equals the difference in plate load voltage divided by the difference in grid voltage.

Now turning to our example we find that:

$$(7) \quad A_v = \frac{7}{1.5} = 4.7$$

By purely graphical means we have found how much this amplifier will amplify. Of course, it will be different for a different plate load resistor R_L, and for different grid and plate voltages, but the procedure is quite the same.

To be sure, you would not have to make all these computations if you did not want to; you could measure the amplification quickly. You could place a voltmeter across R_L and measure the change in voltage when the grid is changed one volt. That would be the amplification of the stage. Simple and direct. But tube manufacturers in their tube manuals show curves *like* Fig. *8*, for the tubes they make. From these curves you could calculate what an amplifier could do without setting up the apparatus. That is radio design in its simplest form.

MORE KINDS OF CALCULATIONS

Suppose you were replacing resistor R_L in a radio receiver brought to your bench for servicing. Would you use any 10,000 ohm resistor you could buy? Of course, you would do nothing of the kind. You should select one that would stand the heat generated by the current flowing through it. Power will be wasted in this resistor, and resistors are rated in watts (a measure of electrical power) they will safely handle without overheating and burning out. How can we compute the power wasted in the case selected? Again we turn to a formula, which in this case is:

(7) *Power in watts equals current times current times resistance.*

$$(8) \quad P = I \times I \times R$$

where it is understood that—
I is in amperes
R is in ohms, and
P is in watts.

But a simpler form is:

$$(9) \quad P = I^2R$$

where the number ² above the right-hand side of I means

I multiplied by itself. This is understood in the language of formulas. Thus—

$$I^3 = I \times I \times I;\ I^4 = I \times I \times I \times I.$$

[Incidentally, expression (9) is read: P equals I squared R.]

Returning to our practical problem, all we need to know is the average current flowing through the resistor. The current varies from 2.1 to 2.8, and 2.1 plus 2.8 divided by 2 gives the average of 2.45 milliamperes. To change this to amperes we divide 2.45 by 1,000 and obtain .00245 ampere as the average current. Then from either (7), (8), or (9) we may compute the power lost as heat. It is:

$$P = .00245 \times .00245 \times 10{,}000$$

and by arithmetic—

$$P = .060025 \text{ watt.}$$

SENSIBLE CALCULATIONS

Would you ask for a 10,000 ohm —.060025 watt resistor? You could not buy a resistor of this type. For radio purposes resistors are made in ½, 1, 5, 10, 25, 50, 75 and 100 watt sizes. Furthermore, the one you select should be from 4 to 5 times the calculated power loss if the resistor is placed under the receiver chassis away from air circulation. If the type to be used is a matter of approximation, or an estimate, what sense is there to an answer like .060025 watt? None whatsoever. In fact, an answer of .06 watt would be quite satisfactory. Now if we multiply this value by 5 (the safety factor as it is called) we get the value .3 watt. Clearly a ½ watt (.5 watt) resistor will do, for it does not matter how much *larger* we make the wattage value.

Recall that in order to find the amount of amplification the amplifier of Fig. *5A* has, I divided 7 by 1.5. I gave the answer as 4.7, but if you were to carry out the division as you were taught in grade school you would get the answer 4.6666 plus as many sixes as you cared to write. Now let us be reasonable. Is this a sensible answer? Of course not. But what is a reasonable answer? From a practical point of view there should be no more numerals (more than one zero does not count) than in the numbers you started with; or the answer should have as many numerals as the value you could measure with a practical meter.

Here is an example. Suppose resistor R_F in Fig. *5A* is to carry a filament current of .060 ampere. (In this case the zero after the numeral 6 has significance, because we specify that the current is .060 and not .061 or .059.) If the resistor is to waste 1.3 volts, then

Ohm's Law, which you will learn in another lesson, tells us that $R_F = 1.3 \div .060$. By the usual grade school method we would get 21.66666+ etc., ohms—a very impractical answer. As the original numbers only had two numerals that were significant, a reasonable answer would be 22 ohms—in fact, if you used a 20 ohm resistor the current would be reasonably near .060 ampere.

The usual scheme is to compute the value in the ordinary manner and then discard the undesired numerals. If the last numeral you are going to discard is 5 or greater, increase the last remaining number by 1. Thus 21.6+, the last 6 is to be discarded so you write the number 22. If the number happened to be 21.4, then the sensible answer would be 21.

You may want to ask, Does a service man have to compute the power rating of every resistor he replaces? Very rarely. Usually they know from experience what power rating they should have. You get this experience from a study of this lesson, special suggestions

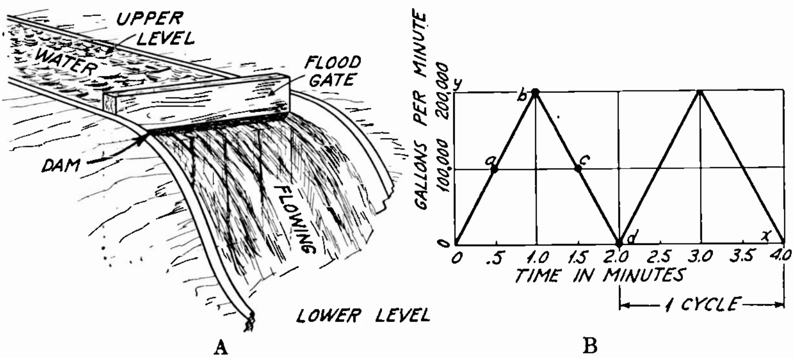


Fig. 9

given in this course—and very often the service circuit diagram of the receiver you are repairing gives the correct size. If you are in doubt, a resistor with a larger rating can be used; the difference in cost is only "small change."

SHOWING CURRENTS GRAPHICALLY

As you will learn early in your course, radio and audio signals are currents that are of a variable nature. One of the cardinal principles of a radio transmitter and receiver system is that the characteristics (shape or form) of the audio current variation entrusted to the system shall not change. In tracing signals through a radio device or radio stage, or a complete radio system, we will want to know just where and how the characteristic of the signal can be "spoiled," primarily so we can put a stop to this undesired change.

How would you picture, in your mind, a varying electric current? You could think of the electrons flowing in a definite direction along a wire conductor, isolate one point of the conductor, imagine that the quantity of electrons flowing was varying from instant to instant, even flowing in the opposite direction. When we say flowing, exactly what do we mean? We mean the number of electrons flowing per second, and when the condition exists for a very small part of a second we mean *how many electrons would flow if the same condition existed for a second.* For example, see Fig. *9A,* water flowing over a dam with the flood gate half open might be 100,000 gallons per minute; with the flood gate entirely open the flow is 200,000 gallons per minute; with the flood gate closed no water flows over the dam.

Suppose you could open the gate or close it in a minute, and suppose you were to repeatedly open and close it, how could you graphically represent the variation in water flow? We could use plotting paper with the distance *ox,* see Fig. *9B,* representing minutes; with the dis-

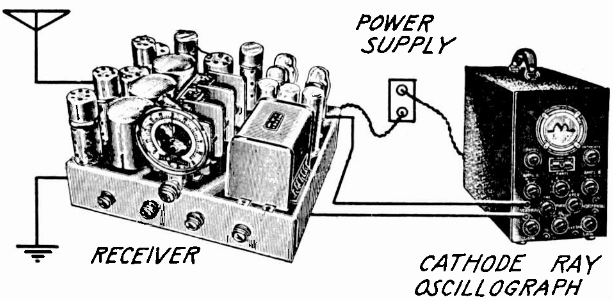


Fig. 10

tances along *oy* representing gallons per minute. At the start no water flows; after a half minute has elapsed and the flood gate is half open, 100,000 gallons are flowing per minute. By this I mean that if the gate were left half open this quantity of water would flow in one minute. In one minute from the instant we started to reckon time, the gate is wide open, and water is flowing at the rate of 200,000 gallons per minute. Immediately we start to close the gate, the water flow decreases and after 2 minutes from the start, the water has ceased to flow. We are now back to the original state of affairs; the conditions existing in these 2 minutes are portrayed by curve $o \rightarrow a \rightarrow b \rightarrow c \rightarrow d$. We may repeat this *cycle* of events over and over again. Two cycles are shown in Fig. *9B.*

Electric currents can be portrayed in the same way, as they are very often. Hydraulic engineers have flow meters for measuring the flow of water; electrical and radio engineers have electric devices or meters to measure electric and radio current flow—called ampere or current meters. But electrical men also have a device which will show on a screen the exact variation in current, just as it is shown in Fig. *9B*. It is called an oscillograph. A cathode ray oscillograph, widely used in laboratories and by well equipped radio service men, is shown at the right of Fig. *10*. It may be connected to any circuit or stage of a radio receiver or transmitter where you want to get a picture of the radio or audio current or voltage at that point.

A number of possible oscillograph pictures are shown in Fig. *11*. The lines in these figures are the bright green lines that will be seen on the circular face of the oscillograph. It depends on the section of the receiver analyzed and on what is being received on the radio set that determines what you see. If you were to analyze the electric power that the power socket furnishes the receiver you would see the characteristic shown in Fig. *11A*. It has, you will agree, a simple wavy form; in fact all of the characteristics in Fig. *11* are wavy, that is why they are called "wave forms." Remember they are not waves, although the currents thus pictured often are capable of producing sound or radio waves.

There is a section of an A.C. receiver which changes A.C. current to D.C. current, incidentally performed by what is called a "rectifier tube." After such a tube operates on the A.C. current from the power supply, the current wave form is like that shown in Fig. *11B*. If we check up on the R.F. system of the receiver, we may see a wave form like Fig. *11C*, if the performer were to whistle a single note in the station studio. Observe that it consists of a simple varying current while the *o* to *y* distance is varying, or swelling. The swelling represents the audio signal, in the case of sound broadcasting, the picture signal in the case of a television broadcast; and either one is carried by the radio signal, the simple wavy current.

If you were to analyze the output of a television receiver, the section ahead of the cathode ray tube which reconstructs the picture, the current wave form would look like Fig. *11D* .

How, you might ask, do these currents differ? First it is the number of cycles per second that determines the pitch or tone of the sound we hear; it is the shape that distinguishes a voice from an instrument, or the difference between musical instruments. For television it is the frequency of the little variations of the large cycle that determines the detail, and the large cycle is determined by the number of lines shown in a picture. The distance from *o* to *y*, the amplitude as it is called, determines the loudness of the sound (sound broadcasting) and the shades (in television).

The wave form shown in Fig. *11A* is the simplest of all wave forms and is called a *sine wave.* Shapes or forms like the others shown in Fig. *11* are really a group of simple sine waves acting at the same time; technicians call the lowest frequency in this group the fundamental (or first frequency); all others are called *harmonics* or *overtones.*

What is a sine wave? It is the simplest form of a variation regardless of whether it has to do with the pendulum swing of a clock, the variation of an electric current, a sound, or a radio wave. Any complicated variation may be reduced to a number of simple sine wave variations. And as variation is the nature of all radio current, the sine wave is important to radio men. Let us consider a practical example. A good

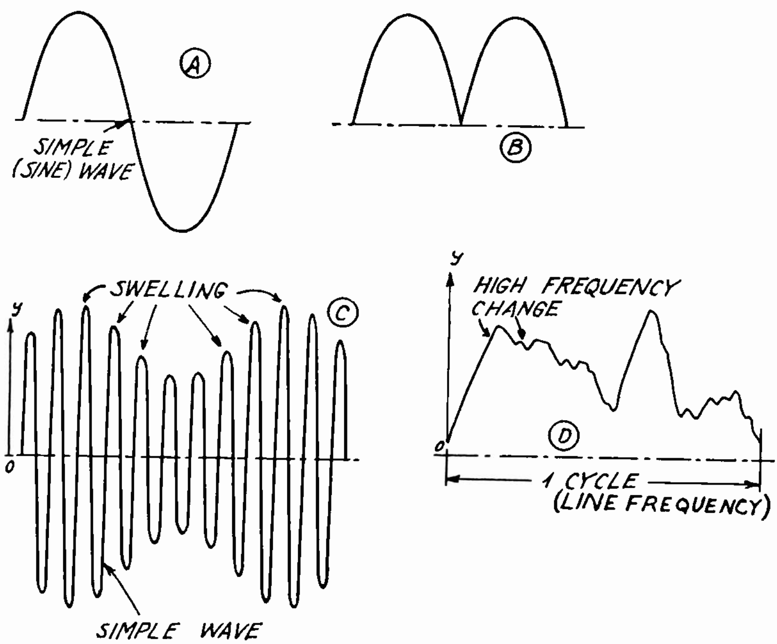


FIG. 11

orchestra emits sounds which can be assumed to consist of sine sound waves of 35 to 8,000 cycles per second. The audio signal will have these frequencies. If the transmitter and receiver used for radio transmission and reception will handle any simple sine wave current between these two limits without changing its shape, then either one will not distort or change the shape of any audio signal produced by the orchestra. We would have high fidelity transmission and reception. As it is simpler for a radio man to handle a single simple sine wave current for purposes of test and design, than hundreds of sine waves acting at one time, service, design and installation work is always done with simple sine waves rather than complicated forms. If the radio device handles all of the desired frequencies individually with the same ability, we know that the complicated signal will come through as it should. This basic radio and electric principle goes by the title "Superposition Theorem." Don't let the name frighten you, the idea is simple.

How could you draw a sine wave? Figure *12A* shows how this is done. The line *AA* is drawn; the arrowed line *01* is next drawn along *AA*, its length representing the largest current value in the variation (called the peak current); the arrowed line is allowed to revolve around its center at a speed (revolutions per second) equal to the frequency of the signal (or power current) we wish to represent as a

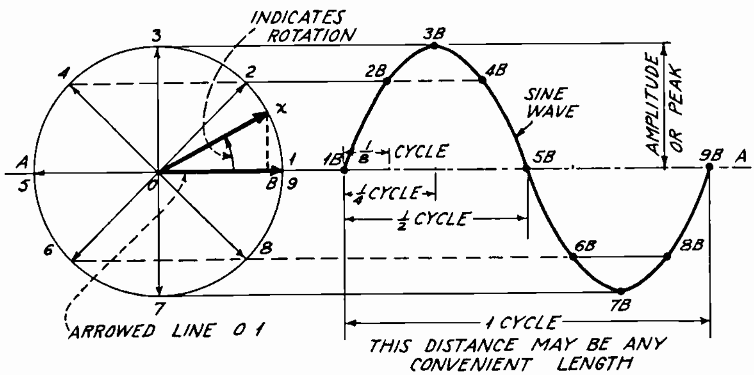


Fig. 12

sine wave, 60 c.p.s. in the case of the usual A.C. power current. As the line *01* rotates it takes various positions like *02, 04, 07, 09*. The line *0X* represents a position which is less than ⅛ revolution. Focus your attention on the distance *XB*. To draw a sine wave we must present to the right of the revolving line *01*, the value of the distance *XB* (which of course is changing in value) for various angular positions of the arrowed line. Along the line *AA* we mark off distances to represent the revolving movement of the line *0X*, such as ⅛, ¼, ½, etc., of a revolution. Points *1B, 3B, 4B*, etc., represent the value of the varying line *XB* for positions *1, 3, 4, etc.* Furthermore, point *2B* represents the value of line *XB* for ⅛ of the cycle, *5B* represents the value of varying line *XB* for ½ of the cycle, etc. Learn from this figure the exact significance of a cycle, ¼ cycle, ½ cycle (or one alternation), and the amplitude or peak of the sine wave. The number of cycles per second is the frequency of the current we thus represent.

Why is such a wave called a sine wave? Actually what we did was to draw a graph showing the value of the distance *XB*, for various positions of the arrowed line. The position of line *02* with respect to line *01* is either measured by the gap (or angle) between the two lines or measured by the distance *2B*. Now the distance *2B* divided by the length of the arrowed line is called, in mathematics, the sine of the angle (or gap) and for this reason the wavy form is called a sine wave. Do not allow the details of the construction to disturb or bother you; they are presented here only for the purpose of telling you the whole story.

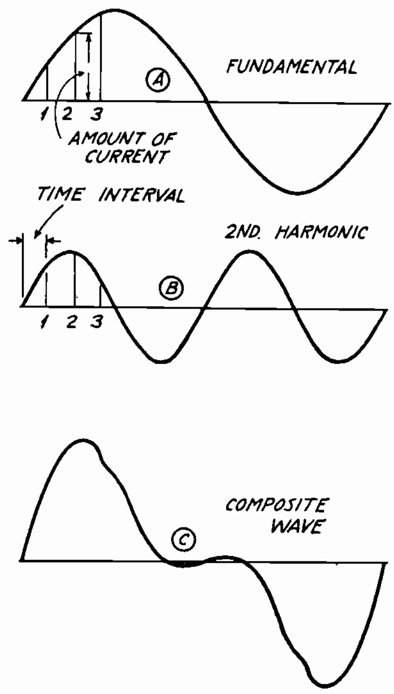


Fig. 13

Now what proof have we to show that a complex wave form is made up of a number of simple sine waves? Unfortunately, this proof is highly mathematical and beyond the ability of the ordinary engineer. But I think you can convince yourself in the following manner. Suppose you were to take two simple or sine waves and consider them to act at the same time. What would be the resulting wave form? Let us do it graphically as shown in Fig. *13*. Here we have (let us say) two currents, one having twice the frequency of the other (frequency of *B* is twice that of *A*). By adding graphically the amount of current both produce at the same time intervals (shown by *1*, *2* and *3*) we can construct the net result. We get the form shown at *C*. Yet if we look at *C* for the first time without this basic idea in mind, it is difficult to see how it is made up of two simple wave forms. Figure *14* shows the result obtained when we combine a fundamental and a third and fifth harmonic.

Here is another practical idea. Suppose we have a public address amplifier and we send into it a simple sine wave signal, but get form *C*,

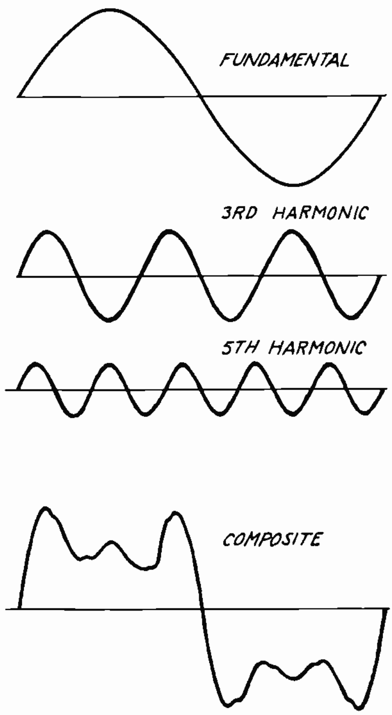


Fig. 14

Fig. *13*, out of it. Immediately we know that the amplifier is not working correctly. Distortion has resulted. Clearly wave forms have an important practical use. We will use this sort of analysis, graphically of course, in telling how radio devices and circuits work. We will in this Course consider what happens to a sine wave when it is fed to a radio circuit, and by graphical study determine what effect the circuit has on the sine wave.

HOW TO START A SPARE TIME RADIO BUSINESS

22X

REFERENCE BOOK

NATIONAL RADIO INSTITUTE
EST. 1914
WASHINGTON, D.C.

FOREWORD

The National Radio Institute Course has been written for men who desire to make money in Radio —who want cash returns just as soon as possible.

Radio lends itself well to the plan. The small amount of capital required enables you to start in a spare-time business early in your training period. Frequently students make several times the price of the tuition, before they complete the Course, and having gotten such a good start they step out into a full time Radio business as soon as they complete the training.

N. R. I. wants you to obtain spare-time Radio work, not solely for the advantage of the earnings, but for the valuable practical experience you will obtain in doing the work.

Of course, there are some types of Radio work which we suggest you not attempt until after graduating as the proper training for this work is received later in the Course. Tackling advanced jobs too soon may have a bad reaction in loss of confidence in yourself and dissatisfied customers.

But there are literally hundreds of jobs you can do. And these are the jobs which make spare-time money and give confidence—cultivating experience. Get them!

NATIONAL RADIO INSTITUTE

WASHINGTON, D.C.

1941 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)

NCP4M541 Printed in U. S. A.

How To Start a Spare Time Radio Business

WHAT TO SELL

The Radio-Trician, seeking spare-time work, is by reason of his special N. R. I. training, particularly fitted for three general fields:

1. Radio Service
2. Radio Receivers Sales
3. Sales of Household Electrical Appliances

Radio Service

Service of Radio Receivers offers a fine opportunity for quick returns. Every person in your community who owns a Radio is a prospect for your services. Radios are everywhere. Your neighbors have sets; so have your friends and acquaintances. The corner barber shop has one—or should have—likewise the restaurant down the street. All these sets will need fixing sometime. The jobs belong to the man who sells his services.

Radio Receiver Sales

There are sufficient people still without Radios to make Radio receiver sales a very worth-while proposition. While the returns may not be so rapid as in the service field, this is offset by the size of the individual earnings. Receiver sales works in well with service work.

The Radio Man doing a spare-time business will naturally not be interested in stocking receiving sets in an effort to demonstrate and sell them.

In the first place, by devoting only part time to his business, his capital would be tied up in his sets too long. Secondly, a store or adequate showroom, which the spare-time Radio man seldom has available, would be required.

However, it is a proven fact that the spare-time service man will quite frequently run into a set sale opportunity and he will naturally wish to be in a position to take advantage of the occasion to make some money.

Therefore, it is a good plan to make arrangements with a good live wire dealer to sell sets for him on a commission basis. You may make a deal with him whereby he will pay a slightly higher commission than he ordinarily pays his salesman, you in turn agreeing to relieve him of the installation and all service in connection with the set.

While the spare-time Radio serviceman may occasionally run across a prospect for a custom built receiver, it is not recommended that he solicit such jobs until he has received all the training N. R. I. can give him. Remember, also, that custom built Radio jobs nowadays quite frequently call for having the sets "built in." Therefore, on such jobs sufficient leeway should be allowed in the estimate to pay a good cabinetmaker to do the necessary installation and finishing work.

Sale of Household Electrical Appliances, and Miscellaneous

The American family of today has gone *Electrical.* In addition to lighting its home, it cleans and polishes its floors; it learns the time of day; cooks its coffee and toast; refrigerates its food; keeps cool or warm as conditions demand; it is entertained by Radio, electrically.

Electrical appliances can be sold. They are priced so the average family can buy. The sale of electrical appliances can be handled as a side-line to Radio sales or Radio service, very profitably.

Do not attempt to stock electrical appliances while operating your Radio business on a spare-time basis. Leave that to the dealers until you have a store of your own. But have an agreement with one or two dealers. Arrange with them for a commission on any equipment you sell. Study their lines and the sales points of the products. You'll be surprised how often a service call on a Radio will lead to conversation about electric irons, vacuum cleaners, electric clocks, toasters, and other electrical specialties. If you are in a position to make a sale—just so much more money for you—without a bit of expense or risk of capital.

If you are located in or near a farming district, it is well to cover the territory thoroughly. The majority of farm receivers operate on batteries. This offers, in addition to a field for service work, a good market for the sale of batteries and for battery charging. It is well, when working such a territory, to have a deal with a battery charging station for commission on all work brought in. Be equipped to leave a rental battery at about 25 cents a day while the customer's battery is away being charged. Renting batteries alone can be made into a profitable side-line business in rural communities.

There is a trend toward ornaments and lamps for the tops of Radios. Be prepared to make suggestions and quotations.

SERVICE METHODS

Some service men prefer to build up their business on what is known as the "Call" basis. They solicit a job, do the work, collect their bill, and by rendering good service at a reasonable price influence the customer to call on them again when another job is necessary.

Service Contracts

Other men operate on what is known as the "Service Contract" plan. After a job is satisfactorily done, or in some cases before any work has been received from a prospect, they sell him a service contract which calls for certain stipulated work at regular intervals, at a fixed price.

While an advantage of this system is that you get a certain price in advance, the point of chief importance is that you are reasonably sure of retaining your customer's business at least for the length of the contract period. You can plan your work more or less definitely in advance, having records to indicate when service calls are due. This allows a certain period of time each day for canvassing for new customers, renewal of contracts, etc. Every Radio owner is a prospect.

In dealing with the prospect it is not wise to refer to "Service Contract." "Contract" has a legal sound which frightens the prospective customer. Call it a "Service Agreement."

Many forms of service contracts may be written. No form which could be presented would serve everywhere. Conditions differ greatly, but the model illustrated in Fig. 1 gives a good general idea of what should be covered.

BLANK'S RADIO SERVICE

Phone
North 1161

RADIO SERVICE AGREEMENT

Service Hours
8 AM to 9 PM

Received from ______________________________

Address ______________________________

the amount of __________________ dollars and __________cents, which entitles the above person to the following service on a ______________________Radio, number ____________for a period of ________________months from the date below.

1. A complete inspection of the equipment, between the ________ and __________ day of each month, unless otherwise requested by the customer.

2. Any adjustments found necessary on these regular calls which are of a minor nature and do not require more than 30 minutes.

3. Free delivery, and installation at 5% less than list, of any tubes or accessories, the installation of which does not require more than 30 minutes.

4. Discount of 10% from our regular rates for time and 5% discount from list for parts required on service over 30 minutes.

5. Free transportation to and from our shop and the same discounts as in section 4 above, when shop work is necessary.

6. A special price of $7 for removals within the city limits, which removals consist of taking down set and all equipment (including aerial, if any), transportation and installation of same on the new premises.

This service agreement is made in consideration of the payment of the amount specified above and the service to be rendered. It is void when any person, company or corporation other than BLANK'S RADIO SERVICE makes any repairs, adjustments or replacements on the set or equipment.

BLANK'S RADIO SERVICE

Date__________________ By__________________

Courtesy National Radio Institute Alumni Association

FIGURE 1

The wording of this blank can be altered to meet local conditions.

As soon as you have sold a single contract, you are a business man with responsibilities which must be carried out. You must make inspections regularly, be courteous and always on the alert to sign up new business to replace that which may be lost by people moving away, etc. Be prompt. If you are due at a home on a certain day of the month, be there, and as near a standard time as possible. You sell customers this inspection service as being very important; keep them sold on its importance by your actions.

Make your customer list as large as possible—up to the point where you can still give good service, for the larger it gets the more rapidly it will grow. As soon as you find it impossible to do this, get another Radio-Trician to help you. Dealing with so many people will enable you to buy your accessories in larger quantities, at a better price. This will keep your bank account growing.

An important class of business is new sets under guarantee. Don't pass these people up and forget about them. Experience has proved that the majority of dealers are more interested in sales than in giving service. You cash in on their mistake.

When you visit a set owner who gets free service from a Radio store, find out all you can about the transaction. If possible, see the set, get the date of purchase. By careful inquiry, you can figure out just when this free service period expires.

Copy down the information you obtain on a card and file it away as valuable business possession. Arrange this file to be under your close observation every day. At the time of the expiration of the free period sell your service contract before someone else beats you to it.

Don't figure too strongly on the payment of the contract price as your chief source of revenue. It is merely an incidental expenditure which you require of the customer to keep him dealing with you. Your chief source of income will be in the service and parts which are found necessary from time to time. You can reasonably figure to make a profit of 40 per cent on the parts and tubes which you install. But do not overcharge. Remember you must keep your customer.

The price charged may range from $3 to $10 a year, depending on conditions and service given. It will not take you long to get the routine of your business worked around to a point where you will find it a simple matter to handle from three hundred to four hundred service contract customers, making two calls a month on each, and still have time to be on the lookout for new business.

Wholesaling Radio Service

Still other service men adopt what is generally termed the "Wholesaling Service" system. They do not contract the set owners as a general policy, but solicit, on contract, the service work of dealers, large and small, who do not care to operate their own service departments.

Two classes of Radio organizations offer the Radio-Trician the best market in the Wholesale Radio Service Field.

One class comprises Radio Sales Organizations, which do not care to handle service, not having space, time, nor personnel to render efficient work. The other class includes the small dealer who cannot afford to operate his own service and installation. Whether these dealers like it or not, service is a necessity—demanded by purchasers of their products.

The far-sighted Radio-Trician will soon have as many of these firms as possible under contract for all their service work. This, in short, is what is meant by Wholesaling Radio Service.

Usually the service wholesaler will not handle the sale of any Radio set. In this way he is looked upon more favorably by his dealers; he is not acting in competition to them. On his service calls he endeavors to keep the individual customers of these dealers sold on Radio and on the store from which they bought. He must often be a diplomat in this respect.

He conceals the fact that he is the "wholesaler" or the "wholesaler's service man," as the case may be. He acts as the direct representative of the store which sold the receiver in the first place.

He must never show partiality to any receiver. To the customer they must all be good. At least one case is on record where the representative of a wholesale Radio service company lost his firm the account of a large department store, and lost himself a good job by criticizing the set owner's selection of a particular Radio.

It will not be possible to stick to any "cut and dried" contract arrangement. You may find it necessary to make a slightly different deal with each of your dealers. The essentials will be the same, naturally, and governed by the business policy you set out to follow, but the details will be altered to the mutual satisfaction of yourself and the dealer.

For instance, in the matter of replacement material for service work, you can either supply it at cost, plus 10 per cent, or allow the store, whose work you contract, to furnish it. The former plan is preferable. It saves time and gives you an added profit, but it must be remembered that it also necessitates carrying parts in stock, ordering, and other details.

Rates usually run at $1.50 per hour flat unless the set must be brought to your shop. In that case make a $2.50 charge for the regular service and a shop charge of $1.50 per hour with a minimum shop charge of $1.50, making the total minimum $4. Of course, to large customers—those giving several hundred service calls a year, for instance—a special price of 1.25 or even $1 per hour should be offered. These rates, however, are only tentative and must be governed more or less by the standard rate for Radio service work in the particular locality in which you are operating the business.

When the size of your business permits, a special "aerial crew" can be used—to save time for the more experienced service man. Give a good aerial job and don't try to make a big profit on it. For about $6 you can afford to give two ten-foot metal poles, lightning arrester of the best type, wire, lead-in, etc., carried to the aerial binding post of the receiver. Add approximately 40 per cent of this price if the aerial installation is to be on a peaked roof.

A profitable side-line to this service, for those having a car or truck, is to maintain a delivery service for sets sold by the dealer. You can charge fifty cents a delivery for a midget, seventy-five cents for a console, and $1 for a highboy model. It stands to reason that your man has to go to the job to install the Radio anyhow—it's a simple matter to have him call on the dealer on his way, pick up the set—and in that way the dealer pays you for the trip your car or truck has to make.

Your business depends on the amount of sales your dealers get. Work with the dealer. If he is in competition for a sale, it's a good idea to have a special "wooden pole aerial job" you can offer for $4.50, or some other such scheme which will allow him to meet the competition of price. But, on the whole, be wary about cutting prices. You may educate the dealer to expect it. If you find the competition for a sale is between two of your "customer-dealers," play safe and let them fight it out. Don't cut prices for either. You'll get the job anyway, regardless of who sells the set.

THE SELLING JOB

Start out by making a list of all your friends who have sets. See each of them. Explain your ability to service receivers. Your local printer will make you up business cards at a reasonable price. Distribute these among your friends.

Ask these same friends for the names and addresses of persons who have receivers. Add these new names to your list and call on them immediately. Perhaps they have no work to be done right away, but leave your cards and ask for more names. Keep a card file of all prospects, noting information on the cards which may be useful later, 3" x 5" index cards are fine for this purpose and can be purchased at the local 5 and 10 cent store.

This first work may seem slow—almost useless—but you've never yet heard of a building being constructed without the foundation being laid first. You are building your foundation; you are making business acquaintances; you are constructing a list of prospects which will grow rapidly and be valuable to your business, if the above system is worked diligently.

Keep a close watch on persons whom you know to have recently purchased sets. The dealer will service his sale for a short time; after that you'll find, generally, he pays little or no attention to the customer. The dealer is interested in sales. It's up to you to get after the service.

Personal Solicitation

Various types of advertising can assist the service man in building up his business, as will be shown later, but no amount of advertising will offset the value of personal contact. The service man must obtain a lot of his prospects, and incidentally his business, by a systematic solicitation of residents of his community. He must spend a large portion of his available spare time in canvassing.

Canvassing constitutes making calls at the homes or offices of all persons in a given locality in an effort to secure business. The value of this plan has been proved in the experience of some of our largest sales organizations. And bear in mind, yours is a sales organization. You are selling services.

The Territory

It is well to lay out a territory for yourself and confine your activities to that section when you first start out. In some cases, where your city is small, you may decide upon the whole town as your territory. But in the larger cities it is well to make your selection carefully. Then work that territory thoroughly until it is fully covered, before spreading out your field.

If the community in which your home or shop is located offers good possibilities, you should lay out your territory nearby. This saves time in traveling to and from jobs. By intensively working a small territory you will become well acquainted with the residents, which is very helpful. Soon they will know you by sight and point you out to their friends.

Our advice to sticking close to your territory and working it well must not be construed to mean that you must never take work elsewhere. Through your friends and acquaintances you will frequently

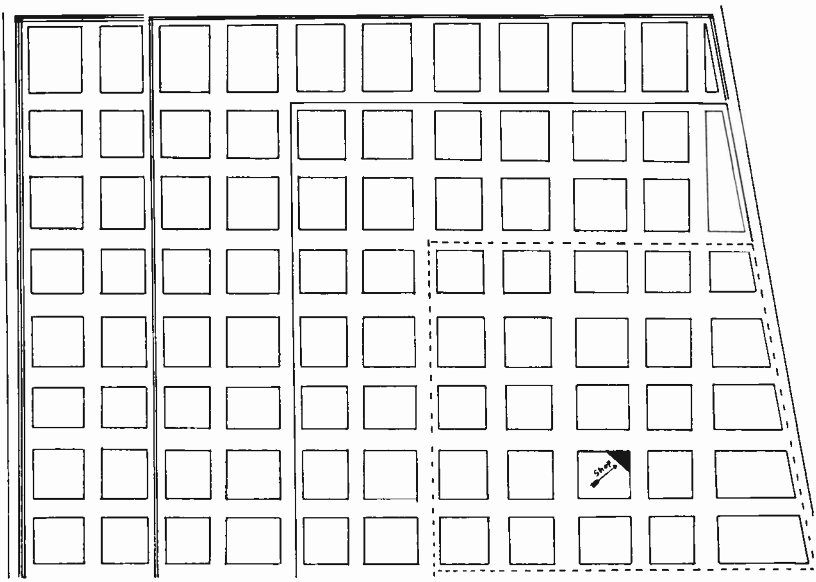


FIGURE 2

obtain jobs in different parts of the city. Take these jobs whenever you can get them. It may even be a good plan to canvass the whole block after you've done such a job.

Fig. 2 shows a diagram of a community and the location of a student's Radio shop. This student laid out twenty-five square blocks as his original territory, shown by the dotted line. After this had been worked to his entire satisfaction he enlarged his territory as indicated by the single line, pushing his boundary two blocks north and two blocks west. This practically doubled his territory. Subsequent extensions are indicated by the double and triple lines. This territory was handled in a very business-like manner.

Every home in your territory should be considered a potential source of income for you. Of course, how much work you get out of the district will depend on how much you put in. A territory is much like a garden. It will only produce if properly cultivated.

Plan to visit, systematically, every home on every street. When you do this, jobs are bound to result.

However, you cannot merely push door bells, stammer through a few words of introduction, say good-bye—and get business. You must prepare your visit in advance, know exactly what to do and say, plan to meet and overcome objections. When this is done you may expect the law of averages to do the rest.

The Attitude

As you go into your territory to begin work, you are a salesman. You are the sales manager of your Radio business. Do not worry about the immediate earnings. They should take care of themselves. Consider the fact that you want to make a sale of your services of secondary importance. Primarily you are building up a business.

Consider that you are bringing your customers a worth while service—a service which will mean pleasure and enjoyment to the homes. If you cannot take such a view of your service, it is better not to sell it. Such an attitude will not be accomplished over night. It must be cultivated, but it will win you favor with your customers. It will take much of the commercial sting from your dealings.

The Approach

It is doubtful if any two men, canvassing for business, use exactly the same approach. Some like one method; others find an entirely different plan effectual.

Another thing, a different approach will be required in starting out to develop a territory than later on in making future calls.

We know of a case of a young man who successfully worked up a Radio business and from whom we have obtained his original method of approach.

As he did not want his name used in this connection, we'll call him Bill Jones. Jones selected the block for his morning's work, walked up to the first house, and rang the door bell. As the door was opened he removed his hat and said: "This is Mrs. Perkins, I believe." (He had already determined the names of the residents on the whole block by reference to the city directory.) "Mrs. Perkins, I have just opened up a Radio shop, right near your home, to render prompt and efficient Radio service to the residents of this community. I'd like to leave my card with you and have you call me any time your Radio isn't working just as it should." Mrs. Perkins thanked him and he left. He made a very favorable impression, first, because he didn't try to high pressure Mrs. Perkins into buying something; second, because he was neat and courteous; third, because he was rendering a service which Mrs. Perkins felt might some time in the future be of value to her.

By this approach, and by a sales talk which was short enough not to take up a lot of his prospect's time, the young man succeeded in becoming very well known in his territory. Incidentally, we understand that he picked up quite a few jobs, even on that first, introductory canvass. In these cases, when he mentioned that he was in the Radio business, left his card and was about to depart, the occupant of the house prolonged the conversation by stating that she had a Radio which was giving a little trouble and asked if he would step in and look at it. These jobs more than paid for the time required for this preliminary canvass. Later on in this book we will show how this young man worked his follow-up canvass on these people and built himself a nice Radio business. He reports that, three days after his first canvass started, he got a telephone call and business began picking up from that time.

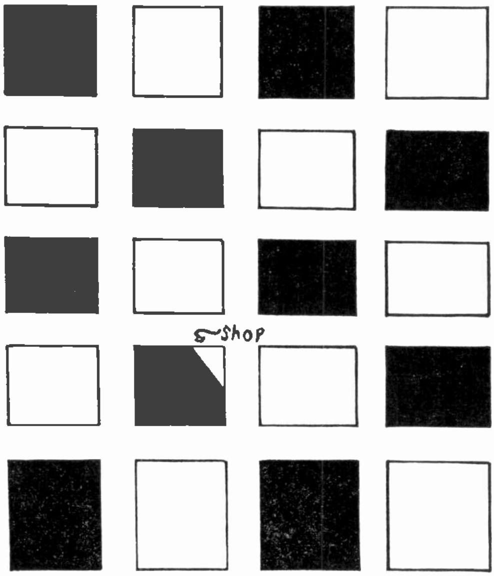


FIGURE 3

The Square Block System

In canvassing, your purpose is to see and place your message before as many persons as possible. It must also be remembered that there are a number of canvassers who may work in your territory, some of whom, by high-pressure methods, have become a nuisance. Housewives do not like to talk to such men, and it is a good plan to show the people in the territory, right at the outset, that you are not that type. Keep away from high-pressure methods.

Having become aggravated by numerous solicitors of the type mentioned, the resident will frequently refuse to answer the doorbell, if she has seen someone canvassing the block. Therefore, the Radio-Trician, desiring to see every one in his territory, will do well to utilize the "Square Block" system of canvassing.

This entire plan may be summed up by the simple rule: "Never canvass both sides of the same street on the same day."

The reason is, while you are canvassing the North side of the street, the occupants of the homes on the South side can see you going from house to house. They don't know what you have to offer; consequently, they label you as just another salesman, and you'll find very few answers to your knock when you start canvassing the South side of the street.

The accompanying chart, Fig. 3, shows the ease with which this difficulty may be eliminated. Consider that the blocks in black and white represent the city blocks in your territory. Never cover a black and a white block in the same day.

The Time To Call

Next in importance to saying the proper thing when making your canvass calls is calling at the proper time. The canvasser's day is short, so he must work rapidly, consistently, in the few hours which he may logically use.

No calls should be made before 9:30 in the morning, nor later than 11:30 a.m. Be considerate of the prospect's time. She may have children who must be dressed and sent to school; she has breakfast dishes to get out of the way. Give her time to do this before you arrive. After 11:30 and until 1:00 in the afternoon she is in the midst of lunch routine. She doesn't want to be annoyed. Your afternoon work can go on from 1:00 until about 4:30 p.m. No later. So you really have only five and a half hours in which to canvass during the day. Of course, you may not have any of this time available, by reason of some other job you are holding. In that case you must make your calls at night.

Call Backs

You'll run across a number of homes where both the man and his wife are away during the day. You must record these cases and arrange to call back on them until they can be seen. Night—between 7:00 and 8:30—is a good time. These people are usually good prospects for Radio work. They most likely have incomes above the average by reason of more than one member of the family being employed.

There is a tendency among most canvassers to pass up this class of business because it entails night work. Don't make that mistake. It is an important angle of your Radio business.

In making call backs at night there are several things which must be guarded against. It would be very serious, for instance, to call while the prospect is entertaining company. Business calls in the day time are more or less expected and are not considered as out of the ordinary, but discretion must be used on night calls or your prospect may be antagonized.

As you are about to make your call, but before you ring the door bell, listen carefully a few seconds. If you hear any unusual sounds which might indicate a party in progress, or company being entertained, make your call the next evening. The evening following such a party or gathering is usually a safe time to call. The resident will most likely not entertain two nights in succession. Then again, the Radio may not have acted so well before the company, embarrassing the host and hostess. That makes them good prospects for Radio repair work.

Apartment Houses

Of course a large number of residents of apartment houses depend upon the programs furnished by loudspeakers, connected to the apartment house set, for their entertainment. Nevertheless, there are many apartment residents who have their own sets. Their business should not be overlooked.

Regulations in some apartment houses prevent canvassing on the premises. It is sometimes possible to get around this by making friends with the building superintendent, by repairing his set free of charge.

At least one Radio-Trician we know of built up a fine business in buildings of this kind. He would call on the building custodian and offer to repair his set whenever called upon, free of charge, to prove his merit. Then he would request that this gentleman, or lady, recommend him to the residents who might then or in the future need Radio service.

Our friend Bill Jones, whom we referred to previously in this book, tells us that, failing to obtain permission to canvass in an apartment house, he would list the names shown on the mail boxes, then return to his shop and make his canvass by phone. Once he obtained permission from a prospect to call, no one could keep him out of the building.

Some apartment houses have all the mail delivered to a clerk's desk, in which case it is impossible to get the names from the boxes. In such a case Jones made the acquaintance of a schoolboy who resided in the building and gave him a dollar for as many of the names of Radio set owners in the building as the boy was able to obtain. Then he made his phone canvass from this list, with the aid of the telephone directory.

City directories, which are available in libraries and most public buildings, will help a lot in this work, but they cannot be relied upon solely, as apartment house dwellers are usually more transient than other classes, and many discrepancies will therefore appear in a list constructed purely from this directory.

If there are apartment houses in the territory you lay out for yourself, find some way to contact the occupants. It may require some ingenuity, but you're setting out as a business man now and you must find a way.

The Sales Talk

If you've ever talked with a good salesman, you probably marvelled at the ease with which he presented his plan—how he first gained your favorable attention, then created an interest—carried your interest into a desire for his product and then obtained your order.

Of course, as you listened to the man's talk you were not aware of these individual processes. You were conscious only of an easy flow of conversation, but those elements of salesmanship were present, nevertheless.

And when you asked questions you were impressed, probably not consciously, at the quick, well phrased answers, which overcame any objections you might have had. Has it occurred to you that the salesman knew exactly what questions you were going to ask and had his answers all ready for you? Furthermore, he probably made you, by leading remarks, ask those very questions so that his reply would make a deeper impression.

He was merely practicing good salesmanship in his sales talk.

You should build a sales talk around your own product or service, incorporating the sales elements of attention, interest, desire and action. Write it out carefully. Check and correct it. Then rehearse it in the privacy of your home until you know it by heart. Change it where occasion demands.

You remember the first time you drove an automobile. You shifted gears with your mind on each particular operation. Later you did it without thinking—in a purely mechanical manner. So it is with your sales talk. At first you will find it requiring conscious effort; later it will become more or less mechanical.

No two men, selling a product or service, will use exactly the same sales talk. Neither will they prepare them in similar manners. Let's get back to our old friend Bill Jones and see how he developed his sales talk.

First, he listed all the items connected with his business, which could be considered as sales points. He then struck from his list those of lesser importance and rearranged the list until he had the following:

Expert Radio Service
Training—Experience
Equipment
24 hour Service
Centrally located—Prompt service

Around these points he built his story. He then considered every possible question a prospect might ask and framed the proper answer. He took into consideration any objections which might be raised in the course of conversation and had his replies to these prepared as well.

It must be remembered that Jones had already made an introductory canvass of his territory, frequently referred to in salesmanship as missionary work, and had done some Radio service work in it prior to starting his second round of calling on his prospects. This gave him an opening or what is termed in salesmanship as entree. The following is one of his standard talks built around the sales point which he had listed:

"You probably remember me, Mrs. Brown. I called about two weeks ago to see you about your Radio and tell you about our Expert Radio Service. Is your set working just the way it should?

"I know you have quite a bit of money invested in your set and naturally you want the best reception possible from it. By the way, Mrs. Brown, what kind of set do you have?

"I have done quite a bit of work on the ———— receivers. In fact, I had special training on them while studying Radio. I like the ———— set very much. I think you were very wise in purchasing that particular brand.

"Do you get all of the distant stations that you would like? Do you get out of town stations without interference from the locals? How is the tone quality? Are you getting deep, clear reception on the bass notes?

"The manufacturers who made your set are fine engineers and they intended this set to give you about the best possible in Radio reception. If you are not getting it, there is a possibility that something is slightly wrong and needs to be remedied. Possibly it's just a tube. Or it may be that the set needs cleaning. These sets are open in the back, you know, and you just can't keep dust from getting in them. And a little bit of dust will sometimes throw your set out of perfect order.

"Suppose you let me take a look at your set, Mrs. Brown, and make a test with my Radio set analyzer which I have right with me. You will be absolutely under no obligations and it won't cost you a cent. With these scientific testing instruments I can tell you, in a few minutes, just what the condition of your set is.

"Don't forget, Mrs. Brown, our shop is centrally located, right here in your neighborhood, to render you prompt, efficient service. Give us a ring any time, day or night, and we'll be on the job to serve you."

It is not always necessary to go through your entire sales talk to get an opportunity to work on the set. And it is seldom possible to go through a complete sales talk in just the manner given above, because if the person is interested at all she will ask questions which must be answered before you can proceed with your sales story.

The sales talk of Bill Jones which we have printed for your information is not given you with the idea that it is perfect. It probably could be greatly improved upon, but the point is this—it got business for Bill Jones, and a similar sales talk should get business for you. Change your sales talk whenever you see room for improvement.

Talking Their Language

An important point taken into consideration is the class of people with whom you are dealing. Folks like to do business with people on their own plane. If you are operating in a territory where the residents are well educated, be particularly careful of your grammar and manner of speech, and if, as frequently is the case, the conversation should drift away from the subject of Radio, talk about something which will interest that class of people. If the neighborhood is populated by a different class, it may be well to talk the way those people talk.

To emphasize this point, let us cite an example of an insurance salesman of our acquaintance who was selling in a farming community. For a long time this gentleman was only partially successful until he happened to overhear a conversation in the country store where he was referred to as "that dude insurance salesman from the city." It didn't take him long then to learn to talk about things which interested farmers: weather, crops, planting, harvesting, farm machinery, etc. It is not unusual—now—to see him perched on a fence in conversation with a farmer about a tractor, or discussing the digging of a well. He learned what interests his clients, he talks their language, and it helps him sell insurance to farmers.

It is well to learn from your prospects, as early in the conversation as possible, the nature of the Radio programs in which they are particularly interested. A record can be kept of this information, as it will always make interesting conversation on later visits. Know the various Radio programs and their contents so that you will be able to discuss them intelligently with your customer.

Do not attempt to use Bill Jones' sales talk as your own. Build your sales talk for the people of your territory. It is to be expected that you will know enough about the locality in which you are going to work, and the people in it, to work up a presentation which will meet their approval and result in business for you.

ADVERTISING

Advertising, good will and business go hand in hand. We once heard of a man who obtained publicity for his business which resulted in a number of sales by selling a Radio to a church which was giving a fair. The Radio was sold below actual cost. The set was kept on exhibition in the church hall for several months, prior to being raffled off at the fair, and it bore the card and the address of the Radio man in full view of all those who inspected the set. Needless to say, the congregation of the church was appreciative of his assistance. Good will and sales were the results. Later, this same man obtained a lot of service work by donating, free of charge, to another church five certificates—each of which entitled the owner to free Radio service for a year. These certificates were raffled off for the benefit of the church. The cost to the dealer was slight, but think of the number of people who heard about him and his Radio service while the tickets were being sold. Cooperation with clubs and lodges can also result in a lot of good business for the wide-awake dealer.

You will develop many prospects by direct canvassing. You will contact other prospects whose names have been given you by friends. No amount of advertising you do through newspapers, letters or other methods will ever take the place of those two methods.

But you'll probably want to do some advertising, not as a substitute for those methods, but to supplement them—make them more productive.

There are several methods of advertising, generally used by Radio service men. Each will be covered separately. It should be understood that no one method of advertising can be considered best, until it proves so in your particular case. In some localities one form pays well; in others another method gets most results. Frequently certain combinations will pay dividends. But, regardless of the scheme of advertising decided upon as best suited to your purpose and location, *canvass your territory.*

Newspaper Advertising

If you live in a large city there will be a number of large daily newspapers. There may also be one or more community papers.

Where community papers are published, they make good advertising media enabling you to cover, with your ad, particular territories.

FREE SERVICE COUPON

Clip this ad and bring it to our store with your Radio Tubes. It will entitle you to a free inspection service by experts. We use only the most modern testing equipment. This offer is good this week only.

BLAND RADIO SERVICE

1234 Summer Street

A

FIGURE 4

One question generally arises, when more than one daily newspaper is available: *"In which paper shall I advertise?"*

An eminent authority on the subject claims the best way to solve the problem is to watch the ads in the papers and see if firms handling Radio Servicing use the paper consistently. He states that this is a good indication that the paper has pulling power; otherwise the Radio firms would not continue their ads.

Courtesy Radio-Craft

FIGURE 5

A combination of publicity and advertising with small space "bullets," frequently repeated.

But another way of looking at the problem is that these firms may not pay much attention to the results of their ads, merely accepting what comes from them as a matter of course. This is a condition all too prevalent among Radio stores.

One service man solved the problem for himself by running an ad similar to the one pictured in Fig. 4, so he could test the reader interested in his ads—one paper against the other. These ads were identical in both papers—run at the same time, one week in each daily. By requiring the ad to be presented to get the free service and by having a key letter on the bottom of the ads he could tell which paper gave him most returns.

Small ads repeated frequently serve to keep your name before the public. They are usually better than large ads run at longer intervals.

A lot of good free publicity can be obtained for your business if you can get the editor of your paper to let you run a Radio Question Box as a regular feature of the paper. In this column you can discuss various phases of Radio, answer questions, and, by the use of your name, keep your business in the eye of persons interested in Radio.

Fig. 5 shows pictures of actual newspaper ads which were run to the financial advantage of the advertiser. At the extreme right and

Courtesy Radio-Craft

FIGURE 6

A group of larger newspaper ads which paid dividends.

left in this group are parts of a "Question" column, edited by the Radio man. To create interest in such a column, at first, it may be necessary to make up the questions and then supply the answers.

One must not expect too much from his newspaper advertising right at the start because a lot of persons, reading the ad, may not need service at the moment. The advertising value is in having readers become familiar with your name. It may be months before their Radio needs attention. In other words, it is quite possible for advertising to work for you, even when it is not producing definite, tangible results.

In Fig. 6 is reproduced another group of ads from newspapers. It has been reported that the ad at left, while using practically the same appeal, was less successful than the one in the center. This goes to prove the necessity of putting the "human interest" touch in advertising copy. These ads and those appearing daily in the papers will give you good ideas for your own advertisements. And your newspaper has an ad man who'll be glad to work with you in preparing them.

If pictures, cartoons, etc., are to be used in your newspaper ads, your newspaper office will be glad to tell you where cuts may be obtained locally.

Phone Book Ads

Every Radio man going in for service business will find it necessary to install a phone to take calls and make solicitations. When this is done it may be advisable to pay a little more and have an ad inserted in the classified section of the phone book.

KENNEDY'S J. P. RADIO SERVICE

PERSONAL
HIGH QUALITY SERVICE

Reasonable
Rates

418 W LaSalle..................3-2414

Courtesy Radio-Craft

FIGURE 7

An advertisement in the classified telephone directory attracts attention at the right moment.

While large ads may serve to pull in more business than small ones, telephone book advertising operates on the same basis as newspaper advertising under what is known as the principle of decreasing returns. By this is meant that if the size of an ad is increased four times, the returns will not be four times that of the smaller ad—and so on.

Therefore, the Radio man operating in a small way may be content with an ad in the phone book similar to the one in Fig. 7. There is no doubt that these ads serve a useful purpose, otherwise they would not be in such general use.

Business Cards

To the Radio-Trician, business cards have a very important use. They are an inexpensive method of advertising and, if properly distributed, can help secure a lot of business.

They can be used to advantage when canvassing, left with the housewife, they serve as a reminder when the Radio needs fixing.

In soliciting service work from a dealer who does not maintain his own service department, they are useful. Ask him to attach one to the front cover of his phone book so he can call on an instant's notice.

Ask each of your friends to carry one in his billfold. He may run across some one who needs Radio work done. You'll find any number of other uses for your business cards.

Fig. 8 shows some business card forms picked at random from those used by Radio men. The form really makes little difference so long as it has the essentials of a good card, which include your name, address, and nature of business, and that the card be neat and easy to read.

Business cards are printed in many sizes. They are also printed in many color schemes. But it has been found that a card 3⅜ inches long by 2 inches wide is most popular because it is handy to carry and fits a standard billfold well. The cards preferred by most Radio-Tricians are white, printed in black, dark blue, or dark green ink.

RADIO SETS AND AERIALS INSTALLED
ADJUSTED, REPAIRED

LEON WHITE
Member of National Radio Institute
Washington, D. C.

278 Berriman St. Brooklyn, N. Y.

Sales—RADIO—Service

THOS. R. BROWN
Conduit Road
BRENTWOOD, ALABAMA

Member N.R.I. Phone—14F

GUARANTEED RADIO SERVICE
MAIN 2843

WHITE'S RADIO SHOP
2614 Albertson St.
WEST VALE, NEBRASKA

Member National Radio Institute

Telephone 3-2414

J. P. KENNEDY
418 West LaSalle Avenue
SOUTH BEND, INDIANA

J. P. Kennedy's Radio Service

FIGURE 8

Some, however, go in for more expensive cards printed in two colors. The extra expenditure, we feel, is not justified.

Any printer can supply these cards. When you are ready to order them, make a rough layout of just what you want; take it to a local printer and he will be glad to quote you a price. In one color ink, the job should be run between 75c. and $1 per hundred; in two colors, about $1.25 to $1.50 for the same amount. Of course, printing costs vary in different localities. In larger amounts the cost per hundred cards is considerably lower.

Direct Mail Advertising

Radio service men frequently find it advisable to use what is known as "Direct Mail" Advertising in conjunction with other plans

ROBERT B. GUBBINS, JR.

RADIO SERVICE AND CUSTOM SET BUILDING
STANDARD ACCESSORIES

3855 N. HAMILTON AVE.

BUCKINGHAM 0813

NORTH SHORE RADIO COMPANY
TELEPHONE GREENLEAF 4900
1703 SHERMAN AVENUE
EVANSTON, ILLINOIS

COMMUNITY RADIO AND NOVELTY STORE
15015 East Warren Avenue at Wayburn
Phone Lenox 9727
DETROIT, MICHIGAN

Authorized Hammerlund Roberts Service Station

Set Building, Repairing and General Service.

HENRY H. CREWS
RADIO SERVICE
TELEPHONE 3255-W.
315 Pine Street

BALL · RADIO · SERVICE
Service and Supplies
Connersville, Ind.

OVIE B. BALL
Graduate of
Natl. Radio Inst.

531 W. 19th Street
Phone 1721
"Real Radio Service"

ELECTRIC APPLIANCES
PHONE 3594
22 SAN GORGONIO AVENUE

BRUNSWICK
RADIOS--PANATROPES RECORDS
RADIO SERVICE

The Radio Shop
of
L. L. BOSWELL
Banning, California

Reiss-Central Radio Service Company
3015 REGENT STREET
EAST ST. LOUIS, ILLINOIS
CONSULTATION SERVICE
CUSTOM BUILDING
SERVICING

FIGURE 9

for getting business. Direct Mail Advertising constitutes placing your sales message before a list of prospects, by use of letters, post-cards or other literature, sent through the mail. It is so called because your message goes *direct* to the person for whom it is intended rather than broadcast to a great number, some of whom are not prospects for your service, as in newspaper advertising. It is in this direct mail plan that the list of prospects you have compiled will be particularly valuable.

Direct Mail in this case can be described in a few words. A form letter is carefully written, telling the prospect of your ability to render good Radio Service. Check and recheck the letter for errors, as well as for possible improvements. When you are satisfied that it will meet the favor of *your particular prospect list*, then have it multigraphed (or typed if the list is small) and mailed.

A modification of this plan is to prepare the letter, then type on the envelope "Personal to Mr. ————." These letters are then

> Is your Radio working like it was the day you bought it? It should be.
>
> Even the best Radio set will deteriorate. It should be inspected by an expert and corrected before the condition becomes serious.
>
> I'll look over your set—regularly, or when called—keep it in tip-top condition. The cost of this service is very small—it more than pays for itself in satisfaction alone.
>
> My technical experience and knowledge of Radio are unreservedly at your call.
>
> Simply mail the postcard which I am enclosing (no obligation whatever). I'll gladly call and discuss the matter with you—any day or hour to suit your convenience. May I hear from you?

FIGURE 10

This letter produced good results for the Graduate who developed it. (*Courtesy National Radio Institute Alumni Assn.*)

slipped under the door at the home of the parties addressed. In this way you save the postage otherwise required for mailing. Follow up direct mail efforts by a personal call as soon as possible after the actual mailing.

Many persons in the Radio Service business try direct mail advertising and give it up as a bad job because it fails to produce as rapidly and the volume expected. One cannot expect to place several hundred letters in the mail and receive an equal number of replies. In fact, large mail order houses are pleased if mail selling efforts pull 1 to 3 per cent returns.

Of course, some letters are more productive than others. There are numerous factors which enter. Letter writing, just like Radio, is an art in itself. No attempt will be made here to delve into the intricacies of letter writing for the simple reason that in the short space allowed for the subject we would be doomed to failure.

However, a few of the most necessary rules for writing a letter will be given, which, together with the sample forms pictured, should enable you to prepare such letters as you need.

You should have a neat letterhead and envelope to match. Your local printer is an authority on the subject. Consult him. Some sample letterheads used by Radio-Tricians appear in Fig. 9. In addition to their use in direct mail work, letterheads are valuable in writing to manufacturers, etc., for literature, samples and discounts. They give a businesslike atmosphere to the request.

I don't sell Radios!

I'm not like the barber who gets you in his chair and then tries to sell you something out of every bottle on his shelf. My business is servicing Radio equipment. It is my job to make your Radio work when you call on me—not to tell you how bad it is—or how obsolete it has become, with the idea of selling you a new set. I'd rather make a set work—and work properly, just the way it did when you first bought it, than anything I know.

So when you call on me to repair your set—feel confident that I'm going to make it like you want it—like the manufacturer of that set intended it to be. I couldn't sell you a Radio if I wanted to—because I'm a Radio Serviceman first and last and *I don't sell Radios.*

Don't put up with improper Radio reception—what sounds like a big trouble in the set may only require a few minutes of an expert's time to correct. Is your Radio just the way you want it? If not—a phone call to Blake's, Main 2476, is all that's necessary.

Cordially yours,

FIGURE 11

An unusual letter, used satisfactorily by an N. R. I. graduate who wished to stress "SERVICE."

For your purpose the letter need not be over one page in length It should be neatly typewritten or multigraphed. Multigraph companies listed in your phone book will give rates on this work.

The letter should be simple and clear. Use small words, fairly short sentences and short paragraphs. This makes it easy to read The best letters are written in unstilted phrases, very much like a person would talk.

Open your letter with a sentence (be sure it deals directly with your message) which will get attention and make the reader want to go further into its contents.

After gaining attention in the opening paragraph, state your proposition clearly in the body of the letter so as to create a desire for your services, then endeavor to use closing paragraphs which will get the action you desire on the part of your prospect.

This action may be to call you on the phone, to send you a card to call, to give you an order for some special work, etc. In case they are supposed to mail you a card, a government post-card should be enclosed for their convenience. This should be mentioned in the closing paragraph, or, if they are to call you, give your phone number as a reminder.

Use care in grammar, spelling, and punctuation. Errors in these matters are unpardonable. If you are not quite sure of your letter's value, ask the representative of the multigraph company which you engage to go over it for you. He is familiar with letters.

Fig. 10 is a letter used in direct mail campaign by an N. R. I. graduate. He reported very favorable results.

Here comes Old Man Winter!

A few years back he brought only the holidays, sleigh-riders, turkey dinners. Now, he brings seven months of *Good Radio Reception.*

Beautiful, inspiring Christmas and New Year's music from the mighty organs of the grandest cathedrals in the country; the sporting and political events—music, drama for every mode—all brought to your fireside—free—if your Radio is operating as it should.

Give your Radio a chance and it will bring you every note of the organ recital—every word of the world-famed lecturers. This wonderful Radio of yours brings the world to your home—give it a chance to do its best.

Give it a little cleaning—a little adjustment by an expert—possibly a new tube or two and it's at your service again. Let me look over the little "wonder cabinet" free of charge and make you an estimate to put it in "NEW" condition.

Act now before the rush is on—don't take chances on missing anything. When may I call?

FIGURE 12

A letter taking advantage of the Christmas season to solicit service work.

In Fig. 11 a letter is shown which is slightly out of the ordinary. In order to get attention the service man has used a startling opening. However, as the open fits in well with the balance of the letter, it is perfectly permissible from a point of letter writing.

Timeliness is a keynote of direct mail advertising. To tie up your mailing with a coming event of importance—a season, a special series of broadcasts—is to make that mailing more to the point and consequently more productive. In Fig. 12 the Radio-Trician ties up his copy with the Christmas season. By slight changes this letter could be used for World Series baseball, college football, political campaigns or any series of Radio broadcasts which have a strong appeal to the listening public.

Five hundred letterheads and an equal number of envelopes, printed, will cost between $8 and $12. Multigraphing that amount of one-page letters should cost around $5 or $6.

The reverse side of this half contains the address of the prospect.

Dear Radio Owner:

For a limited time we are offering a *free inspection* of all Radios in the neighborhood. This is being done so that we may get acquainted. We want you to know our company.

Though your set is in perfect order it should be checked periodically—just to make sure. Physical examinations help people keep fit—and Radios are like that, too.

As we said before, this service is free—there's no obligation. With our modern testing equipment we'll give you an accurate report on the condition of your set.

Just mail the attached card telling us when our expert may call.

John Murphy Company,
Radio-Tricians.

John Murphy Co., Radio-Tricians,
3823 Broad Street,
Miami, Florida.

FIGURE 13

The reverse side of this lower half contains a form for the prospect to fill in the name, address, and time for the Radio-Trician to call.

The sample shown above is smaller than your card should be. Make your card 5½ inches wide by 3¼ inches deep.

The inside of a double postcard. The top half carries the message. The lower section is the return form. The card is folded and the open ends sealed together with a one cent postage stamp which carries it through the mail.

A very popular form of mail advertising among Radio Service men is the government post-card. This is due to the small expense involved.

One side of the card contains the prospect's address; the other side carries the Radio-Trician's message. The messages can be multigraphed, printed, or typed. Multigraphing or typing is preferable.

Great use is made of these cards to pave the way for an inspection or canvass call. Copy similar to the following is frequently used:

"Our representative will call on you in the next few days to test your Radio free of charge;" or "Our representative will call to tell you about our new service plan," etc.

These cards are also used to induce the prospect to call you on the phone and request service.

A modification of the plain government post-card mailing plan is the use of the "double post-card" system. In this plan a double size post-card stock is used. The set-up is that of a mailing card and a return card attached. See Fig. 13. This card may be sealed at the bottom by a one cent postage stamp. (It is well to inquire at your post-office about rates on mailings before any literature is prepared, as these rates may change from time to time.)

A post-card mailing, to prospects, single or double, once every several weeks, is an inexpensive method of keeping your name and business before them. All mailings should be followed as soon as possible by a personal call. Change the message frequently on your mailings.

WHAT TO CHARGE

It is not possible to make any hard and fast rule regarding the charges to be made by the Radio Service man. The standard price charged in the locality in which you are doing business will have a lot to do with your charge for Radio Service work.

Then, also, the method in which you are operating your business will have a decided bearing on your charge. Naturally, if you are operating on the service contract plan your scale of charges will be different than if you were working on the wholesale service business. In other words, charges will depend upon the service to be rendered.

The Minimum Charge

There is no doubt that every service organization operating on the "Call" basis should make a policy of having a minimum service charge. By that is meant that, regardless of the reason for the call, regardless of the work necessary upon the arrival of the service man, there should be a certain fixed charge which the customer will be required to pay. This minimum service charge is necessary, even though the work you will be required to do is of a trivial nature; nevertheless, it was necessary for you to spend your time going to and from the customer's home, expenses of driving your car. street car fare, etc.

Minimum charges used by service men and dealers all over the country vary from $2.50 down to 50c. Both of these extremes are wrong. One is too high; the other too low, for a proper minimum service charge. But when we take an average of a large number of minimum charges, we find that the figure is $1.25. which makes a very fair price for a minimum service charge.

Miscellaneous Charges

Watch your jobs very closely at first, especially those jobs requiring some construction work like antennas and ground. Keep an accurate record of all the items which go into such a job, including time, labor, material, and in this way know just exactly the cost at which you can do the work and still make a good margin of profit. Whenever a job is obtained on aerial or ground work, it is safest to make no estimate, no quotation, until you see the job, look it over carefully, and know just what you may expect. Numerous service organizations make a policy of doing aerial and ground jobs on a time and material basis. Figure an extra charge for an aerial job if it is on a sloping roof. It will require more time. In connecting up a set to an old aerial always first inspect the job thoroughly. The old antenna may not be satisfactory and may cause trouble for which your installation may be held responsible. Improperly installed or inferior lightning arresters and grounds can cause no end of difficulty for the set owner. Inspect them carefully.

Just as lining up new customers is important to the Radio Service man, so is it important to retain old customers. It is advisable to contact the persons for whom jobs have been done at regular intervals. A phone call, a post-card or a personal call will do. Let them know you are interested in how the job turned out and if the set is working satisfactorily.

ADDING PERSONALITY TO YOUR EQUIPMENT

In addition to tools and testing equipment the Radio Service man can well add additional equipment. This is personality.

Personality is something none of us have enough of; there is room for improvement in the best of us.

It is easy to improve personality and it is advantageous to do so regardless of business or position, but the chief difficulty lies in making any person realize that he is not perfect along the lines of personality.

To improve personality we must analyze our personal habits, decide frankly those traits or personal habits which need improvement, then strive for perfection in each instance where we find ourselves below par.

Read over the following list of questions. Answer each of them with one of two words, "YES" or "NO." Be frank with yourself; you can afford to be because no one will know the answers but you. If your answer is "NO," then you must strive for improvement. Write your answer in pencil in the space provided. Then, once a month, check up on yourself, go over the entire list and strive until you know positively that your answer is "YES" in every case. You'll find it will pay dividends. Some of these questions are very personal—but one has to be personal to improve personality.

PERSONALITY IMPROVEMENT CHART

Question	*Answer*
Do I keep my clothes clean, my suit well pressed, my shoes shined?	______
Do I select my clothes carefully so they are not the extremes in style or color?	______
Do I practice cleanliness of body? Are my face and hands clean, my nails well cared for? Is my hair neatly combed?	______
Am I doing all in my power to keep healthy? Do I care for my teeth, eyes, and digestion? Do I get sufficient sleep and exercise?	______
Am I friendly, pleasant, dignified; at ease before strangers? Do I meet problems as they come, solve them myself without shunning responsibility and looking to someone else for guidance?	______
Do I put in a real day's work? Do I start early, quit late? Do I put in as much time when working alone as when working under supervision?	______
Am I careful with my method of speech? Do I avoid slang as much as possible? Do I talk the language of the persons with whom I am dealing?	______
Do I plan each day's work in advance and follow out the plan? Do I aim to have each day carry me a step nearer my ultimate goal?	______
Do I please each customer? Do I make sure of satisfaction in every transaction? Do I charge properly, consider the customer's welfare, and avoid shady transactions?	______
Do I keep my temper, always?	______
Is my word to be relied upon?	______
Am I loyal to my friends?	______
Do I pay my bills promptly and thereby improve my credit?	______
Do I strive to improve my memory?	______
Do I continually conduct myself so as to improve my standing in my community?	______
Am I trustworthy in little things?	______
Do I keep appointments?	______
Do I establish my reliability as thoroughly as my ability?	______

When you can conscientiously answer "YES" to every one of the above questions you will find yourself a bigger, better man in your own estimation and in the regard of others. You will have passed an important milestone in your march to Success.

CREDIT

While being a good Radio-Trician will go a long way in helping you to success, as a business man you must consider the phases of business practice which have a definite bearing on your Success.

Good credit is a necessary foundation for Success.

Credit is like a frail flower. It flourishes in the sunlight of truthful dealings. It withers and fades when individuals make promises they are unable or unwilling to fulfill.

It is estimated that 70 per cent of all business today is conducted on credit. Everything from daily newspapers to international warfare is operated on the deferred payment plan.

No one should hesitate to buy on credit, but, before buying, definite plans should be made for paying for the merchandise or services received. And there is no disgrace in asking a bank for a loan for business purposes; in fact, it is good business to do so.

Suppose a man has several hundred dollars due his creditors at a certain time and doesn't see his way clear to pay them. If his credit is good, he should be able to borrow the money at from 6 to 10 per cent, pay off his bills, and take advantage of discounts for prompt payment.

J. Pierpont Morgan, the outstanding financier of the last generation, says that the best security for a loan is character. And a big factor in any man's good character is his willingness and ability to meet his bills and obligations on time. Good credit is little more than reputation for reliability.

The man who insists on your making your payments on time is doing you a big favor. He is helping you maintain a most valuable asset—your credit.

Modern business has established an elaborate system of individual credit ratings. Every town of any size and consequence has its trade association. These associations maintain Credit Information Bureaus, which supply credit information not only locally but maintain reporting services to other bureaus all over the country.

Apply for credit in a store or business house of any kind and your application is referred to the Credit Agency. If they have no unfavorable reports from merchants or other credit bureaus, you get what you want. Otherwise, you pay cash.

Excuses don't go with these fellows. They are not interested in a hard luck story. With them it is a case of "*Do you pay, or don't you?*" They feel that a man should analyze conditions far enough in advance to know when and how he can meet his credit obligations.

Employers frequently check up on the general character of a man before they hire him. A man who is conscientious in paying his bills is usually straightforward in his dealings with his employer.

To the man in business for himself, good credit is a most valuable asset. He can get along on a small capital if he has good credit, but if not, as soon as his capital is invested in equipment, etc., he has no place to turn for additional capital.

I have in mind the case of a man who made $15,700 in his business in three years. Then came a period of depression. He lost it all and $4,300 besides. That was a big hole to climb out of, but he did it. He had a reputation for paying his bills promptly; consequently, very liberal credit. Right now he is well on his feet again, but he wouldn't be if his credit hadn't been good.

The best rule for establishing a credit standing is to never buy anything you can't pay for and to pay all bills promptly as they fall due.

THINGS TO DO

The wise Radio-Trician is he who searches for every opportunity to make money with his knowledge. This is a list of some of the things the Radio-Trician can do to cash in. You'll probably think of many more. Check over the list to see if you are passing up any opportunities.

Repair Radio receivers.

Charge batteries—particularly in rural sections.

Remodel old sets.

Install or improve aerials and grounds.

Install interference eliminating circuits and grounds.

* Locate and remedy minor interference cases.

Install sets for dealers.

Sell and install lightning arresters.

Clean Radio sets.

Replace tubes, sell spare tubes.

Sell sets on commission for dealers.

Sell service contracts.

Wholesale the service of dealers.

Contact dealers and garages for automobile Radio Installation and service work.

Install new chassis in expensive cabinets, removing old chassis.

Install new chassis in special cabinets, walls, etc.

Install tone controls on old receivers.

Electrify phonographs and install pick-ups where Radio has pick-up jacks already built in the circuit.

Modify sets for phone pick-up.

Build and install short wave converters.

Install additional speakers.

Construct and install wave traps.

Install automatic line voltage controls.

Build and rent small public address systems for public gatherings of many sorts.

Install and service sets on boats and yachts.

Add remote control to sets.

Sell on commission all sorts of electrical appliances, such as electric clocks, Radio lamps, irons, vacuum cleaners, etc.

It is well to carry a midget set along on service calls. A customer may complain about noises in a set which are beyond the power of the service man to remedy. When this condition arises, connect up

---

* The elimination of interference often offers a splendid opportunity for the Radio Service man to make money. In the ordinary household are usually numerous electrical appliances which may cause Radio interference. Set owners frequently blame the poor reception in such instances to improper functioning of the set. They will usually authorize you to correct the trouble, particularly when it is explained that they may be interfering with their neighbor's reception as well as their own.

However, the more complicated interference jobs, especially those involving commercial apparatus, should not be tackled by the service man until he is a full-fledged graduate Radio-Trician, as his more advanced lessons will be a big factor in enabling him to carry the job through successfully.

the small set; let the customer listen to the reception. If the noises persist in the midget, it will satisfy him that his Radio and service are not to blame.

It is a nice gesture to leave a midget with a customer whose set must be taken to the shop for repairs. Remove the chassis and leave the midget on top of the cabinet for his entertainment until his set is returned.

You'll find children very favorably impressed by midget sets. Possibly because of the size, they compare them to toys. In many cases a midget, left while the large set is being repaired, can be sold for the children's room.

Ask the housewife if she wouldn't like an inexpensive midget on top of her kitchen cabinet.

NOW YOU MUST ACT

Your N. R. I. training and the hints given in this book have fitted you to go out, right now, and make spare-time Radio profits.

The same training you have received, up to this point in the Course, has enabled thousands of N. R. I. students to make fine profits in their spare time. What they can do, you can do.

Up till now you have been studying, reading, thinking. Now you must act if you want to make your start for a successful Radio Business of your own!

All ideas in this book, while written primarily for the spare time Radio worker, can be elaborated and used successfully by a man in full-time Radio.

PHOTOELECTRIC CONTROL CIRCUITS WITH RELAYS

25X

REFERENCE BOOK

NATIONAL RADIO INSTITUTE
EST. 1914
WASHINGTON, D.C.

FOR YOUR REFERENCE LIBRARY

This reference book will prove very valuable should you ever have occasion to deal with photoelectric apparatus, for it contains logical and understandable explanations of the operating principles and characteristics of basic electronic circuits. Give especial attention to the relay section of the text, for you will encounter relays many times in work with radio transmitters and in remote control radio installations such as are used in two-way police car systems, in aircraft radio, and in a host of other commercial radio systems.

Read through the material on the photoelectric and electronic control circuits at least once; each circuit has been carefully selected to show certain fundamental principles which, once understood, can be utilized in designing many other useful circuits of the same general type.

Electronic tubes such as the well-known General Electric Thyratron and the Westinghouse Grid-Glow tubes are being used more and more in industry today; you will find in this text more than ample reference material on this particular subject.

J. E. SMITH.

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

1941 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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Photoelectric Control Circuits with Relays

A REVIEW

YOUR study of light-sensitive cells has shown that these "electric" eyes" interpret a change in light as a change in their electrical characteristics. Thus, light causes a photoconductive cell to change its resistance, this change being converted into either a current or voltage change by the cell circuit; a photovoltaic cell actually produces an e.m.f. directly, this generally being used to give a current change in an electrical circuit; a photoemissive cell controls the electron flow in its circuit, thereby producing changes in voltage and current. Although these actions are quite definite, it must be clearly borne in mind that the current changes are quite small, usually of the order of microamperes, but occasionally as large as several milliamperes, depending upon the kind and type of cell used. In order to control electrical apparatus with light-sensitive cells, it is sometimes necessary to build up these comparatively small current changes. Obviously relay devices are necessary; before typical photoelectric circuits are considered, the basic principles of the different types of relays should be understood.

In any practical control circuit, the impulse or electrical power change originating at the photoelectric cell must actuate an electromagnetic relay whose contacts either open or close the circuit to the device which is to be controlled by changes in light. The greater the current required by the device, the greater must be the pressure of one contact against the other, the larger must be the contacts, and the greater must be the power required to operate the relay; a single sensitive relay in the photoelectric cell circuit can therefore control only small loads. Where large currents are to be controlled, the sensitive relay is made to actuate a power relay which has large contacts, capable of handling heavy currents.

Many different schemes for linking the light-sensitive cell with the power relay have been introduced. Electromagnetic relays connected in succession, so the contacts of one control the input to the next, are widely used where conservation of power is desired. For example, a photovoltaic cell may actuate a supersensitive relay which controls a semi-sensitive relay, and this secondary relay in turn operates the final heavy-duty relay.

Because super-sensitive relays are expensive and require considerable attention, many methods have been developed to eliminate their use. A voltage change in the cell circuit can be amplified sufficiently by one or more vacuum tube amplifiers to operate sensitive or heavy-duty relays. The voltage change originating at the cell can also be applied between the grid and cathode of a gas triode (such as a "grid-glow" or a Thyratron tube), and a heavy-duty power relay can be inserted in the plate circuit of the gas triode; in many cases the device being controlled can be connected directly into the plate circuit of the gaseous tube, in place of the power relay.

Thus, you may find between the light-sensitive cell and the controlled device either an electronic relay (consisting of one or more gaseous or vacuum type amplifier tubes), an electromagnetic relay, or a combination of the two. The intervening relay circuits may impart special characteristics to the complete photoelectric control unit, but in general, the final action is to open or close the circuit at the desired time interval after the light on the cell has changed by a certain definite amount.

In considering the characteristics of relays and the selection of a relay for a particular application, certain fundamental facts must be

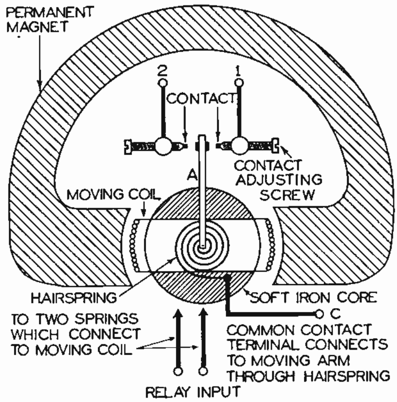


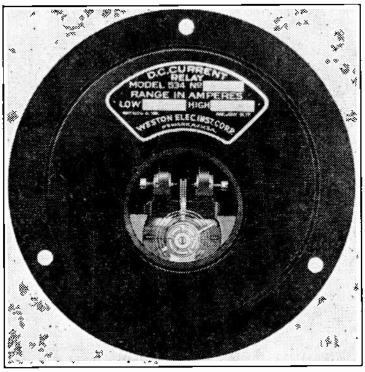
FIG. 1A. The basic construction of a supersensitive or meter type relay, shown above, is very similar to that of a high quality moving coil type meter.

considered. How much current is required to make the relay contacts close? This current is called the *pull-up* current of the relay. At what value of current will the relay contacts open? This is called the *drop-out* current. Other important factors are: How long does it take after the current or voltage reaches the pull-up value before the contacts close completely? How much time elapses, after the relay current is reduced to the drop-out value, before the contacts are opened? Where rapid counting or fast action is required, fast relays are used; for certain jobs, such as illumination control applications, extremely slow relays are needed; where light changes on the cell are small, the difference between pull-up and drop-out currents must be small. The nature of the power supplied to the relay circuit must be considered, for relays designed for D.C. use are as a rule more sensitive than A.C. relays. The ohmic value of the relay coil is another important factor, for the voltage drop across the coil must be considered in the design of the control circuit.

Other factors affecting the selection of a relay are the current, the voltage and the nature of the load in the circuit being controlled. The contacts must be able to carry and break the current through the circuit without serious arcing or sparking. The voltage must not be so high that current will jump across the contacts when they are open. With these basic facts in mind, I will now consider the various types of relays used for photoelectric and electronic control systems.

SUPER-SENSITIVE RELAYS

From a practical viewpoint, super-sensitive electromagnetic relays are really modified moving coil type microammeters, with platinum-iridium contacts mounted on the moving pointer and adjustable contacts, one on each side of the pointer, mounted on the meter scale. Platinum-iridium contacts are used because this alloy does not oxidize or tarnish in air, and resists the pitting (eroding) action of the current.



Courtesy Weston Electrical Instr. Co.

FIG. 1B. Weston Model 534 meter type relay, capable of operating on coil currents as low as 15 microamperes.

The basic arrangement of a typical super-sensitive relay is shown in Fig. *1A;* the two moving coil terminals are connected into the controlling circuit (light-sensitive cell circuit), and the remaining three terminals, going to contacts *1* and *2* and to pointer *A*, are for the controlled circuit. An increase in current through the relay coil will send arm *A* to contacts *1* or *2*, depending on the direction of current flow in the coil circuit. The sensitivity of this relay depends on the strength of the permanent magnet, the number of turns on the coil, and the spring restoring torque (twist), just as with ordinary meter movements; units which will make contact on currents as low as 5 microamperes are obtainable. One commercial form of this relay, the Weston meter-type relay, is shown in Fig. *1B;* the minimum current required to close the contacts is 15 microamperes and the contacts are rated to handle up to 200 milliamperes (non-inductive load) at 6 volts.

A simple super-sensitive relay of this type can be used in the following three ways:

I. With *no current* flowing through the relay coil, arm *A* (Fig. *1A*) is set midway between contacts *1* and *2*, so a positive current (a current flowing in such a direction that it causes the pointer to swing clockwise) will move arm *A* to contact *1* and a negative current (making pointer swing counter-clockwise) will move the arm to contact *2*. The closer together the contacts are placed, the smaller is the current required to move the arm over to one of the fixed contacts.

II. Arm *A* is made to center itself halfway between contacts *1* and *2* for a *definite value* of coil current, making contact with *1* when the current exceeds this value and making contact with *2* when the current falls below this mid-value. Moving contacts *1* and *2* closer together gives relay action for smaller changes in current.

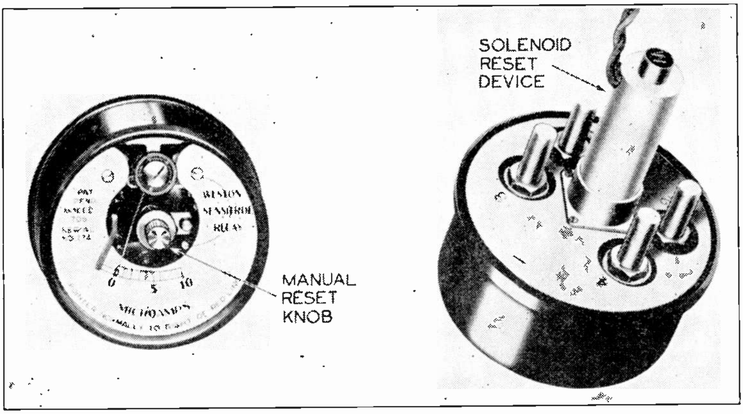
III. Arm *A* is set to make contact with *2* for all coil currents from zero up to a certain definite value in the relay range; currents above this value then move the arm over to contact *1*. The reverse of this action is also possible.

The speed of operation of meter type relays can be increased by moving the fixed contacts closer together; small currents and voltages, usually not over 200 milliamperes at 6 volts, can be controlled where fast operation is desired. There must be no appreciable inductance in the contact circuit which would cause serious arcing.

Any current or voltage range for the moving coil of the relay can be obtained by the proper use of shunts and multipliers. Super-sensitive relays having ranges below 200 microamperes can be connected directly across dry or wet type photovoltaic cells, or placed in series with a battery across photoconductive cells. The contacts of the relay are usually connected through a 4.5 to 6-volt battery to the coil of a semi-sensitive relay, which may in turn actuate a power relay.

The extremely high sensitivity of the meter type (super-sensitive) relay is offset by a number of disadvantages. There is a tendency for the contacts to "chatter," or open and close repeatedly when the actuating coil current is just about enough to make or break a contact; this results in arcing, faulty operation of the relay and eventual destruction of the contacts. To overcome this chattering without depriving the relay of its low current pull-up value, the Weston Instrument Corporation has introduced their so-called *Sensitrol* relay, shown in Fig. *2A*. The basic construction of this relay is like that shown in Fig. *1A*, except that a small soft iron piece or "rider" replaces the contact points on moving arm *A*, and a small but powerful permanent magnet replaces the contact at 1. When the arm swings over to the right it is snapped up against the face of the magnet, making a solid contact. External force must be applied to the pointer to free the rider from the magnet and break the contact. This can be done in either of two ways, by turning the reset knob in the center of the relay, which pushes the pointer back to its no-current position, or by using a solenoid to reset the pointer electrically. The solenoid type Sensitrol is pictured in Fig. *2B*.

Sensitrol relays can be obtained in many different types, to open or close a circuit on either an increase or a decrease in current. These relays are most often used for installations where repeated or continuous control is unnecessary, such as in locations where an attendant can reset the relay after each closing. Time relays can be used in conjunction with the solenoid type Sensitrol to reset the relay automatically; although the apparatus required is quite expensive, it gives the only practical solution to certain types of control problems.



Courtesy Weston Electrical Instrument Co.

FIG. 2A. Weston Model 705 Sensitrol relay with single fixed contact. The manual reset knob must be turned after each operation of this relay.

FIG. 2B. Rear view of solenoid reset type of Weston Model 705 Sensitrol relay. The twisted wires go to a source which provides relay reset current; the four terminal posts are for relay coil and contact connections.

SENSITIVE RELAYS

Relays of the sensitive type require currents of from .5 to 3.0 milliamperes for their operation. This type of relay is used in the plate circuit of a vacuum tube amplifier whose grid is connected to the control element (light-sensitive cell, thermostat, beat frequency oscillator, etc.), and in circuits where it is controlled by the contacts of a super-sensitive relay.

In general a sensitive relay consists of a soft iron armature, pivoted at one end and having contacts on each face at the other end, this armature being attracted to the iron core of an electromagnet when the required current is passed through the electromagnet coil.

Figure *3A* gives the construction of a typical sensitive relay. A large number of turns of No. 30 to No. 40 B. & S. gauge enamelled or insulated copper wire is wound on a bobbin which slips over one leg of a U-shaped core. These coils are designed to have the greatest number of ampere turns for a given operating voltage and current. The weaker the rated pull-up current of the relay, the greater must be the number of turns on the coil; increasing the turns means increasing the resistance of the coil. Relay coils have resistances varying from 1 to 10,000 ohms, depending upon the operating current; sensitive relays for photoelectric work ordinarily have resistances of from 1,000 to 8,000 ohms.

Relay coils are generally rated according to the power in watts required to pull up the armature and close the contacts. This wattage rating allows relays of different voltage and current ratings to be compared as to sensitivity.

Pivoted at one end of the U-shaped core (Fig. *3A*) is the soft iron armature which is attracted to the U-shaped core when the solenoid is excited with sufficient current. The armature is normally held against contact C_2 by the action of the spring; when pull-up current passes through the coil the armature is pulled up against C_1. Thus, by making

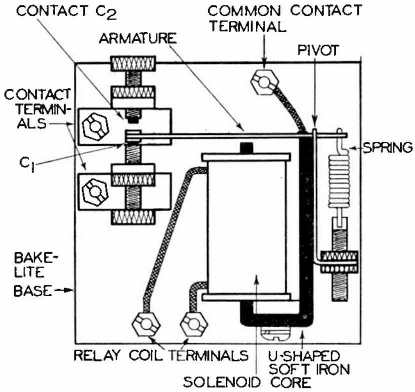
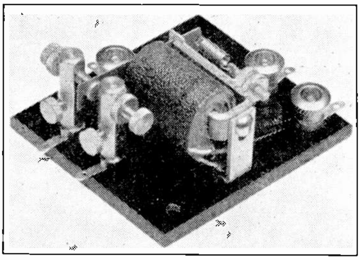


FIG. 3A. Sketch showing construction of a typical sensitive relay. The common contact terminal connects to the armature.



Courtesy Samuel Wein

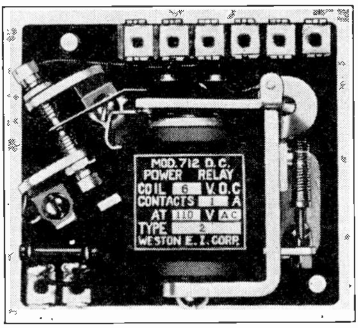
FIG. 3B. This commercial sensitive relay is very similar in construction to that shown in Fig. 3A.

the proper connections to contacts C_1 and C_2 the control circuit can either be opened or closed by the relay, or two separate circuits can be controlled.

It is important that the armature and the core of the relay coil be made of material which will not retain its magnetism when the current falls below the pull-up value. Special alloys of iron with silicon, which change their magnetism as the magnetizing current changes and lose practically all magnetism when the current drops to zero, are therefore used. These alloys have a high permeability, which means that they produce a large magnetic attraction for low values of ampere turns; the lower the electrical power required to pull up the armature, the more sensitive is the relay. Note that one end of the armature (the lower end in Fig. *3A*) rests against one of the poles of the U-shaped core; this reduces the reluctance of the magnetic circuit, giving greater sensitivity.

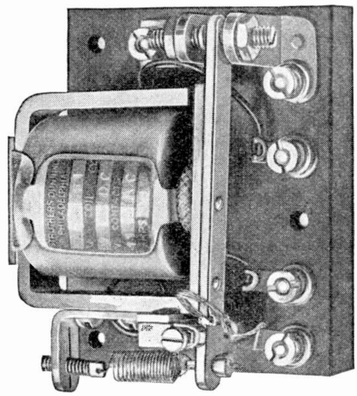
The armature must be properly balanced so it will move freely without wasting any of the attractive force, if maximum sensitivity is to be obtained. The connection to the armature is ordinarily made at some point on the U-shaped core, current passing through the pivot and out along the armature to the double contacts. Pigtails (flexible leads) are sometimes used to bridge the pivot and give a more dependable electrical connection. Sensitive relays of this type will handle about 2 amperes at 110 volts A.C. or ¼ ampere at 110 volts D.C., provided the loads are non-inductive (have no coils which offer an inductive reactance to current flow). Typical sensitive relays are shown in Figs. *3B*, *4A* and *4B*.

Another type of sensitive relay, shown in Fig. *5*, is commonly known as a *telephone type relay*, because it is widely used in telephone circuits. The coil of this relay is about 3 inches long and 1 inch in diameter, and



Courtesy Weston Electrical Instr. Co.

FIG. 4A. Weston Model 712 D.C. sensitive relay, capable of handling up to 1 ampere at 110 volts A.C. The coil is wound for 6 volts D.C. The common contacts are here mounted on a thin springy blade attached to the armature; this gives a wiping motion at the contacts, which tends to keep them clean.



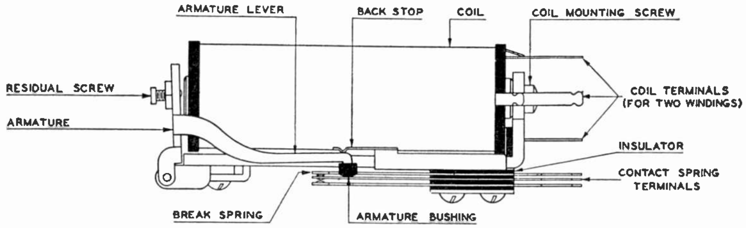
Courtesy Struthers Dunn, Inc.

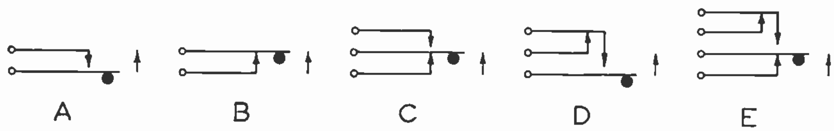
FIG. 4B. Dunco Type CXB51 sensitive relay, which can be obtained with coils of various voltage and current ratings for either A.C. or D.C. This relay will operate on as little as .01 watt D.C. or .2 watt A.C. U-shaped core has central leg on which coil is mounted. Note pigtail connection to armature.

has a cylindrical soft iron core. At one end of the core a rectangular soft iron armature is so pivoted that it is attracted to the core when current flows through the coil. There are no contacts on the armature; instead there is an armature lever having at its tip an insulated bushing. When the armature pulls up, this lever pushes against springy steel blades on which the contacts are mounted; these contact blades can be arranged either to open or close circuits when the relay operates. The blades are very similar to those used on plug-in telephone jacks. Any number of combinations of make-and-break circuits is possible. A few of the fundamental contact possibilities are shown in Fig. *5*. When the armature button moves in the direction of the arrow, the indicated "make-and-break" or open-and-close action takes place.

The telephone relay is an extremely flexible device; with certain modifications it can be adapted to any practical speed or function. It will pull up in .02 to .05 seconds, and drop out in the same time. A residual magnetism screw, set into the armature to prevent it from sticking to the core when coil current is zero, can be adjusted to reduce the movement of the armature, thus speeding up its action.

The drop-out time of the telephone relay can be increased by using an electrical means for preventing a rapid decrease in magnetic flux.





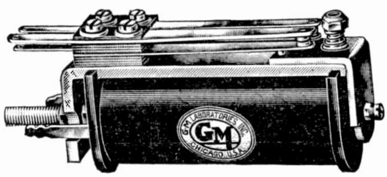
Courtesy Automatic Electric Co.

FIG. 5A. Diagram of a typical telephone type relay, widely used in electronic control apparatus as well as in telephone work. The relay contacts are, according to the manufacturer, capable of handling up to 450 watts; as a general rule, however, it is necessary to use a power relay when the load to be controlled exceeds 200 watts. Below the relay are five basic contact assemblies for telephone type relays (shown in their normal position when no current flows through the relay coil): Form A—Make; B—Break; C—Break before Make; D—Make before Break; E—Break and Make before Break.

For instance, a medium speed relay is obtained by placing a copper sleeve over the iron core (between the coil and the core). A slow speed relay is obtained when a heavy copper washer is slipped over the end of the core. The thickness of the washer determines the speed of operation of the relay. The principle of mutual induction explains why relays can be slowed up in this way; the copper washer or sleeve is really a single turn coil of low resistance, mutually coupled magnetically (by

Courtesy G-M Laboratories

FIG. 5B. A type of telephone relay designed especially for photoelectric work; note that there are two pairs of contacts.



the core) to the relay coil. The thicker the washer, the lower its resistance and the longer it can prevent a change in the flux through the core.

Super-sensitive relays are generally of the fast type; however, sensitive relays are made with fast, medium and slow operating speeds. Fast, sensitive relays are recommended for use in the plate circuit of a vacuum tube. The most dependable relays have a drop-out current which is about one-half the pull-up current; this gives a relay differential (ratio of drop-out current to pull-up current) of 50 per cent. Relays with differentials of 15 per cent to 25 per cent are available, but these in general require more frequent attention; they operate on small differences in exciting current, but this low differential makes for a less sturdy relay and one which has a tendency to chatter.

The sensitive relay can be used in A.C. or pulsating D.C. current control circuits if certain precautions are observed. A.C. voltages are almost always easier to obtain in the various required values, whereas batteries change in voltage and require constant replacement. Where a super-sensitive relay controls a sensitive relay, the exciting voltage, say 6 volts A.C., could be obtained by a step-down transformer; where the sensitive relay is placed in a self-rectifying plate circuit whose supply voltage is raw A.C., pulsating D.C. current would pass through the relay coils; these are practical instances where control equipment is operated directly from an A.C. power line, with no auxiliary batteries.

A telephone relay (designed specifically for D.C. use) may be used in a self-rectified plate circuit if a condenser is shunted across the relay coil. The lower the coil resistance the larger must the condenser capacity be to prevent contact chatter. Always use the smallest capacity

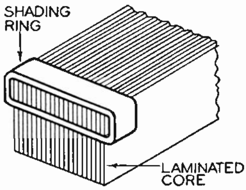


FIG. 6. In order to prevent chatter when relays are operated on A.C., a heavy copper shading ring like that shown here is forced into a slot cut into that end of the laminated iron core which faces the armature.

which will prevent chatter, for too large a condenser would take too much current away from the relay coil. A 2 mfd. condenser is about correct for a 5,000-ohm relay coil.

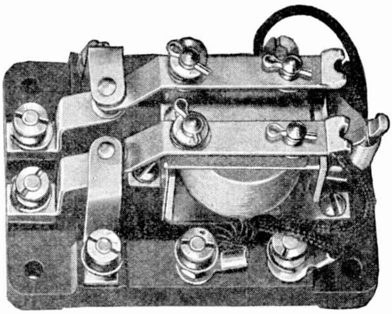
Special types of relays are available for use in A.C. circuits; these are generally less sensitive than the D.C. type, for power is lost because of *eddy currents* and *hysteresis*. A.C. and D.C. relays have much the same construction; the cores and armatures of some A.C. relays are made up of very thin sheets of silicon iron, like audio transformers, while other types use solid cores having one or more slots along one side to reduce eddy currents. Then, too, the mass (weight and shape) of the moving armature, and the spring tension must be such that the moving system has a vibration period which is less than the frequency of the exciting current. As an additional check on chattering, that pole of the core which faces the armature has a split end, in which is embedded a heavy copper ring, called a "shading" ring or coil; this is shown in Fig. *6*. This ring acts like a short-circuited secondary winding, its induced current producing a flux which holds the armature down during that part of the cycle when the current (and the main flux) drops to zero. This shading coil is commonly referred to as a *split phase* device. All these factors tend to make A.C. relays less sensitive and more expensive than D.C. types.

HEAVY-DUTY OR POWER RELAYS

When the power that is to be turned on or off by a relay exceeds 200 watts for A.C. and 25 watts for D.C., the maximum values which can be handled by the *average* sensitive relay, this type of relay is generally connected to actuate a power relay.

The coil of a power relay requires a D.C. input power of about 2 watts, in general, for satisfactory control of up to 1,000 watts A.C.; if a 100 volt D.C. source is used to excite the power relay coil the operating or pull-up current ($I = P/E$) will be $2 \div 100$ or .02 ampere (20 milliamperes). The resistance of the relay coil ($R = E/I$) should therefore be $100 \div .02$ or 5,000 ohms in this case. The required resistance for any relay coil can be figured in this manner. In general, A.C. relays require a higher power input than D.C. relays.

The principle of operation of the power relay is essentially like that



Courtesy Struthers Dunn, Inc.

FIG. 7. Dunco midget heavy-duty relay (Type CDBX1), having two contact blades mounted on the clapper type armature to give double-pole double-throw operation.

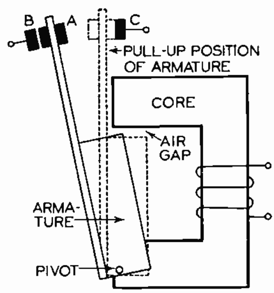
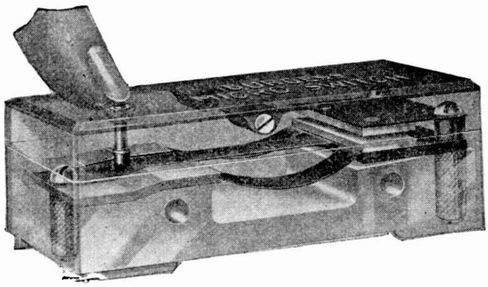


FIG. 8. Diagram illustrating the principle of operation of the minimum reluctance type of power relay. Dotted lines show pull-up position of armature.

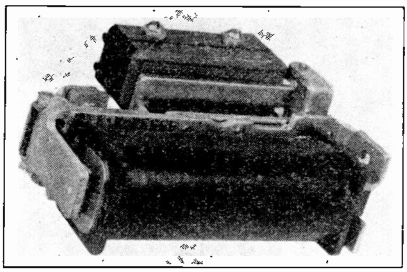
of the sensitive relay. The same precautions are taken to prevent chatter on power relays designed for A.C. excitation. A typical power relay (also called an auxiliary relay) is shown in Fig. 7. A rectangular clapper type armature is pivoted in front of an electromagnet, the clapper carrying one or more contact arms which move between fixed contacts. The one shown is a double-pole, double-throw switching relay, one circuit being closed when the relay pulls up, the other being closed when the relay drops out. A large number of make-and-break combinations are possible. Where a super-sensitive relay controls a sensitive relay and this in turn actuates the power relay, the first two relays are essentially simple make-and-break types, while the power relay furnishes the desired type of switching, often quite complex.

Another form of power relay, one which can apply heavy contact pressures, makes use of the suction or minimum reluctance action of a magnetic circuit. The principle is explained in Fig. *8;* when A.C. or D.C. is fed to the relay coil the armature has a tendency to take a position which will make the reluctance of the magnetic circuit a minimum (by making the air gap between the armature and the poles as small as possible). The armature then takes the position shown by the dotted lines, the contact arm moving from *B* to *C*. (Figure *11B* shows one example of a minimum reluctance type of power relay.)

Both sensitive and power type relays can be made with a small latch or mechanical lock which will hold the armature in position once it has been attracted to the core. Relays with this device are known as *latch-in relays;* they must be released either mechanically (by pushing on the latch) or by an auxiliary electromagnet whose armature is attached to the latch. Latch-in type relays are useful where the relay-



Courtesy C. F. Burgess Laboratories, Inc.
FIG. 9A. Phantom view of the Burgess micro-switch. A slight pressure on the plunger at the left either opens or closes the silver contacts at the other ends of the spring steel blades, depending upon how the contacts are arranged.



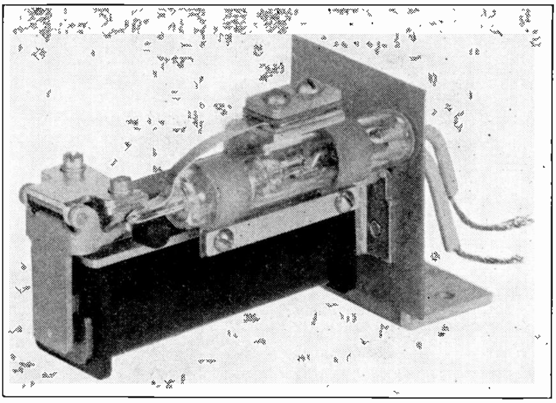
Courtesy Automatic Electric Co.
FIG. 9B. A Series FMS Automatic Electric Relay with a micro-switch mounted on one side, its plunger being actuated by the relay armature. This unit can handle loads as large as a ½ h.p. A.C. motor.

actuating current is an impulse (produced by pushing a button or interrupting a light beam) which must keep mechanisms in operation until the desired condition has been reached; the latch can then be released by some type of limit switch, opening the relay in readiness for another control operation. For example, when an intruder passes through a light beam, the photocell, through its relays, can be made to ring a bell continuously until the owner of the establishment releases the latch-in relay.

SPECIAL RELAYS

Although unique control arrangements can be obtained by using sensitive and auxiliary relays together, the use of combinations of relays in this way, where each relay is a potential cause of failure of the entire system, is by no means entirely satisfactory in many cases. The ideal relay is one sensitive enough to operate on extremely low power inputs, yet capable of controlling large amounts of power; the micro-switch and the mercury type contacts, when used on ordinary sensitive relays, closely approximate the ideal relay.

A *micro-switch* of the Burgess type is shown in Fig. *9A*. The operation of this unit depends on the production of sufficient change in the relative forces of two opposing spring systems to cause the contacting silver plates to separate or come together with a positive snap action. This switch operates when a pressure of about 14 ounces is applied to the operating plunger, and releases with the same snap action when the pressure is reduced to about 10 ounces. The actual travel of the plunger is approximately .001 inch. The moving contact is attached to one flat spring and two curved springs. When the flat spring is depressed by the plunger the lower springs bring the contact up to the



Courtesy Automatic Electric Co.

FIG. 10. Vacuum contact switch mounted on telephone type sensitive relay. Insulated knob on armature at left presses against glass lever which extends into the glass vacuum tube and operates the contacts which are inside.

fixed contact with a snap. Switches of this type are available in a number of simple make-and-break combinations.

The micro-switch will continuously control 500 watts of A.C. power, provided the load has no inductive reactance. A typical combination sensitive A.C. relay and micro-switch is shown in Fig. *9B;* the micro-switch is so mounted that its plunger rests against the relay armature. About 100 contacts per second can be obtained, for the relay will pull up in .005 seconds and release in about the same time.

Vacuum contacts are extensively used on relay installations where sparking at contacts may cause an explosion and fire. Reasonably large circuits can be controlled with a sensitive relay and the special vacuum contact shown in Fig. *10.* The contact points, mounted in a highly evacuated glass tube, are operated by means of a glass lever which acts through a flexible glass, lifting the movable contact. As the contacts are in a vacuum only a small gap is required between them, there being no gas to cause ionization or arcing. The contacts therefore have a long life. As much as 6 amperes at 220 volts A.C. or D.C. can be controlled by the unit shown, regardless of whether the load is inductive or resistive, and as many as 40 make-and-break operations per second can be made.

Mercury Contact Switches.—If you place a quantity of mercury on a flat sheet of glass you will observe that the mercury remains in a globule and that the slightest tilt to the glass will cause the mercury to move. This characteristic, together with the fact that mercury is a metal and therefore a good electrical conductor, has resulted in the *mercury contact switch.* A quantity of mercury is placed in a small capsule-shaped glass tube having two (or more) contact wires sealed

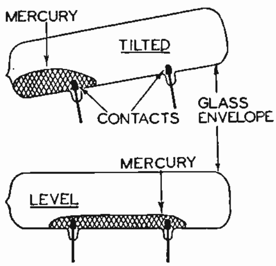
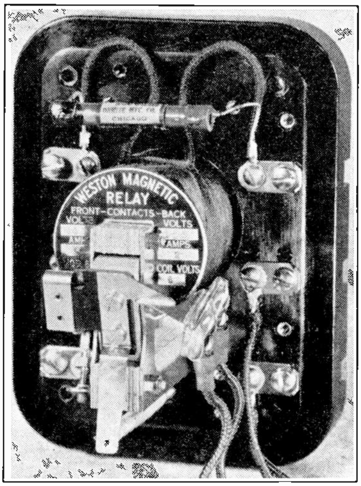


FIG. 11A (above). Tilted and level positions of a simple mercury switch, where a globule of mercury makes electrical connection between the two contacts.



Courtesy Weston Electrical Instr. Co.
FIG. 11B (at right). Model 630 Weston power relay using mercury tube switches in place of contacts. As many as four separate mercury switches can be mounted on one relay. This relay is of the minimum reluctance type, the armature being pivoted at its center. The coil power required is ¾ watt; with a 6-volt source, the coil current would then be 125 ma.

into the glass. The tube is sealed after air is pumped out; an inert gas is sometimes placed in the tube after evacuation, to prolong its life. When the switch is tilted as shown in Fig. *11A*, the mercury makes contact with only one wire or electrode, but in a level position the globule of mercury spreads out over both electrodes, closing the circuit between them. If both electrodes are placed at one end of the tube, tilting the switch in that direction will close the circuit. Many other arrangements of two and more contacts are possible. Mercury tube switches are available in many different types, some with mercury to metal contacts and others where the mercury pools themselves form the contacts; some require large, others small angles of tilt. Switches which must carry large amounts of power in general require more mercury, heavier contacts, and a larger angle of tilt and larger forces to cause the tilt.

Mercury tube switches can be mounted on sensitive or low powered relays, in combinations capable of controlling up to several kilowatts of A.C. power. As many mercury tube switches can be attached to a relay as are required for the control operations, when the desired contacts cannot be made by a single switch. Figure *11B* shows a low power, minimum reluctance type of relay actuating a mercury tube switch capable of controlling 1,000 watts of non-inductive A.C. power. A 6-volt D.C. source will operate the electromagnet. Even greater powers can be handled if larger mercury switches are used. Note that flexible wire leads are used to make connections to the mercury switches.

Time Delay Relays.—Quite often a relay is needed which will not close its contacts for a definite interval of time (5 seconds to 3 minutes) after the coil is energized. An illumination control system for a schoolroom, office or store is a typical system where a time delay type of relay

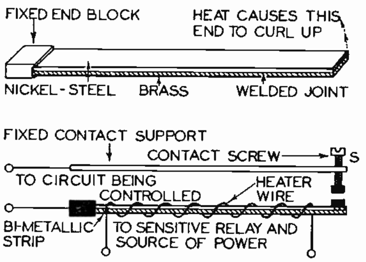
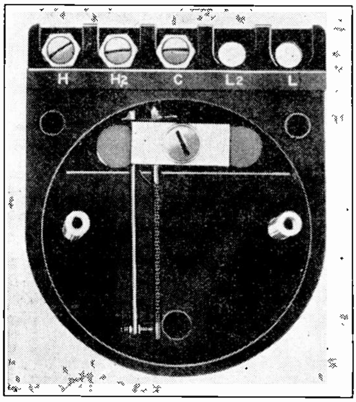


FIG. 12A. Basic principles of the bi-metallic strip type time delay relay are illustrated here. The four connections shown to the relay are often reduced to three by attaching one heater wire to the bi-metallic strip.



Courtesy Weston Electrical Instr. Co.

FIG. 12B. Weston Model 613 time delay relay with cover removed. Heater coil requires 6 volts D.C., while contacts will control 25 watts.

is required. Here a single photocell is made to operate two sensitive relays, one of which turns on lights when room illumination drops below the desired value, and the other turns off the room lights when the photocell "sees" too much light. Clearly, steps must be taken to prevent passing clouds or passing objects from flashing the lights on and off. A time delay relay solves the problem, for it requires current for a definite period of time before the contacts close.

Any mechanism which will produce a mechanical motion when heated can be used to provide a time delay relay; the control current applied by a sensitive relay is sent through a resistance wire which heats the mechanism. For example, the stretching of a wire which is heated by passing a current through it will produce a motion which can close a movable contact. A simpler and more positive type of heat-affected mechanism is the so-called *bi-metallic strip*. If a nickel-steel strip and a hard brass strip are welded together, as in Fig. *12A,* and one end is firmly anchored, a very positive motion will be obtained when heat is applied to the device. For a given temperature increase, the brass increases in length 18 times more than the nickel-steel; the strip must therefore curl upward to allow the brass to stretch. By sending current through a coil of resistance wire wound around this bi-metallic strip, it can be heated. If contacts are placed on the free end of the strip and fixed contacts mounted on either side, this bi-metallic strip can be used to open or close a circuit. By adjusting the positions of the fixed contacts, the time required to make contact can be changed. The contact is usually mounted on an adjusting screw, as at *S*.

Figure *12B* shows a simple but effective time delay relay requiring about 6 volts of D.C. or A.C. for its operation and intended for use with a sensitive relay. The time delay contacts will handle about 25 watts (¼ ampere at 110 volts) A.C.; if more power is to be handled, a heavy-duty relay must follow the time delay relay. This relay always requires 60 seconds for a complete make-and-break operation, but it can be adjusted to make contact in an interval varying from 15 to 45 seconds.

CARE AND OPERATION OF MAGNETIC RELAYS

Prevention of Sparking at Contacts.—To obtain long contact life from relays, sparking must be reduced to a minimum. The most effective protection for a super-sensitive relay, where sparking is especially

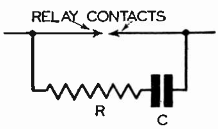


FIG. 13A. A condenser and resistor in series across relay contacts tend to prevent sparking at these contacts.

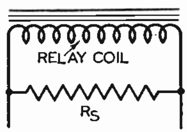


FIG. 13B. A resistor across a relay coil tends to prevent sparking at contacts which control current to the relay coil.

serious, involves connecting a condenser *C* and a resistor *R* in series across the relay contacts, as shown in Fig. *13A*. The time constant (R in ohms times C in mfd. gives time in microseconds; divide by 1,000,000 to get time in seconds) of the combination of *R* and *C* should be much lower than the speed of the relay. In general, a 1 mfd. condenser in series with a 100-ohm resistor will be satisfactory. In A.C. circuits the reactance of the condenser must be sufficiently high (the capacity low) so current passing through the condenser will not operate the power relay or other device being controlled by the contacts. The condenser should have a working voltage of at least 400 volts for circuits using 110 volts or less.

When the relay contacts are connected into the coil circuit of another relay, it is wise to shunt the coil of the second relay with a resistor like R_S in Fig. *13B* whose resistance is at least five times the coil resistance, so that it will not appreciably raise the pull-up current. For a 6-volt coil a resistor value of 500 ohms should suffice. This resistor tends to neutralize the inductance of the relay coil and lessen the tendency towards sparking at the contacts which are in series with that relay coil.

Cleaning Contacts.—To begin with, relays exposed to the air should be kept in dust-proof housings or at least partially protected from dust, chemical fumes and foreign particles. Relays should be cleaned regularly with an air bellows or air pressure line; all contacts and moving parts should be cleaned with carbon tetrachloride (Carbona). When flat type contacts become pitted or corroded, they should be filed flat and bright by placing a thin file (such as that used in cleaning automobile distributor contacts, or a jeweler's file) between the contacts, squeezing the contacts together and slowly drawing out the file, repeating the process as often as necessary. When the contacts are shaped (rounded or cylindrical) they should be polished with fine "crocus" cloth. Never oil or grease the moving parts of relays, for they are designed to give free action without a lubricant. These instructions apply only to sensitive and power relays; super-sensitive relays must be handled just as carefully as meters.

Adjusting Relay Contacts.—All relays come from the manufacturer properly adjusted for pull-up and drop-out current. Tampering with the adjustments should be avoided, but if adjustments are necessary, the following general rules, dealing specifically with sensitive relays, will be helpful:

1. Connect the relay in the test circuit shown in Fig. *14*, which is capable of supplying enough direct current to operate the relay. With current flowing through the coil, loosen the spring tension screw, then adjust the pull-up stop (this is also the pull-up contact in most cases) so the armature gap is about .002″. If there is a copper cap or copper stud in the pole piece (to prevent the armature from sticking), adjust for zero air gap, making certain that good contact is being made between the armature and pull-up contact.

2. Reduce the coil current to the desired drop-out value and gradually increase the spring tension until the armature drops out.

3. Turn out the drop-out stop, adjust the current to the desired pull-up value, then slowly turn in the drop-out stop, bringing the armature nearer to the coil core, until the armature pulls up. The relay is now properly adjusted for the desired pull-up and drop-out currents.

Always adjust the relay in the position in which it is to be used. A relay may just as easily be adjusted in its final operating circuit, following the procedure given above while using operating conditions for pull-up and drop-out currents. If armature drops out sluggishly, increase the armature gap and repeat adjustments *2* and *3*. If the armature pulls in sluggishly, turn in the drop-out stop a little more. It is always wise to check adjustments a few times.

Ordering Relays.—In ordering relays or getting a quotation as to cost, you must first decide upon the type (meter, sensitive, power, mercury contact, etc.) and the manufacturer, after studying the catalogs of different relay manufacturers. You will find that each type of relay can be secured in a number of different voltage and current ratings; in most

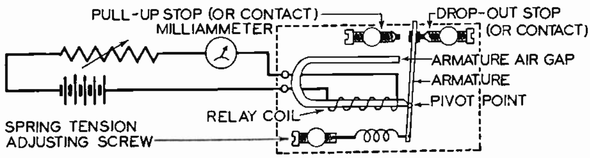


FIG. 14. Test circuit for sending required current through the coil of a sensitive relay when making adjustments.

cases it is best to let the manufacturer use his own judgment in making the final choice. When writing to a manufacturer, always supply at least the following information:

1. Catalog number and name of the type of relay you desire.
2. Pull-up and drop-out current (or voltage) values required.
3. State whether exciting current will be A.C. or D.C.
4. Contact arrangements desired.
5. Power to be handled by contacts (voltage and current); state whether A.C. or D.C. power is used and whether or not load is inductive.
6. Speed of pull-up and drop-out, or time for one complete operation (if important in your case).
7. Special information as to how relay will be used.

PHOTOELECTRIC CONTROLS WITH RELAYS ONLY

Inasmuch as a super-sensitive relay will operate on currents below ¼ milliampere—currents which photovoltaic and photoconductive cells will produce with normal changes of light, these cells may be connected directly to super-sensitive relays. Photoemissive cells, however, are not suitable for direct connection to a relay, as the safe current which they can pass is generally insufficient for relay actuation.

Photoconductive cells in general require high D.C. voltages for direct relay operation, but some types operate on low voltages and control enough current to actuate a *sensitive* relay directly. The photovoltaic cell, on the other hand, will supply ample current for a *super-sensitive* relay; it is the only type of cell which is *commercially* used to operate a relay directly. The current outputs of the photoemissive and photoconductive cells are first amplified by vacuum or gaseous tubes in practical commercial equipment.

The simplicity of the connections between a photovoltaic cell and a relay is best demonstrated by a practical circuit like that shown by the heavy lines in Fig. *15*. P is a Model 594 Weston Photronic Cell and R_1 is any of the 0-200 microampere super-sensitive (or meter type) relays. The contacts of relay R_1 control the exciting current to relay R_2, which can be either an ordinary sensitive relay or one with micro-contacts, vacuum or mercury contacts. When the control circuit is to be on intermittently and only for short intervals, the battery B may be used. If the sensitive relay is of the D.C. type, a voltage step-down transformer and a full-wave rectifier can be used to permit operation on A.C.; if relay R_2 is of the A.C. type, a step-down transformer is generally needed. Simply remove battery B and connect the rectifier unit or the step-down transformer to points x and y. In the circuit shown in Fig. *15* the super-sensitive relay operates when light falls on P; this relay closes the circuit to relay R_2, and its contacts close the circuit to the load. If illumination on P is to disconnect the load from the power source, connect lead f to contact e instead of to d; if interruption of a light beam directed on P is to actuate relay R_2 connect lead a to contact c instead of b. Should a time delay be desired in the control, the super-sensitive relay can be connected to a time delay relay, which in turn can actuate a power relay.

When a Sensitrol relay is used and it is desired to keep the load on but to disconnect the original actuating circuit, use a latch-in type power relay and a solenoid reset type Sensitrol relay. Connect the solenoid of the Sensitrol relay in parallel with the load, placing a resistor in series with the solenoid to limit the current to a safe value. Only your imagination plus a knowledge of the relays available is needed to develop any desired type of photoelectric control. For example, by placing P (Fig. *15*) near the window of an office and connecting R_1 to actuate R_2, which turns on room lights when the general illumination in the office is just insufficient for good work, an illumination control is obtained. A time delay relay takes care of passing clouds which normally would throw the lights off and on. If R_2 is replaced with an electromagnetic counter, objects would be counted by passing through a light beam, which would interrupt the light on P.

Recommendations.—A photovoltaic cell delivers the largest current when its terminals are shorted. In selecting a relay which is to have a given pull-up current rating, that which has the lowest coil resistance will give best results. When the illumination on the photovoltaic cell is too low to give relay operation, use two or more cells in parallel to get the current output required by the super-sensitive relay. In figuring the speed of a relay system, *add* the speeds of the individual relays; the more relays used, then, the slower will be the system.

VACUUM TUBE AMPLIFIERS FOR SENSITIVE RELAY OPERATION

The necessity of continually cleaning the contacts of a meter-type relay and the high initial cost of the device are two factors influencing the choice between photovoltaic cells and the other two types of cells for a particular photoelectric control job. In a good many cases control engineers have a decided preference for a vacuum tube amplifier connected between the light-sensitive cell and a sensitive relay. To be sure, the amplifier tube must be replaced periodically (the estimated life of the average tube is the equivalent of 1,000 hours of continuous use), and power must be supplied constantly. When these features are not objectionable, rugged, positive and reliable controls are possible. Photoemissive cells of the gas type and photoconductive cells are generally employed.

The basic circuits are of three types: *1,* the *rise* and *fall* type, where the photoelectric cell causes the vacuum tube plate current to rise or fall in value; *2,* the *impulse* type, where a rapid change in light is converted into an electrical impulse causing quick positive relay action; *3,* the *light differential* circuit, where the vacuum tube amplifier operates the relay when light falling on one photoelectric cell differs from that falling on another cell. The amplifier tubes generally used (tubes like the 30, 31, 01A, 12A and 6C5) have maximum operating values of 2 to 12 milliamperes; in many cases these values can be reduced more than 50 per cent, giving longer tube life if sufficiently sensitive relays can be used. When the light change is too small to actuate a relay through a single vacuum tube stage, two or more direct coupled amplifiers acting in cascade may be employed.

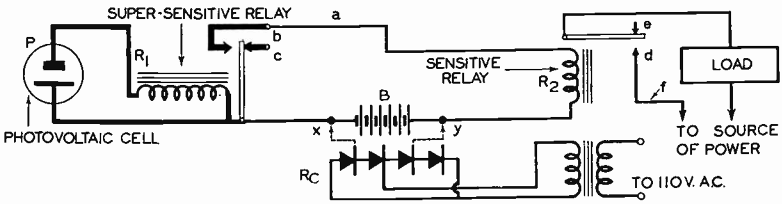


FIG. 15. Typical photovoltaic cell circuit using two relays.

Rise and Fall Circuits, Forward Type.—If the current in the plate circuit of the vacuum tube *rises* when the illumination on the cell is *increased,* we have what is commonly called a *forward* circuit. Figure *16A* shows a simple practical forward circuit which can be used with a selenium cell. Figure *16B* is a forward circuit for a photoemissive cell.

In either case the potentiometer K_1 is adjusted, with illumination removed from the cell, until the relay armature drops out and makes contact with L (this is the armature position for low or drop-out current). Now when the cell is normally illuminated, the resistance of the cell reduces in value, bringing the potential of the grid nearer that of the cathode. The grid, originally highly negative, thus becomes more positive with respect to the cathode, plate current increases and the relay pulls up. Potentiometer K_2 should be adjusted for a pull-up contact pressure just strong enough to prevent chattering. The gas type photoemissive cell (used in Fig. *16B*) should never be operated at a peak voltage greater than recommended for the cell used, and a resistance of at least one megohm should be in series with the cell to limit the current in case the voltage is accidentally exceeded. (Note that a 3 megohm resistor is used for this purpose in Fig. *16B*.) The photoconductive cell should be operated at the minimum voltage which will give satisfactory control if long cell life is to be secured.

In general, in a forward circuit, the C bias voltage (controlled by K_1) is varied to give the desired minimum value of illumination, and the cell excitation voltage (controlled by K_2) is adjusted to give relay pull-up with the desired maximum value of illumination, if the control circuit is to work between definite limits of light values. Only the grid bias control (K_1) is needed in circuits where light is completely cut off to secure the control operation; here either the light beam intensity or the relay contacts can be adjusted to vary the value of illumination which actuates the relay.

Reverse Circuit.—By connecting the load to terminals *C* and *H* in Fig. *16B*, a reduction or interruption of the light will open the load circuit; by connecting to terminals *C* and *L*, light reduction or cut-off will connect the load to its supply. In both cases the relay armature is pulled up as illumination on the cell increases. When the control unit is to be in operation for long periods of time, and the cell is illuminated the greater part of the time, the amplifier tube is passing maximum current most of the time and its life is consequently shortened. A control circuit can be designed in which illumination on the light-sensitive cell produces a low plate current, so that a reduction in light causes the plate current to increase and actuate the relay. This *reverse circuit*, as it is called (where the relay closes when light is *decreased*), gives longer amplifier tube life and consequently less attention need be given the unit. Such a circuit, using a photoemissive cell, is shown in Fig. *16C;* a photoconductive cell can also be used in this circuit.

The variable arm of potentiometer K_1 in Fig. *16C* is adjusted so the relay drops out when maximum light is on the cell. The photocell current passing through the 3 megohm grid leak places a high negative bias on the amplifier tube, this bias being varied by the potentiometer to get the desired minimum value of plate current. When the light is reduced or cut off little or no cell current flows through the grid leak; the grid bias becomes practically zero, raising the plate current and pulling up the relay armature. If the load circuit is now connected to *H* and *C*, light cut-off connects the load to its supply; if the *L* and *C* terminals are used, light cut-off disconnects the load from its supply.

You can easily tell whether a vacuum tube amplifier control circuit is of the forward or reverse type. In a *forward* circuit the photoelectric cell connects between the *grid* and a point more *positive* than the cathode; in a *reverse* circuit the cell connects between the grid and a point more *negative* than the cathode. In Fig. *16, A* and *B* are forward circuits and *C* is a reverse circuit.

Impulse Control Circuits.—The principal objection to circuits of the forward and reverse type using *photoconductive* cells is that there is some cell current even when no light is on the cell, this current serving to reduce the differential needed for positive control with small changes in illumination. Where simple, rapid off-on light conditions exist, this

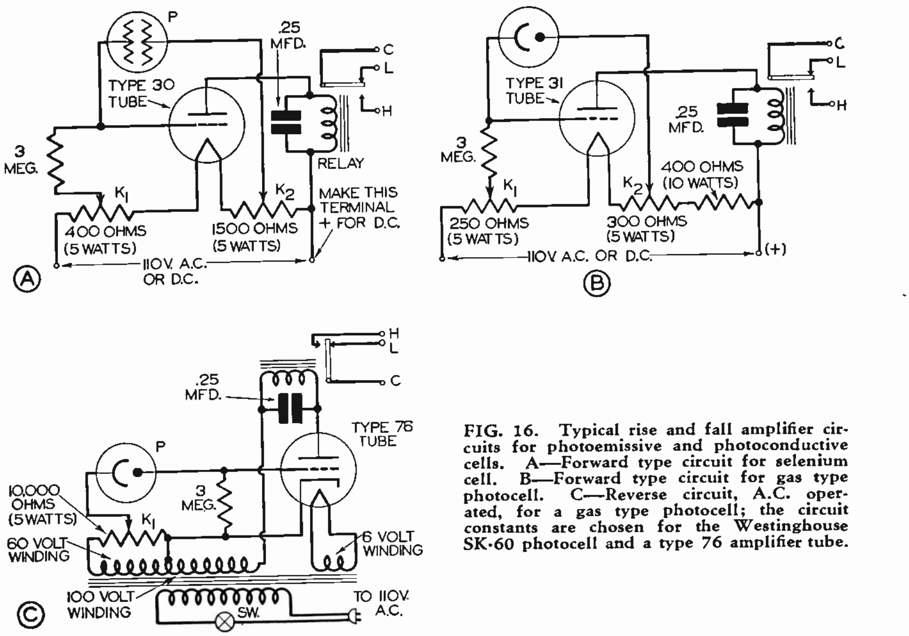


FIG. 16. Typical rise and fall amplifier circuits for photoemissive and photoconductive cells. A—Forward type circuit for selenium cell. B—Forward type circuit for gas type photocell. C—Reverse circuit, A.C. operated, for a gas type photocell; the circuit constants are chosen for the Westinghouse SK-60 photocell and a type 76 amplifier tube.

objection may be eliminated by employing a circuit which utilizes the charge and discharge ability of a condenser.

A simple *impulse* or so-called *trigger* circuit, using a selenium (photoconductive) cell, is shown in Fig. *17A*. A photoemissive cell can be used as well, provided its anode is connected to the potentiometer arm. The unique feature of this circuit is that when the cell is illuminated with *any* steady light value, the plate current is always a definite value which is fixed by the potential of the floating grid of the type 30 tube. The impulse circuit operates in this manner. Assume that the cell is illuminated. Point *A* (Fig. *17A*) is positive with respect to the cathode *K*. As the leakage resistance of the mica condenser is many times greater than the grid-to-cathode resistance, the potential of the grid with respect to cathode is zero or slightly negative, the condenser being charged with the polarity shown. When the light is suddenly cut off, the condenser immediately discharges through the amplifier tube and grid leak circuit. The grid is instantly placed at a high negative potential with respect to the cathode, the plate current goes down and the relay drops out. Gradually the condenser discharges through the grid-to-cathode path, placing the grid at the potential of a floating grid (practically at zero potential with respect to the cathode). When light comes on again the condenser charges as before, and the circuit is ready for another interruption of light.

When the light on the cell is initially low, the grid is near zero potential and the relay is in the pull-up position. An increase in light causes the condenser to become charged with the polarity shown in Fig. *17A*, but since the grid is already near zero potential and the relay arma-

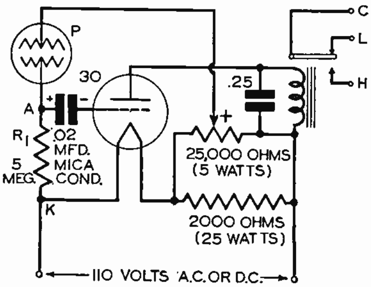


FIG. 17A. One form of the impulse circuit, using a selenium cell and a type 30 amplifier tube. The relay, normally closed, drops out when illumination on the cell is suddenly cut off. The relay remains pulled up for all constant values of illumination, and pulls up by itself at a definite time after each interruption of light.

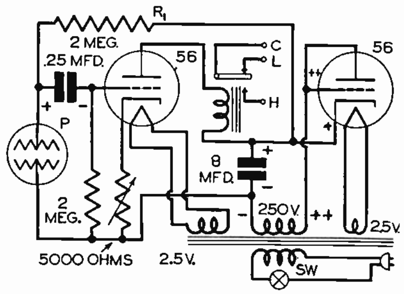


FIG. 17B. Another form of impulse circuit, which uses an extra tube to secure D.C. Here the relay pulls up only when light on the cell is suddenly interrupted, and drops out automatically in a definite time interval. Current flows through the tube circuits only during the half of each cycle for which polarity is as indicated.

ture is pulled up, no relay change takes place. Increasing the cell voltage by moving the arm of the 25,000-ohm potentiometer to the plus end produces stronger impulses. This impulse circuit responds well only to sudden light changes; the relay remains closed or in its pull-up position for all constant values of illumination as well as for gradual changes in illumination, and drops out only when the light is suddenly interrupted.

A more practical impulse circuit which insures long cell and tube life and strong, positive trigger action is shown in the circuit of Fig. *17B*. As D.C. is supplied by the 56 tube used as a rectifier, the grid condenser may have a large capacity. With normal light on the cell the 5,000-ohm cathode variable resistor is adjusted to give a negative bias to the grid, so the relay drops out. Now, when the light on the cell is suddenly cut off, the relay coil current "shoots up," pulling up the relay long enough to operate a counting mechanism or other quick-acting electromagnetic device.

Here is how the circuit of Fig. *17B* works. With normal light the cell resistance is low, the voltage drop across the cell is consequently low, and the .25 mfd. condenser receives only a low charge. When the light is cut off the cell resistance rises, there is a larger voltage drop across the cell, the + terminal of the condenser becomes more positive, and electrons flow up through the 2-megohm grid leak to make the — terminal of the condenser correspondingly more negative. These electrons flowing through the grid leak produce in it a voltage drop which reduces the negative bias to zero or even swings the grid positive, and plate current rises, actuating the relay.

When the condenser becomes fully charged (the time required depends on the time constant of the charging circuit) the grid leak current reduces to zero, restoring the normal high negative bias, and the relay

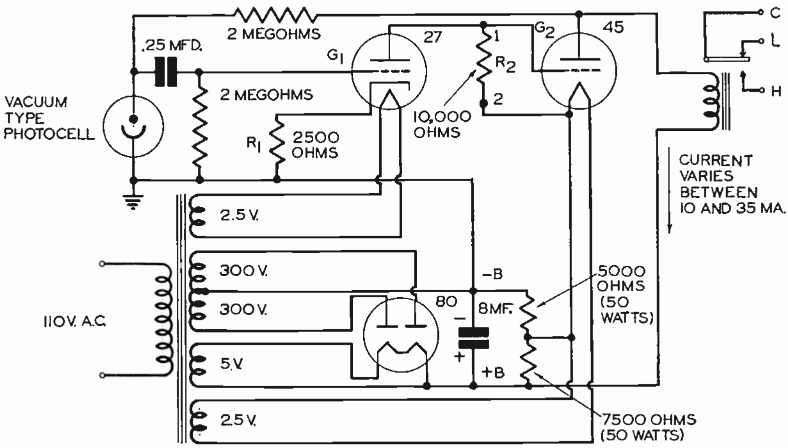


FIG. 18. Typical two-stage amplifier circuit for a vacuum type photocell connected into an impulse circuit; the type 80 tube supplies full-wave rectified D.C.

drops out. When the cell light comes on again the cell resistance drops, and the fully charged condenser partly discharges through the C bias circuit, driving the grid more negative, but as the relay is already in a drop-out condition no further relay action takes place.

In any of these impulse circuits, increases in resistance of the cell (in the case of selenium cells) with age and use can be offset by increasing the ohmic value of the grid leak resistor.

Two or More Amplifier Stages.—Where the change in light is small, sufficient change in current for relay operation can be obtained by adding a second vacuum tube amplifier. With normal light change the use of a second amplifying stage permits the direct use of a heavy duty relay. As the variation in light is generally not a repeated (or cyclic) change, direct coupled amplifiers are needed. Impulses or slow current changes thus are relayed through the amplifying circuits.

A typical two-stage direct coupled photocell control circuit is given in Fig. *18.* A photoemissive cell is shown, but a photoconductive cell may just as well be used. The circuit is shown operating a heavy-duty relay; if small light changes are used for control, the power tube is replaced with a high mu triode voltage amplifier tube which feeds into a sensitive relay, the operating voltages being adjusted. Although an impulse or trigger type input circuit is shown, a forward or reverse photocell connection can be used with good results. A gas cell can be used by lowering the excitation voltage; a tap on the voltage supply divider resistance will give the required low voltage.

This circuit works in the following manner. Grid G_1 is biased negatively by resistor R_1; grid G_2 is biased negatively by the plate voltage drop in resistor R_2 (note that terminal *1* is nearer ground or $B-$ potential than terminal *2*). With normal light on the photocell, all currents in the circuits are at adjusted values. When the light to the photocell is cut off, grid G_1 becomes more positive, increasing the plate current of

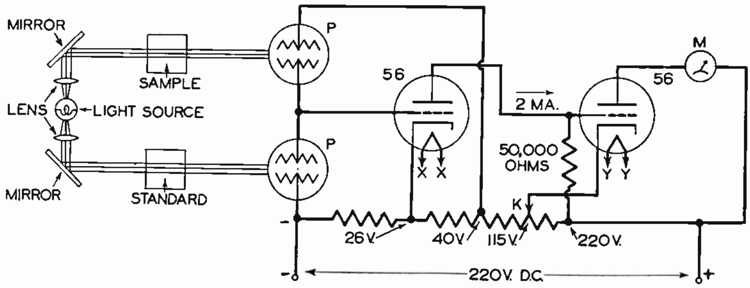


FIG. 19. Typical light differential circuit. The power supply is not shown, but should produce 220 volts D.C.; two separate 2.5 volt secondary windings are needed for XX and YY to prevent leakage reaction between the two amplifier tubes.

the 27 tube (this impulse circuit is practically the same as that in Fig. *17B*); the voltage drop across resistor R_2 increases, driving the grid of the second tube more negative. The plate current of the second tube drops, releasing the armature of the relay. As the power tube plate current will drop from about 35 ma. to 10 ma., a heavy-duty relay may be used. A more sensitive circuit can be designed by using a screen grid tube in place of the 27 in the first stage.

Light Differential Circuits.—Quite often a circuit is desired which will respond to a difference in light from two light sources. Color matching of liquids (such as dyes) is a typical case. The same kind (color content) and intensity of light passes through the standard solution and the solution under test. By using two cells so connected into a control circuit that the difference in the currents which they pass causes a voltage change, the change can be amplified to actuate a meter.

A typical light differential circuit is shown in Fig. *19,* where the light of a single lamp is split into two light beams by two lenses. Each beam is reflected from a mirror, one beam being directed through a glass container holding the standard liquid, the other beam passing through the glass container in which is the liquid whose color or density is being compared. The beam emerging from each container is viewed by a photoelectric cell, which can be either of the emissive or conductive type.

With both containers removed, the arm of potentiometer K is adjusted until meter M reads mid-scale. When the standard and sample products are introduced into the light paths, any difference in the light transmitted to the cells shows up as a deviation of the meter from mid-scale. A relay is sometimes used in place of the meter to give a desired control operation when the two solutions differ in characteristics by a specific amount.

GAS TUBES FOR DIRECT POWER RELAY ACTUATION

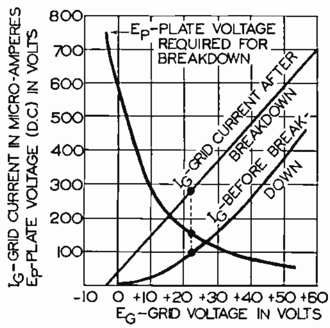
A heavy-duty or power relay can be operated directly from a single amplifier tube circuit without using any sensitive relays, provided that the amplifier tube is of the gas or vapor type.

When triode amplifier tubes have gas in their envelopes, as in the case of Thyratron tubes, they are no longer suitable for linear amplification, but have properties which are valuable for electronic control circuits. The action of such a tube is briefly this: When the tube is given a definite grid bias, and the plate voltage is gradually varied from zero upward to a certain positive anode-cathode voltage, a very large space current suddenly starts to flow through the tube. Now, no matter how the grid voltage is varied, the grid has no control over the plate current. Only the plate *voltage* determines the amount of plate current, and this voltage must be reduced to about 20 volts before the space current stops flowing. The anode voltage must then be raised to the "striking" or "firing" potential, determined by the value of grid voltage, before space current will again flow through the tube. The higher the negative grid bias, the higher the striking voltage required before current flows; likewise if the C bias is reduced or made positive, the required striking voltage will be reduced.

On alternating current the grid has a continuous control over a gaseous tube, for current flow stops once per cycle (when the anode voltage drops to zero); on direct current, however, the grid loses its control once breakdown occurs, and can regain control only if the anode voltage is interrupted by some means. Gas-filled tubes are therefore almost always used in A.C. circuits.

Hot Cathode Gas-Filled Tubes.—Gas triodes and pentodes (gas pentodes work exactly like triodes except that the screen grid protects the cathode and reduces the grid current) are designed to have an oxide cathode of large surface so large quantities of electrons can be emitted. The anode voltage is limited to a value which gives a safe space current; if this current is exceeded, the cathode emitting surface is bombarded by positive ions and destroyed. Although mercury vapor is used in certain tubes which operate on high voltages and deliver high plate currents, argon, helium and neon gases are preferred for low voltage and low current tubes; these gases result in tubes which are fairly independent of temperature. Gas tubes are called *Thyratrons* by the General Electric Company (G.E.), and *grid-glow tubes* by the Westinghouse Electric and Manufacturing Company (W.E.&M.). Mercury vapor tubes are made in sizes capable of passing up to hundreds of amperes, but for control purposes ½ ampere tubes are sufficient to control the heaviest power relays needed.

In hot cathode gas tube control circuits it is highly important that the grid current shall not flow directly through the light-sensitive cell; the cell current should supplement the normal grid current which is made to flow through a *grid resistor*.



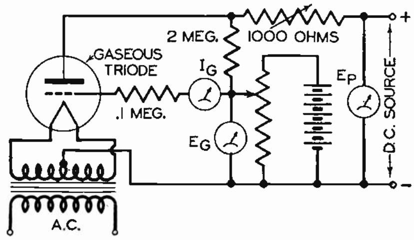


FIG. 20. Characteristic curves of a typical hot-cathode gas filled tube, the Westinghouse type KU-610 grid-glow tube. D.C. starting characteristics for rated anode current are given at the left; the test circuit used appears above.

Figure *20* shows the characteristics of a typical low power grid-glow triode tube, in this case the W.E.&M. type KU-610, which has a maximum rated plate current of ¾ ampere. The circuit used to obtain these characteristics is also shown; the 1,000-ohm resistor prevents the tube from acting as a short circuit across the load when break-down occurs and the tube passes current, this resistor being adjusted to give rated plate current. This tube uses neon gas and has a constant anode-cathode drop of about 22 volts when passing current, which means that the 1,000-ohm resistor must waste the remainder of the source voltage in the test circuit shown in Fig. *20*. The .1 and 2 megohm resistors serve to stabilize the circuits. Although the tube characteristics shown are for D.C. voltages and currents, they also represent instantaneous values in the case of A.C. power.

The curves are used as follows: Assume that the tube is to operate at a plate voltage of 110 volts A.C.; the peak voltage is then 110×1.41, which equals about 155 volts. Referring to the E_p curve, we find that about + 23 volts on the grid will just allow breakdown of the tube; the grid current before breakdown is about 100 μa and after breakdown it is about 300 μa.

With these facts in mind, we may now consider the practical gas tube relay circuit shown in Fig. *21A*. Although a photoconductive cell of a type which has a low minimum resistance and a large dark-to-light resistance ratio is used here, photoemissive cells can also be used. The connections to the secondary of the transformer are such that when the plate of the KU-610 tube is positive with respect to the cathode (here the filament), the grid is also positive with respect to the cathode. The potentiometer across the 60-volt secondary winding furnishes the grid bias for the tube by varying the potential of the cathode with respect to the grid. With light on the cell, this potentiometer is adjusted so the voltage between *P* and *A* (on the positive half of the A.C. cycle) minus the voltage drop in R_G due to the cell and gas tube grid currents is just below the value which allows the tube to break down. Now when the cell is darkened, the cell current drops, the voltage drop in R_G becomes less, the grid becomes more positive and the grid of the tube loses control. The plate current rises, actuating the relay.

This action is best understood by studying Fig. *21B*, which shows

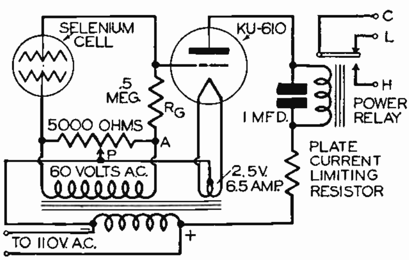


FIG. 21A. A practical photoconductive cell circuit, using a Westinghouse type KU-610 grid-glow tube to operate a power relay directly. Circuit operates entirely from A.C.

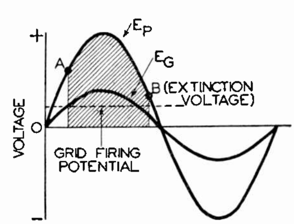


FIG. 21B. When plate and grid voltages of the KU-610 grid-glow tube are in phase, plate current passes for that part of a cycle shown shaded.

the phase relations between the grid and plate voltages. As the circuit is essentially non-reactive, the grid and plate voltages can be made to be entirely in phase or 180° out of phase, simply by reversing connections to the 60-volt winding. The out-of-phase condition is undesirable because as the plate swings positive the grid swings negative and too-high plate voltages are required for breakdown or *firing*. With both grid and plate swinging positive simultaneously (in phase), firing occurs at the plate voltage indicated at point *A*, this being the first point in the cycle at which the plate and grid voltages together allow breakdown. At point *B* the plate voltage is no longer enough to sustain plate to cathode ionization (below 22 volts), and the plate current stops. Of course, when the plate and grid swing negative on the next half of the cycle, no plate current can flow. Although there is no control over the plate voltage in this circuit, the grid bias can be adjusted by varying *P*, which determines the position of *A*, the point of firing; this potentiometer can be set so the grid bias is sufficient to fire the tube only when the cell resistance goes up (light on the cell is interrupted).

Cold Cathode Gas-Filled Tube.—A hot cathode is not needed to cause ionization in a tube, as you already know from your study of gaseous rectifier tubes. When a gas like neon is used, an appreciable tube current can be obtained with a cathode having no electron emitting surface. Ionization of the gas takes place at a voltage depending on the amount and nature of the gas and upon the distance between the anode and cathode; this ionization results in liberation of the electrons required for the tube space current. A grid can be used to control the breakdown or firing voltage; the more negative (less positive) is the grid, the higher is the voltage required to start ionization and a flow of current.

The arrangement of the internal elements of a cold cathode grid-glow tube is shown in Fig. *22*. The shield, when connected to the cathode through a 2 to 10 megohm resistor, insures greater uniformity and

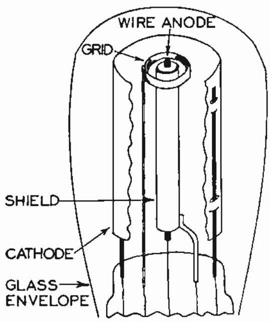


FIG. 22. Cut-away view of a cold-cathode grid-glow tube, showing arrangement of electrodes. The anode is inside a porcelain tube which in turn is surrounded by a metal cylinder, the shield. The grid is simply a thin band or ring of metal surrounding the exposed tip of the anode.

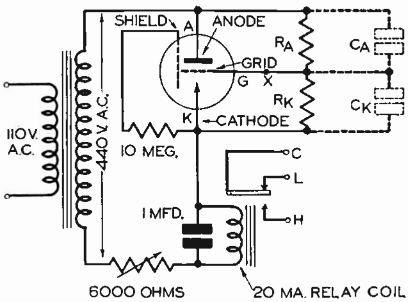


FIG. 23. Basic operating circuit for the Westinghouse KU-618 grid-glow tube. A photoemissive cell or a photoconductive cell of high resistance can be substituted for either of the resistors or condensers connected to the grid. The arrow in the tube symbol represents the cold cathode.

stability of operation, and insures definite tube failure when the maximum useful life of the glow tube is reached.

The Westinghouse KU-618 is a typical high sensitivity, cold cathode grid-glow tube, which has an anode to cathode drop of 180 volts when plate current is flowing. In the basic operating circuit for this tube, shown in Fig. *23,* the tube is connected in series with a relay coil and a 6,000-ohm resistor across the 440-volt secondary winding of the transformer; this current limiting resistor prevents the space current from exceeding 100 ma., for excessive currents would destroy the tube.

In actual practice the *A* and *G* terminals of the gas tube are shunted with either a resistor of 10 to 100 megohm value or a 0 to 50 mmfd. variable condenser, while the *G* and *K* terminals are shunted with either a resistor or condenser of the same value. When resistors are used it is customary for purposes of stability to insert a high ohmic value leak at point *X;* the highest value which will give satisfactory operation is employed, values up to 250 megohms being commonly used. The supply is usually the 440-volt terminal of a small step-up transformer. The values of R_A and R_K determine the potential of the grid; increasing R_A or lowering R_K makes the grid less positive and prevents the tube from firing. If condensers are used instead of resistors, increasing the impedance of C_A (by lowering its capacity) or decreasing the impedance of C_K makes the grid less positive. A voltage divider made up of a resistor and a condenser can be used if desired; in any case either a resistor or a condenser is made variable to allow adjustment of the grid potential. As it is inconvenient to secure variable resistors of such high values, one element is usually a variable condenser.

In actual practice a light-sensitive cell or other device having either a high ohmic resistance or a low capacity which will change in resistance or capacity as a result of the action which is to be controlled is connected in place of one of the resistors (or condensers), and is used as the primary control. The other resistor (or condenser) is made variable to permit adjustment of the point at which control action occurs. This cold cathode glow tube has many electronic control applications.

For a light-sensitive control, vacuum type emissive cells are best, as they have large dark resistances (as much as 5,000 megohms), and will operate safely on high excitation voltages (500 volts is a common value for small cells). In one practical circuit an emissive cell is connected between the anode and grid, and a 0-50 mmfd. variable condenser is connected between the grid and cathode terminals. The condenser is adjusted when the cell is dark so the grid glow tube does not ignite. Illuminating the cell swings the grid more positive and causes the relay to pull up; when the cell light is cut off the relay drops out.

Photoemissive type cells can also be connected between the grid and cathode, the variable condenser being placed between the anode and grid. The condenser is adjusted so the grid glow tube does not ignite when the cell is illuminated; now the tube will break down and pass current, causing the relay to pull up, only when the cell is darkened.

The anode of the photocell should be connected to the anode of the gas tube when the cell is placed between *A* and *G*. The cell anode should be connected to the grid of the gas tube when the cell is wired to *G* and *K*.

A light-sensitive control using a cold cathode gas tube has the advantage that no power is used in the control circuit when the control circuit is idle, yet heavy-duty relays can be actuated directly. Note that the power used to feed the filament of a hot cathode gas tube is eliminated. Furthermore, the cold cathode tube is extremely sensitive.

14 CIRCUIT DIAGRAMS EACH WITH TESTING INFORMATION

27 SS

SERVICE MANUAL

PIONEER HOME STUDY RADIO SCHOOL

NRI

NATIONAL RADIO INSTITUTE
EST. 1914
WASHINGTON, D.C.

FOREWORD

This booklet is one of a series of service manuals which contain service sheets giving typical information on radio receivers. Each service sheet shows the circuit diagram in the usual symbolic form for that radio receiver. Many of the service sheets will contain such special service information as space will permit.

By studying each service sheet, you will gradually develop the ability to read any diagram or manufacturer's service manual and learn the usual methods of set adjustment. Enough typical receivers have been selected to give you quickly a good insight to the entire radio problem.

In reading a circuit diagram, learn to trace independently the power supply and the signal circuits. Then locate the special control circuits, such as the automatic volume controls, tuning indicators, manual volume controls, etc. Detailed information on power supply, signal and control circuits, as well as set servicing, is given in the course, to which reference should be made.

J. E. SMITH.

A LESSON TEXT OF THE N. R. I. COURSE
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RADIOTRICIAN & TELETRICIAN
(REGISTERED U. S. PATENT OFFICE) (REGISTERED U. S. PATENT OFFICE)

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Service Sheet

Compiled Solely for Students and Graduates

NATIONAL RADIO INSTITUTE, WASHINGTON, D. C.

PHILCO MODELS 38-4 AND 38-5—CODE 121

Alignment of Compensators

Equipment Required: (1) Signal Generator, having a fundamental frequency range covering the tuning and intermediate frequencies of the receiver. Philco Model 077 Signal Generator which has a fundamental frequency range from 115 to 36000 K.C. is the correct instrument for this purpose; (2) Output meter, Philco Model 026 circuit tester incorporates a sensitive output meter and is recommended; (3) Philco Fibre Handle Screw Driver, part No. 27-7059 and Fibre Wrench, part No. 3164.
Output Meter: The 026 output meter is connected to the plate and cathode terminals of one of the 6F6G tubes. Adjust the meter to use the (0-30) volt scale and advance the attenuator control of the generator until a readable indication is noted on the output meter after signal is applied.

Intermediate Frequency Circuit

Insert the signal generator shielded output lead into the "Med" jack on the panel of the generator. Connect the other end of the output lead through a .1 mfd. condenser to the grid of the 6A8G, det. osc. tube and the ground connection of the signal generator to the chassis. Set the signal generator and receiver controls, and adjust the I.F. compensators as follows:

1. Set Signal Generator at 470 K.C. Turn "Multiplier" Control to 1000 and the "Attenuator" for maximum output.

2. Turn the receiver dial to 580 K.C.

3. Receiver Volume Control maximum.

4. Range Switch Broadcast Position.

5. Adjust compensators (28B), (28A), (23B), and (23A) for maximum output. If the output meter goes off scale when adjusting the compensators retard signal generator attenuator.

Radio Frequency Circuit

Tuning Range: 5.7 to 18.2 M.C.
1. With one end of the shielded lead of the signal generator output lead in the "Med" jack, connect the other end through the .1 mfd. condenser to the "Red" terminal of the aerial panel of the receiver. The output lead ground must be connected to the black terminal or to the chassis.

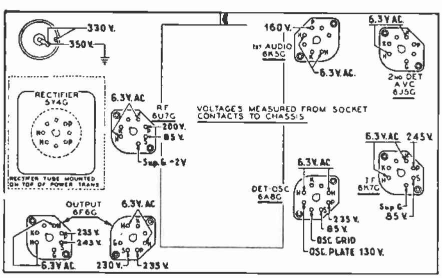
2. Set the controls and adjust the R.F. compensators as follows:

Volume Control	Range Switch	Signal Generator and Receiver dial	Compensators in Order
Max.	2	18 M.C.	(5C) See Note A

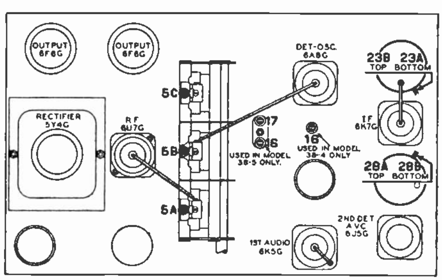
Tuning Range: 530 to 1720 K.C.

Range Switch	Signal Generator and Receiver Dial	Compensators in Order
1	1500 K.C.	(16), (5B), (5A)
1	580 K.C.	(17)
1	1500 K.C.	(16), (5B), (5A)

NOTE A—To adjust high frequency oscillator compensator to fundamental instead of image signal, turn oscillator compensator to maximum capacity position (clockwise). From this position slowly turn compensator counterclockwise until a second maximum peak is obtained on output meter. Adjust compensator for maximum output using this second peak.



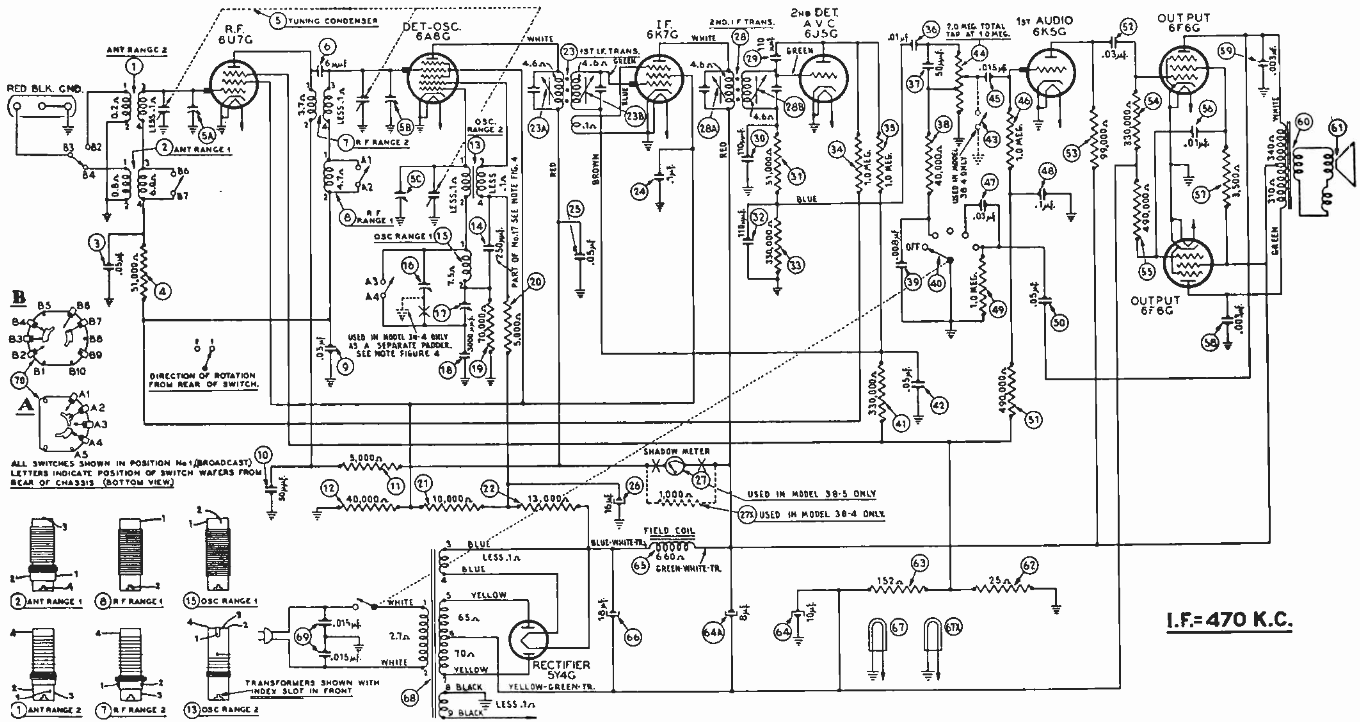
Socket Voltages—Underside of Chassis View



Locations of Compensators—Top Chassis

The Voltages indicated by arrows in the left hand illustration were measured with a Philco 026 Circuit Tester which contains a sensitive voltmeter. Volume Control at minimum, range switch in broadcast position, line voltage 115 A.C.

Courtesy of Philco Radio and Television Corporation.



Courtesy Philco Radio and Television Corporation.

SCHEMATIC DIAGRAM

PHILCO MODELS 38-4 AND 38-5—CODE 121

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Service Sheet
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NATIONAL RADIO INSTITUTE, WASHINGTON, D.C.

EMERSON MODEL 109, CHASSIS U4A

GENERAL NOTES

1. The filament dropping resistor (R13—see schematic) is a resistance wire built into the special line cord. The cord will, therefore, become warm under normal conditions. To insure good heat radiation stretch out the line cord to its full length. Do not attempt to shorten it by cutting.

2. One side of the power line is directly grounded to the chassis base. Under no circumstances, therefore, should a ground wire be permitted to come in contact with any metal part of this receiver.

3. If replacements are made or the wiring disturbed in the r-f section of the circuit the receiver should be realigned.

4. When replacing the oscillator coil, be sure to mount it in the correct position. The locating hole in the square fibre terminal strip should be nearest the rear of the chassis.

TUBE DATA

1—6A7—Pentagrid oscillator-modulator
1—6F7—Triode amplifier-pentode detector
1—43—Pentode power output
1—25Z5—Dual half-wave rectifier

VOLTAGE ANALYSIS

Voltage readings should be taken with a 1000 ohms-per-volt-meter. Voltages listed below are from point indicated to ground (chassis).

Tube	*Plate*	*Screen*	*Cathode*	*Osc. Plate*	*Fil.*
6A7	105	60	1.35	105	5.5
6F7 {Pentode / Triode}	55	15	2.25	...	5.5
43	98	105	14.4	...	23.0

Voltage across speaker field—115
Voltage across choke—10.5

ADJUSTMENTS

An oscillator with frequencies of 456 and 1425 kc. should be used.

An output meter should be used across the voice coil or output transformer for observing maximum repsonse.

Location of I-F's and Trimmers: The first i-f transformer, is in an oblong coil can, located on top of the chassis directly behind the speaker. The two trimmers for this i-f are acessible through holes in the top of the coil can.

The second i-f transformer, is in a round coil can located on top of the chassis to the left of the speaker. The single trimmer for this i-f is accessible through a hole in the top of the coil can.

The oscillator and antenna trimmers are located on the top of the variable condenser. The oscillator trimmer is on the rear section and the antenna trimmer is on the front section.

Alignment Procedure: 1. Rotate variable condenser to minimum.

2. Feed 456 kc to grid of 6A7 tube.

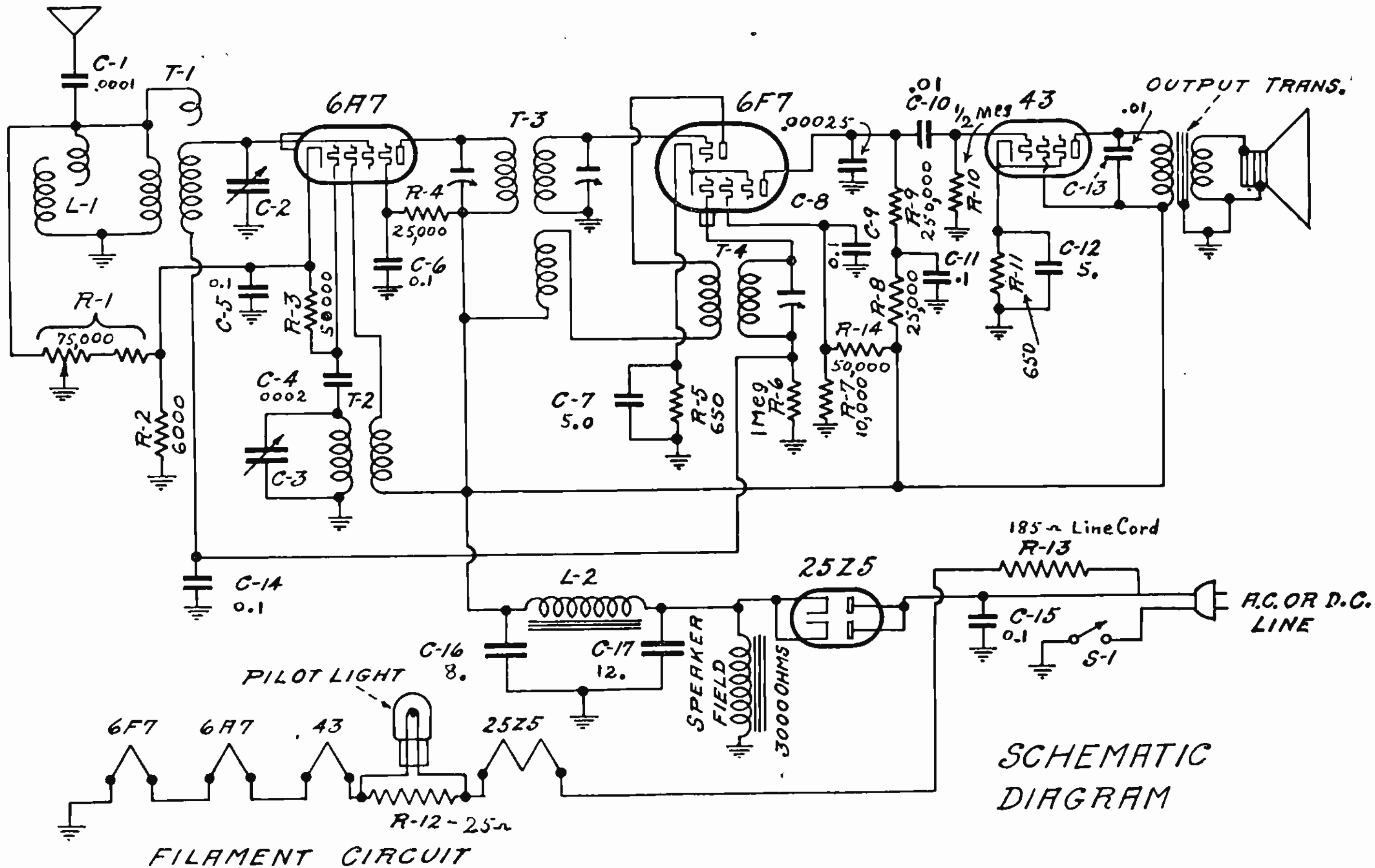
3. Adjust the three i-f trimmers, repeating for maximum response.

4. Set dial pointer to 1425 and feed 1425 kc through the antenna.

5. Adjust the oscillator (rear) trimmer for maximum response.

6. Adjust antenna trimmer for maximum response.

Emerson Model 109, Chassis U4A



RADIO-TRICIAN
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SPARTON MODEL 636 MX

VOLTAGE-RESISTANCE CHART

Line Voltage : 115 volts

Voltage Tap : 95 to 115 volts

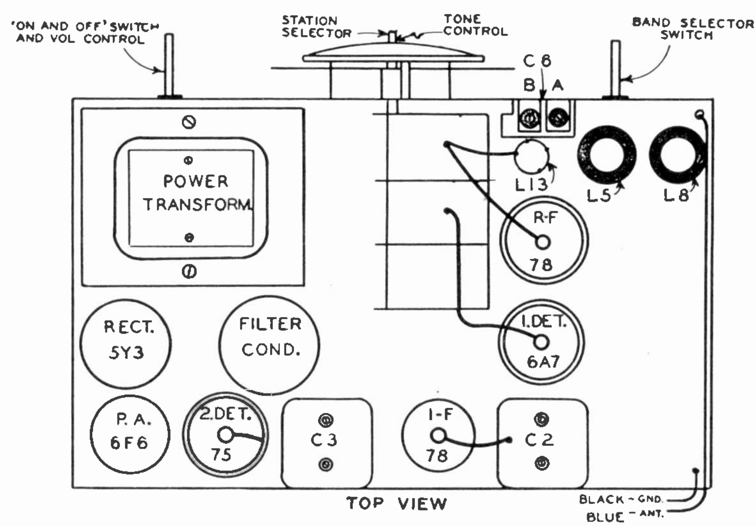
Position of Volume Control: Full with Antenna Disconnected

Position of Band Selector Switch: Broadcast

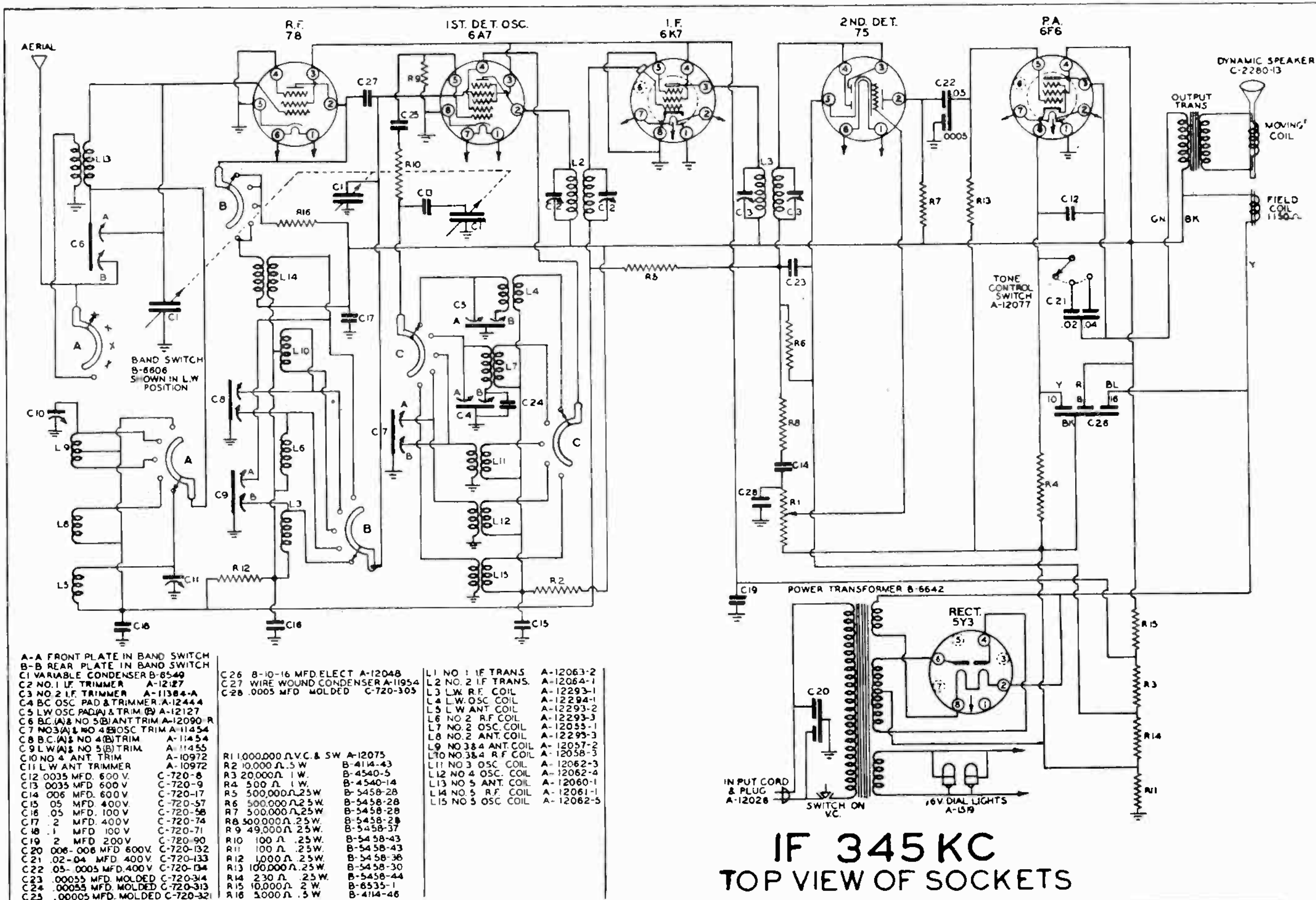
Tube	Function	Voltage and Resistance of Each Socket Prong to Ground (See Prong Numbers on Schematic Diagram)									
		Measurement	Prong No. 1	Prong No. 2	Prong No. 3	Prong No. 4	Prong No. 5	Prong No. 6	Prong No. 7	Prong No. 8	Grid Cap
78	R-F Amplifier	Volts	*	300	150	0	0	*	-	-	0
		Ohms	0	35000	22500	0	0	0	-	-	1000000
6A7	1st. Det-Oscillator	Volts	*	290	140	290	0	0	*	-	0
		Ohms	0	30000	22000	40000	45000	0	0	-	1000000
6K7	I-F Amplifier	Volts	0	*	300	150	0	-	*	0	0
		Ohms	0	0	30000	22000	0	-	0	0	1000000
75	2nd. Det-A.V.C.	Volts	*	100	0	0	0	*	-	-	0
		Ohms	0	500000	500000	500000	330	0	-	-	1000000
6F6	Power Amplifier	Volts	0	*	360	360	0	-	*	0	-
		Ohms	0	0	30000	30000	100000	-	0	600	-
5Y3	Rectifier	Volts	0	5	-	400	-	400	-	0	-
		Ohms	0	30000	-	0	-	0	-	30000	-

NOTES: Voltage and resistance readings are for schematic diagram shown on back of sheet. Allow 15% + or - on all measurements. Always use meter scale which will give greatest deflection within scale limits. All measurements made with Weston Selective Analyzer No. 665, Type 1.

* 6.2 or zero volts, depending on twist of filament hook-up wire.



TOP VIEW



A-A	FRONT PLATE IN BAND SWITCH	
B-B	REAR PLATE IN BAND SWITCH	
C1	VARIABLE CONDENSER	B-6549
C2	NO. 1 I.F. TRIMMER	A-12127
C3	NO 2 I.F. TRIMMER	A-11384-A
C4	BC OSC PAD & TRIMMER	A-12444
C5	LW OSC PAD(A) & TRIM (B)	A-12127
C6	B.C.(A) & NO 5(B) ANT TRIM	A-12090-R
C7	NO3(A) & NO 4(B) OSC TRIM	A-11454
C8	B.C.(A) & NO 4(B) TRIM	A-11454
C9	L W(A) & NO 5(B) TRIM	A-11455
C10	NO 4 ANT. TRIM	A-10972
C11	L W ANT TRIMMER	A-10972
C12	.0035 MFD. 600 V.	C-720-8
C13	.0035 MFD 600 V	C-720-9
C14	.006 MFD. 600 V	C-720-17
C15	.05 MFD. 400 V.	C-720-57
C16	.05 MFD. 100 V	C-720-58
C17	.2 MFD. 400 V	C-720-74
C18	.1 MFD 100 V	C-720-71
C19	2 MFD 200 V	C-720-90
C20	.006-.006 MFD 600V.	C-720-132
C21	.02-.04 MFD 400V.	C-720-133
C22	.05-.0005 MFD. 400 V	C-720-134
C23	.00055 MFD. MOLDED	C-720-314
C24	.00055 MFD. MOLDED	C-720-313
C25	.00005 MFD. MOLDED	C-720-321

C26	8-10-16 MFD. ELECT	A-12048
C27	WIRE WOUND CONDENSER	A-11954
C-28	.0005 MFD MOLDED	C-720-305

R1	1,000,000 Ω V.C. & SW	A-12075
R2	10,000 Ω .5 W	B-4114-43
R3	20,000 Ω 1 W.	B-4540-5
R4	500 Ω 1 W.	B-4540-14
R5	500,000 Ω .25 W	B-5458-28
R6	500,000 Ω .25 W.	B-5458-28
R7	500,000 Ω .25 W	B-5458-28
R8	500,000 Ω .25 W.	B-5458-28
R9	49,000 Ω .25 W.	B-5458-37
R10	100 Ω .25 W.	B-5458-43
R11	100 Ω .25 W.	B-5458-43
R12	1,000 Ω .25 W.	B-5458-38
R13	100,000 Ω .25 W.	B-5458-30
R14	230 Ω .25 W.	B-5458-44
R15	10,000 Ω 2 W.	B-6535-1
R16	5,000 Ω .5 W	B-4114-46

L1	NO. 1 I.F. TRANS	A-12063-2
L2	NO. 2 I.F. TRANS.	A-12064-1
L3	L.W. R.F. COIL	A-12293-1
L4	L.W. OSC COIL	A-12294-1
L5	L W ANT COIL	A-12293-2
L6	NO 2 R.F. COIL	A-12293-3
L7	NO. 2 OSC. COIL	A-12055-1
L8	NO. 2 ANT. COIL	A-12293-3
L9	NO 3 & 4 ANT. COIL	A-12057-2
L10	NO. 3 & 4 R.F. COIL	A-12058-3
L11	NO 3 OSC COIL	A-12062-3
L12	NO 4 OSC. COIL	A-12062-4
L13	NO 5 ANT. COIL	A-12060-1
L14	NO. 5 R.F. COIL	A-12061-1
L15	NO 5 OSC COIL	A-12062-5

Schematic Diagram—Sparton Model 636 MX

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ZENITH MODELS 6S301, 6S304, 6S305, 6S306, 6S321, 6S322, 6S340

Chassis No. 5651

NOTE

Voltages measured from socket contacts to chassis using a 1000 ohm per volt meter. Antenna disconnected—volume control on full.

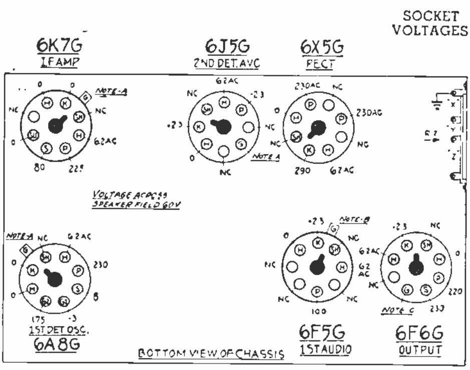
Line voltage 115 v. Consumption 60 watts.

Power Output 4.5 watts.

(A) Bias for 6A8—6K7 and 6J5 measured across X which is neg. 2.3 volts.

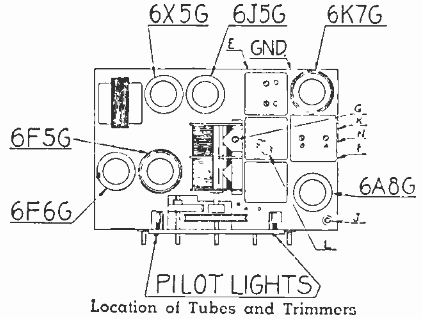
(B) Bias for 6F5 measured across X and Y which is neg. 3.8 volts.

(C) Bias for 6F6 measured across XY and Z which is neg. 16 volts.



LEGEND

NC—No Connection
SH—Shield
H—Heater
P—Plate
S—Screen
G—Grid
SU—Suppressor
D—Diode
K—Cathode
F—Filament

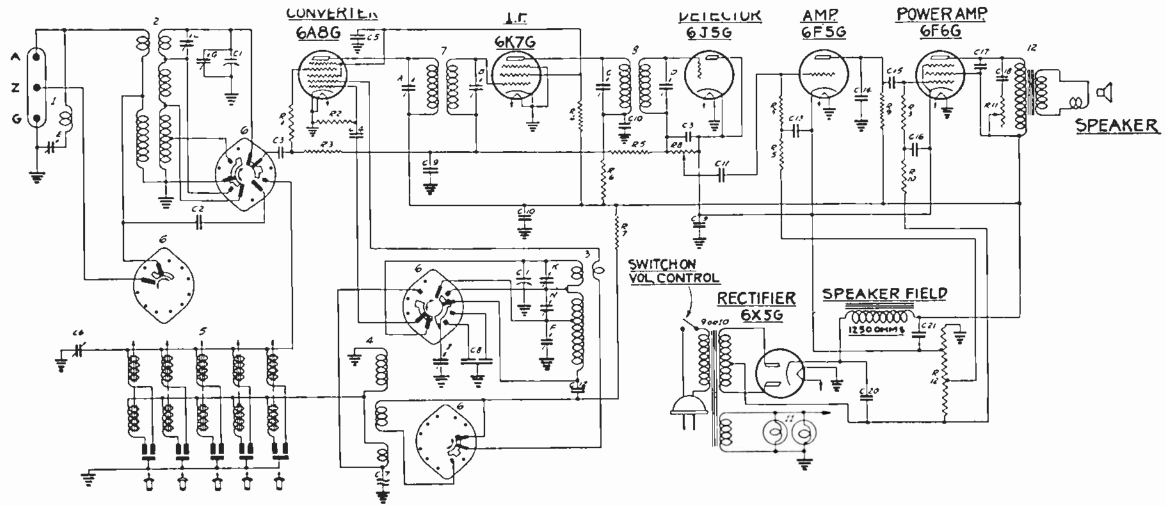


Location of Tubes and Trimmers

ALIGNMENT PROCEDURE

Operation	Connect Test Oscillator to	Dummy Antenna	Set Test Osc. to	Band	Set Dial at	Adjust Trimmers	Purpose
1	1st Det. Grid	½ Mfd.	455	Br'dc't	600	ABCD	I. F. Alignment
2	Rec. Ant. Post	200 Mmfd.	455	Br'dc't	600	E	See Note
3	Rec. Ant. Post	200 Mmfd.	1500	Br'dc't	1500	F	Set Osc. to Scale
4	Rec. Ant. Post	200 Mmfd.	1500	Br'dc't	1500	G	Alignment of Ant.
5	Rec. Ant. Post	200 Mmfd.	600	Br'dc't	600	J	Rock gang & adj. for max. output
6	Rec. Ant. Post	200 Mmfd.		Br'dc't		FG	Repeat 3 & 4
7	Rec. Ant. Post	400 Ohms	18000	S.W.	18000	K	Set Osc. to Scale
8	Rec. Ant. Post	400 Ohms	18000	S.W.	18000	L	Rock gang & adj. for max. output
9	Rec. Ant. Post	400 Ohms	6000	Police	6000	N	Rock gang & adj. for max. output

Note: If receiver is used in location subject to code interference adjust wave trap (E) for minimum interference with antenna connected and receiver operating in broadcast band.



NOTE. BAND SWITCH SHOWN IN BROADCAST POSITION

Diag. No.	Part No.	Description	
C-1	22-717	Two gang variable	
C-2	22-289	50 Mmfd.	600V
C-3	22-162	.0001 Mfd.	600V
C-4	22-127	25 Mmfd.	600V
C-5	22-170	.1 Mfd.	400V
C-6	22-519	Trimmer Cond.	
C-7	22-740	Compensating Cond.	
C-8	22-708	Dual Fixed Padder	
C-9	22-250	.05 Mfd.	200V
C-10	22-212	.05 Mfd.	400V
C-11	22-327	.02 Mfd.	200V
C-12	22-358	.002 Mfd.	600V
C-13	22-190	.1 Mfd.	200V
C-14	22-147	.0005 Mfd.	600V
C-15	22-435	.02 Mfd.	600V
C-16	22-219	.03 Mfd.	200V
C-17	22-492	.002 Mfd.	600V

Diag. No.	Part No.	Description	
C-18	22-171	.05 Mfd.	600V
C-19	22-185	.01 Mfd.	200V
C-20	22-718	12 Mfd. Electrolytic	450V
C-21	22-719	16 Mfd. Electrolytic	350V
R-1	63-621	39 Ohm	1/4W
R-2	63-592	33 M Ohm	1/4W
R-3	63-597	470 M Ohm	1/4W
R-4	63-677	33 M Ohm	1W
R-5	63-271	1 Megohm	1/4W
R-6	63-605	1000 Ohm	1/2W
R-7	63-680	10 M Ohm	1W
R-8	63-983	220 M Ohm Vol. Cont.	
R-9	63-296	220 M Ohm	1/4W
R-10	63-595	100 M Ohm	1/4W
R-11	63-982	Tone Control	
R-12	63-984	3 Section Candohm	

CHASSIS NO. 5651, MODELS 6S301, 6S304, 6S305, 6S306, 6S321, 6S322, 6S340

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PHILCO MODELS 38-7, Code 121, 124; 38-8, Code 121; 38-9, Code 121

Electrical Specifications

Models 38-7, 38-8 and 38-9 receivers employ a six tube A.C. operated superheterodyne circuit with such features as: Two tuning ranges covering standard and short wave broadcasts; Philco foreign tuning system; automatic volume control; bass compensation; tone control, and pentode audio output circuit. The same circuit is used in each receiver. The features, however such as, tuning mechanism, speakers and cabinets differ in each model.

Model 38-7 in addition to the features given above employs the Philco automatic tuning mechanism with cone-centric tuning. The chassis of this model is built into a console cabinet type XX, Table Cabinet Type "T" and is designated code 121. The same chassis built into a type "CS" cabinet is identified as code 124.

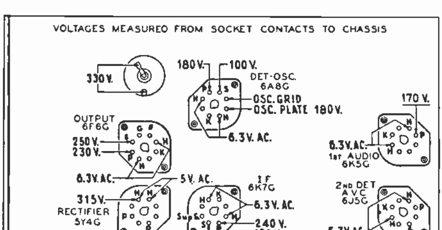
Model 38-8 differs from the 38-7 in that a manually operated tuning mechanism with shadow-meter tuning is used. This receiver is built into a type "X" cabinet with a type "HS" dynamic speaker.

Model 38-9 is identically the same as model 38-8 with the exception that the shadow meter is not used, and that the speaker and cabinet types differ. This model is assembled in a type "T" cabinet with dynamic speaker type "S7" and a "K" type cabinet using a dynamic speaker type "HS."

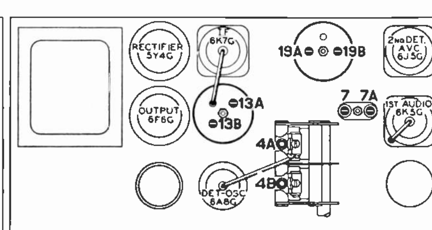
Shadow Meter Adjustment Model 38-8

Apply power to the receiver and allow tubes to warm up. Then adjust shadow meter as follows:

1. Move the shadow meter coil backwards and forwards, until the opposite edges of the shadow are ⅛ of an inch from each end of the shadow screen, measuring along the bottom edge of the screen. Adjustment of the shadow meter light bracket may be necessary for perfect centering.
2. Remove the rectifier tube from its socket, and rotate the shadow meter coil until shadow reaches minimum width. This width should not exceed 3/32 of an inch.
3. Replace the 5Y4G rectifier tube in its socket. The shadow should then widen to not more than 3/16 inch or less than 1/16 inch from each side of the screen measuring along the bottom edge. If these limits are not obtained readjust the shadow meter as given in paragraphs 1 and 2 again.



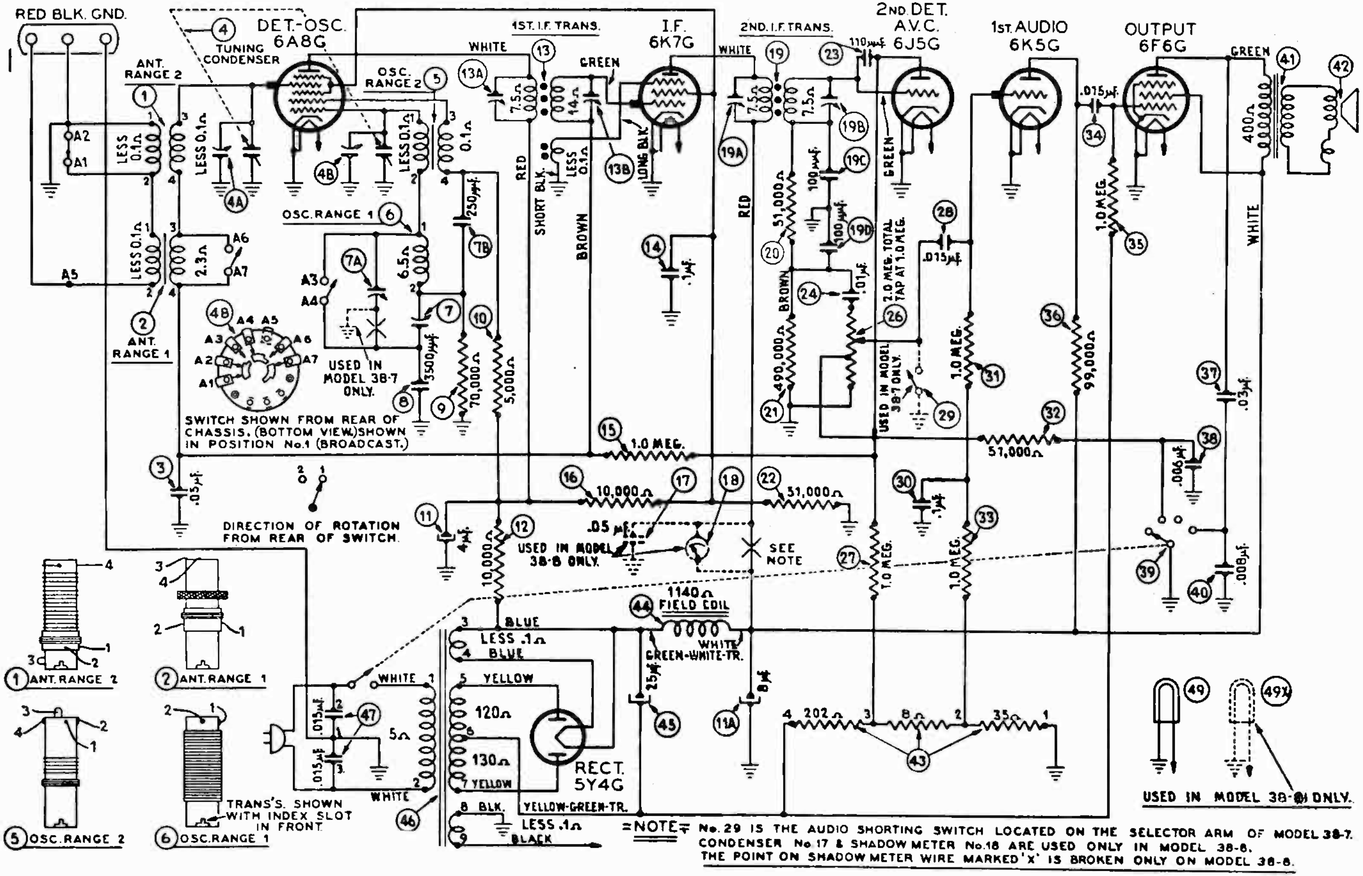
Socket Voltages—Underside of Chassis View



Locations of Compensators—Top Chassis

The Voltages indicated by arrows in the left hand illustration were measured with a Philco 026 Circuit Tester which contains a sensitive voltmeter. Volume Control at minimum, range switch in broadcast position, line voltage 115 A.C.

Courtesy Philco Radio and Television Corporation



=NOTE= No. 29 IS THE AUDIO SHORTING SWITCH LOCATED ON THE SELECTOR ARM OF MODEL 38-7. CONDENSER No. 17 & SHADOW METER No. 18 ARE USED ONLY IN MODEL 38-8. THE POINT ON SHADOW METER WIRE MARKED 'X' IS BROKEN ONLY ON MODEL 38-8.

Courtesy Philco Radio and Television Corporation

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EMERSON MODEL 106, CHASSIS U6B

(Serial Numbers Higher Than 636,900)

I. F. and Wave-Trap Alignment. The I. F. coils are located in cans on top of chassis. The second I. F. transformer is directly behind speaker. The four trimmers are located at tops of cans.

Turn wave-band switch to broadcast position, clockwise. Rotate variable condenser to minimum position and feed 456 kc. to grid of 6A7 tube. Adjust four I. F. trimmers for maximum response. Feed 456 kc. through antenna lead and adjust 456 kc. wave-trap trimmer for *minimum response.* Trimmer is on small wave-trap which is mounted on bracket extending from right-hand chassis wall.

Location of Coils. Broadcast and short-wave antenna coils are wound on one form, mounted on vertical bracket at right-hand side of chassis. Trimmers for these coils are on same assembly facing outward, and available through holes in bracket. Lower trimmer is for short-wave antenna coil; upper for broadcast antenna coil.

Broadcast and short-wave oscillator coils are wound on one form mounted below chassis deck. Trimmers are mounted on same assembly, facing outward, and accessible through holes in right-hand chassis wall. Front one is for short-wave oscillator coil and rear one for broadcast oscillator coil.

Dual padding condenser for oscillator coils is mounted inside of front chassis wall. Adjusting screws available through holes in front wall of chassis. Upper screw, broadcast padder; lower, short-wave padder.

Broadcast Alignment. Turn wave-band switch to clockwise position (broadcast), set dial to 600 (use center of speaker as reference point), and feed 600 kc. through antenna. Adjust broadcast oscillator padder for maximum response. Set dial to 1425; feed 1425 kc. through antenna. Adjust broadcast oscillator trimmer for maximum response and adjust broadcast antenna trimmer for maximum response. Reset dial to 600 and rock variable condenser while re-aligning broadcast oscillator padder.

Short-Wave Alignment. Turn wave-band switch to counter-clockwise position (short-wave), set dial to 570; feed 1600 kc. through antenna. Adjust short-wave oscillator padder for maximum response. Set dial to 1280, feed 3600 kc. through antenna. Adjust short-wave oscillator trimmer for maximum response and then adjust short-wave antenna trimmer for maximum response. Reset dial to 570, feed 1600 kc. and rock variable condenser while readjusting short-wave oscillator padder.

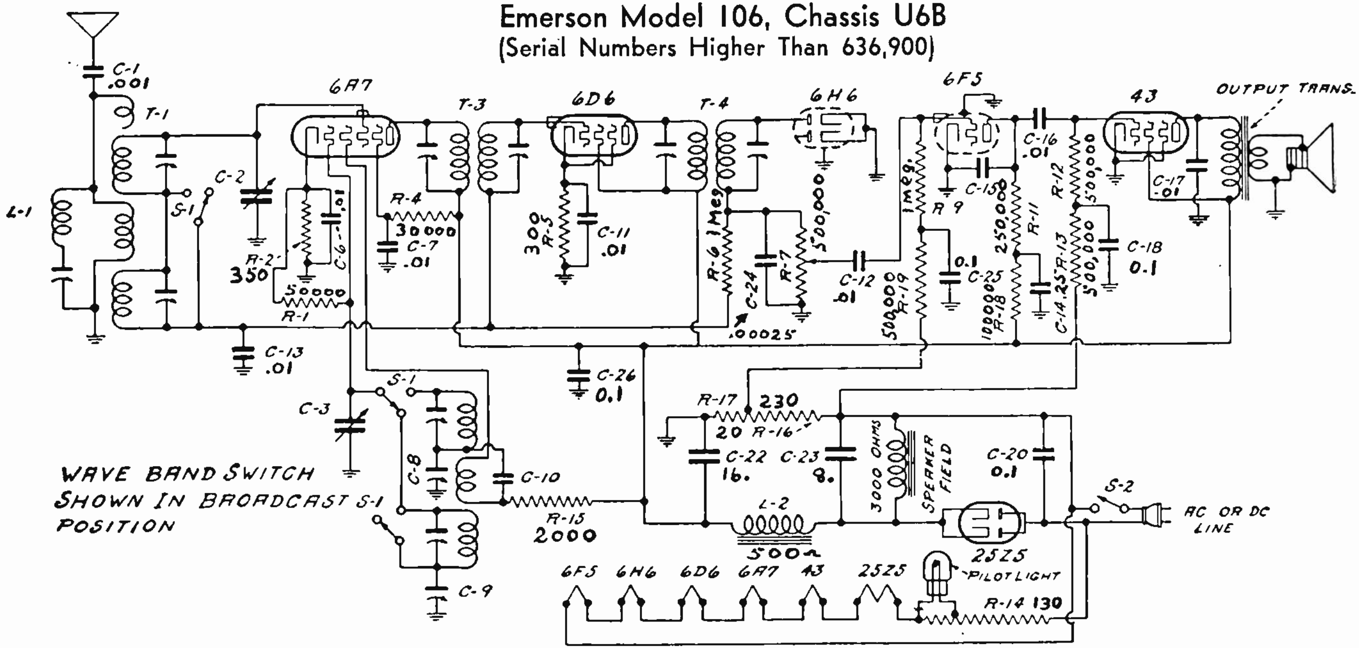
GENERAL NOTES

1. On early production runs bias for the grid of the 6F5 is obtained by a small, one-volt battery (bias cell). Cell assembly is mounted on a bakelite strip inside of the left-hand chassis wall. Do not put a voltmeter across this bias cell. If the set distorts, check by temporarily replacing with a new cell, or other one-volt source. To remove bias cell simply pull up on the spring clip and lift the cell from its cap. On replacing, be sure clip makes good contact.

2. If adjustment of sliding scale dial is necessary, loosen two slotted hexagon-head guides at top edge of scale. Adjust guides by moving up or down in slotted holes in chassis. Do not bring them so far down that the pinion gear binds on rack. Scale should move freely —without appreciable vertical movement.

3. After replacing a dial scale take care to align it properly with variable condenser. Rotate variable condenser to maximum capacity, loosen set-screw on hub of pinion gear and slide scale so that extreme right-hand mark (near 55) is in line with center of speaker. Then tighten set-screw.

Emerson Model 106, Chassis U6B
(Serial Numbers Higher Than 636,900)



VOLTAGE ANALYSIS

Readings should be taken with a 1000 ohms-per-volt meter. Voltages listed below are from point indicated to 43 cathode (B minus). Line voltage for these readings was 117.5 volts, 60 cycles, a-c. Voltage across speaker field (25Z5 cathode to line switch—125 volts).

Tube	*Plate*	*Screen*	*Cathode*	*Osc. Plate*	*Fil.*
6A7	105	55	1.7	100	6 a-c
6D6	105	105	2.75	...	6 a-c
6H6	...	...	0	...	6 a-c
6F5	55	...	0	...	6 a-c
43		105	0	...	24 a-c

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Stewart-Warner Model R-119 Chassis

CIRCUIT DESCRIPTION

The Stewart-Warner Model R-119 Chassis is a six-tube super-heterodyne. It will cover the broadcast and short wave ranges from 530 to 3750 K. C. The tuning dial is calibrated from 530 to 1740 K. C. and a short wave range is provided through a switch on the back of the chassis, for reception up to 3750 K. C. (80 meters).

The R-119A Chassis is designed for operation on 115 volt, 60 cycle power circuits while the R-119EF is adaptable for use with voltages of 115, 125, 230, 240, or 250 at any frequency from 25 to 60 cycles. To accomplish this, the power transformer has two separate tapped primaries. The method of connecting these primaries is shown on a tag attached to the chassis. The R-119-EF chassis is wired for operation with a high impedance phonograph pick-up.

In the R-119A and EF chassis, the incoming signal is amplified by a stage of tuned radio frequency to improve selectivity and sensitivity, and to prevent image frequency interference. It then goes to the 6-A-7, first detector and oscillator, where its frequency is converted to 177.5 K. C.

The 177.5 K. C. intermediate frequency signal is amplified by the high gain I. F. stage, and is then rectified by the diodes of the 85 tube. Detection is accomplished by the diode connected directly to the I. F. transformer. A modulated D. C. voltage drop is produced across the 500,000 ohm potentiometer by the rectified current. The volume is controlled by selecting any desired portion of the A. F. voltage with the moving arm of the potentiometer which is connected to the grid of the 85 tubes. The triode section of this tube acts as an audio amplifier and is resistance-coupled to the 42 output tube.

Delayed A. V. C. is obtained by using the voltage drop produced by the rectified current of the second diode of the 85 tube, for bias on the 78 and 6A7 tubes. This diode, which is coupled to the I. F. transformer by a .002 mfd. condenser, is 17.5 volts negative with respect to the cathode since it is biased by the cathode bias resistor. Consequently, no rectification and no A. V. C. action can take place in this circuit until the incoming signal is strong enough to exceed this value. This represents the minimum signal capable of giving full audio output. Through the use of the delayed A. V. C. any signal which cannot be amplified to this minimum value is not reduced in volume by the action of the A. V. C. circuit.

Short wave reception is accomplished by shorting a portion of the antenna coil, shorting the secondary of the broadcast r. f. coil so that only the short-wave r. f. coil is active, and by switching in a short wave oscillator coil. These operations are performed by a single two-position switch located on the back of the chassis.

ALIGNING THE R-119 CHASSIS

Before attempting to align a set, the service man should become familiar with the general layout of the chassis and with the function and location of the various trimmer condensers. The following discussion briefly explains the action of each alignment step.

R. F. alignment and calibration are accomplished by the three trimmer condensers located on the top of the variable condenser gang. The oscillator is kept in exact step with the other R. F. circuits by the special shape of the stator plates in the oscillator tuning section.

Both windings of the first I. F. transformer are tuned but only the plate coil (primary) of the second I. F. transformer is tuned. The three I. F. tuning trimmers are mounted on the rear of the chassis and may be reached through holes which are covered with flat metal buttons. The buttons may be pried out with a knife or screw-driver.

EQUIPMENT AND PRELIMINARY STEPS

A good modulated oscillator and an output meter are essential for proper alignment. The attenuator on the oscillator must be capable of reducing the signal to a low value because the A. V. C. will function if the signal is too strong and thus make correct alignment impossible. The output meter must be sensitive enough to give a satisfactory reading with this low signal.

The output meter should be connected from the plate of the 42 tube to ground through a .25 mfd. condenser or across the speaker voice coil, depending upon the type used.

All alignment adjustments should be made with the volume control full on but with no broadcast signal being received.

ALIGNING THE I. F. CIRCUITS

An insulated, ¼ inch socket wrench is needed for I. F. alignment since two of the trimmers are connected to B plus. A Stewart-Warner phasing tool (No. T-79890, net price 75c) should be used although a Spintite wrench insulated with tape so that it will not short to the chassis, can be employed.

The step-by-step routine given below should be carefully followed after reading the preceding instructions:

1. The modulated oscillator must be tuned exactly to 177.5 K. C. This frequency can be acurately determined by checking the oscillator harmonics against broadcast stations. First check the accuracy of the broadcast dial, and then tune in either the fourth or eighth harmonic of the 177.5 K. C. signal. If they come in at exactly 710 or 1420 K. C. the oscillator frequency is correct. To be sure that you have the harmonic of a 177.5 K. C. signal instead of some other frequency, tune in the other 177.5 K. C. harmonics on the broadcast dial. These should come in 177.5 K. C. on either side of the original setting. **Do not use the oscillator calibration curve to determine this intermediate frequency.**

2. Connect the oscillator output across the 6-A-7 grid cap and ground.

3. Set the oscillator output to give about half scale deflection on the output meter.

4. Adjust all three I. F. trimmer condensers, in each case tuning carefully to get maximum deflection of the output meter. Reduce oscillator output if output meter goes off scale.

It is very important that no inward or sideward pressure be applied to the alignment tool or the condenser may spring back to a different setting as soon as the tool is removed.

5. Repeat all three adjustments since the adjustment of each I. F. trimmer may affect the others to a certain extent. Replace buttons covering trimmer holes to prevent tampering.

ADJUSTING R. F. AND OSCILLATOR CIRCUITS

1. Connect a .0001 mfd. condenser from the blue aerial wire to the output of the oscillator, and ground both set and oscillator. Adjust the oscillator frequency to 1400 K. C. and carefully tune the receiver to give maximum output. Set the oscillator output to produce about half scale deflection of the output meter.

2. Carefully tune the radio frequency, "A" trimmer, which is the back one on the condenser gang, until the output meter reading reaches a maximum.

3. Retune the set and adjust the first detector "B" trimmer, which is the middle one, for maximum output. The oscillator, or "O" trimmer should not be touched unless the set is badly out of calibration at the high frequency end of the dial.

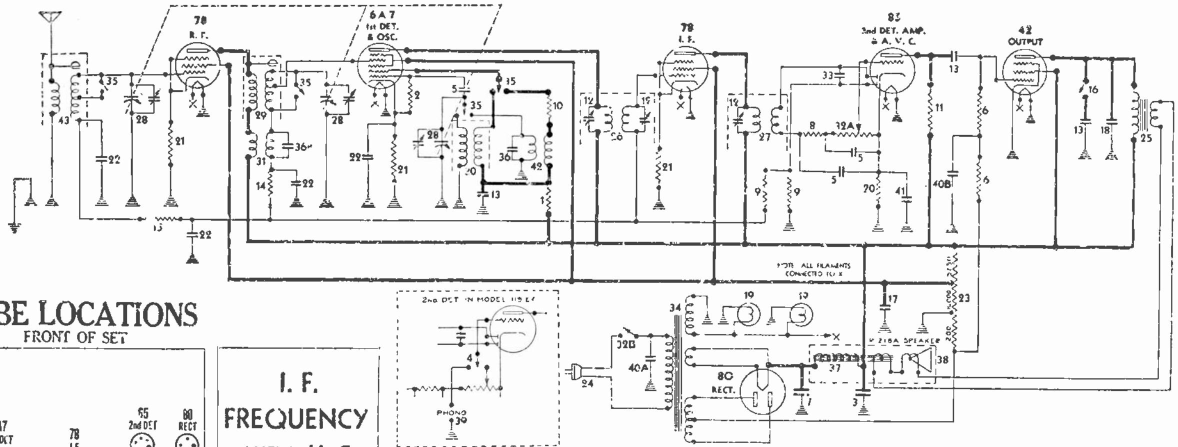
CALIBRATION

Calibration can be checked by arranging a wire pointer above the condenser shaft center and then tuning in several stations of known frequency. With the condenser plates fully meshed, the lowest dial division (530 K. C.) should line up with the pointer

If the set is out of calibration, it can be re-calibrated as follows: Disconnect the test oscillator, connect an aerial to the blue wire, and set the tuning dial at the frequency reading of some station between 1200 and 1500 kilocycles, whose exact frequency is known and which can be picked up without any difficulty. Adjust the oscillator trimmer "O" until this station is brought in with maximum volume. Then use the modulated oscillator and output meter to re-adjust the "A" and "B" trimmers, since these are always affected by any change in the oscillator tuned circuit, taking care to retune the set between adjustments.

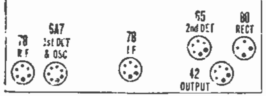
No adjustment is provided for aligning the set for the short wave band.

STEWART-WARNER MODEL R-119



TUBE LOCATIONS

FRONT OF SET



I. F.
FREQUENCY
177.5 K. C.

VOLTAGE TABLE

Line Voltage 115 A.C. — Volume Control Full On

Type of Tube	Position in Circuit	Filament Voltage	Plate Voltage	Screen Grid Voltage	Control Grid Voltage	Cathode (Bias) Voltage
78	R. F.	6.1	260	104		3.2
6A7*	1 Det. & Osc.	6.1	260	104		3.0
78	I. F.	6.1	260	104		3.0
85	2nd Det	6.1	50	—		17.5
42	Output	6.1	247	260	-1.8†	0
80	Rectifier	5.1	320 Volts D. C. From Filament to Ground			

* Oscillator plate voltage 175; Oscillator grid voltage -5.

† Actual bias on 42 tube is 17.3 volts measured across 200 ohm section of voltage divider.

Speaker Field Voltage, 60.

All D. C. voltages are to be measured with respect to ground, using a high resistance voltmeter of 1000 ohms per volt. Readings will vary, depending upon voltage range of meter, being higher for higher range instruments. This variation is most marked for the second detector plate voltage. Readings taken with set analyzers will be different because such instruments generally measure voltages with respect to cathode.

R-119 PARTS LIST

Diag. No.	Part No.	Description	List Price
1	67100	20,000 ohm, 1 watt Carbon Resistor	
2	67301	75,000 ohm, ¼ watt Carbon Resistor	
3	67328	8 Mfd. 440 volt, Wet Electrolytic Condenser	
4	73689	Phonograph Switch (Note: Used in Models R-119 EF only)	
5	81157	.00025 Mfd. Mica Fixed Condenser	
6	81161	250,000 ohm, ½ watt Carbon Resistor	
7	81347	8 Mfd. 485 volt Wet Electrolytic Condenser	
8	81681	29,000 ohm, ¼ watt Carbon Resistor	
9	81682	1.1 Megohm, ¼ watt Carbon Resistor	
10	81727	1000 ohm, ¼ watt Carbon Resistor	
11	81810	100 000 ohm, 1 watt Carbon Resistor	
12	81940	I. F. Trimmer Condenser	
13	83007	.02 Mfd. 600 volt Fixed Condenser	
14	83078	2000 ohm, ¼ watt Carbon Resistor	
15	83081	76,000 ohm, ½ watt Carbon Resistor	
16	83179	Tone Control Switch	
17	83214	.25 Mfd. 250 volt Fixed Condenser	
18	83219	.01 Mfd. 600 volt Fixed Condenser	
19	83278	6.3 volt Pilot Light Bulb	
20	83285	10,000 ohm, ½ watt Carbon Resistor	
21	83293	300 ohm, ⅓ watt Carbon Resistor	
22	83353	.05 Mfd. 100 volt Fixed Condenser	
23	83398	9250-10,000-200 ohm Voltage Divider	
24	83406	Power Cord and Plug	
25	83408	Output Transformer	
26	83410	1st Intermediate Transformer Coil	
27	83412	2nd Intermediate Transformer Coil	
28	83413	3 gang Variable Condenser	
29	83418	Broadcast 1st Detector Coil	
30	83419	Broadcast Oscillator Coil	
31	83420	Short-Wave 1st Detector Coil	
32-A	83424	500,000 ohm Volume Control } In one unit	
32-B	83424	Line Switch } In one unit	
33	83436	.002 Mfd. 1000 volt, Fixed Condenser	
34	83442	Power Transformer, 115 volt, 60 cycle (Note: See No. 83469 for 25-60 cycle 115-250 volt Transformer used in Model R-119EF)	
35	83444	Range Switch (4 sections)	
36	83448	25 Mmfd. Fixed Condenser	
37	83454	Speaker Field and Humbucking Coil As'mbly	
38	83455	Diaphragm, Voice Coil, Spider and Shell Assembly	
39	83463	Terminal Strip (Used in Model R-119EF only)	
	83469	Power Transformer, 115-250 volts, 25-60 cycles (Note: Used on Model R-119-EF only)	
40-A	83476	.02 Mfd. 1000 volt Fixed Condenser } In one unit	
40-B	83476	.5 Mfd. 100 volt Fixed Condenser } In one unit	
41	83537	10 Mfd. 25 volt Electrolytic Condenser	
42	83599	Short Wave Oscillator Coil	
43	83402	Antenna Coil	

MISCELLANEOUS PARTS NOT SHOWN ON DIAGRAM

Part No.	Description
67236	Rubber Drive Roller
81834	6 prong Tube Socket
81837	4 prong Tube Socket
31941	Tube Shield
81949	7 prong Tube Socket
83049	Button for covering trimmer holes
83405	Pilot Light Bracket and Socket
83458	Pilot Light Socket and Volume Control Dial
83460	Dial and Gear
83461	Escutcheon for Models R-1191-2-3
83497	Knob for Model R-1191-2
83505	Knob for Model R-1193
R-218A	Dynamic Speaker (8 inch)

RADIO-TRICIAN
REG. U.S. PAT. OFF.
Service Sheet
Compiled Solely for Students and Graduates
NATIONAL RADIO INSTITUTE, WASHINGTON, D.C.

SPARTON MODEL 516

VOLTAGE-RESISTANCE CHART

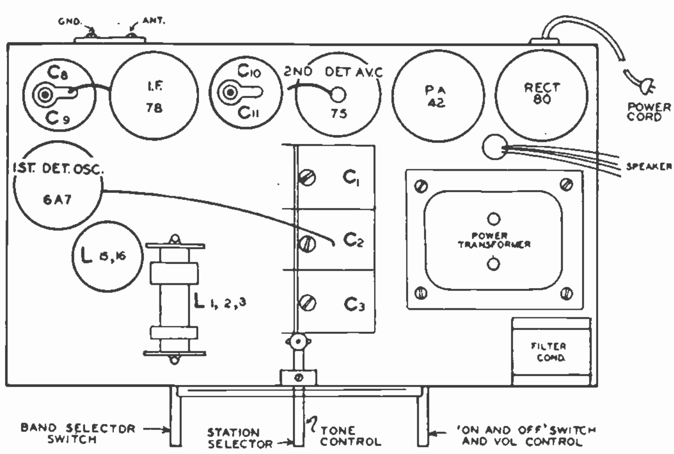
Line Voltage: 115 volts

Position of Volume Control: Full with Antenna Disconnected

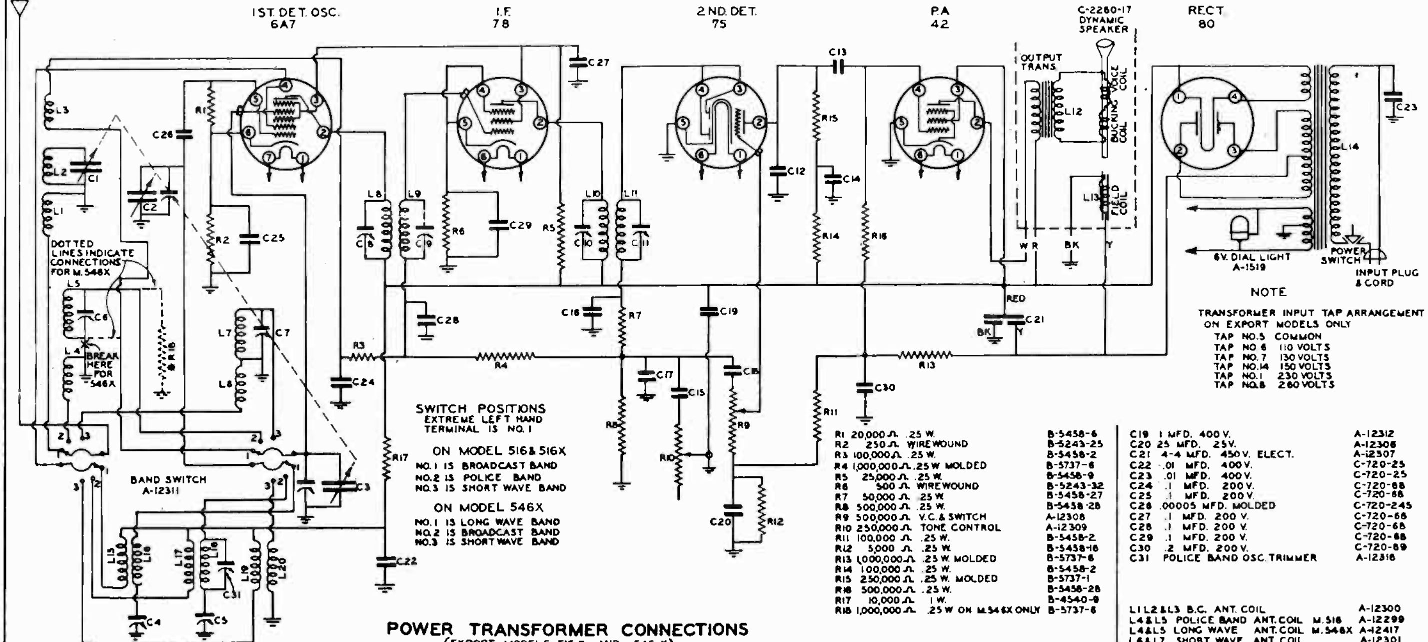
Position of Band Selector Switch: Broadcast

Tube	Function	Voltage and Resistance of Each Socket Prong to Ground (See Prong Numbers on Schematic Diagram)								
		Measurement	Prong No. 1	Prong No. 2	Prong No. 3	Prong No. 4	Prong No. 5	Prong No. 6	Prong No. 7	Grid Cap
6A7	1st. Det-Oscillator	Volts	0	225	150	210	0	0	0	*
		Ohms	0	500000	500000	350000	20000	250	0	500000
78	I - F Amplifier	Volts	0	0	220	110	0	0	-	*
		Ohms	0	175000	350000	0	500	0	-	500000
75	2nd. Det-A.V.C.-1st. Audio	Volts	0	90	0	0	0	0	-	*
		Ohms	0	*	500000	500000	0	0	-	500000
42	Power Amplifier	Volts	0	310	315	0	0	0	-	-
		Ohms	0	500000	500000	500000	0	0	-	-
80	Rectifier	Volts	0	380	380	0	-	-	-	-
		Ohms	500000	0	0	500000	-	-	-	-

NOTES: Voltage and resistance readings are for schematic diagram shown on back of sheet. Allow 15% + or - on all measurements. Always use meter scale which will give greatest deflection within scale limits. All measurements made with Weston Selective Analyzer No. 665, Type 1.
* Cannot be measured with Weston No. 665, Type 1.



TOP VIEW



NOTE

TRANSFORMER INPUT TAP ARRANGEMENT ON EXPORT MODELS ONLY

TAP NO.5	COMMON
TAP NO.6	110 VOLTS
TAP NO.7	130 VOLTS
TAP NO.14	150 VOLTS
TAP NO.1	230 VOLTS
TAP NO.8	260 VOLTS

SWITCH POSITIONS
EXTREME LEFT HAND TERMINAL IS NO. 1

ON MODEL 516 & 516X
NO. 1 IS BROADCAST BAND
NO. 2 IS POLICE BAND
NO. 3 IS SHORT WAVE BAND

ON MODEL 546X
NO. 1 IS LONG WAVE BAND
NO. 2 IS BROADCAST BAND
NO. 3 IS SHORT WAVE BAND

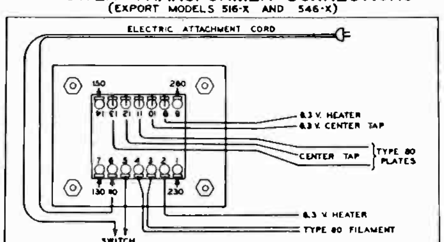
R1	20,000 Ω .25 W.	B-5458-6
R2	250 Ω WIREWOUND	B-5243-25
R3	100,000 Ω .25 W.	B-5458-2
R4	1,000,000 Ω .25 W MOLDED	B-5737-6
R5	25,000 Ω .25 W.	B-5458-9
R6	500 Ω WIREWOUND	B-5243-32
R7	50,000 Ω .25 W.	B-5458-27
R8	500,000 Ω .25 W.	B-5458-28
R9	500,000 Ω V.C. & SWITCH	A-12308
R10	250,000 Ω TONE CONTROL	A-12309
R11	100,000 Ω .25 W.	B-5458-2
R12	5,000 Ω .25 W.	B-5458-16
R13	1,000,000 Ω .25 W. MOLDED	B-5737-6
R14	100,000 Ω .25 W.	B-5458-2
R15	250,000 Ω .25 W. MOLDED	B-5737-1
R16	500,000 Ω .25 W.	B-5458-28
R17	10,000 Ω 1 W.	B-4540-9
R18	1,000,000 Ω .25 W ON M.546X ONLY	B-5737-6

C1, C2 & C3	VARIABLE CONDENSER	A-12314
C4	B.C. OSC. TRIMMER	A-12315
C5	POLICE BAND OSC. TRIMMER	A-12315
C6	POLICE BAND PRES. TRIMMER	A-12316
C7	SKIP BAND PRES. TRIMMER	A-12316
C8 & C9	1ST. I.F. TRIMMER	A-12415
C10 & C11	2ND. I.F. TRIMMER	A-12416
C12	.001 MFD. MOLDED	C-720-297
C13	.01 MFD. 400V.	C-720-25
C14	.1 MFD. 400V.	C-720-83
C15	.01 MFD. 400V.	C-720-25
C16	.0001 MFD. MOLDED	C-720-293
C17	.0001 MFD. MOLDED	C-720-293
C18	.01 MFD. 400V.	C-720-25

C19	1 MFD. 400 V.	A-12312
C20	25 MFD. 25V.	A-12306
C21	4-4 MFD. 450 V. ELECT.	A-12307
C22	.01 MFD. 400 V.	C-720-25
C23	.01 MFD. 400 V.	C-720-25
C24	.1 MFD. 200 V.	C-720-68
C25	.1 MFD. 200 V.	C-720-68
C26	.00005 MFD. MOLDED	C-720-245
C27	.1 MFD. 200 V.	C-720-68
C28	.1 MFD. 200 V.	C-720-68
C29	.1 MFD. 200 V.	C-720-68
C30	.2 MFD. 200 V.	C-720-69
C31	POLICE BAND OSC. TRIMMER	A-12316

L1, L2 & L3	B.C. ANT. COIL	A-12300
L4 & L5	POLICE BAND ANT. COIL M.516	A-12299
L4 & L5	LONG WAVE ANT. COIL M.546X	A-12417
L6 & L7	SHORT WAVE ANT. COIL	A-12301
L12	SINGLE OUTPUT 42 TRANS.	C-2280-17-3
L13	2500 Ω SPEAKER FIELD	C-2280-17-2
*L14	POWER TRANSFORMER SEE NOTE ABOVE	
L15 & L16	B.C. OSC. COIL	A-12297
L17 & L18	POLICE BAND OSC. COIL M.516	A-12298
L17 & L18	LONG WAVE OSC. COIL M.546X	A-12418
L19 & L20	SHORT WAVE OSC. COIL	A-12302
L8 & L9	1ST. I.F. COIL	A-12303
L10 & L11	2ND. I.F. COIL	A-12304
*L14	M. 516	A-12317
L14	M. 516X 546X	A-12317-X

POWER TRANSFORMER CONNECTIONS
(EXPORT MODELS 516-X AND 546-X)



Schematic Diagram—Sparton Model 516

RADIO-TRICIAN
REG. U.S. PAT. OFF.
Service Sheet
Compiled Solely for Students and Graduates

NATIONAL RADIO INSTITUTE, WASHINGTON, D.C.

ZENITH CHASSIS 5528, MODELS 5R303, 5R312, 5R316, 5R317, 5R337

NOTE

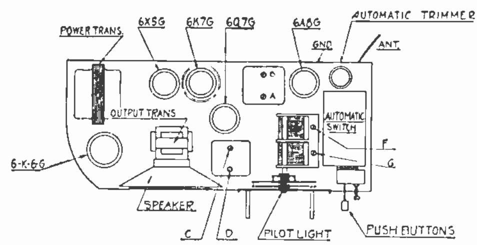
Voltages measured with a 1000 ohm per volt meter from chassis to socket contacts. Antenna disconnected—volume control on full.

Line voltage 115 v. Consumption 45 watts.

Power output 3.5 watts.

(A) Bias for 6A8-6K7 and diodes of 6Q7 measured across resistor R9.

(B) Bias for triode section of 6Q7 and 6K6 measured across R8 and R9.



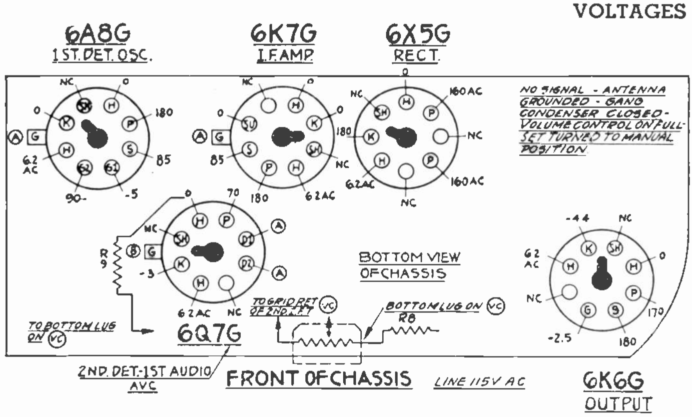
Location of Tubes and Trimmers

No Signal—Antenna Grounded—Gang Condenser closed—Volume Control on full—set turned to manual position.

SOCKET VOLTAGES

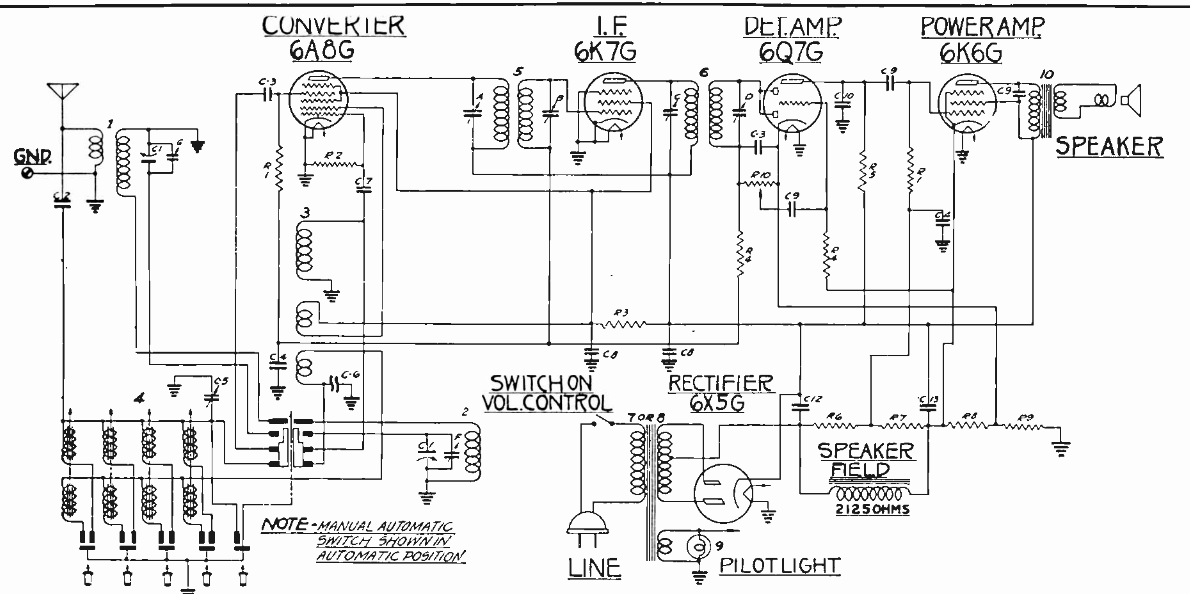
LEGEND

NC—No Connection
VC—Volume Control
SH—Shield
H—Heater
P—Plate
S—Screen
G—Grid
SU—Suppressor
D—Diode
K—Cathode
F—Filament



ALIGNMENT PROCEDURE

Operation	Connect Test Oscillator to	Dummy Antenna	Set Test Osc. to	Band	Set Dial at	Adjust Trimmers	Purpose
1	1st Det. Grid	½ Mfd.	455	Br'dc't	600	ABCD	I. F. Alignment
2	Rec. Ant. Lead	200 Mmfd.	1500	Br'dc't	1500	F	Set Osc. to Scale
3	Rec. Ant. Lead	200 Mmfd.	1500	Br'dc't	1500	G	Al'gment of Ant.



Diag. No.	Part No.	Description	
C-1	22-695	Two Gang Var. Cond.	
C-2	22-289	50 Mmfd.	600V
C-3	22-162	.0001 Mfd.	600V
C-4	22-250	.05 Mfd.	200V
C-5	22-519	Trimmer Cond.	
C-6	22-729	Compensating Cond.	
C-7	22-182	.00025 Mfd.	600V
C-8	22-212	.05 Mfd.	400V
C-9	22-196	.01 Mfd.	600V
C-10	22-147	.0005 Mfd.	600V
C-12	22-691	8 Mfd. Electrolytic	450V
C-13	22-692	8 Mfd. Electrolytic	350V

Diag. No.	Part No.	Description	
R-1	63-597	470 M Ohm	1/4W
R-2	63-593	47 M Ohm	1/4W
R-3	63-208	12 M Ohm	1W
R-4	63-271	1 Megohm	1/4W
R-5	63-296	220 M Ohm	1/4W
R-6	63-658	390 M Ohm	1/4W
R-7	63-260	100 M Ohm	1/4W
R-8	63-563	80 Ohm Wire Wound	1/4W
R-9	63-686	150 Ohm Wire Wound	1/2W
R-10	63-955	220 M Ohm Vol. Cont.	

ZENITH CHASSIS 5528, MODELS 5R303, 5R312, 5R316, 5R317, 5R337

RADIO-TRICIAN
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NATIONAL RADIO INSTITUTE, WASHINGTON, D.C.

Stromberg-Carlson No. 60 Type Radio Receivers

ELECTRICAL SPECIFICATIONS

Type of Circuit .... Superheterodyne
Tuning Ranges .... 540—1570 k. c. and 5.5 to 15.5 mc.
Type and Number of Tubes .... 1 No. 6D6, 1 No. 6A7, 1 No. 6B7, 1 No. 37, 2 No. 41, 1 No. 80
Voltage Rating .... 105-125 Volts
Frequency Rating .... 50-60 Cycles
Power Consumption Rating .... 80 Watts

CIRCUIT DESCRIPTION

The No. 6D6 tube is used as the R. F. amplifier. The No. 6A7 tube is used for the oscillator-mixer. The No. 6B7 tube serves as the I. F. amplifier, A. V. C., and demodulator. The No. 37 tube is the first audio amplifier and the two No. 41 tubes function as the power output stage. The No. 80 is the rectifier in the power supply circuit.

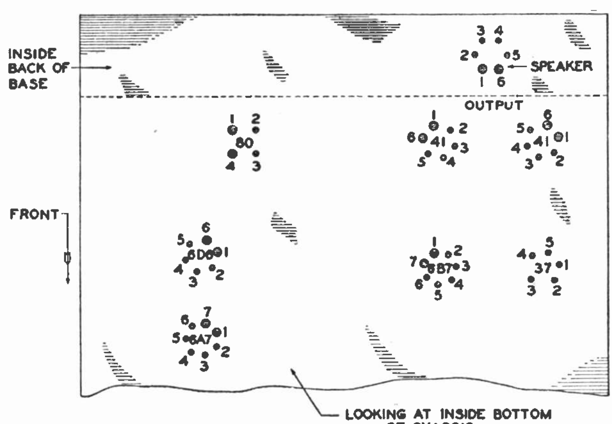


Fig. 2. Terminal Layout for Voltage Measurement Chart.

Tube	Circuit	Cap.	Terminals of Sockets 1	2	3	4	5	6	7	Heater Voltages Between Terminal Nos.
6D6	R. F. Amp.	G 0	H 0	P 145	S 85	Sup. 5.5	K 5.5	H 0	—	1-6—*6.5* volts
6A7	Mixer-Osc.	Mix. G 0	H 0	Mix. P 145	S 85	Osc. P. 175	Osc. G —20	K 5.5	H 0	1-7—*6.5* volts
6B7	I. F., Dem.	G 0	H 0	P 145	S 85	D 0	D 0	K 3	H 0	1-7—*6.5* volts
37	1st Audio	—	H 0	P 140	G 0	K 8	H 0	—	—	1-5—*6.5* volts
41's	Output	—	H 0	P 250	S 250	G 0	K 16	H 0	—	1-6—*6.5* volts
80	Rectifier	—	F 270	P *298*	P *298*	F 270	—	—	—	1-4—*4.9* volts
Speaker Socket			245	145	270	270	250	245		

A. C. voltages are indicated by italics

NORMAL VOLTAGE READINGS

These voltage readings are obtained by measuring between the various tube socket contacts and the bases with the tubes and speaker plug in place. The set is therefore in operation when the measurements are made. Fig. 2 shows the terminal layout of the sockets with the proper terminal numbers. The terminals of each socket are numbered, starting with one heater or filament pin and proceeding around the pin circle clockwise to the other heater or filament pin. This is done looking at the bottom of the socket. Tune Receiver to 1500 k. c.

Voltages are given for a line voltage of 120 volts and allowance should be made for differences when the line voltage is higher or lower. A meter with a resistance of 1,000 ohms per volt should be used for measuring the D. C. voltages. The Volume Control should be set all "On" (clockwise) before measuring voltages.

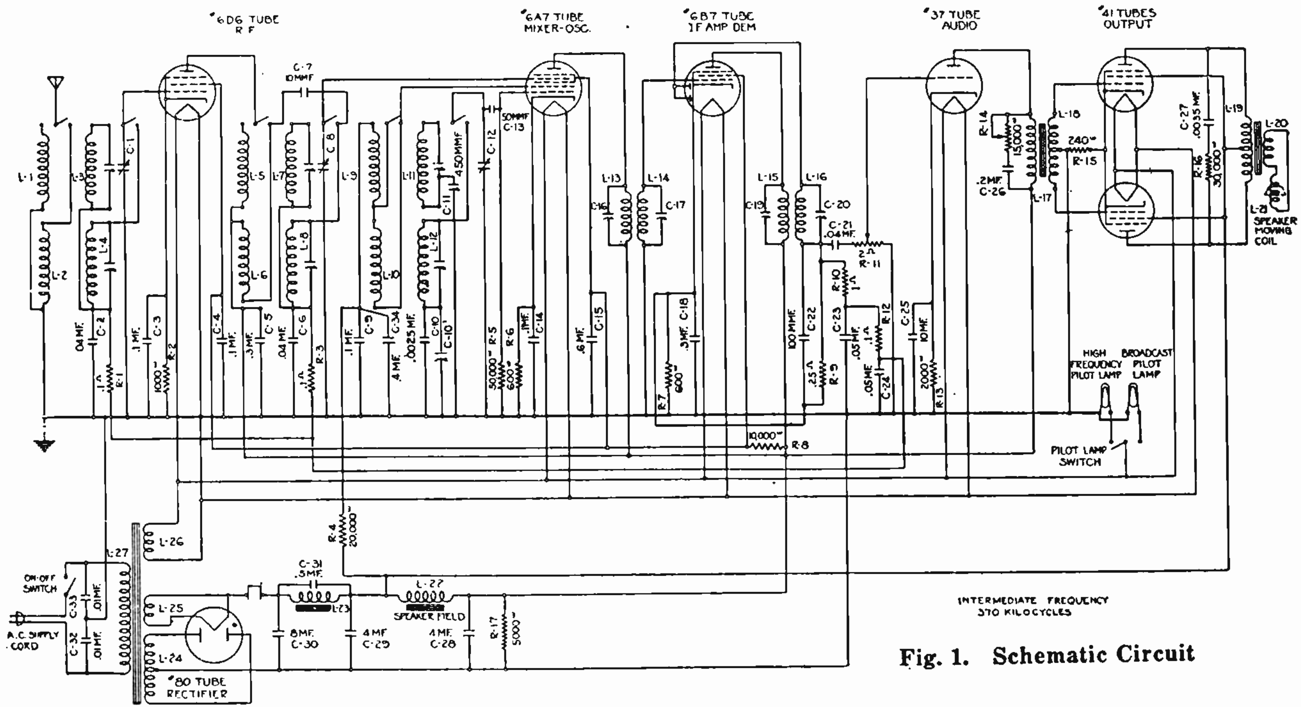


Fig. 1. Schematic Circuit

RADIO-TRICIAN
REG. U.S. PAT. OFF.

Service Sheet

Compiled Solely for Students and Graduates

NATIONAL RADIO INSTITUTE, WASHINGTON, D.C.

FAIRBANKS-MORSE

The Model 56 Chassis
Employed In The Models
5619 and 5645

ALIGNMENT PROCEDURE

To obtain maximum performance the model 56 receiver must be aligned perfectly. It is urged that the following instructions be studied carefully before any alignment adjustments are attempted. Proper adjustment of the various tuned circuits will be possible only through the use of an accurate and reliable signal generator employed in conjunction with an output meter, which may be connected across the voice coil leads of the loud speaker.

NOTE—All adjustments should be made with the volume control "full on." Any desired variation in signal strength should be obtained by adjusting output of signal generator.

INTERMEDIATE FREQUENCY ALIGNMENT

1. Turn the gang condenser to maximum capacity (fully meshed).
2. Set the band selector switch on the "Broacast" position.
3. Supply a 456 kilocycle signal from the signal generator to the antenna lead of the receiver through a .1 Mfd. condenser connected in series with the signal generator lead.
4. Adjust the four trimmers of the two intermediate frequency transformers (see Figure 1) for maximum output with minimum input from the service oscillator.
5. Adjust the wave trap trimmer "A" (see Figure 1) for **minimum** output.

RADIO FREQUENCY ALIGNMENT The parallel or high frequency trimmer condensers for the broadcast band are on the gang condenser. These trimmers are used for aligning the high frequency end of the broadcast band. Location of the trimmers is shown in Fig. 1. The oscillator adjustable series padding condenser is used for tracking the oscillator at the low frequency end of the broadcast band. The padding condenser may be adjusted from the top of the chassis through the hole indicated in Figure 1. While making padding condenser adjustments the gang condenser should be rotated back and forth across the signal to insure adjustment to the peak of greatest intensity.

DIAL ADJUSTMENT Before making any alignment adjustments, close the variable tuning condenser (maximum capacity), place the dial pointer in a horizontal position (gang condenser still closed) and then proceed with the following adjustments.

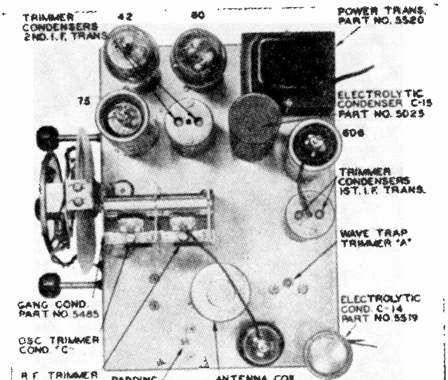


Fig. 1. Top view of model 56 chassis

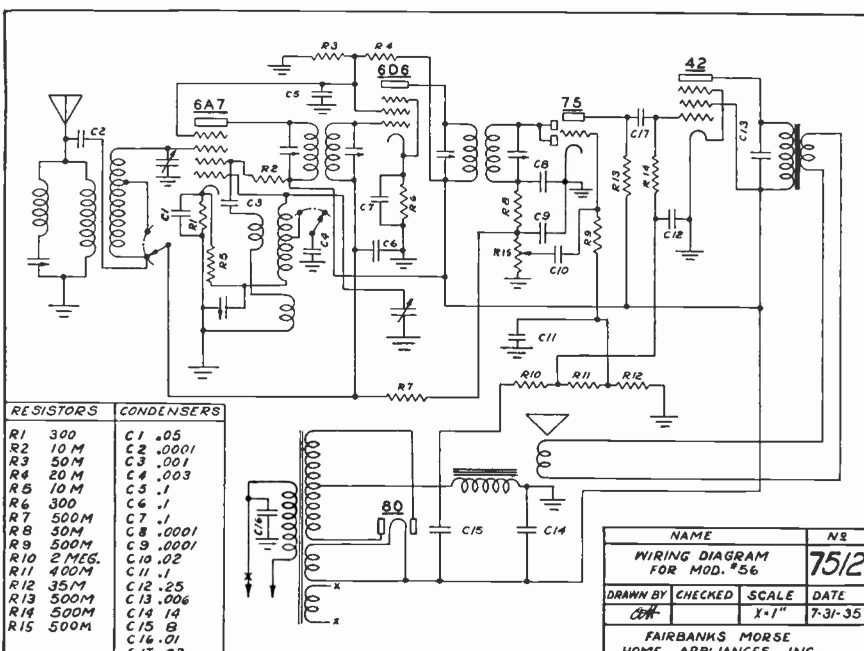
Alignment Procedure

BROADCAST BAND

1. Turn the band selector switch to the broadcast (counter-clockwise) position.
2. Tune the receiver to 1500 kilocycles.
3. Supply a 1500 kilocycle signal from the signal generator to the antenna lead of the receiver through a standard dummy antenna or a 200 Mmfd. (.0002 Mfd.) condenser, connected in series with the signal generator lead.
4. Adjust the trimmer condensers on the gang condenser (Figure 1) for maximum output with minimum input from the signal generator.
5. Tune the receiver to 600 kilocycles.
6. Supply a 600 kilocycle signal to the antenna of the receiver through the same connections as previously used.
7. Adjust the broadcast band oscillator padding condenser "B" (top of chassis, see Figure 1) for maximum output with minimum input from the signal generator, at the same time rocking the tuning condenser back and forth across the signal to insure the peak of greatest intensity.
8. Check at 1500 kilocycles and then at 600 kilocycles. Make any adjustments necessary to obtain satisfactory calibration.

SHORT WAVE BAND

1. Turn the band selector switch to the short wave position.
2. Tune the receiver to 6 megacycles.
3. Supply a 6 megacycle signal from the signal generator to the antenna lead of the receiver through a 400 ohm carbon resistor (dummy antenna), connected in series with the signal generator lead.
4. The 6 megacycle signal should be received near the 6 megacycles on the dial. If this is not the case, check the oscillator tube, switch connections and coils. No adjustment is necessary on this band.



RESISTORS	
R1	300
R2	10 M
R3	50 M
R4	20 M
R5	10 M
R6	300
R7	500M
R8	50M
R9	500M
R10	2 MEG.
R11	400M
R12	35M
R13	500M
R14	500M
R15	500M

CONDENSERS	
C1	.05
C2	.0001
C3	.001
C4	.003
C5	.1
C6	.1
C7	.1
C8	.0001
C9	.0001
C10	.02
C11	.1
C12	.25
C13	.006
C14	14
C15	8
C16	.01
C17	.02

NAME			Nº
WIRING DIAGRAM FOR MOD. #56			7512
DRAWN BY	CHECKED	SCALE	DATE
C.H.		X-1"	7-31-35
FAIRBANKS MORSE HOME APPLIANCES, INC.			

Schematic Diagram of the Model 56 Chassis

RADIO-TRICIAN
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Service Sheet
Compiled Solely for Students and Graduates
NATIONAL RADIO INSTITUTE, WASHINGTON, D.C.

FAIRBANKS-MORSE

The Model 43 Chassis
Employed in the Models
43T1B and 43C1B

ALIGNMENT PROCEDURE

To obtain maximum performance the model 43 receiver must be aligned perfectly. It is urged that the following instructions be studied carefully before any alignment adjustments are attempted. Proper adjustment of the various tuned circuits will be possible only through the use of an accurate and reliable signal generator employed in conjunction with an output meter, which may be connected from plate to ground on the output tube. A fixed condenser (.1 Mfd.) should be connected in series with the output meter.

NOTE—All adjustments should be made with the volume control "full on." Any desired variation in signal strength should be obtained by adjusting output of signal generator.

INTERMEDIATE FREQUENCY ALIGNMENT

1. Turn the gang condenser to maximum capacity (fully meshed).
2. Set the dial pointer at 530 kilocycles and then tighten the set screw.
3. Supply a 456 kilocycle signal from the signal generator to the grid of the type 1C6 first detector tube through a .1 Mfd. condenser connected in series with the signal generator lead.
4. Adjust the four trimmers of the two intermediate frequency transformers (see Figure 1) for maximum output with minimum input from the service oscillator.

RADIO FREQUENCY ALIGNMENT The parallel or high frequency trimmer condensers for each stage are located on the gang condenser (see Figure 1).

1. Tune the receiver to 1500 kilocycles.
2. Supply a 1500 kilocycle signal from the signal generator to the antenna lead of the receiver through a standard dummy antenna or a 200 Mmfd. (.0002 Mfd.) condenser, connected in series with the signal generator lead.
3. Adjust the oscillator stage trimmer condenser ("A" Figure 1) for maximum output with minimum input from the signal generator.
4. Adjust the Radio frequency trimmer ("B" Figure 1) for maximum output with minimum input from the signal generator.

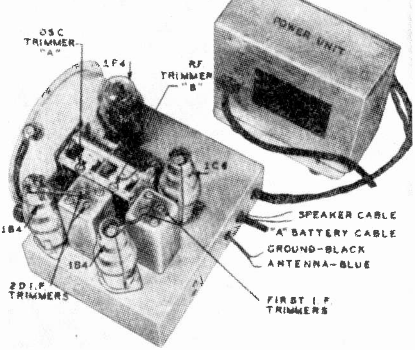
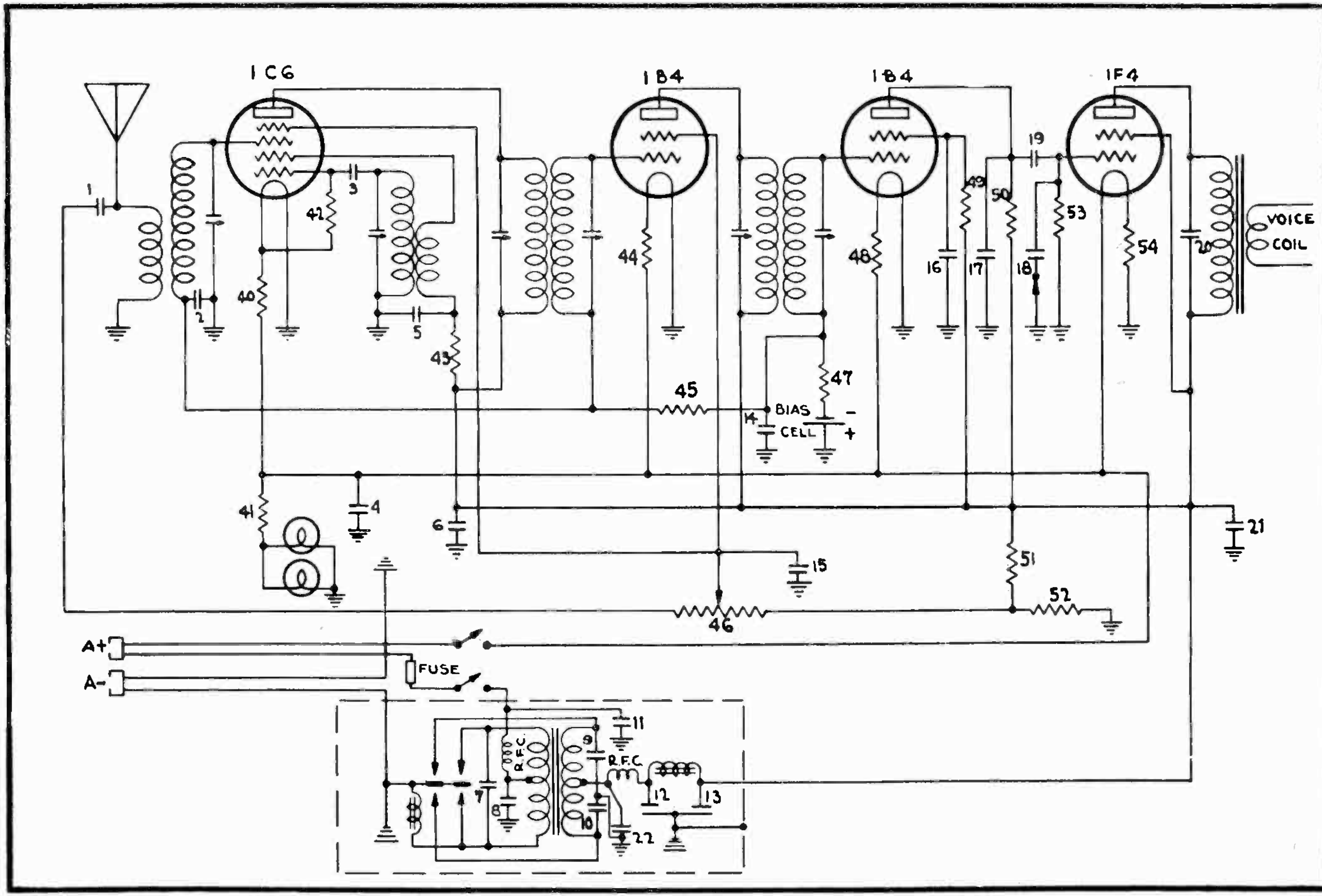


Fig. 1. Top view of model 43 chassis



Schematic Diagram of the Model 43 Chassis

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Service Sheet

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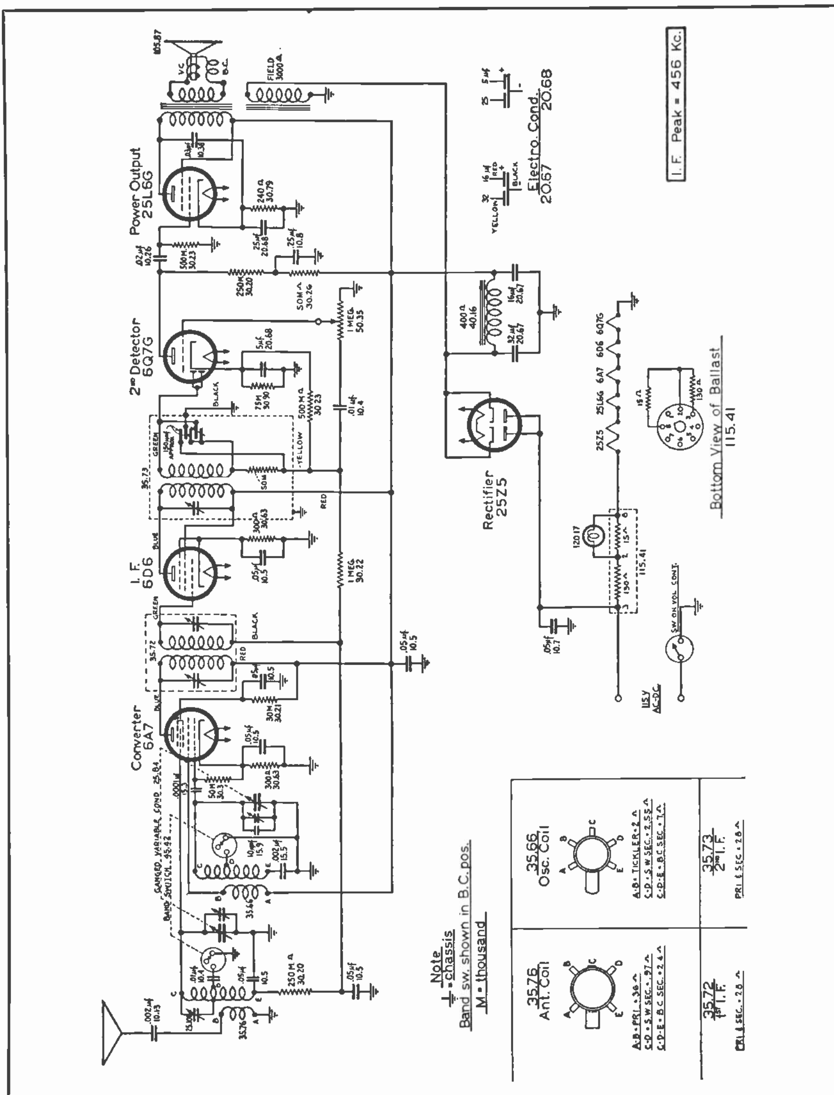
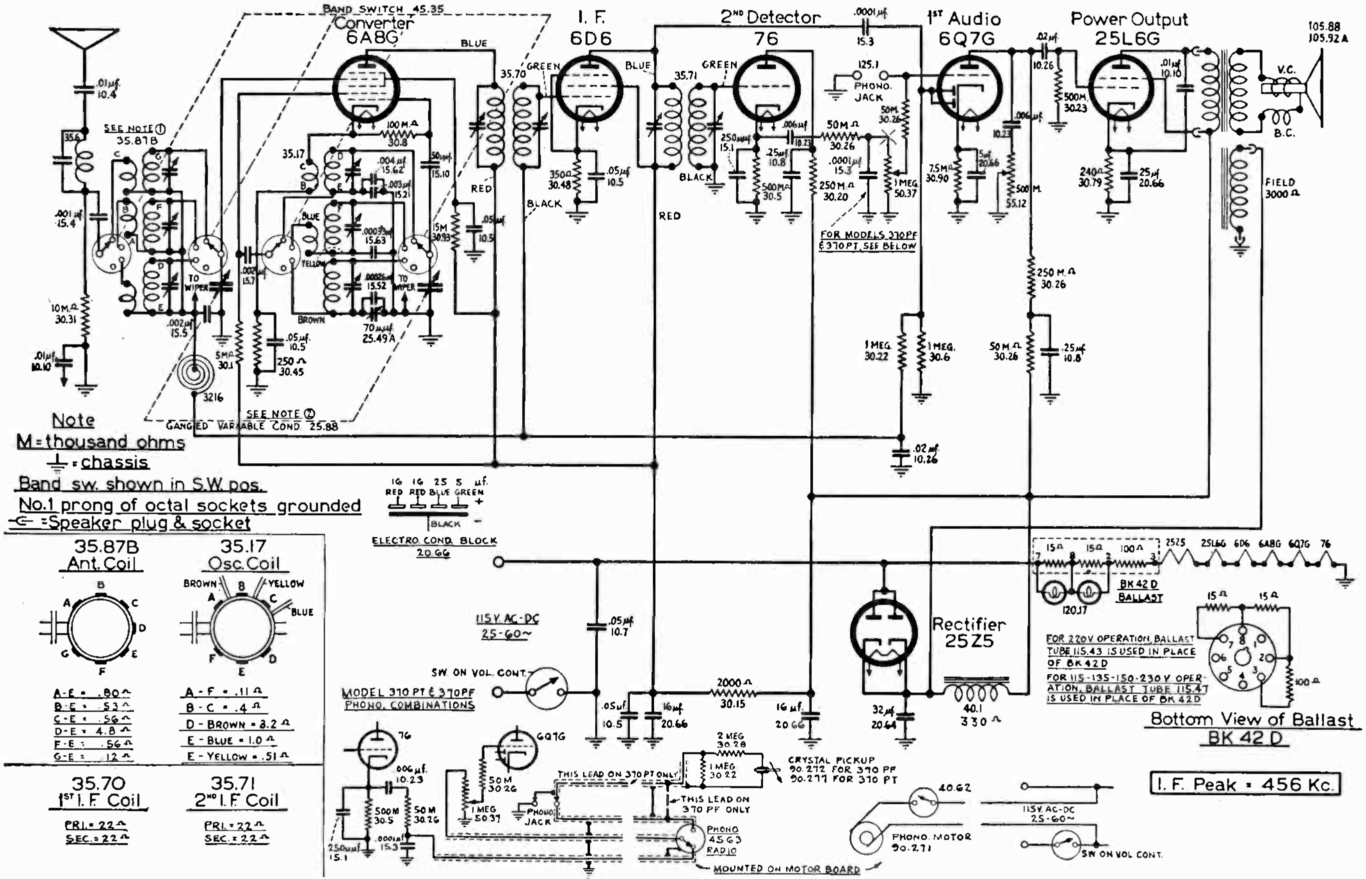
FADA MODEL 360





Fada Model 370

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R.C.A.-Victor 121, 122, General Electric K64, Westinghouse WR37, Canadian General Electric K64, Canadian Westinghouse W64.

LINE UP CAPACITOR ADJUSTMENTS

In order to properly align this receiver it is essential that an oscillator be used. This oscillator should cover the frequencies of 370 K. C. to 15,000 K. C. continuously. In addition to the oscillator, a non-metallic screwdriver and an output meter are required. The output meter should be preferably a thermo-couple galvanometer connected across or in place of the cone coil of the loudspeaker.

I. F. Tuning Adjustments—Two transformers, comprising three tuned circuits (the secondary of the second transformer is untuned), are used in the intermediate amplifier. These are tuned to 370 K. C. and the adjustment screws are accessible, as shown in Figure 1. Proceed as follows:

(a) Short circuit the antenna and ground leads and tune the receiver so that no signal is heard. Set the volume control at maximum and connect a ground to the chassis.

(b) Connect the test oscillator output between the first detector control grid and chassis ground. Connect the output meter across the voice coil of the loudspeaker, and adjust the oscillator output so that, with the receiver volume control at maximum, a slight deflection is obtained in the output meter.

(c) Adjust the primary of the second, and the secondary and primary of the first I. F. transformers until a maximum deflection is obtained. Keep the oscillator output at a low value, so that only a slight deflection is obtained on the output meter at all times. Go over these adjustments a second time as there is a slight interlocking of adjustments. This completes the I. F. adjustments.

R. F. and Oscillator Adjustments—The R. F. line-up capacitators are located at the bottom of the coil assemblies instead of their usual position on the gang capacitor. They are all accessible from the bottom of the chassis, except the 600 K. C. series capacitor, which is accessible from the rear of the chassis. Proceeds as follows:

(a) Connect the output of the oscillator to the antenna and ground leads of the receiver. Check the position of the indicator pointer when the tuning capacitor plates are fully meshed. It should be coincident with the radical line adjacent to the dial reading of 54. Then set the test oscillator at 1,400 K. C., the dial indicator at 140 and the oscillator output so that a slight deflection will be obtained in the output meter when the volume control is at its maximum position.

(b) With the range switch at the "in" position, adjust the three trimmers under the three R. F. coils, designated as L. W. in Figure D, until a maximum deflection is obtained in the output meter. Then shift the test oscillator frequency to 600 K. C. The trimmer capacitor, accessible from the rear of the chassis, should now be adjusted for maximum output while rocking the main tuning capacitor back and forth through the signal. Then repeat the 1,400 K. C. adjustment.

(c) Now place the range switch at the "out" position, shift the test oscillator to 15,000 K. C. and set the dial at 150. Adjust the three trimmer capacitors designated as SW in Figure 1 for maximum output, beginning with the oscillator trimmer. It will be noted that the trimmer on the oscillator will have two positions at which the signal will give maximum output. The position which uses the minimum trimmer capacity, obtained by turning the screw counter-clockwise, is the proper adjustment. The other point is known as the "image." This completes the line-up adjustment.

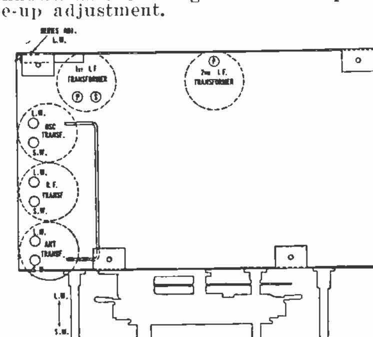
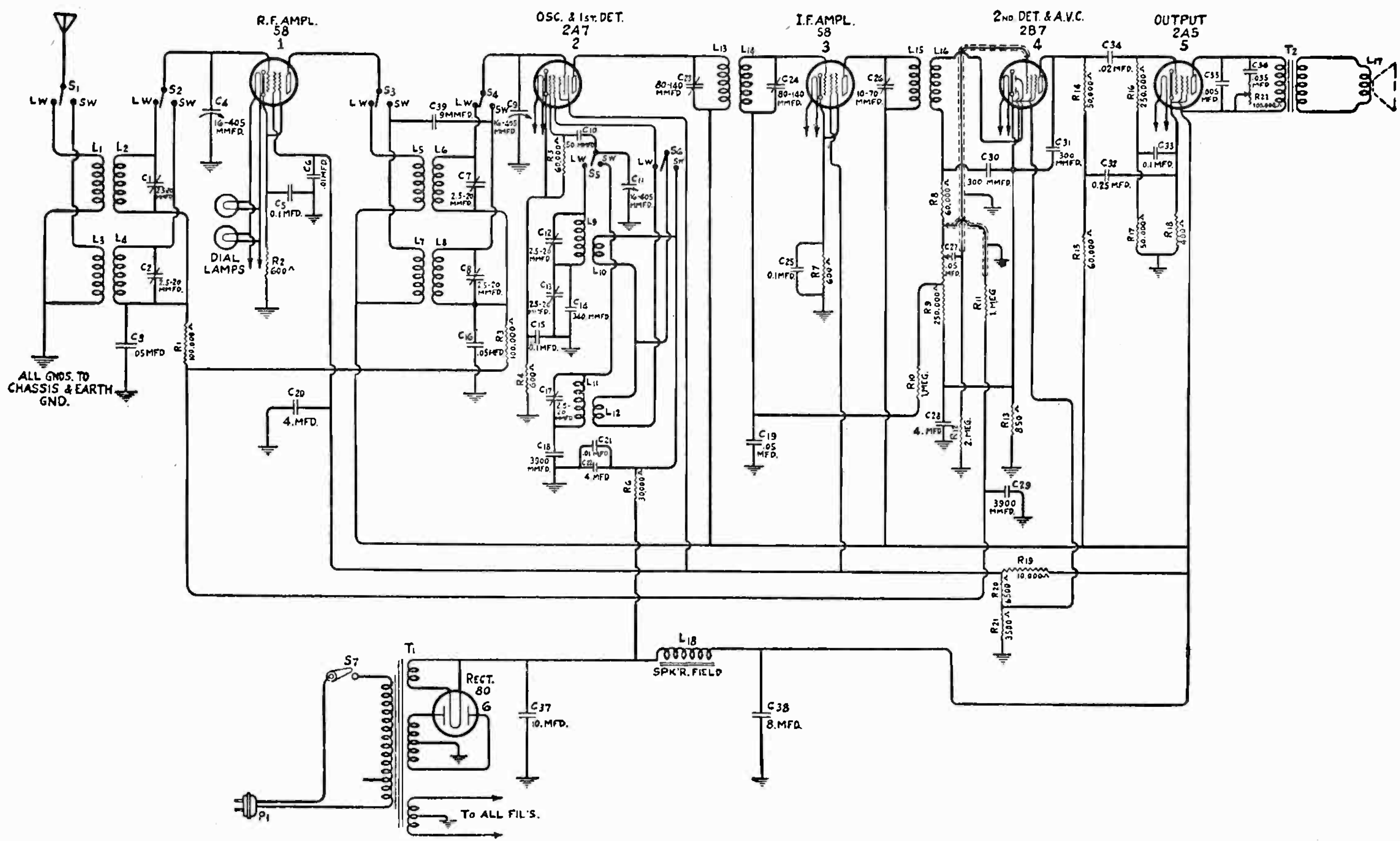


Figure 1


R.F. AMPL.
58
1
OSC. & 1st. DET.
2A7
2
I.F. AMPL.
58
3
2nd DET. & A.V.C.
2B7
4
OUTPUT
2A5
5
RECT.
80
6
DIAL LAMPS
ALL GNDS. TO CHASSIS & EARTH GND.
SPK'R. FIELD
To ALL FIL'S.
C4 16-405 MMFD.
C5 0.1 MFD.
C6 .01 MFD
C20 4. MFD.
C39 9 MMFD.
C9 16-405 MMFD
C3 .05 MFD
R1 100,000
R2 600
R3 100,000
R4 600
R5 60,000
R6 30,000
C7 2.5-20 MMFD.
C8 2.5-20 MMFD.
C2 2.5-20 MMFD.
C16 .05 MFD
C10 50 MMFD
C11 16-405 MMFD.
C14 340 MMFD
C15 0.1 MFD.
C18 3900 MMFD.
C21 .01 MFD
C22 4 MFD
C23 80-140 MMFD
C24 80-140 MMFD.
C25 0.1 MFD.
R7 600
C26 10-70 MMFD.
C19 .05 MFD.
C30 300 MMFD
C31 300 MMFD.
C27 .05 MFD.
R8 60,000
R9 250,000
R10 1 MEG.
R11 1 MEG
R12 2. MEG.
C28 4. MFD
R13 850
C29 3900 MMFD.
C34 .02 MFD.
C32 0.25 MFD.
C33 0.1 MFD.
R14 50,000
R15 60,000
R16 250,000
R17 50,000
R18 400
C35 .005 MFD
C36 .035 MFD
R22 100,000
R19 10,000
R20 6500
R21 3500
C37 10. MFD.
C38 8. MFD.
L18
T1
T2
S7
P1

14 CIRCUIT DIAGRAMS EACH WITH TESTING INFORMATION

17 SS

SERVICE MANUAL

NATIONAL RADIO INSTITUTE

EST. 1914

WASHINGTON, D.C.

FOREWORD

This booklet is one of a series of service manuals which contain service sheets giving typical information on radio receivers. Each service sheet shows the circuit diagram in the usual symbolic form for that radio receiver. Many of the service sheets will contain such special service information as space will permit.

By studying each service sheet, you will gradually develop the ability to read any diagram or manufacturer's service manual and learn the usual methods of set adjustment. Enough typical receivers have been selected to give you quickly a good insight to the entire radio problem.

In reading a circuit diagram, learn to trace independently the power supply and the signal circuits. Then locate the special control circuits, such as the automatic volume controls, tuning indicators, manual volume controls, etc. Detailed information on power supply, signal and control circuits, as well as set servicing, is given in the course, to which reference should be made.

J. E. SMITH

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)

FM5M1240

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Service Sheet
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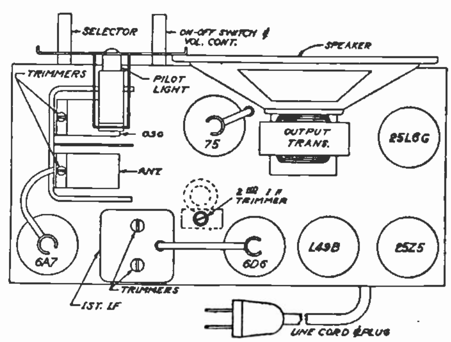
ADMIRAL MODEL 5L AND 5LL

Alignment Data

GENERAL DATA. The alignment of this receiver requires the use of a test oscillator that will cover the frequencies of 456, 600, 1400, and 1730, and an output meter to be connected across the primary or secondary of the output transformers. If possible, all alignments should be made with the volume control on maximum and the test oscillator output as low as possible, to prevent the AVC from operating and giving false readings.

CORRECT ALIGNMENT PROCEDURE. The intermediate frequency (I.F.) stage should be aligned properly as the first step. After the I.F. transformers have been properly adjusted and peaked, the Broadcast Band alignment should be the next procedure.

I.F. ALIGNMENT. Adjust the test oscillator to 456 KC and connect the output to the grid of the first detector tube (6A7) through a .05 or .1 mfd. condenser. Connect ground of test oscillator to chassis ground through a .1 mfd. condenser. Align all three I.F. trimmers to peak or maximum reading on the output meter. BROADCAST BAND ALIGNMENT. Adjust the oscillator to 1730 KC and connect the output to the antenna lead, through a .0002 mfd. mica condenser. Set the gang condenser to minimum capacity and adjust the gang condenser trimmer (oscillator) to receive this signal. After this has been carefully done, the next step is to set the generator to 1400 KC and after tuning in the signal adjust the antenna trimmer to peak. This is all that is necessary for the alignment unless the plates of the gang condenser have been bent out of shape. In case of bent plates, set the test oscillator and the receiver to 600 KC and bend the plates into the position for maximum output.



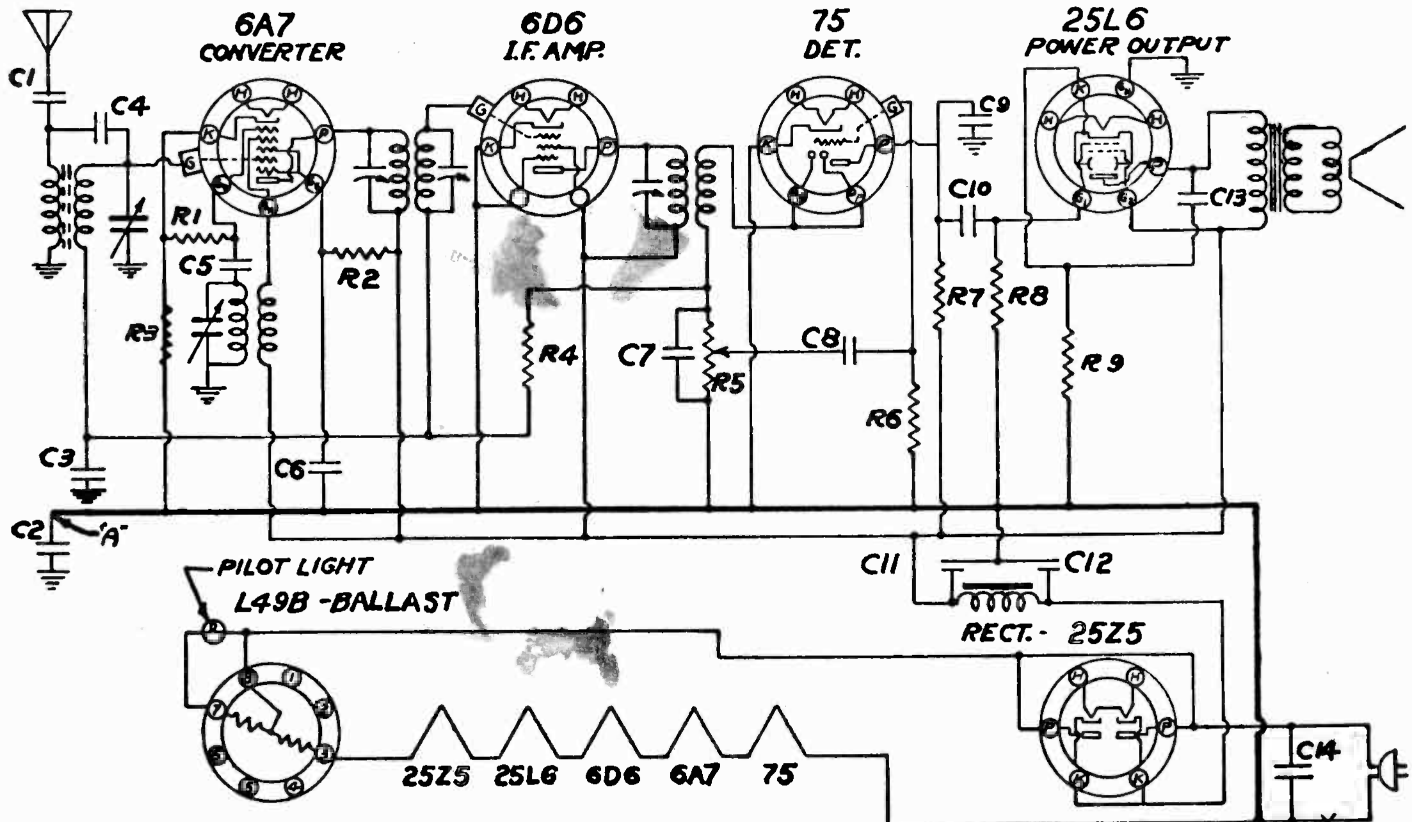
PARTS LIST

CONDENSERS

No.	MFD.	VOLTS
C1	.00025	MICA
C2	.25	200
C3	.02	400
C4	.000005	GIMMIC
C5	.00005	MICA
C6	.05	400
C7	.00025	MICA
C8	.01	400
C9	.00025	MICA
C10	.01	400
C11	20.	150
C12	20.	150
C13	.005	600
C14	.05	400

RESISTORS

No.	OHMS	WATTS
R1	50,000	½
R2	30,000	½
R4	2,000,000	½
R5	500,000	VOL. CONT.
R6	5,000,000	½
R7	250,000	½
R8	500,000	½
R9	150	½ ±10%



ADMIRAL MODEL 5L AND 5LL

NOTE: C2 used on Model 5LL only. On Model 5L point "A" is connected to chassis.

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ARVIN HOME RADIO MODEL 508

Balancing Instructions

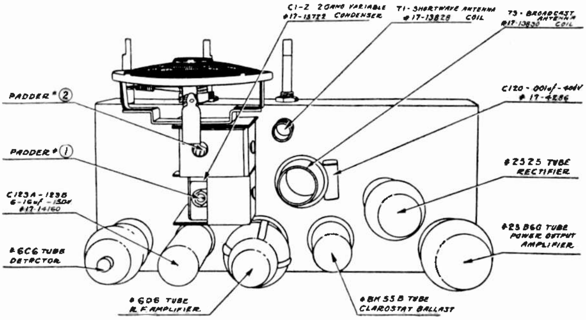
Rotate tuning condenser to extreme left and check to see that pointer lines up with horizontal lines across dial face. Connect balancing oscillator to antenna terminal through a standard 200 uuf. dummy antenna. Set dial of radio and output of oscillator to 1,400 K.C. Set wave band switch to Broadcast position.

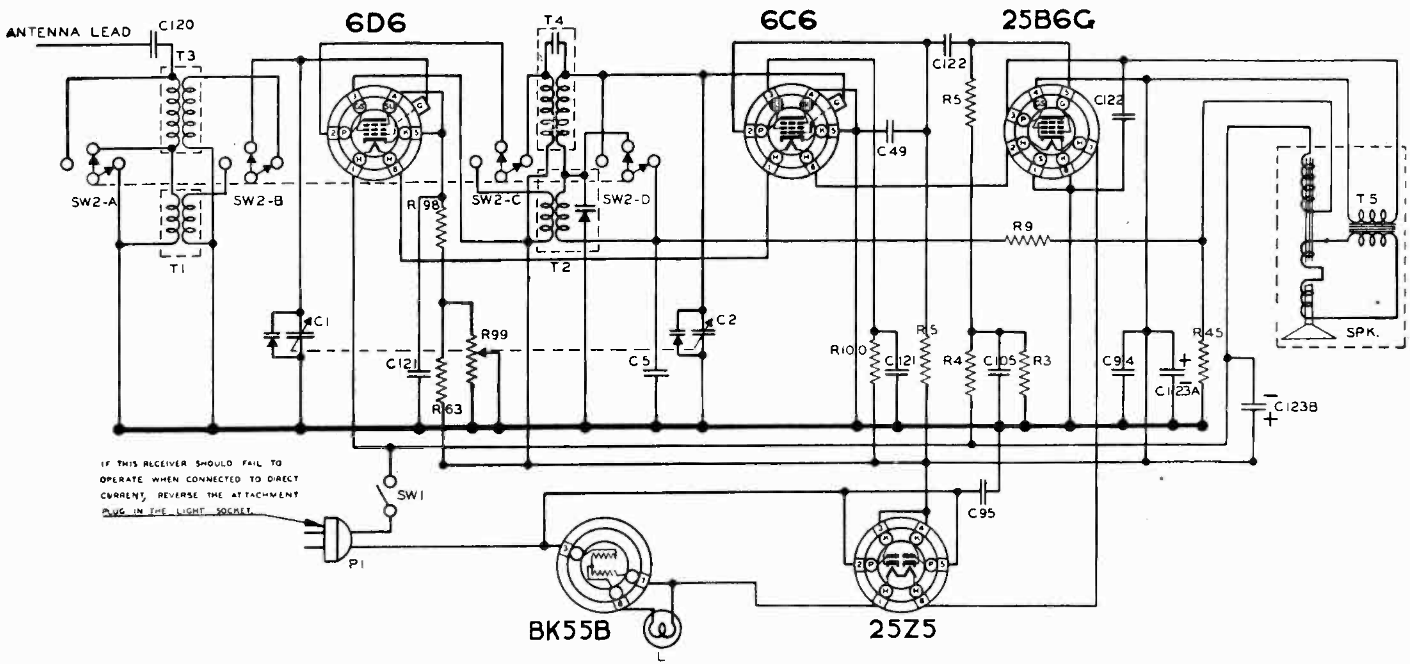
Adjust padders 1 and 2 for maximum output.

Set dial of radio and output of oscillator to approximately 2,400 K.C. Set wave band switch to short wave position. Adjust padder No. 3 for maximum output.

Coil, Transformer and Speaker Resistances

T1 Broadcast Ant. Pri.	60.0 ohms	T4 Short Wave R. F. Pri.	.5 ohms
T1 Broadcast Ant. Sec.	3.6 ohms	T4 Short Wave R. F. Sec.	1.0 ohms
T3 Short Wave Ant. Pri.	.3 ohms	T5 Output Trans. Pri.	110 ohms
T3 Short Wave Ant. Sec.	.2 ohms	T5 Output Trans. Sec.	.6 ohms
T2 Broadcast R. F. Pri.	60.0 ohms	Speaker Field	740 ohms
T2 Broadcast R. F. Sec.	3.7 ohms	Speaker Voice Coil	1.7 ohms





ARVIN HOME RADIO MODEL 508

LIST OF PARTS

RESISTORS

R3	100,000	ohms	1/4 watt
R4	200,000	ohms	1/4 watt
R5	500,000	ohms	1/4 watt
R9	1 Meg.	ohm	1/4 watt
R45	25	ohms	1/2 watt
R63	25,000	ohms	1/4 watt
R98	200	ohms	1/4 watt
R99	15,000	ohms	VC
R100	3 Meg.	ohms	1/4 watt

CONDENSERS

C5	.05	200 Volt
C49	.0005	600 Volt
C94	.1	200 Volt
C95	.02	600 Volt
C105	.25	200 Volt
C120	.001	400 Volt
C121	.02	200 Volt
C122	.01	400 Volt
C123A	6.	150 Volt
C123B	16.	150 Volt

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DETROLA MODELS 14, 142, 142ES

RECEIVER ALIGNMENT

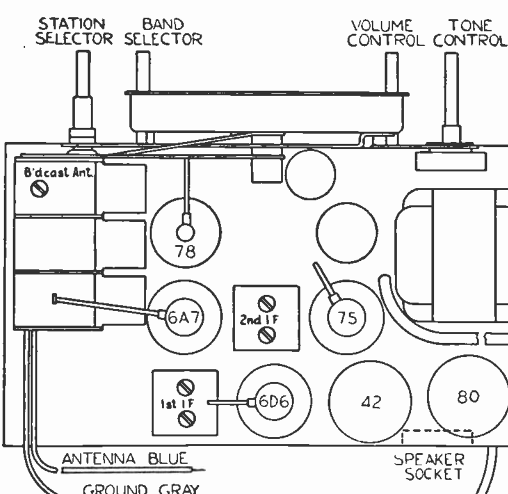
I. F. Alignment. Couple the signal generator to the grid of the 6A7 tube with a .1mfd condenser in series with the "high" lead of the signal generator. Connect the ground side of the signal generator to the chassis. Set the signal generator to 456 K.C. Be sure the wave switch of the set is in the broadcast position and the volume control set at maximum. Attenuate the signal generator so that the signal is just audible in the speaker. If an output meter is used, it should be connected across the voice coil terminals of the speaker. Use ½ volt as standard output.

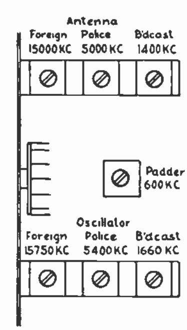
Adjust the 2nd I.F. transformer first. Each screw should be adjusted for maximum output. After number two I.F. has been adjusted, number one I.F. should be adjusted for maximum output. After both transformers have been adjusted, it is necessary to recheck No. 2 transformer and then recheck No. 1. See TUBE LAYOUT for location of I.F. and R.F. trimmers and padder.

R.F. (See diagram for location of trimmers). Using 200 mmf condenser in series with the generator, feed 1660 kc to antenna lead and adjust broadcast oscillator trimmer for top frequency. Set generator to 2400 kc, tune receiver and adjust the *two* antenna trimmers. Set generator to 600 kc, tune receiver to signal and adjust padder. The tuning condenser should be rocked back and forth through the signal while the padder is being set in order to secure perfect alignment.

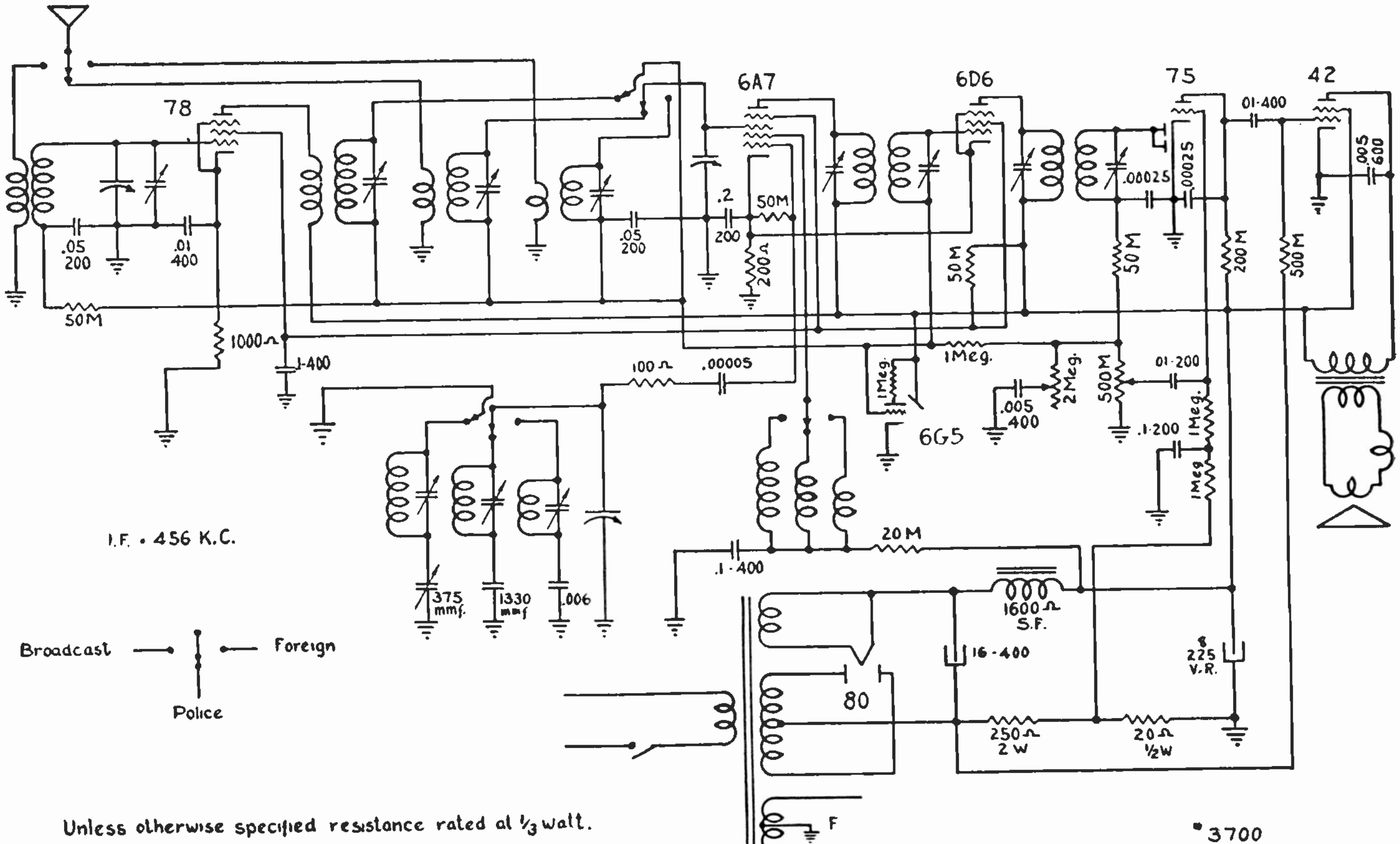
Using 400 ohm resistor in series with generator, set band selector in center position, set generator to 5400 kc and adjust oscillator trimmer for top frequency. Set generator to 5000 kc, tune receiver to signal and adjust antenna trimmer.

Turn band selector to extreme clockwise position. Using 400 ohm resistor in series with generator, set oscillator top frequency for 15,750 kc—screw trimmer down tight, then unscrew to *second* peak. Set generator to 15,000 kc, tune receiver to signal and adjust antenna trimmer — Screw trimmer down tight, then unscrew to *first* peak, rocking the tuning condenser back and forth through the signal while the adjustment is being made. Above procedure for alignment at 15,000 kc must be followed exactly to insure proper tracking. A dead spot at about 12,000 kc will result if antenna and oscillator circuits are not set in proper relation to each other.





TRIMMER ADJUSTMENT



Unless otherwise specified resistance rated at ⅓ watt.

*3700

DETROLA MODELS 14, 142, 142ES

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DETROLA MODEL 223 SERIES

ALIGNMENT PROCEDURE

Connect a high impedance AC voltmeter across loud-speaker terminals. Volume control should be set a few degrees back of maximum volume position. Use a weak signal from generator, strong signals tend to cause improper adjustments.

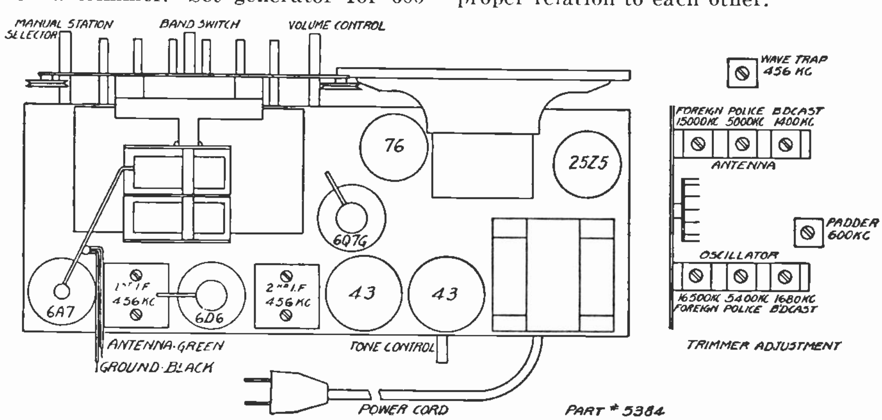
I.F.: Connect the generator ground to receiver chassis. Using .1 mfd. condenser in series with high side of generator, apply 456 kc. signal to grid of 6D6 I.F. amplifier tube, and align transformer No. 2. Connect generator to grid of 6A7 tube and align transformer No. 1.

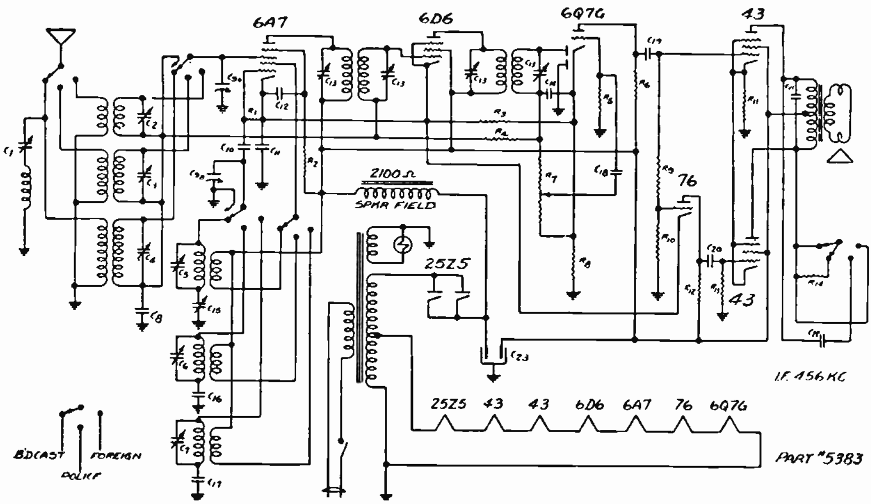
RF. (See diagram for location of trimmers).

Using a 200 MMF. condenser in series with the high side of the generator, turn band selector switch to left hand position and the tuning condenser to about 600 kc. Feed a 456 kc. signal to the antenna and adjust wave trap trimmer for minimum response. With the tuning condenser at minimum capacity feed 1660 kc. signal to the antenna and adjust broadcast oscillator trimmer for top frequency. Set generator frequency at about 1400 kc. Adjust broadcast antenna trimmer. Set generator for 600 kc. Tune receiver to signal and adjust the padder. The tuning condenser should be rocked back and forth through the signal while varying the padder in order to assure perfect alignment.

Using 400 ohm resistor in series with generator, set band selector in center position. Set generator to 5400 kc. and adjust oscillator trimmer for top frequency. Set generator to 5000 kc., tune receiver to signal and adjust antenna trimmer.

Turn band selector to extreme clockwise position. Using 400 ohm resistor in series with generator, set oscillator top frequency for 16,500 kc.—screw trimmer down tight, then unscrew to *second* peak. Set generator to 15,000 kc., tune receiver to signal and adjust antenna trimmer—screw trimmer down tight, then unscrew to *first* peak, rocking the tuning condenser back and forth through the signal while the adjustment is being made. Above procedure for alignment at 15,000 kc. must be followed exactly to insure proper tracking. A dead spot at about 12,000 kc. will result if antenna and oscillator circuits are not set in proper relation to each other.





DETROLA MODEL 223 SERIES

PARTS LIST

No order for parts will be accepted unless PART NUMBER, DESCRIPTION and CHASSIS MODEL NUMBER are given.

Symbol	Part No.	Description
C-1	3272	30-140 mmf Trimmer
C-2, 5, 7	1611	3-35 mmf Trimmer
C-3, 4, 6	2597	1-10 mmf Trimmer
C-8, 11	572	.1 200 V.
C-9a, b	5377	Tuning Condenser
C-10	2780	50 mmf Mica
C-12	580	.05 200 V.
C-13		IF Trimmer
C-14	4810	.0005 400 V.
C-15	2560	220-500 mmf Padder
C-16	2741	1330 mmf 5%
C-17	3871	.006 600 V. 5%
C-18	568	.01 400 V.
C-19, 20		.02 400 V.
C-21	581	.005 600 V.
C-22	2600	.02 600 V.
C-23	5389	20, 12 mf Electrolytic
R-1, 10	631	50M 1/3 W.
R-2	617	20M 1/3 W.
R-3	2605	200 ohm 1/3 W. 10%
R-4, 5	624	1 Meg. 1/3 W.
R-6	598	200M 1/3 W.

Symbol	Part No.	Description
R-7	5332	500M Volume Control
R-8	2698	100 ohm 1/3 W. 10%
R-9	2881	400M 1/3 W. 10%
R-11	5395	500 ohm wire wound 10%
R-12	603	100M. 1/3 W.
R-13	615	500M 1/3 W.
R-14	4529	10M 1/3 W. 10%
	5393	Power Transformer
	3463-10	1st IF Transformer
	3463-4	2nd IF Transformer
	5096	Oscillator Coil
	5392	Antenna Coil
	5390	Band Switch
	5394	Tone Control Switch
	530	Pilot Light Bulb
	5387	Dial Chart
	5396	Escutcheon
	5397	Button escutcheon
	5353	Tuning Buttons
	5357	Call Letter Sheets
	5388	Speaker
	3904	Knobs

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PHILCO MODEL 645

General Specifications

TYPE CIRCUIT: Superheterodyne, with preselector R.F amplifier, and push-pull pentode output (7 watts) built in connections for Philco All-wave aerial aerial selector built into and operated by wave-band switch

POWER SUPPLY: 115v, 60 cycle A.C

TUBES USED: 1 type 78, R F 1 type 6A7 Detector-Oscillator 1 type 78, I F 1 type 85. 2d Detector and 1st A.F.; 2 type 42 Push-Pull Output 1 type 80 Rectifier

WAVE BANDS: Three (1) Short-wave (2) Police, aircraft and amateur (3) Standard

COVERAGE OF EACH BAND: Band 1, 5.75-18 M C Band 2, 1.75-5.8 M.C. Band 3, 540-1750 K.C

TUNING DRIVE: Dual planetary, ball bearing. 80 to 1 ratio for slow-speed tuning glowing arrow wave band indicator

PROGRAM CONTROL. 4-position, with bass compensation effective in first position (counter-clockwise)

INTERMEDIATE FREQUENCY: 460 K.C

POWER CONSUMPTION: 85 watts

SPEAKER: 645 Baby Grand Model—K31 Furniture Model—H21

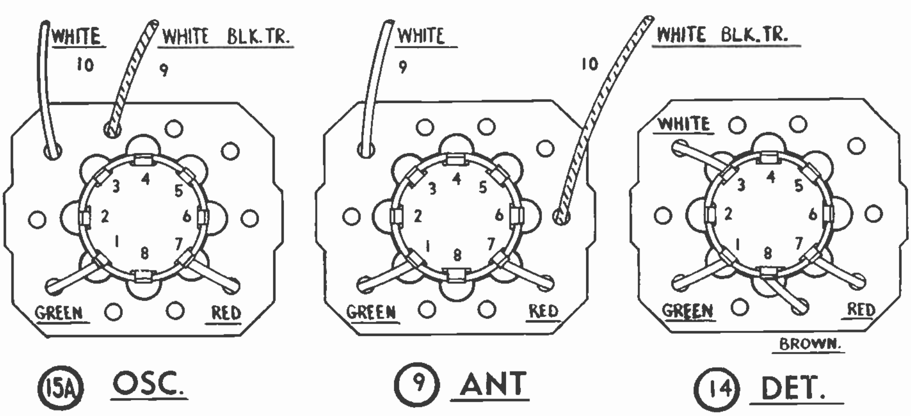


Fig. 1. R.F. Transformers

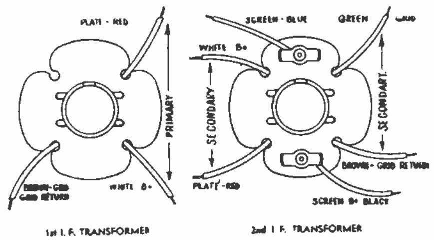


Fig. 2. I.F. Transformers

TUBE SOCKET VOLTAGES
(Measured from Tube Contact to Gnd.)

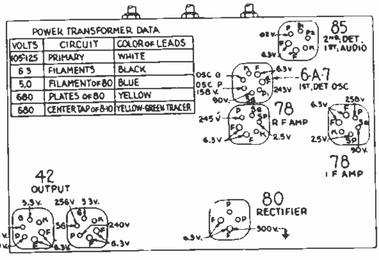
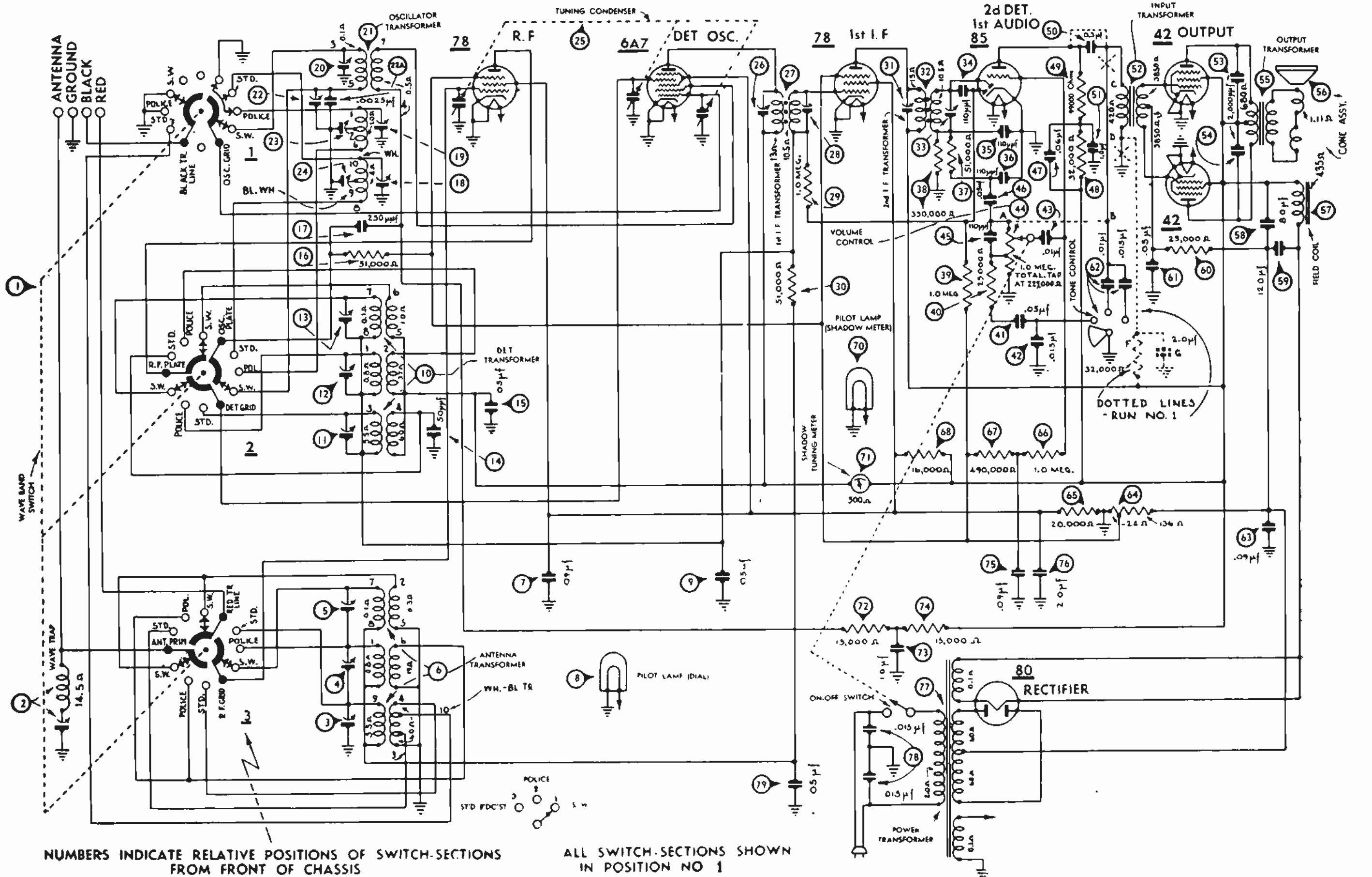


Fig. 3. Tubes as Viewed from Bottom

The voltages at the points indicated by the arrows above were obtained with a Philco type 025 Circuit Tester which contains a high resistance (1000 ohms per volt) voltmeter Volume control at minimum, waveband switch at standard broadcast. K31 speaker



NUMBERS INDICATE RELATIVE POSITIONS OF SWITCH-SECTIONS FROM FRONT OF CHASSIS

ALL SWITCH-SECTIONS SHOWN IN POSITION NO 1

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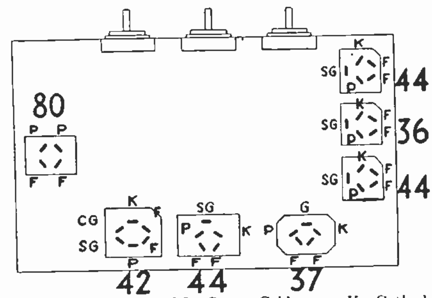
NATIONAL RADIO INSTITUTE, WASHINGTON, D. C.

PHILCO MODEL 71 SERIES

The Philco Radio of the 71 series is a seven tube superheterodyne, employing the high efficiency 6.3 volt filament tubes, automatic volume control and pentode output. The chassis is made in two different types, one known as the 121 code, employing a single dynamic speaker, and the other known as the 221 code, employing twin dynamic speakers. These code numbers appear on the radio chassis as a part of the model number. Chassis of one code are not interchangeable with those of another. The intermediate frequency used in adjusting the superheterodyne circuit of the 71 series is 260 kilocycles. The power consumption of the various models is as follows:

Chassis	Volts	Cycles	Watts
71 -121	115	50-60	63
71 -221	115	50-60	80
71A-121	115	25-40	65
71A-221	115	25-40	85
71E-121	230	50-60	63
71E-221	230	50-60	80



F = Filament
P = Plate
SG = Screen Grid
CG = Control Grid
K = Cathode

Fig. 1—Tube Sockets

Table 1—Tube Socket Data*—A.C. Line Voltage 115 Volts

Tube Type	Tube Circuit	Filament Volts—F to F	Plate Volts—P to K	Screen Grid Volts—SG to K	Control Grid Volts—CG to K	Cathode Volts—K to F
44	R. F.	6.3	245	90	4.	20
36	Det. Osc.	6.3	235	90	2.3	20
44	I. F.	6.3	255	90	.2	20
37	Det. Rect.	6.3	0	.	. .	15
44	Audio	6.3	50	50	.3	20
42	Output	6.3	250	260	.2	15
80	Rectifier	5.0	365/plate	. .	. .	. .

*All of the above readings were taken from the under side of the chassis, using test prods and leads with a suitable A.C. voltmeter for filament voltages and a high resistance multi-range D.C. voltmeter for all other readings. Volume control at maximum and station selector turned to low frequency end.

Table 2—Power Transformer Data

Terminals	A.C. Volts	Circuit	Color
1-2	105 to 125	Primary	White
3-5	6.3	Filament	Black
6-7	5.0	Filament of 80	Light Blue
8-10	685	Plates of 80	Yellow
4	. . . . .	Center Tap of 3-5	Black Yellow Tracer
9	. . .	Center Tap of 8-10	Yellow Green Tracer

Table 3—Resistor Data

No. on Figs. 4 & 5	Power (Watts)	Resistance (Ohms)	Color Body	Color Tip	Color Dot
82		185 & 245	Round	Tubular	
24	.5	1,000	Brown	Black	Red
57 58	.5	5,000	Green	Black	Red
48	(Twin	Speaker) 5,620	Round	Tubular	
1 64	.5	10,000	Brown	Black	Orange
59	3.	13,000	Brown	Orange	Orange
18	.5	15,000	Brown	Green	Orange
35	.5	25,000	Red	Green	Orange
35	5	(Twin Speaker) 51,000	Green	Brown	Orange
34	.5	70,000	Violet	Black	Orange
27	.5	99,000	White	White	Orange
37	.5	490,000	Yellow	White	Yellow
17 23 33	.5	1,000,000	Brown	Black	Green

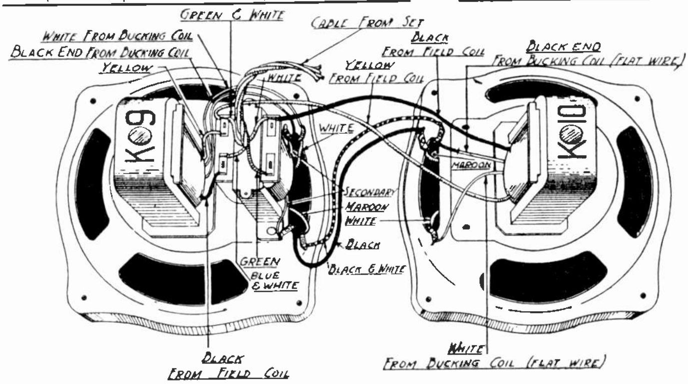


Fig. 2—Twin Speaker Connections—221 Code

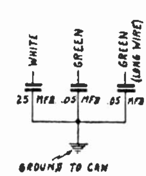
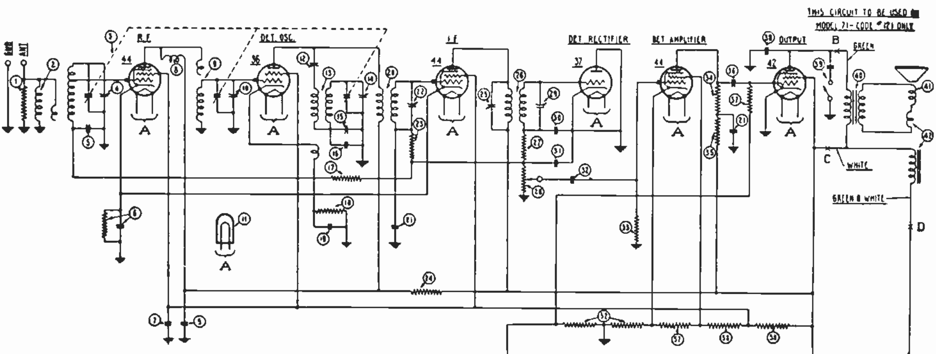
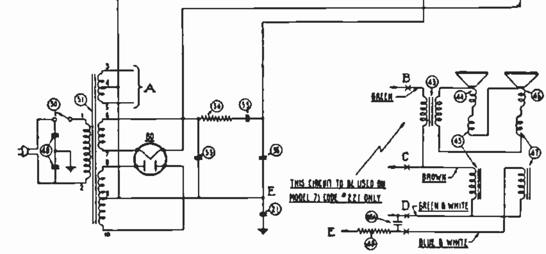


Fig. 3—Internal Connections Filter Condenser

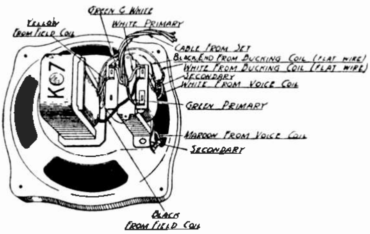


Fig. 6—Speaker Connections—121 Code **Fig. 4—Schematic Wiring Diagram**

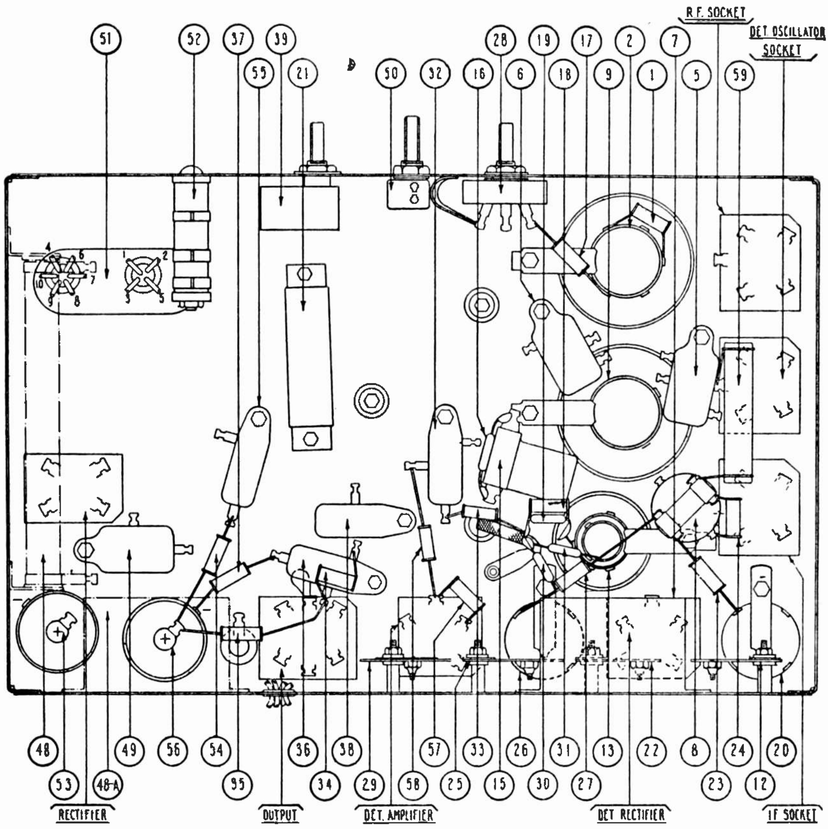


Fig. 5—Parts Diagram

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RCA Victor Radiolette R-5; Graybar Model 4 Graybarette; Westinghouse Model WR-14 and General Electric Model "G. E. T-12"

The RCA Victor Radiolette circuit is used also in the Graybar Model 4 Graybarette, the Westinghouse Model WR-14, and in the General Electric Model G.E. T-12, so that the information in this Service Sheet applies to all four receivers.

The receiver uses four Radiotrons, two UY-224, one UX-280, and one RCA-247 Power Output Pentode. Referring to Figure 1 and tracing a signal through the various stages we find the following action taking place.

The antenna and ground are connected to each side of a 20,000 ohm potentiometer. The moving contact of the potentiometer is connected to the primary of the first R.F. transformer through a .00013 MFD. condenser, the other side of the transformer being connected to ground. The action of the potentiometer, reducing the voltage applied to the grid of the first R.F. tube, constitutes that of a volume control. The secondary of the R.F. transformer is connected to the grid circuit of the R.F. Radiotron UY-224, which is tuned by one unit of the gang condenser. The plate circuit of this tube works into the primary coil of the 2nd R.F. transformer.

The detector is of the regenerative, grid bias type and its output is coupled by means of resistance coupling to the output Radiotron RCA-247. The regenerative feature of the detector is unusual in that it uses two regeneration coils. One of these resonates at a low frequency and improves the sensitivity at that end, while the other has but few turns and brings up the sensitivity at the high frequency end.

The output stage uses the RCA-247 Output Pentode which gives a high undistorted output—2.5 watts—together with a high gain in the stage.

The grid bias for this tube is obtained by using a portion of the drop across the reproducer field. Due to the fact that the plate current of the RCA-247 represents the greatest portion of the total plate current, using the drop across the field acts as a semi-self biasing arrangement.

Plate and grid supply to all tubes is supplied through the use of Radiotron UX-280. The filter is of the "brute force" type. The reproducer unit field coil functions as the reactor. One electrolytic 10 MFD. capacitor and one paper 2 MFD. capacitor act as filter capacitors.

Line-up Capacitor Adjustments

Two adjustable capacitors are provided for aligning the two tune circuits at the high frequency end of the scale. The following procedure may be used for making any readjustments that may be necessary.

A. Procure an oscillator giving a modulated signal at exactly 1400 K.C. Also procure a special socket wrench such as RCA Victor Stock No. 3007.

B. An output indicator is necessary. This may be a current squared thermogalvanometer connected to the secondary of the output transformer in place of the cone coil or other types of output indicators.

C. Turn the station selector until the knob reads exactly 0. Then remove the chassis from the cabinet, being careful not to disturb the setting of the dial. The gang condenser rotor plates should be fully meshed with the stator plates. If not, then the dial drum must be adjusted until such a condition exists. Replace the chassis in the cabinet.

D. Place the oscillator in operation at exactly 1400 K.C. and couple its output to the antenna lead. Set the dial scale at 85 and place the Radiolette in operation. Place a soft pad on the bench and turn the instrument on its side. Now with the special wrench, adjust each line-up capacitor until maximum output is obtained in the output meter. Be careful to adjust the volume control or oscillator output so that an excessive reading is not obtained. Go over each adjustment a second time to compensate for any interlocking of adjustments.

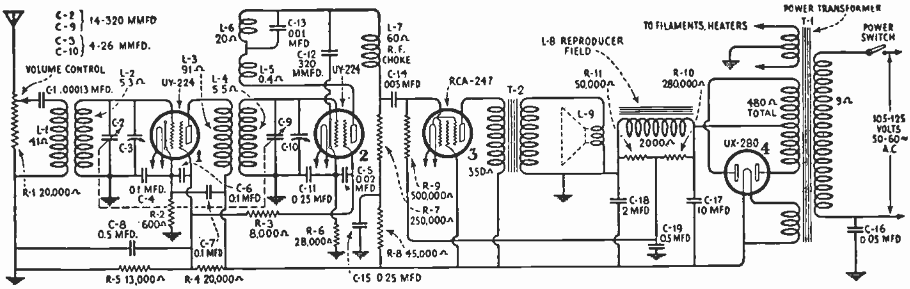


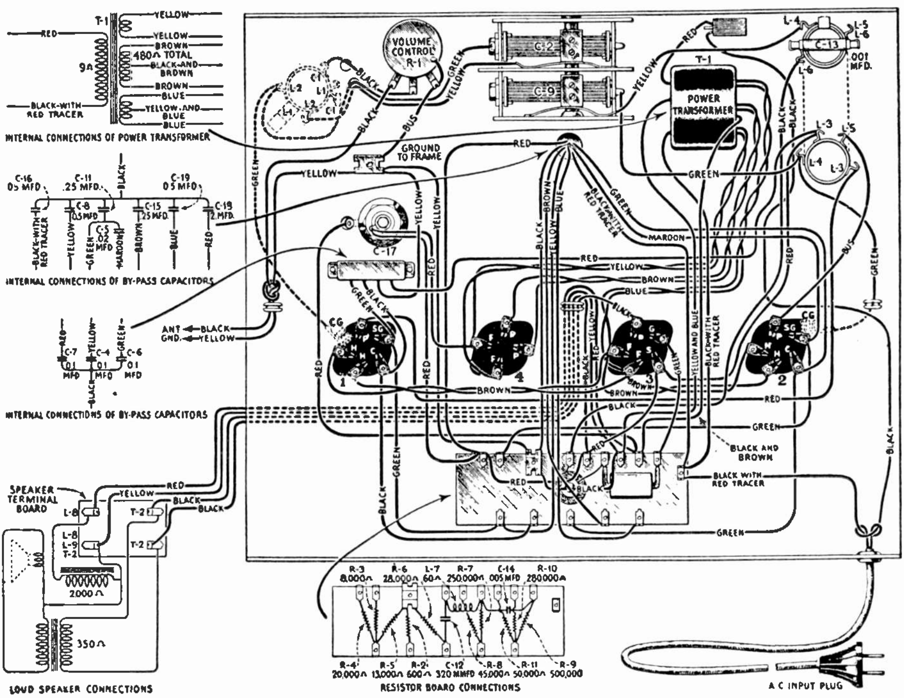
Figure 1—Schematic Circuit Diagram of Model R-5

SOCKET VOLTAGE READINGS

110-VOLT LINE

These are readings obtained with the usual Set Analyzers and are not true readings of the voltages at which the Radiotrons operate.

Radiotron No.	Heater to Cathode Volts	Cathode or Filament to Control Grid Volts	Cathode or Filament to Screen Grid Volts	Cathode or Filament to Plate Volts	Plate Current M. A.	Heater Volts
1	3.0	3.0	85	225	4.0	2.2
2	7.0	7.0	65	100	0.25	2.2
3	——	2.0	225	215	30.0	2.2



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R. C. A.-VICTOR MODEL T5-2

Alignment Procedure

I. F. Tuning Adjustments. There are two I. F. transformers associated in the intermediate amplifier system. Both are tuned by accessible trimmers. To obtain correct alignment:

(a) Short-circuit antenna and ground terminals. Tune receiver so no signal is received. Set volume control to maximum. Ground receiver.

(b) Connect output of test oscillator between first detector control grid and chassis ground. Attach an indicating meter to speaker circuit.

(c) Place external oscillator at 460 kc. Adjust output so a slight registration occurs on output indicator. Output should be set at as low a value as will give a convenient indication during adjustment; this is important for the AVC action is voided by such a method. Adjust trimmers, C-49, C-48, C-18 and C-17 in order, for maximum receiver output.

R. F. and Oscillator Adjustments. Three trimmers are provided, two for adjustment at 1720 kc. and one for oscillator line-up at 600 kc. No adjustments are required on medium wave band. Locations of trimmers are shown on Fig. 1. Adjust them as follows:

(a) Connect output of the modulated full range oscillator to antenna and ground terminals of receiver. Check position of dial pointer. It should set exactly on radial line, adjacent to dial reading of 540 when tuning capacitor plates are at full mesh. After correcting dial pointer, place receiver in operation. Set selector at 1720 kc., advance volume control to maximum and turn range switch to broadcast position.

(b) Adjust frequency of the external oscillator to 1720 kc. and regulate output until perceptible indication appears on output indicator. Hold indication at minimum. Then tune trimmers C44 and C45 to point giving peak receiver output.

(c) Retune test oscillator, setting its frequency to 600 kc. Turn receiver selector control to point where incoming oscillator signal is received best. This point will not always be exactly 600 on dial. Then adjust low-frequency trimmer, C40, simultaneously rocking tuning capacitor slowly through the signal until maximum receiver output results from these combined operations. Make this adjustment irrespective of dial calibration. Repeat the 1720 kc. adjustment of oscillator trimmer C44 to correct for change caused by tuning of C40.

Wave Trap Adjustment. Operate receiver, using normal antenna. Tune to point where intermediate-wave interference is most intense. Then adjust wave-trap trimmer to point which causes maximum suppression of interference. If no interference is present the adjustment need not be made.

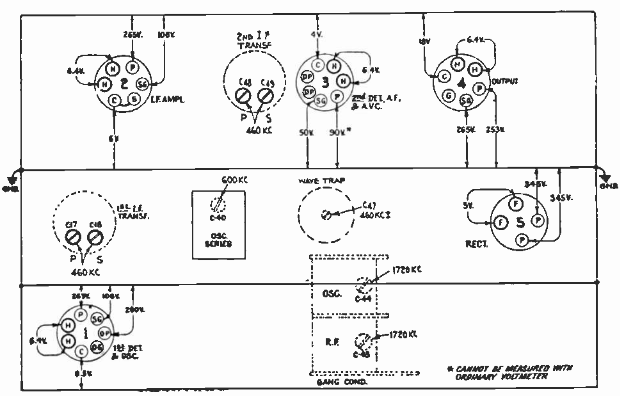

Fig. 1

RCA-T5

R.C.A.-VICTOR MODEL T5-2

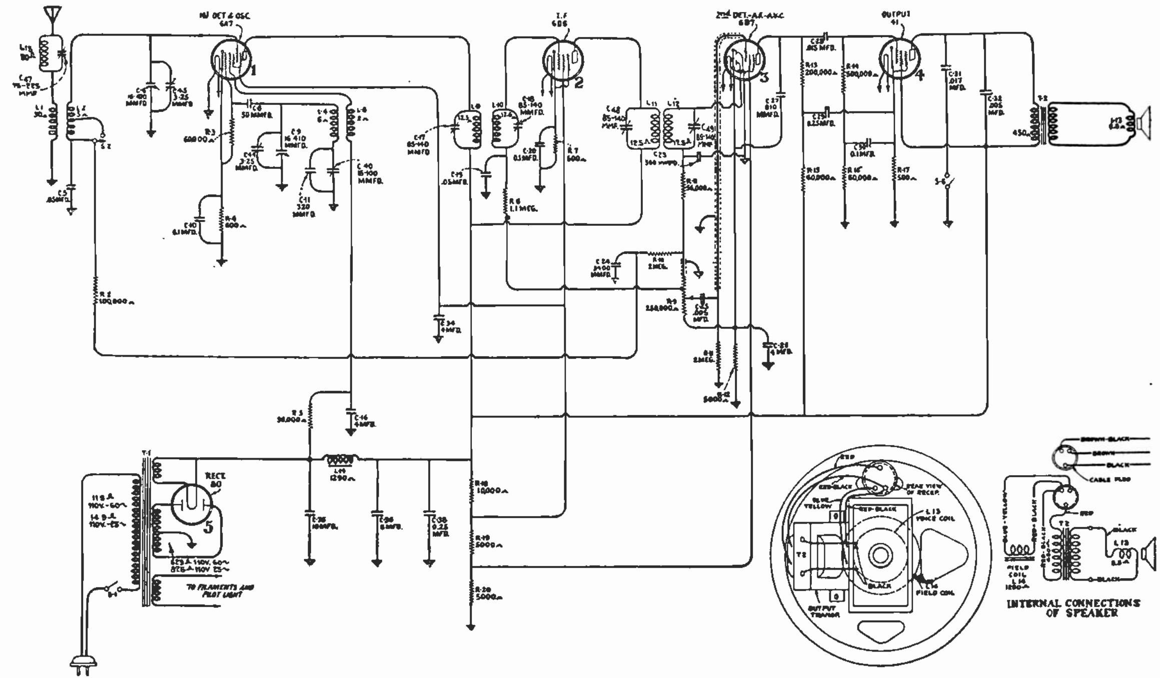

Figure 2. Schematic Circuit Diagram.

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R. C. A.-VICTOR MODEL T6-9

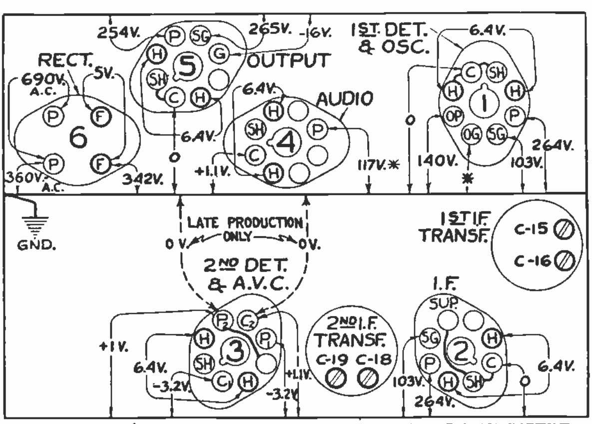
Alignment Procedure

I. F. Trimmer Adjustment. The location of the four I. F. trimmers is shown in Fig. 1. Each trimmer must be aligned to a frequency of 460 kc. Attach the output indicator across the voice coil or across the output transformer primary. Connect output of test oscillator between control grid of the RCA-6A8 and chassis-ground. Tune oscillator to 460 kc. Advance receiver volume control to its full-on position and adjust receiver tuning control to a point within its range where no interference is encountered either from local broadcast stations or from the heterodyne oscillator. Increase output of test oscillator until a slight indication is present on output indicator. Then adjust two trimmers of second I. F. transformer to produce maximum (peak) indicated receiver output. Then adjust two trimmers of first I. F. transformer for maximum (peak) receiver output as shown by indicating device. During these adjustments, regulate test oscillator output so that the indication is always as low as possible. By doing so, broadness of tuning due to AVC will be avoided. It is advisable to repeat adjustment of all I. F. trimmers to assure that interaction between them has not disturbed original adjustment.

R. F. Trimmer Adjustment. Calibrate tuning dial by setting pointer to horizontal line at low frequency end of broadcast band scale while variable condenser is at maximum capacity.

The output indicator should be left connected to output system. Attach output of test oscillator between antenna and ground terminals of receiver input. Adjust oscillator to 1720 kc. and set receiver tuning control to a dial reading of 1720 kc. Leave volume control of receiver at its maximum position. Make sure that range selector is at its broadcast position. Regulate output of test oscillator until a slight indication is perceptible at receiver output. Adjust two trimmers of oscillator and antenna transformer coils (mounted on the variable condenser) so that each produces maximum (peak) receiver output. After this maximum has been accurately obtained, shift test oscillator to 600 kc. Tune receiver to pick up this signal, disregarding dial reading at which it is best received. Then adjust receiver oscillator series trimmer, simultaneously rocking tuning control backward and forward through the signal until maximum receiver output results from these combined operations. The adjustment of 1720 kc. should then be repeated to correct for any change caused by oscillator series trimmer adjustment.

Wave-Trap Adjustment. With receiver in operation using normal antenna, tune station selector to point at which intermediate frequency interference is most intense. Then adjust wave-trap trimmer to point which causes maximum suppression of interference. If no interference is present, omit the adjustment.



(*) CANNOT BE MEASURED WITH ORDINARY VOLTMETER

R.C.A.-VICTOR MODEL T6-9

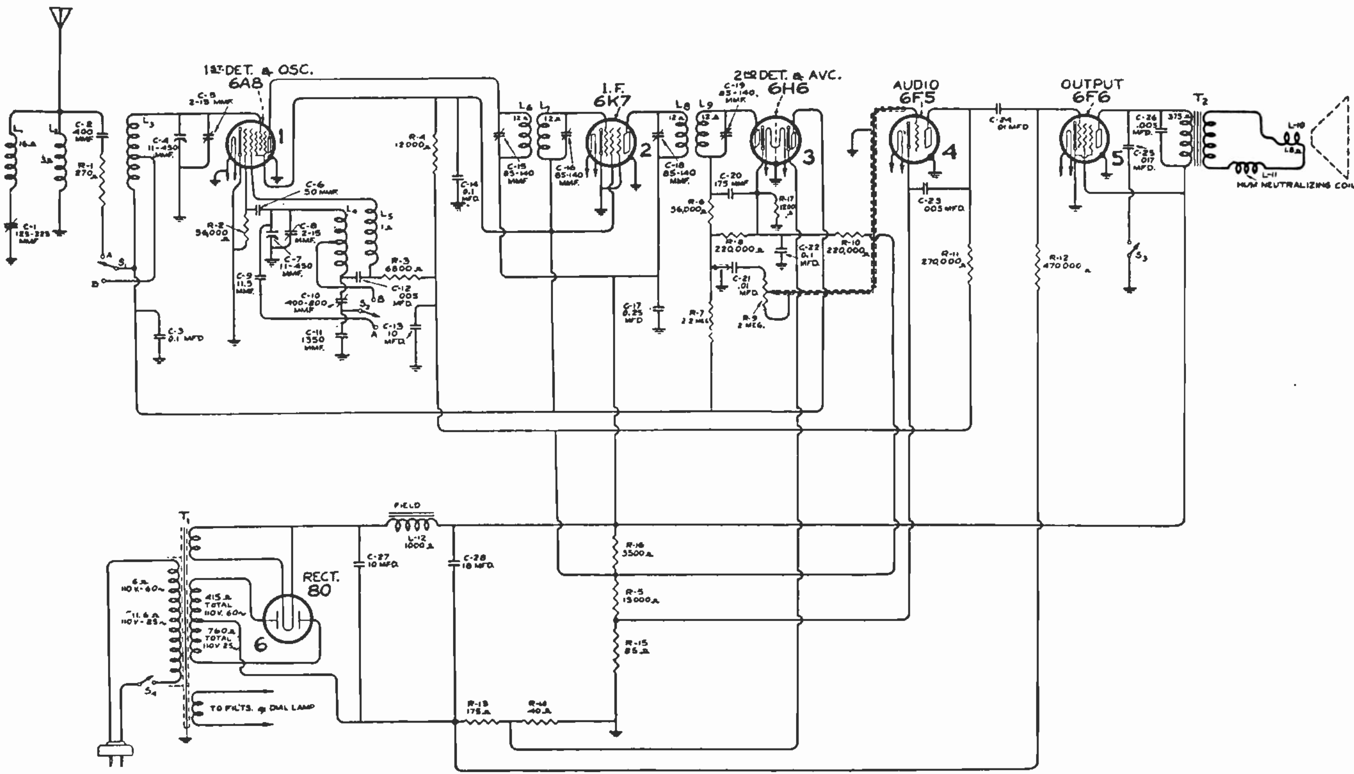


Figure 2. Schematic Circuit Diagram

On some instruments, R-10, R-17, and C-22, are omitted and the RCA-6H6 first Cathode is directly grounded.

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CROSLEY MODEL 527 (Battery Fiver)

Alignment Procedure

All the circuits in this receiver are very accurately adjusted at the factory and normally should need no further adjustment. However, if it is definitely known that an adjustment is necessary the circuits can best be properly aligned with the use of a modulated signal generator and an output meter.

Connecting Output Meter

Connect one terminal of the output meter to the plate and the other terminal to the screen of the 1J5G Output tube. Be sure the meter is protected from D.C. by connecting a condenser (.1 mfd. or larger—not electrolytic) in series with one of the leads.

1. Tuning I-F Amplifier to 455 Kilocycles.

(a) Connect the output of the signal generator through a .02 mfd., or larger condenser to the top cap of the 1C7G Osc-Mod tube, leaving the tube's grid clip in place. Connect the ground lead from the signal generator to the "GND" terminal of the receiver.

(b) Set the station selector so that the tuning condenser plates are completely out of mesh. Turn the volume control knob to the right (ON).

(c) Set the signal generator to 455 kilocycles.

(d) Adjust both trimmers located on top of the 2nd I-F transformer for maximum output. (See Top View.)

(e) Adjust both trimmers located on top of the 1st I-F transformer for maximum output.

(f) Check operations (d) and (e) for more accurate adjustments.

ALWAYS USE THE LOWEST SIGNAL GENERATOR OUTPUT THAT WILL GIVE A REASONABLE OUTPUT METER READING.

2. Aligning R-F Amplifier.

(a) Connect the output lead from the signal generator through a .00025 mfd. condenser to the "ANT" terminal of the receiver.

(b) Set the signal generator to 1400 kilocycles.

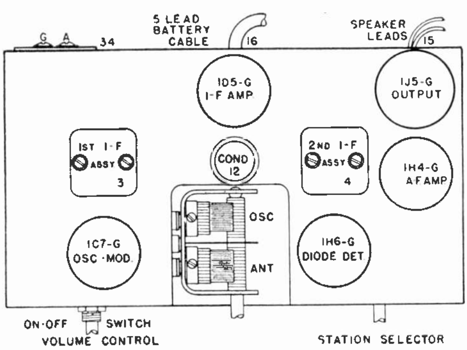
(c) Adjust the station selector to 140 on the dial.

(d) Adjust the trimmer located on the "OSC" section of the condenser gang for maximum output.

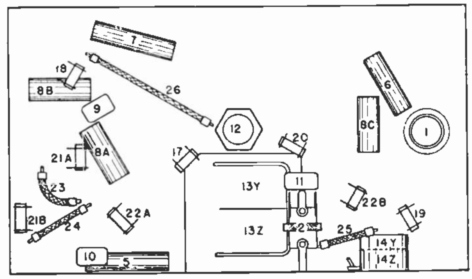
(e) Adjust the trimmer located on the "ANT" section of the condenser gang for maximum output.

(f) Tune the station selector to the generator signal for maximum output.

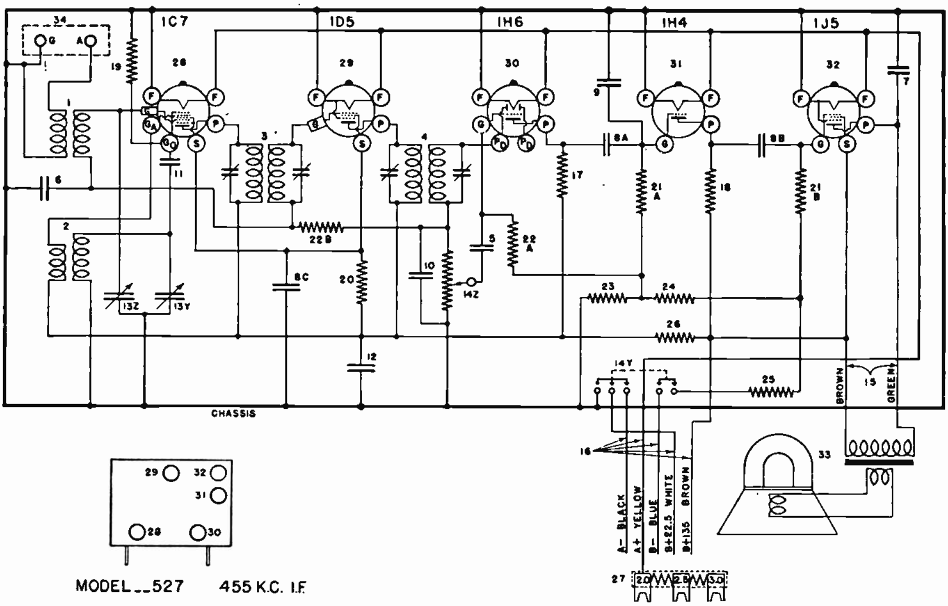
(g) Repeat operation (e) for more accurate adjustment.



Top View 527



Bottom View 527



WIRING DIAGRAM—CROSLEY MODEL 527

PARTS LIST

Item	Description	Item	Description
5	Condenser .01 Mf. 200 V.	18	Resistor 60,000 Ohm 1/4 W.
6	Condenser .02 Mf. 160 V.	19	Resistor 100,000 Ohm 1/4 W.
7	Condenser .004 Mf. 200 V.	20	Resistor 50,000 Ohm 1/4 W.
8ABC	Condenser .02 Mf. 200 V.	21AB	Resistor 500,000 Ohm 1/4 W.
9	Condenser 500 Mmf. (.0005)	22AB	Resistor 3 Megohm 1/4 W.
10	Condenser 175 Mmf. (.000175)	23	Resistor 140 Ohm 1/2 W. Flex.
11	Condenser 100 Mmf. (.0001)	24	Resistor 500 Ohm 1/2 W. Flex.
12	Condenser 16 Mf. 250 V.	25	Resistor 750 Ohm 1/2 W. Flex.
14Z	Vol. Cont., 1 Meg.	26	Resistor 2600 Ohm 1 1/2 W. Flex.
14Y	Battery Switch	27	Fil. Reg. Resistor 1.83 Ohm Tap, 1.1 Ohm
17	Resistor 150,000 Ohm 1/4 W.		

TUBE SOCKET VOLTAGE READINGS

Tube	Function	H	P	S	G	Ga	Go
1C7-G	Oscillator-Modulator	2.0	112	37	0	112	—4**
1D5-G	I-F Amplifier	2.0	112	37	0	—	—
1H6-G	Detector & 1st A-F Amp.	2.0	56	—	0	—	—
1H4-G	2nd A-F Amplifier	2.0	43	—	0	—	—
1J5-G	Output	2.0	110	112	—4*	—	—

Power Output approximately .5 Watt.

"A" Battery Drain approximately .42 Ampere at 2 Volts.

"B" Battery Drain approximately 16 Milliamperes at 135 Volts.

*Measured at Grid Terminal through 500,000 Ohm Grid Resistor.

**Measured at Go Terminal with Dial Set at approximately 1000 kc. .

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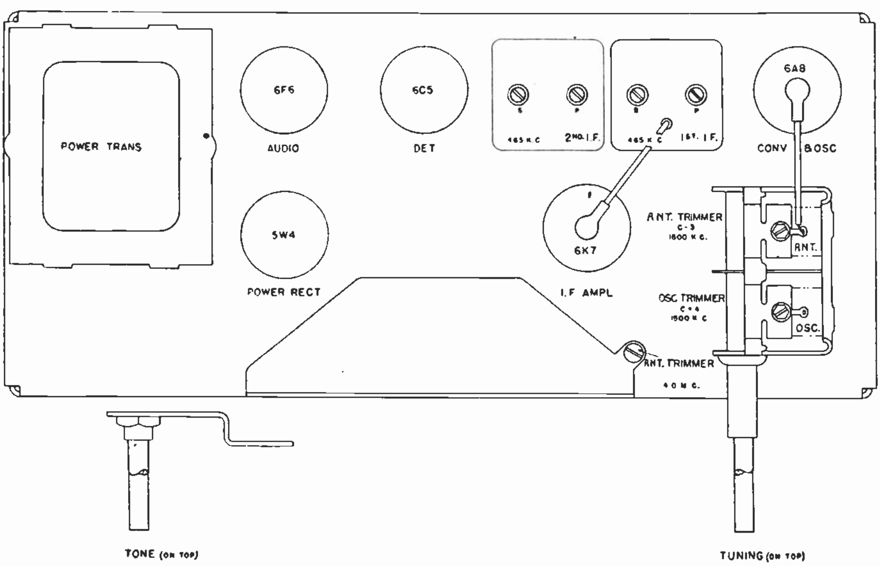
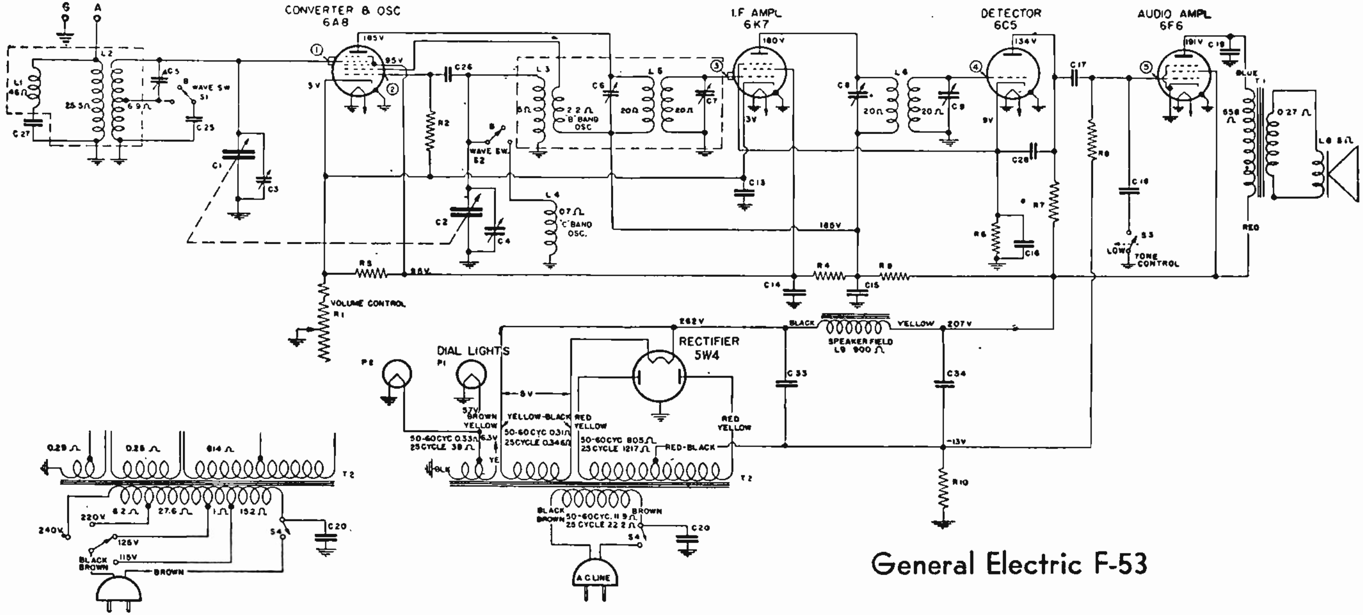
GENERAL ELECTRIC MODEL F-53

VALUES OF PARTS

SYMBOL	DESCRIPTION		
C5	TRIMMER	CAP.	5-40 MMF
C6	TRIMMER	CAP.	35-80 MMF
C7	TRIMMER	CAP.	35-80 MMF
C8	TRIMMER	CAP.	35-80 MMF
C9	TRIMMER	CAP.	35-80 MMF
C13	PAPER	CAP.	.25 MF
C14	PAPER	CAP.	.1 MF
C15	PAPER	CAP.	.1 MF
C16	PAPER	CAP.	.1 MF
C17	PAPER	CAP.	.03 MF
C18	PAPER	CAP.	.002 MF
C19	PAPER	CAP.	.006 MF
C20	PAPER	CAP.	.01 MF
C25	MICA	CAP.	1100 MMF
C26	MICA	CAP.	100 MMF
C27	MICA	CAP.	50 MMF
C28	MICA	CAP.	1000 MMF
C33	DRY ELECTROLYTIC CAP.		8 MF
C34	DRY ELECTROLYTIC CAP.		8 MF

SYMBOL	DESCRIPTION	
R1	VOLUME CONTROL	4500 OHMS
R2	CARBON RESISTOR	56000 OHMS
R3	CARBON RESISTOR	18000 OHMS
R4	CARBON RESISTOR	10000 OHMS
R6	CARBON RESISTOR	100000 OHMS
R7	CARBON RESISTOR	270000 OHMS
R8	CARBON RESISTOR	470000 OHMS
R9	CARBON RESISTOR	1000 OHMS
R10	CARBON RESISTOR	240 OHMS
L1	WAVE TRAP COIL	
L2	ANTENNA COIL	
L3	OSC. COIL "B"	
L4	OSC. COIL "C"	
L5	1st I.F. TRANSFORMER COIL	
L6	2nd I.F. TRANSFORMER COIL	
L8	SPEAKER VOICE COIL	
L9	SPEAKER FIELD COIL	





General Electric F-53

UNIVERSAL POWER TRANSFORMER 105-250 V.

DESCRIPTION OF ELECTRICAL CIRCUIT

The signal from the antenna is applied to the control grid of the 6A8 tube through the R. F. transformer, the secondary of which is tuned to the incoming signal by the rear section of the main tuning condenser. In the 6A8 tube the incoming signal is combined with the local oscillator signal which is 465 kc. higher in frequency. The local signal is generated by the oscillator section of this tube, and the proper frequency difference is maintained throughout the tuning range by the front section of the tuning condenser in conjunction with the oscillator coils. The special-cut rotor of the front condenser section permits dispensing with the usual padding capacitor.

The combination of the two signals produces the intermediate frequency of 465 kc. This particular frequency is chosen to reduce image response and improve short-wave performance. The intermediate frequency amplifier consists of a 6K7 tube and two transformers, both of which have tuned primaries and secondaries. Volume is controlled by the 4500-ohm variable resistor, R-1, which varies the bias applied to the control grids of the 6A8 and 6K7 tubes.

The output of the I. F. amplifier is applied to the grid of the 6C5 detector which is properly biased for this service by the .1 megohm cathode resistor, R-6.

The output of the 6C5 detector is resistance coupled to the grid of the 6F6 power amplifier pentode. The plate circuit of the 6F6 is suitably matched to the loud-speaker by means of a step-down output transformer.

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BELMONT MODEL 589

SERIES A, ISSUE B

Aligning Instructions

Caution: No aligning adjustments should be attempted without first thoroughly checking over all other possible causes of trouble, such as defective tubes, poor installations, open or grounded antenna systems, defective condensers and resistors.

In order to properly align this chassis, an oscillator (generator) is necessary.

All adjustments should be made with a non-metallic screw-driver.

Resonance Indicator:

Use as a resonance indicator an output meter connected across the primary of the speaker input transformer or by means of an adapter between the plate and screen terminals of the type 6K6G output tube. Maximum deflection of the meter indicates resonance. Use only enough signal to get a readily readable output. A low range output meter or the low scale of a multirange meter should be used.

Dummy Antennas:

The following dummy antennas are used in aligning and are referred to in the following alignment instructions as "Dummy 1," "Dummy 2" and "Dummy 3."

Dummy 1: (I.F.)—Consists of a .1 mfd. condenser connected in series with the external oscillator.

Dummy 2: (Broadcast)—Consists of a 200 mmfd. condenser and a 20 ohm resistor connected in series with each other and in series with the external oscillator.

Dummy 3: (Short Wave)—Consists of a .1 mfd. condenser and a 400 ohm resistor connected in series with each other and in series with the external oscillator.

Aligning I. F. Transformers: (465 K.C.)

The I. F. transformers have two adjustments, both of which are accessible from the top of chassis.

1. With volume control full on (the extreme right of its rotation), the band changing switch in the broadcast position, (extreme left of its rotation), and with the variable condenser in its minimum capacity position, plates entirely out of mesh, make the following adjustments:

   (a) Connect external oscillator set at 465 kilocycles, in series with "Dummy 1," to the control grid cap of the type 6K7G tube, and adjust the output I.F. transformer to resonance.

   (b) With "Dummy 1" still connected, move oscillator output clip from grid of 6K7G to grid cap of 6A8G and adjust input I.F. transformer to resonance.

Short Wave Band Alignment:

5.5 to 18.1 Megacycles

1. With band changing switch in the short wave position, extreme right of its rotation, and with external oscillator set at 17 megacycles and connected in series with "Dummy 3" to the antenna and ground leads, make the following adjustments:

   (a) Move dial pointer to 17 megacycles and adjust short wave oscillator trimmer to resonance.

   This adjustment is the trimmer mounted on the top of rear section of the variable gang condenser.

   (b) Adjust short wave antenna trimmer (Adjustment No. 1), to resonance (See Fig. 1, bottom view).

(Page 20, please)

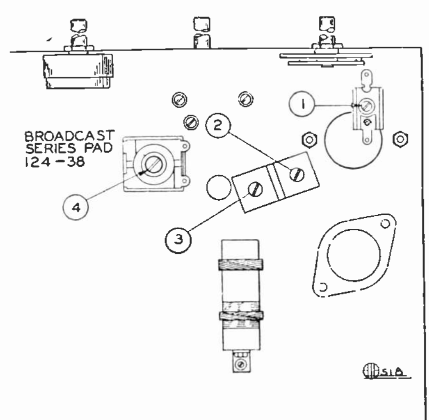

Figure 1. Bottom View Showing Trimmers

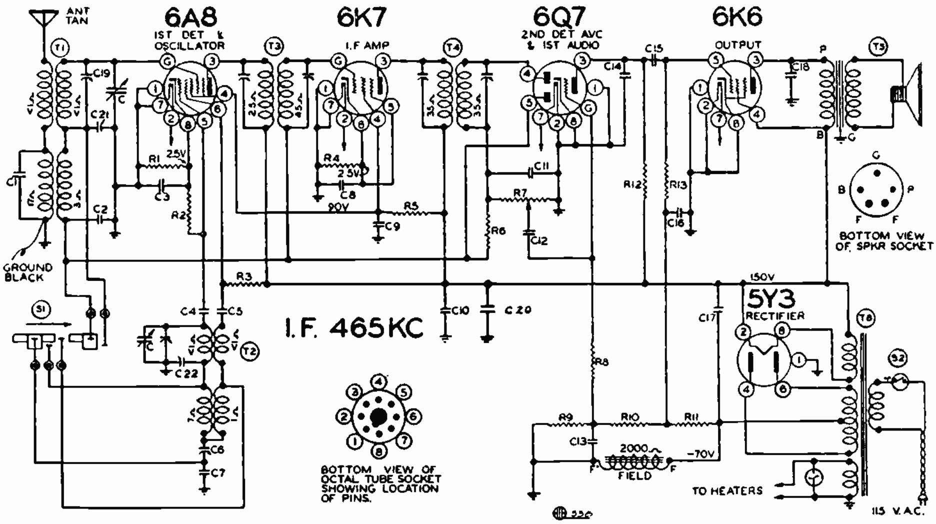

FIGURE 2—SCHEMATIC DIAGRAM

Broadcast Band Alignment:

535 to 1720 Kilocycles

1. With band changing switch in the broadcast position, extreme left of its rotation, and with gang condenser in its minimum capacity position, plates entirely out of mesh, and with external oscillator connected in series with "Dummy 2" to antenna and ground leads make following adjustments:

   (a) Set external oscillator to 1720 K.C. and adjust broadcast oscillator trimmer to resonance. (Adjustment No. 3, see bottom view of chassis, Fig. 1).

   (b) Reset external oscillator to 1400 K.C., rotate variable gang condenser and pick up signal. Adjust broadcast antenna trimmer (adjustment No. 2) to resonance.

   (c) Reset external oscillator to 600 K.C. and adjust broadcast series pad (adjustment No. 4) to resonance by rotating condenser to approximately 600 K.C., rocking it slowly to and fro until by adjusting series pad maximum output is attained. This adjustment is located on the bottom of the chassis directly under the variable gang condenser. (See bottom view of chassis, Fig. 1).

   (d) Repeat adjustments "a" and "b" until sensitivity is at its maximum.

   (e) Check for tracking and sensitivity at 1400, 1000 and 600 kilocycles. **Under no circumstances bend plates of variable condenser sections to correct tracking.**

LIST OF REPAIR PARTS

Resistors

R1 300 ohm—1/3 w.
R2 50M ohm—1/3 w.
R3 10M ohm—1/3 w.
R4 450 ohm—1/3 w.
R5 15M ohm—1/3 w.
R6 3 megohm—1/3 w.
R7 1 megohm volume control
R8 3 megohm—1/3 w.
R9 20M ohm—1/3 w.
R10 150M ohm—1/3 w.
R11 800M ohm—1/3 w.
R12 200M ohm—1/3 w.
R13 500M ohm—1/3 w.

Condensers

C 2 gang variable condenser
C1 .0001 mica
C2 .05 x 200 v.
C3 .1 x 200 v.
C4 .00005 mica
C5 .002 x 600 v.
C6 600 mmf. Series Pad Adj.
C7 .003 Mica
C8 .1 x 200 v.
C9 .1 x 400 v.—50
C10 5.0 mfd.—250 w.v. 'Lytic
C11 .0001 Mica
C12 .01 x 400 v.
C13 .1 x 200 v.
C14 .0005 Mica
C15 .02 x 400 v.
C16 .1 x 200 v.
C17 5.0 mfd.—250 w.v. 'Lytic
C18 .003 x 600 v.
C19 2—25 mmf. Adj. Cond.
C20 .05 x 400 v.
C21 Adj. Trimmer 1—10 mmf
C22 Adj. Trimmer 2—20 mmf.
C21—C22 in same unit.

RADIO-TRICIAN

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Service Sheet

Compiled Solely for Students and Graduates

NATIONAL RADIO INSTITUTE, WASHINGTON, D.C.

PHILCO MODEL 37-600

Specifications

TYPE CIRCUIT: Superheterodyne with pentode output.

POWER SUPPLY: 115 V., 60 cycle A.C.

TUBES USED: 1 type 6A8G, Det. Osc., 1 type 6J7G, 2nd Det., 1 type 6K6G, Output, 1 type 5Y4G Rectifier.

FREQUENCY RANGE: 530-1800 K.C.

INTERMEDIATE FREQUENCY: 470 K.C.

CURRENT CONSUMPTION: 45 watts.

SPEAKER: B-6.

POWER OUTPUT: ½ watt.

Adjusting Compensating Condensers

To accurately adjust the compensating condensers in the **Model 37-600** receiver, it is necessary to use a signal generator of high stability on all frequencies, such as the **PHILCO Model 088 Signal Generator.** This instrument has a continuous frequency range from 110 to 20,000 K.C., and is designed to meet every requirement of the serviceman.

An output meter is also needed,—**PHILCO MODEL 025 Circuit Tester** includes a very sensitive output meter.

Convenient tools to use in adjusting the compensators are the **Philco No. 3164 Fibre Wrench** and **No. 27-7059 Fibre Handled Screw-driver.**

The locations of the various compensating condensers are shown in Fig. 1. Connect the output meter to the plate and cathode contacts of the 6K6G power tube, and adjust it to use the 0-30 volt range.

When adjusting each circuit, care should be taken to have the signal generator attenuator set for approximately ¼ scale reading on output meter.

Intermediate Frequency Circuit

1. Connect the 088 signal generator output lead through a .1 mfd. condenser to the grid of the 6A8G tube and the ground lead to the chassis.

2. Turn the sensitivity compensator (23) to maximum capacity position (clockwise), and then release it; 1½ turns (counter-clockwise).

3. Turn gang condenser to approximately 600 K.C. Set the signal generator at 470 K.C.

4. Adjust the compensator (18) and (20) for maximum reading on the output meter. Then turn the sensitivity compensator (23) clockwise until a hiss, (oscillation) is heard. Now turn the compensator (23) counter-clockwise until hiss ceases, then continue for ¼ turn more.

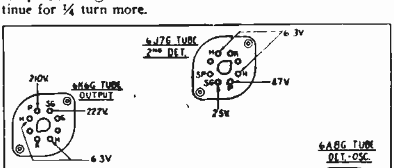


Fig. 2. Tube Sockets as Viewed from Underside of Chassis. (Measured from Socket Terminal to Ground Volume Control in Maximum Position)

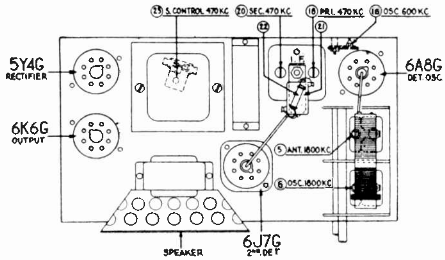


Fig. 1. Location of Compensators

Radio Frequency Circuit

1. Remove the signal generator output lead from the 6A8G tube, and connect it to the aerial lead of the receiver through a 100 mmfd. condenser.

2. Turn the gang condenser to minimum capacity position, (counter-clockwise) and place a .006" (six-thousands inch) gauge between the stator and rotor plates. Now turn the gang clockwise until stator and rotor plates touch gauge.

3. Remove gauge from gang condenser. Now set signal generator at 900 K.C., (using second harmonic 1800 K.C.), adjust compensators (6) and (5) for maximum reading on output meter.

4. Turn the signal generator and receiver gang condenser to 600 K.C., and adjust compensator (16). In doing so, the gang condenser must be rolled slightly above and below the 600 K.C. signal until the maximum reading is indicated on the output.

5. Turn the gang condenser to 1800 K.C. and signal generator to 900 K.C., (using second harmonic of signal generator 1800 K.C.), readjust compensator (6) for maximum reading on output meter. Set gang as per paragraph 2, for this adjustment.

6. Turn the gang condenser and signal generator to 1400 K.C., readjust compensator (5) for maximum reading on output meter. After the above adjustments are completed and receiver is placed in the cabinet, the dial pointer is properly placed by turning the signal generator to 1000 K.C. Then tune receiver for maximum signal. The dial pointer is then placed on gang shaft, so that it indicates 1000 K.C. on dial.

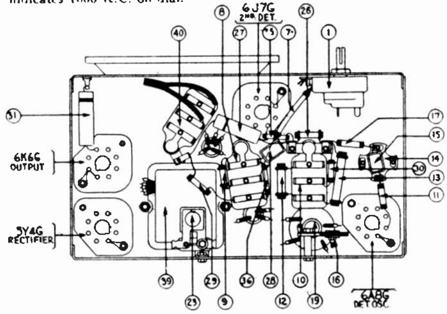
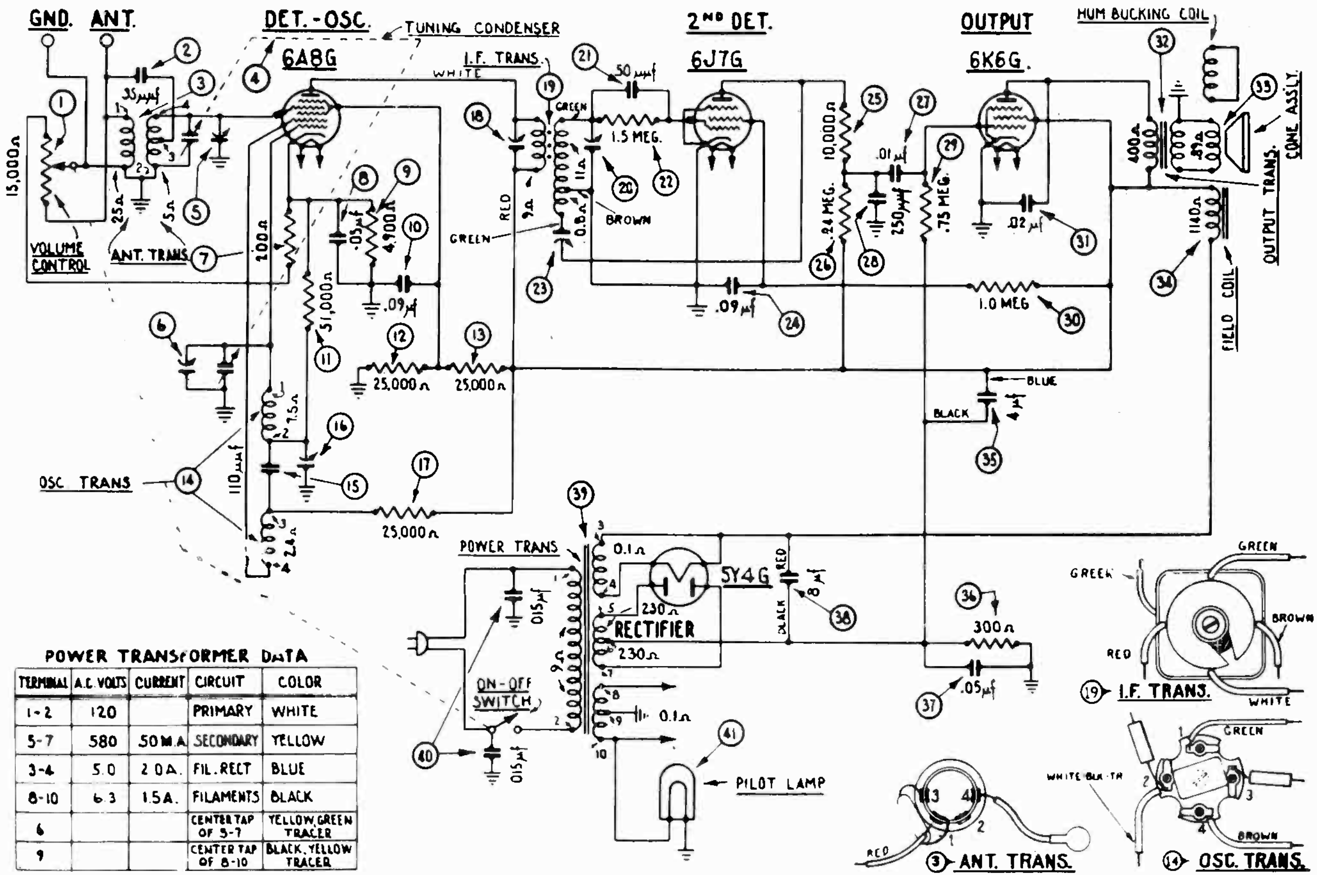


Fig. 3. Base View



POWER TRANSFORMER DATA

TERMINAL	A.C. VOLTS	CURRENT	CIRCUIT	COLOR
1-2	120		PRIMARY	WHITE
5-7	580	50 M.A.	SECONDARY	YELLOW
3-4	5.0	2.0 A.	FIL. RECT	BLUE
8-10	6.3	1.5 A.	FILAMENTS	BLACK
6			CENTER TAP OF 5-7	YELLOW, GREEN TRACER
9			CENTER TAP OF 8-10	BLACK, YELLOW TRACER

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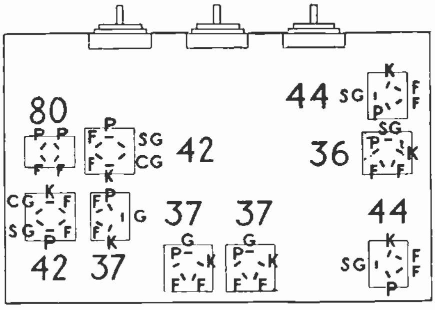
NATIONAL RADIO INSTITUTE, WASHINGTON, D.C.

PHILCO MODEL 91 SERIES

The Philco Radio of the 91 series is a nine tube superheterodyne, employing the high efficiency 6.3 volt filament tubes, automatic volume control, shadow tuning, and push-pull pentode output. The chassis is made in two different types, one known as the 121 type, employing a single dynamic speaker and the other known as the 221 type, employing twin dynamic speakers. These type numbers appear on the radio chassis as a part of the model number. Chassis of one type are not interchangeable with those of another. The intermediate frequency used in adjusting the superheterodyne circuit of the 91 series is 260 kilocycles. The power consumption of the various models is as follows:

Model	Volts	Cycles	Watts
91-121	115	50-60	90
91-221	115	50-60	95
91A-121	115	25-40	92
91A-221	115	25-40	97
91E-121	230	50-60	90
91E-221	230	50-60	95



F = Filament SG = Screen Grid K = Cathode
P = Plate CG = Control Grid

Fig. 1—Tube Sockets

Table 1—Tube Socket Data*—A.C. Line Voltage 115 Volts

Tube Type	Tube Circuit	Filament Volts	Plate Volts	Screen Grid Volts	Control Grid Volts	Cathode Volts
44	R.F.	6.3	200	50	.6	25
36	Det.—Osc.	6.3	250	80	10	10
44	I.F.	6.3	250	85	.2	5
37	Det.—Rect.	6.3	0	...	.2	2
37	Det.—Ampl.	6.3	60	...	.2	2
37	Audio	6.3	100	...	0	2
42	Output	6.3	240	250	15	15
42	Output	6.3	240	250	15	15
80	Rectifier	5.0	310/Plate	...	...	..

*All of the above readings were taken from the under side of the chassis, using test prods and leads with a suitable A.C. voltmeter for filament voltages and a multi-range D.C. voltmeter for all other readings. Volume control at maximum and station selector turned to low frequency end.

Table 2—Power Transformer Data

Terminals	A.C. Volts	Circuit	Color
1-2	105 to 125	Primary	White
3-5	6.3	Filament	Black
6-7	5.0	Filament 80	Blue
8-10	670	Plates of 80	Yellow
4	...	Center Tap of 3-5	Black Yellow Tracer
9	...	Center Tap of 8-10	Yellow Green Tracer

Table 3—Resistor Data

Nos. on Figs 4	Resistance (ohms)	Power (Watts)	Terminals	Color Body	Color Tip	Color Dot
46 Single Speaker	900	..	1-2	LONG	TUB	ULAR
	2700	..	2-3			
	95	.	3-4			
	205	..	4-5			
46a Twin Speaker	136	..	1-2	LONG	TUB	ULAR
	Blank	..	2-3			
	85	..	3-4			
	205	..	4-5			
14	1,000	.5	....	Brown	Black	Red
1	10,000	.5	...	Brown	Black	Orange
21	15,000	.5	....	Brown	Green	Orange
40 41	25,000	.5	...	Red	Green	Orange
41a	13,000	1.	....	Brown	Orange	Orange
32	99,000	.5	....	White	White	Orange
39	490,000	.5	....	Yellow	White	Yellow
43 3 38	1,000,000	.5	...	Brown	Black	Green
26	1,000,000	1.	....	Brown	Black	Green

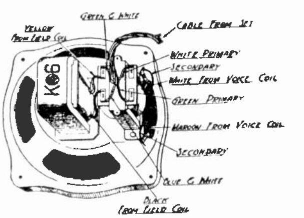


Fig. 2—Speaker Connections—121 Code

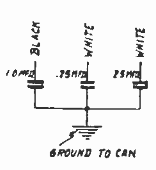
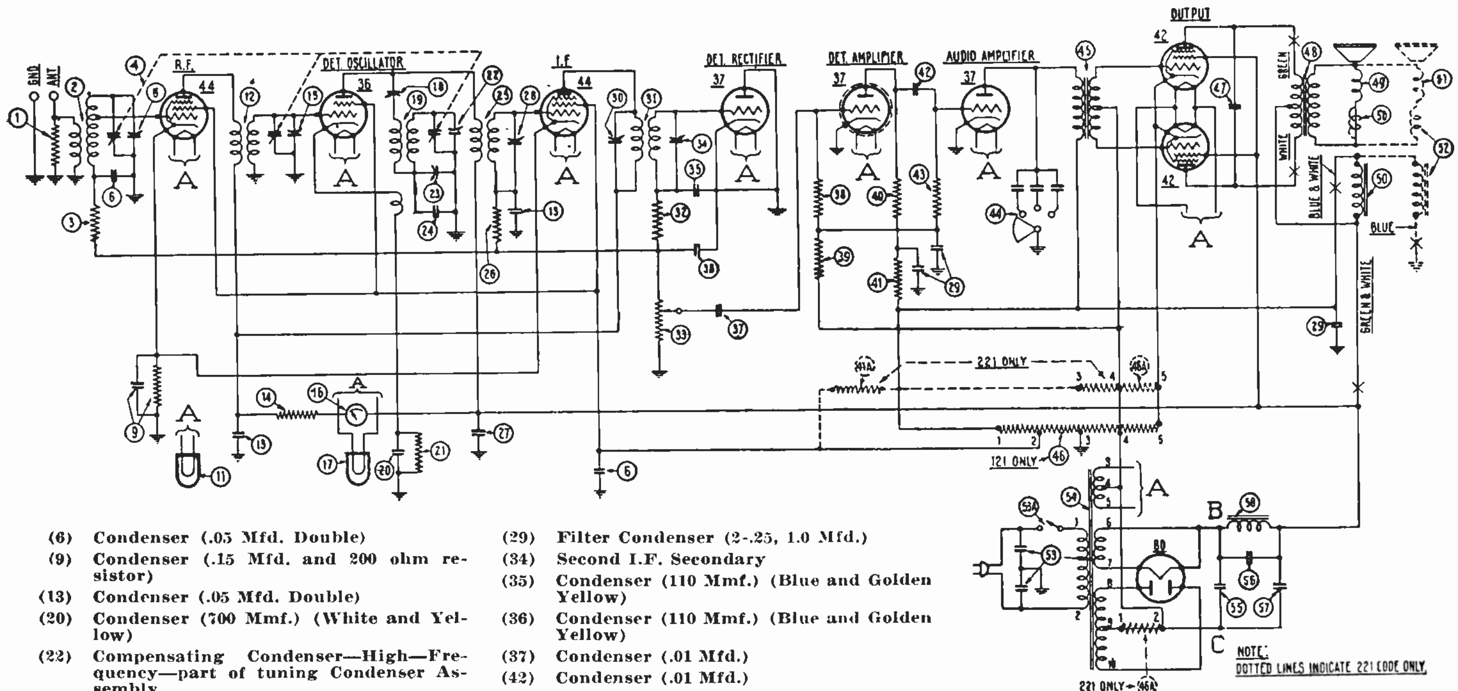


Fig. 3—Internal Connections Filter Condenser



(6)	Condenser (.05 Mfd. Double)	(29)	Filter Condenser (2-.25, 1.0 Mfd.)
(9)	Condenser (.15 Mfd. and 200 ohm resistor)	(34)	Second I.F. Secondary
(13)	Condenser (.05 Mfd. Double)	(35)	Condenser (110 Mmf.) (Blue and Golden Yellow)
(20)	Condenser (700 Mmf.) (White and Yellow)	(36)	Condenser (110 Mmf.) (Blue and Golden Yellow)
(22)	Compensating Condenser—High—Frequency—part of tuning Condenser Assembly	(37)	Condenser (.01 Mfd.)
		(42)	Condenser (.01 Mfd.)
(23)	Compensating Condenser — Low Frequency	(47)	Condenser (.001 Mfd.)
		(53)	Condenser (.015 Mfd. Double)
(24)	Condenser (410 Mmf.) Yellow and Orange) Assembled with I.F. Condenser	(55)	Electrolytic Condenser (8 Mfd.)
		(56)	Condenser (.18 Mfd.)
(27)	Condenser (.01 Mfd.)	(57)	Electrolytic Condenser (8 Mfd.)

14 CIRCUIT DIAGRAMS EACH WITH TESTING INFORMATION

19 SS

SERVICE MANUAL

PIONEER HOME STUDY RADIO SCHOOL

NRI

NATIONAL RADIO INSTITUTE
EST. 1914
WASHINGTON, D.C.

FOREWORD

This booklet is one of a series of service manuals which contain service sheets giving typical information on radio receivers. Each service sheet shows the circuit diagram in the usual symbolic form for that radio receiver. Many of the service sheets will contain such special service information as space will permit.

By studying each service sheet, you will gradually develop the ability to read any diagram or manufacturer's service manual and learn the usual methods of set adjustment. Enough typical receivers have been selected to give you quickly a good insight to the entire radio problem.

In reading a circuit diagram, learn to trace independently the power supply and the signal circuits. Then locate the special control circuits, such as the automatic volume controls, tuning indicators, manual volume controls, etc. Detailed information on power, supply, signal and control circuits, as well as set servicing, is given in the course, to which reference should be made.

J. E. SMITH.

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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Service Sheet

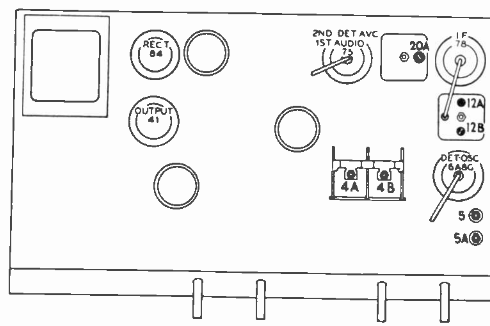
Compiled Solely for Students and Graduates

NATIONAL RADIO INSTITUTE, WASHINGTON, D. C.

PHILCO MODEL 39-25

Alignment of Compensators

EQUIPMENT: (1) Signal Generator; Philco Model 077 Signal Generator which has a fundamental frequency range from 115 to 36,000 K. C. is the correct instrument for this purpose. (2) Output meter, Philco Model 027 Circuit Tester, incorporates a sensitive output meter and is recommended. (3) Philco Fiber Handle Screw Driver, part No. 27-7059, and Fiber Wrench, part No. 3164.

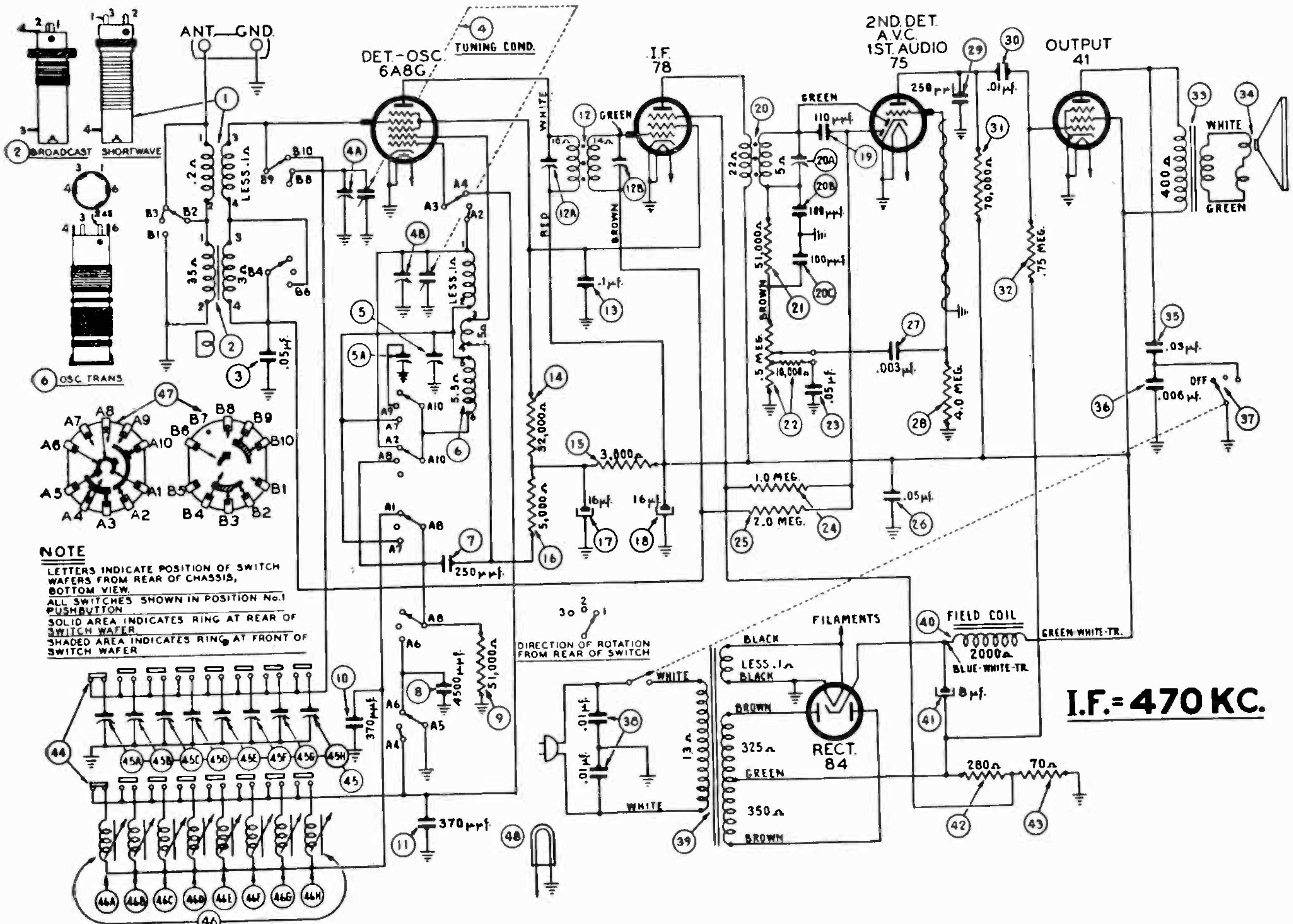


Location of Compensators

OUTPUT METER: The Philco 027 Output Meter is connected to the plate and cathode terminals of the Type 41 tube. Set the meter to use the 0-30 volt scale. After connecting the output meter adjust compensators in the order as given below.

Signal Generator				Receiver			
Operations in Order	Output Connections to Receiver	Dummy Antenna (Note A)	Dial Setting	Dial Setting	Control Settings	Adjust Compensators in Order	Special Instructions
1	6A8G Grid	.1 mf.	470 KC	580 KC	Vol. Cont. max.	(20A) (12B) (12A)	
2	Ant. Ter.	100 mmf.	18.0 MC	18.0 MC	Vol. Cont. max.	(4B)	See Note B
3	Ant. Ter.	100 mmf.	1550 KC	1550 KC	Vol. Cont. max.	(5) (4A)	
4	Ant. Ter.	100 mmf.	580 KC	580 KC	Vol. Cont. max.	(5A)	
5	Ant. Ter.	100 mmf.	1550 KC	1550 KC	Vol. Cont. max.	(5)	

NOTE A—The "Dummy Antenna" consists of a condenser connected in series with the signal generator output lead (high side). Use the capacity as specified in each step of the above procedure. NOTE B—DIAL CALIBRATION: In order to adjust the receiver correctly the dial pointer must be aligned to track properly with the tuning condenser. To adjust the dial proceed as follows: With the tuning condenser closed, set the dial pointer on the extreme left index line at the low frequency end of the scale.



ANT.
GND.
DET.-OSC. 6A8G
TUNING COND.
I.F. 78
2ND. DET. A.V.C. 1ST. AUDIO 75
OUTPUT 41
BROADCAST
SHORTWAVE
OSC TRANS
WHITE
GREEN
RED
BROWN
FIELD COIL
2000Ω
BLUE-WHITE-TR.
GREEN-WHITE-TR.
FILAMENTS
BLACK
LESS .1Ω
RECT. 84
325Ω
350Ω
13Ω
280Ω
70Ω
400Ω
OFF
DIRECTION OF ROTATION FROM REAR OF SWITCH
NOTE
LETTERS INDICATE POSITION OF SWITCH WAFERS FROM REAR OF CHASSIS, BOTTOM VIEW.
ALL SWITCHES SHOWN IN POSITION No.1 PUSHBUTTON
SOLID AREA INDICATES RING AT REAR OF SWITCH WAFER
SHADED AREA INDICATES RING AT FRONT OF SWITCH WAFER

I.F. = 470 KC.

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NATIONAL RADIO INSTITUTE, WASHINGTON, D. C.

PHILCO MODEL 18

ALIGNMENT

The intermediate frequency compensating condensers should be adjusted first. The intermediate frequency is 260 kilocycles. These compensating condensers are situated:

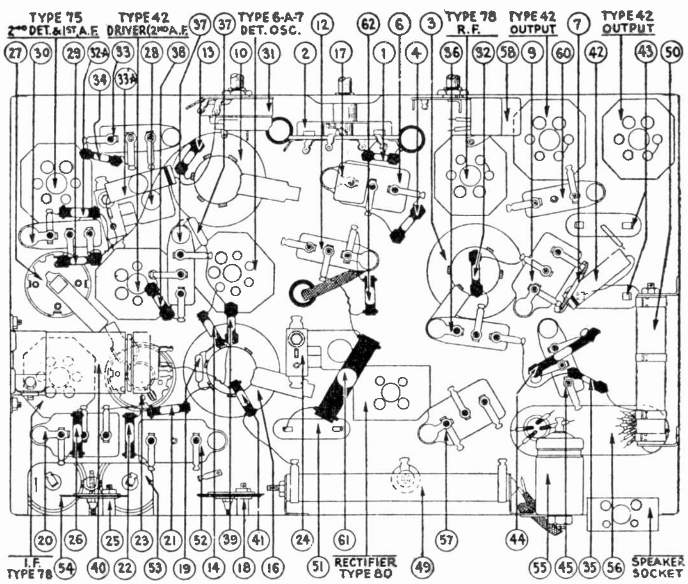
(a) 1st I. F. PRIMARY—(24), underneath chassis. Access from above through hole in sub-base, back of Tuning Condenser Assembly (5). Shield covers the hole and may be removed by prying with screw driver.

(b) 1st I. F. SECONDARY — (25), at rear of chassis, beneath the two vertically mounted electrolytic condensers (53) and (54). Accessible from rear of chassis.

(c) 2nd I. F. PRIMARY—(28), underneath chassis. Accessible from above through hole in chassis sub-base, in front of Type 42 (Driver; 2nd A. F.), and to right of Type 75 tube. The shield can be removed as under (a). The "OSC.: H. F." (15), the "DETECTOR" (11), and the "ANT.; H. F." (8) compensating condensers are then adjusted, in this sequence. The signal generator is set at 1500 K.C. for (15); at 1400 K.C. for (11) and (8). These are mounted upon the Tuning Condenser Assembly (5). (8) is mounted upon the condenser section nearest front.

The "OSC.; L. F." (18) compensating condenser, located at rear of chassis is adjusted next; with the signal generator set at 600 K.C. It is accessible from rear of chassis. The Tuning Condenser (5) should be "rocked" while the "OSC.; L. F." adjustment is made.

The "Push-on Button" shields should be replaced over (24) and (28) after the adjustments are finished.

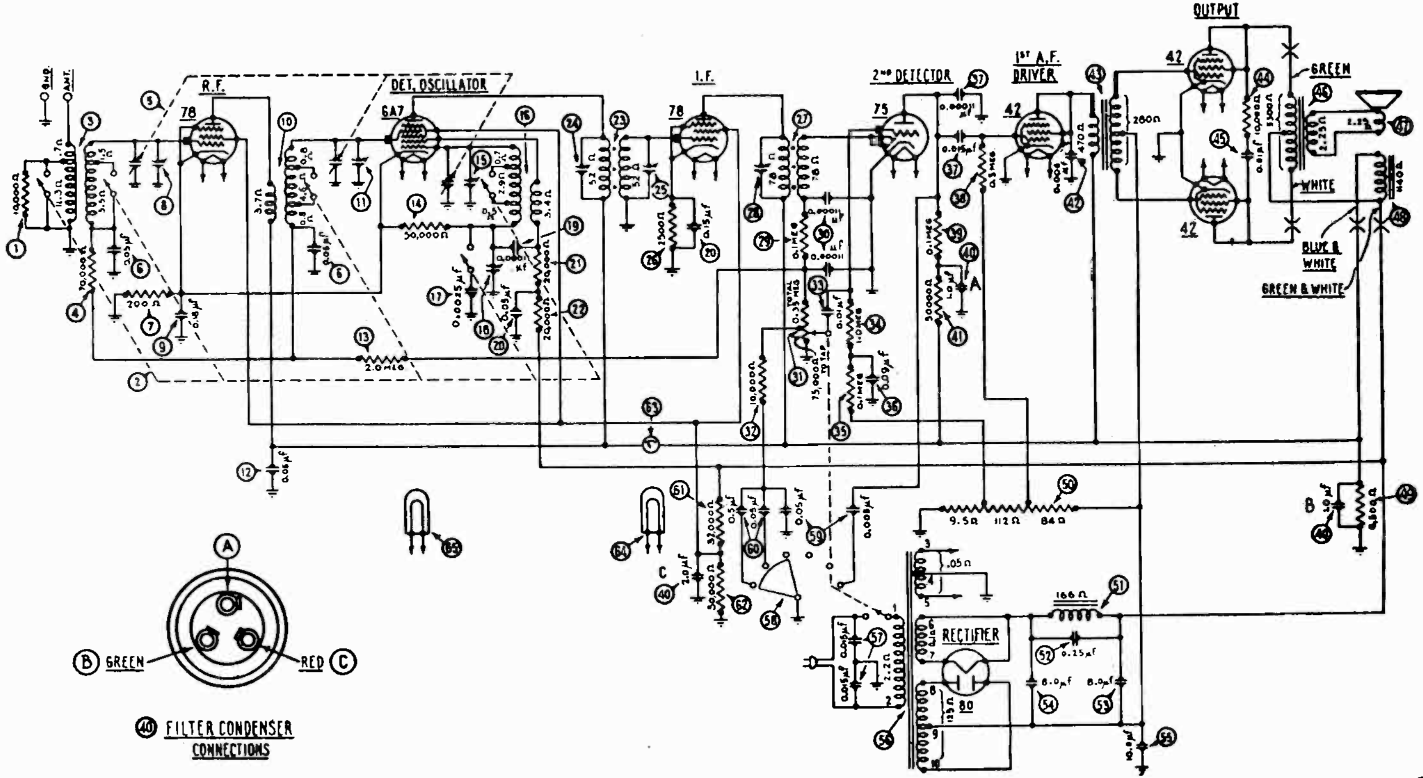


Bottom view of Chassis, showing parts

Tube Socket Voltages

Circuit	R. F.	Det. Osc.	I. F.	1st A. F.	Driver	Output (Class "A")		Rectifier
Type Tube	78	6A7	78	75	42	42	42	80
Filament (F-F)	6.3	6.3	6.3	6.3	6.3	6.3	6.3	5.0
Plate (P-K)	210	210	210	120	205	280	280	350
Screen Grid (SG-K)								
(6A7)	80		80		200	300	300	
G1-K		35						
G2-K		130						
Cathode (K-F)	2.8	2.8	5.3	0	0	0	0	

All the above values were obtained from the underside of the chassis.
Volume control at maximum and station selector at 520 K. C.



(40) FILTER CONDENSER CONNECTIONS

NOTE: In later production—(32)-a Resistor (240,000) (Red-Yellow-Yellow), Part No. 4410—(*not* shown in Schematic), is connected *between* line running from (18) to junction of (29), (30); and ground. (33)-a Condenser (.05), Part No. 30-4020—(*not* shown in Schematic), is connected *between* high side of Volume Control (31) and junction of (29), (30). (60) External Condenser in Tone Control circuit has but one section (in later production),—the .05 mfd. on point two. Point one goes directly to (32).

NOTE: Values of primary and secondary of (46) Output Transformer, and value of (47) Voice Coil, are given in impedance at 200 cycles, 30 volts. The D. C. resistance of the primary is 350 ohms; of the secondary, .09 ohm, D. C. resistance of (47) is 1.11 ohm.

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MOTOROLA 41B and 41F
Alignment Procedure

1. Connect signal generator to control grid of Osc.-Mod. tube (1A7G) through a .05 MF condenser and to chassis. Do not remove grid cap. Also connect output meter across speaker voice coil. Turn condenser gang completely out of mesh. Set band switch in B.C. position. NOTE: The band switch is the slider switch on the rear of the chassis base. The UP position is for Short-Wave. The DOWN position is for Broadcast.

2. Set signal generator at 455 K.C. and carefully adjust the four I.F. trimmers (located on top of I.F. coil pans) to point showing highest reading on output meter.

3. Set band switch in "Short-Wave" position (UP). Connect signal generator to antenna and ground terminals, using 400 ohm carbon resistor in antenna lead.

4. Set signal generator at 18.0 MC and with condenser gang completely out of mesh adjust the S.W. OSC. trimmer until the 18.0 MC signal is heard.

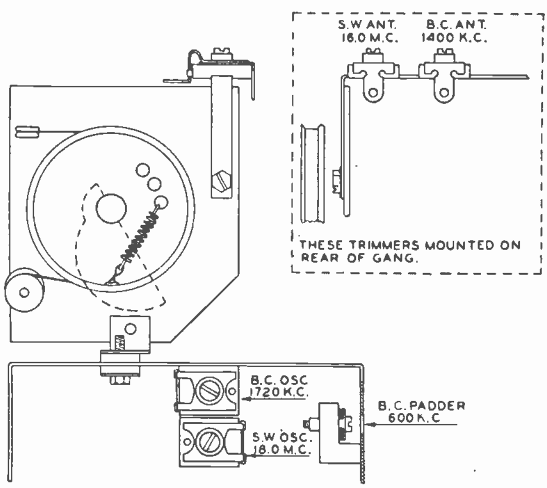
5. Set signal generator at 16.0 MC and tune the condenser gang to signal at 16.0 MC. Adjust S.W. ANT. trimmer to point giving greatest output reading.

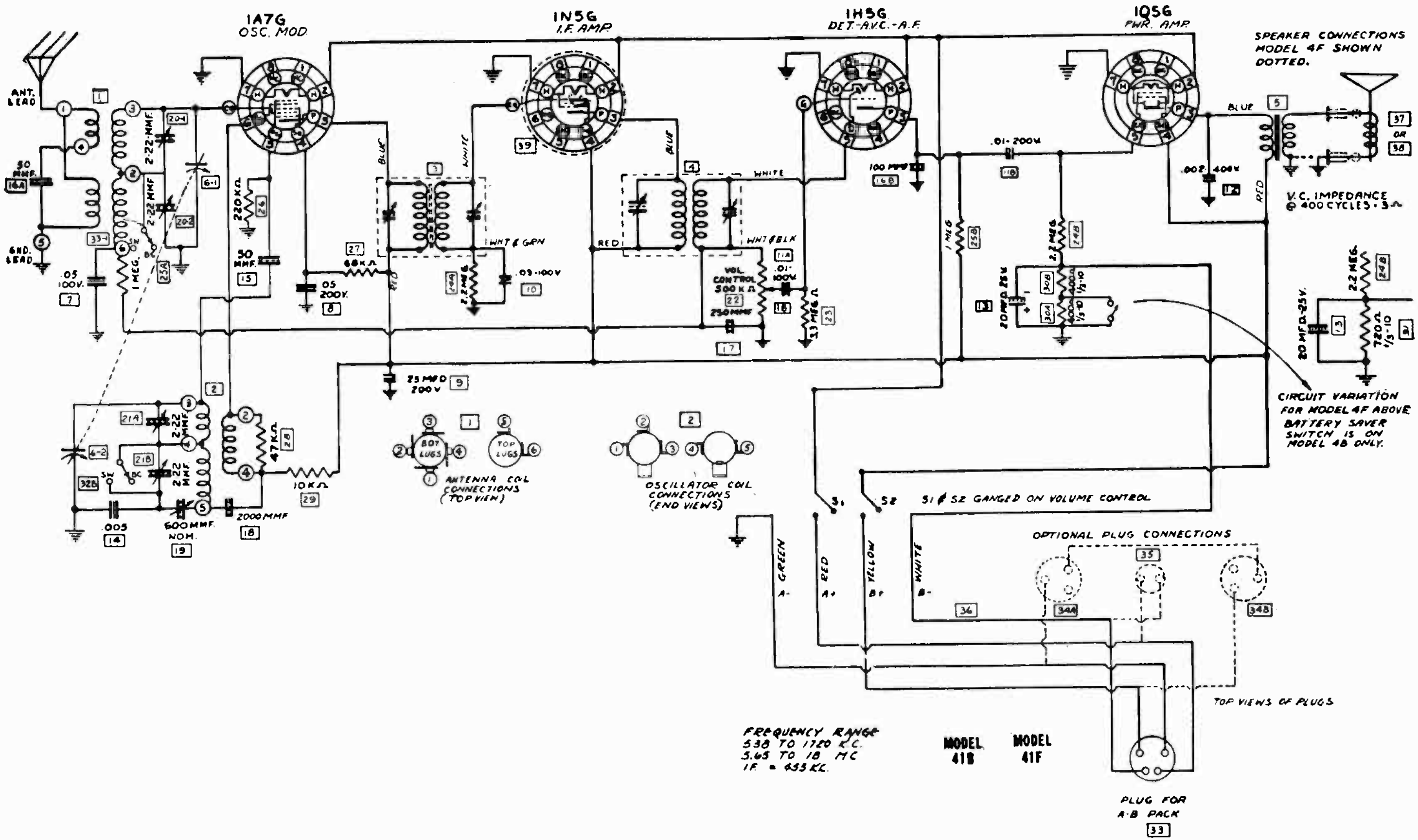
6. Set band switch in Broadcast position (DOWN) and replace 400 ohm resistor in signal generator lead with .0002 MF condenser.

7. Set signal generator at 1720 K.C. and turn condenser gang to out of mesh position. Adjust B.C. OSC. trimmer until 1720 K.C. signal is heard.

8. Set signal generator at 600 K.C. and rock pointer at 600 K.C. position on dial scale, while adjusting B.C. padder, until combination is found which gives highest output reading.

(NOTE: If there is noise at 600 K.C., padder can be adjusted to maximum noise without rocking gang and without use of signal generator. Use short wire for pick-up if necessary.)





MOTOROLA MODELS 41B and 41F

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MOTOROLA 5A CHASSIS (51A, 53A and 54A)

Alignment Procedure

When aligning AC-DC receivers it is advisable to use a blocking condenser in series with the ground connection to the signal generator. If your signal generator is AC operated, it may not be possible to connect to the Modulator grid for IF alignment because of hum. If this is so, feed 455 K.C. signal into the antenna lead, advancing signal generator attenuator accordingly. (In loop models, connect to the coupling turn in the loop.)

1. Connect the signal generator to the antenna lead through a 200 MMF condenser and to chassis ground. Turn the condenser gang completely out of mesh. Connect an output meter across the speaker voice coil.

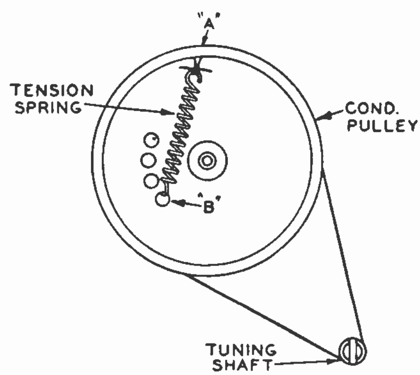
2. Set signal generator at 455 K.C. and carefully adjust the two I.F. trimmers and the two DIODE trimmers to point showing highest reading on output meter. Advance signal generator attenuator if necessary.

3. Turn signal generator to 1750 K.C., and with condenser gang completely out of mesh, adjust OSC. trimmer (on small section of condenser gang) until 1750 K.C. signal is heard.

4. Set signal generator at 1400 K.C. and turn condenser gang to the signal at 1400 K.C. Adjust ANT. trimmer (on large section of condenser gang) to point showing highest reading on output meter.

TO RESTRING DIAL DRIVE CORD

1. Remove dial crystal, pointer, dial scale, and plate.



2. Cut a length of silk fish cord approximately 12 inches long.

3. Make two turns with cord around tuning shaft.

4. Continue both ends of cord around condenser pulley in opposite directions until they meet at the hole (A) in the rim of the pulley.

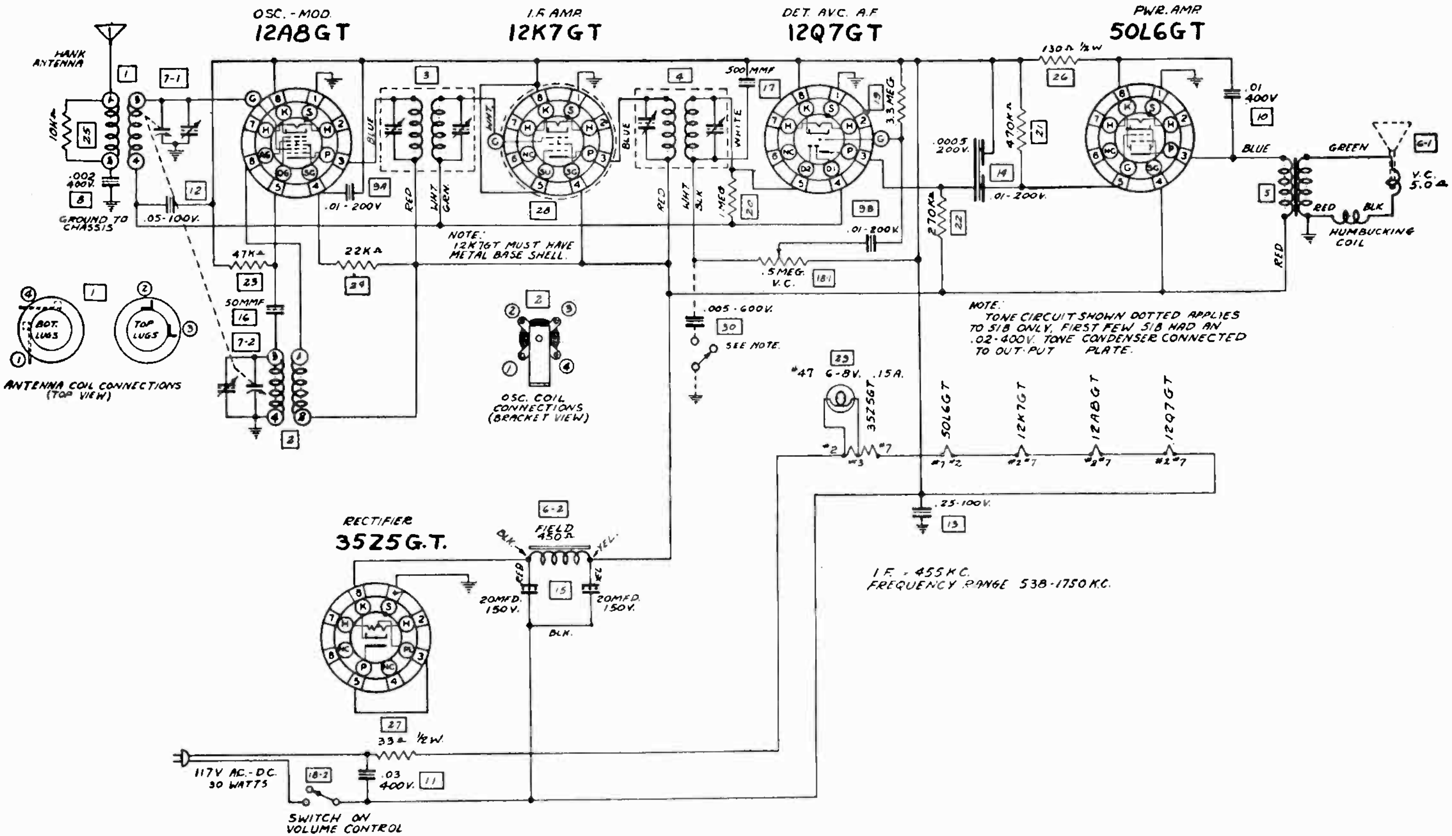
5. Thread both ends through the hole and tie them securely together inside the hole.

6. Tie in the dial cord tension spring and hook the free end of the spring in the hole (B). Cut off surplus cord.

VOLTAGE CHART 5A

TUBE	POSITION	PLATE	SCREEN	CATHODE	OSC. PLATE
12A8GT	Osc.-Mod.	95	65	0	90
12K7GT	IF	95	95	0	—
12Q7GT	Det.-Avc.	55	—	0	—
50L6GT	Output	85	95	5	—
35Z5GT	Rect.	AC	—	120	—

All measurements from B— to socket terminal, using 1000 ohms per volt meter.



MOTOROLA 5A CHASSIS (51A, 53A and 54A)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MAJESTIC MODEL 15 AND 15B CHASSIS
ELLSWOOD, SHERWOOD AND FYFEWOOD MODELS

Alignment

In checking the alignment of Model 15 (and also the 25) chassis the intermediate frequency transformers should not be aligned unless there is a definite reason to believe that they are out of alignment. The alignment of these transformers at the factory is more or less permanent and should not need further adjustment except in rare cases. In all alignment procedure an output meter must be used.

R. F. and Oscillator Alignment

Tune in station in the vicinity of 1500 kilocycles, or put output of local oscillator (if available) into receiver. Align R. F. stage, and oscillator tuning condenser. The R. F. stage and oscillator aligning condensers are on the gang condenser.

Oscillator Tracking Condenser Alignment

Tune in local oscillator to 600 kilocycles.

Adjust both tuning control and tracking condenser simultaneously to give maximum signal as noted on output meter. This will be obtained by rocking tuning control across resonance point while adjusting tracking condenser to give maximum output at the point of resonance. This operation cannot be performed without local oscillator and output meter.

Method of Biasing

The necessary bias is obtained on the first detector and oscillator stage through a 10,000 ohm resistor between cathode and ground. The intermediate frequency amplifier is biased through the volume control and a balance resistor of 264 ohms which is contained in the volume control. The second detector is biased through a 40,000 ohm resistor to ground in the cathode circuit.

Volume Control System

Control of volume is obtained in the Model 15 chassis by a 11,500 ohm control which controls the bias of the oscillator, first detector and I. F. amplifier stages. This control is so arranged in this circuit that in addition to controlling the bias of these two tubes, it also controls the input voltage to the pre-selector stage.

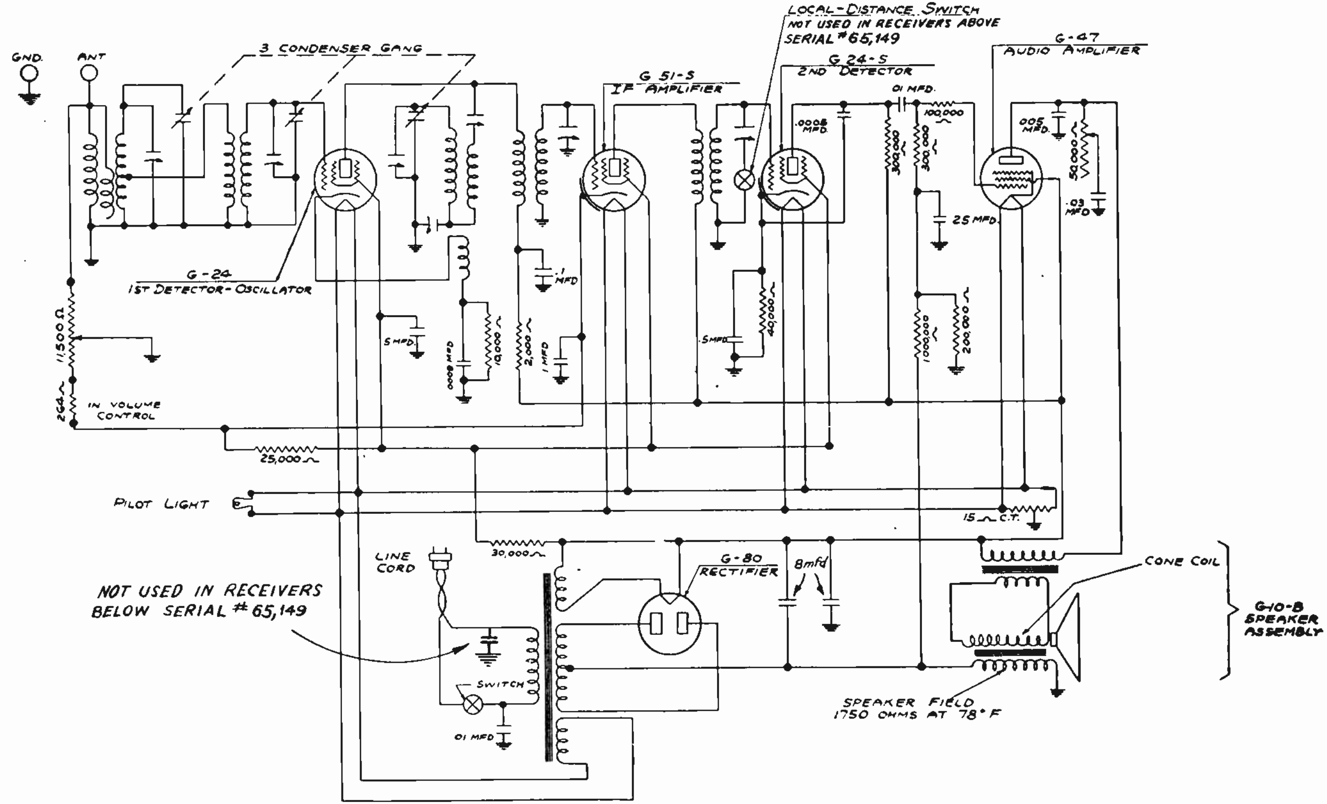
MODEL 15 CHASSIS
Table of Voltages to Ground

Tube — Purpose	Tube — Type	Fil. Volts A. C.	Plate Volts D. C.	Grid Volts D. C.	Cathode Volts D. C.	Plate Current M. A.—D. C.	Screen Volts D. C.
1st Det.—Osc	G-24	2.5	250	......	9	0.9	90
I. F. Amplifier	G-51-S	2.5	250	......	3.0**	7.0	90
2nd Detector	G-24-S	2.5	250	......	9	0.17	90
Power and Amplifier .	G-47	2.5	250	—16.5*	—	32	250
Rectifier	G-80	5.0	—	......	—	54	—

*This cannot be measured with the customary 1000 ohm per volt meter because of the high resistance between the grid and ground. If there is any doubt about the pentode bias, check the 100,000 ohm, 1 megohm, 200,000 and 300,000 ohm resistors and .25 M.F.D. Condenser in this circuit and be sure the speaker field voltage is correct, 112 volts. Also measure the pentode plate and screen voltages and if they are 250 volts, the plate current should be 32 M.A.

**This should rise to 42 when the volume control is turned to minimum.

SCHEMATIC DIAGRAM OF MAJESTIC SCREEN GRID SUPERHETERODYNE RECEIVER
MODEL 15 CHASSIS 115 AND 230 VOLTS, 25-50 AND 50-60 CYCLES.
POWER REQD.—60 WATTS



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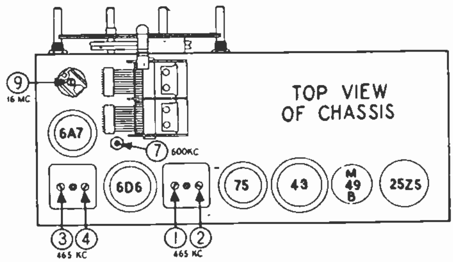
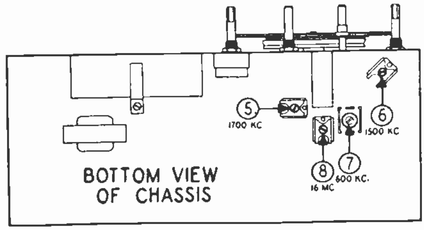
STEWART-WARNER R-188 CHASSIS

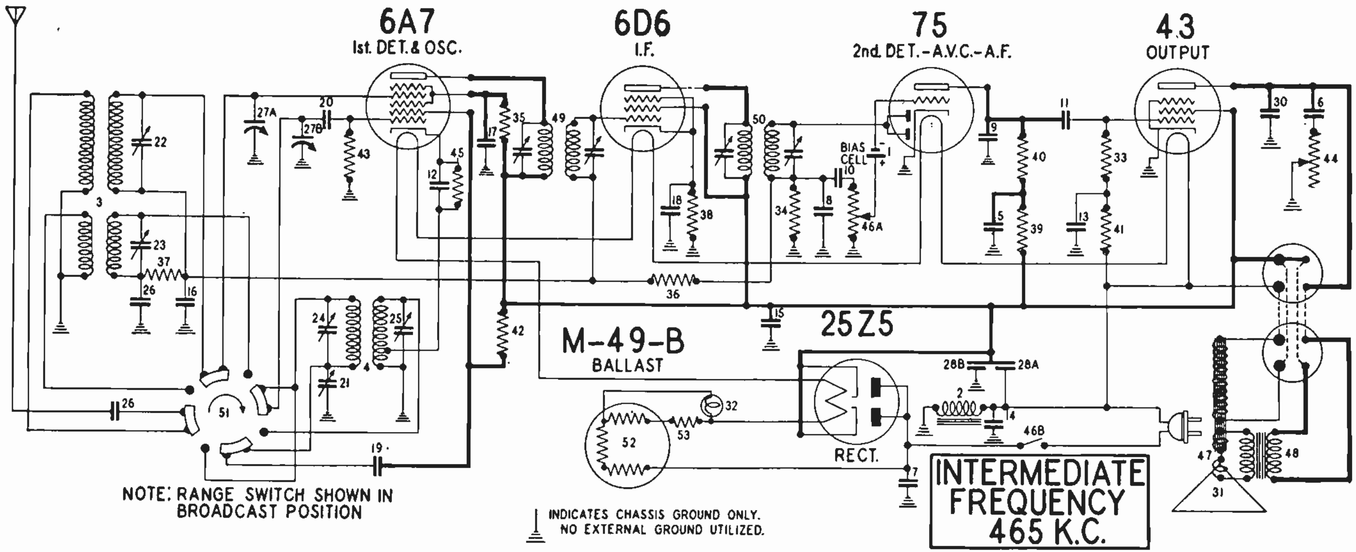
(Models 1881 to 1889)

PARTS LIST

DIAGRAM NUMBER	DESCRIPTION
1	--Cell—bias (1.25 volt)
2	—Choke—filter
3	—Coil—antenna
4	—Coil—oscillator
5	—Condenser—paper .25 mfd. 200 volt
6-7	—Condenser—paper .05 mfd. 600 volt
8-9	—Condenser—mica 250 mmfd.
10-11-12	—Condenser—paper .05 mfd. 200 volt
13	—Condenser—paper .2 mfd. 200 volt
14-15-16 17-18	—Condenser—paper .1 mfd. 200 volt
19	—Condenser—mica .004 mfd.
20	—Condenser—mica 100 mmfd.
21	—Condenser—padding (200-600 mmfd.)
22-23 24-25	—Condenser—trimmer—(3-45 mmfd.)
26	—Condenser—mica .0045 mfd.
27A-27B	—Condenser—variable gang
28A-28B	—Condenser—electrolytic (Sect. A-40 mfd. 150 volt) (Sect. B-8 mfd. 150 volt)
29-30	—Condenser—paper .005 mfd. 400 volt
31	Cone & voice coil assem. for 8" spkr. / Cone & voice coil assem. for 6" spkr.
32	—Lamp—pilot 6.3 volt .2 amp.
33-34	—Resistor—carbon ½ meg. ¼ watt
35	—Resistor—carbon 6000 ohms ¼ watt
36-37	—Resistor—carbon 1 meg. ½ watt
38	—Resistor—carbon 150 ohms 1 watt
39-40-41	—Resistor—250,000 ohms ½ watt
42	—Resistor—carbon 10,000 ohms ½ watt
43	—Resistor—carbon 100,000 ohms ¼ watt
44	—Resistor—tone control 50,000 ohms
45	—Resistor—carbon 250 ohms ⅓ watt
46A-46B	Resistor—volume control ½ meg. (with on-off switch)
47	Speaker—dynamic 8" / Speaker—dynamic 6"
48	—Transformer—output
49	—Transformer—1st I.F.
50	—Transformer—2nd I.F.
51	—Switch—range
52	—Tube—ballast
53	—Resistor—wire wound 15.4 ohm 1 watt







IMPORTANT: Use a high resistance voltmeter of 1,000 ohms per volt.

NOTE A: The self bias of the control grid of the 6A7 is —2 volts measured across resistor 45.

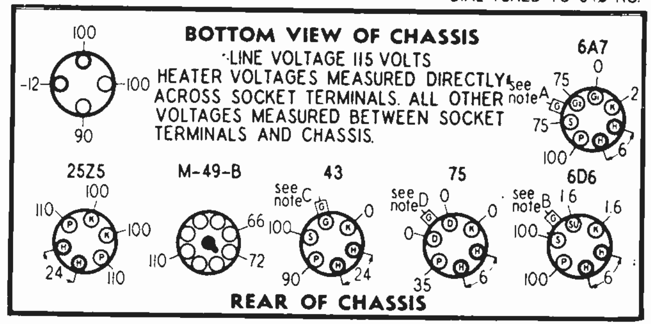
NOTE B: The self bias of the control grid of the 6D6 is —1.6 volts measured across resistor 38.

NOTE C: The bias on the control grid of the 43 is —12 volts measured across the filter choke 2.

NOTE D: The bias on the grid of the triode section of the 75 is —1 volts supplied by a bias cell. CAUTION: Use only a VERY HIGH resistance voltmeter when checking this voltage, otherwise the cell may be damaged.

ANTENNA GROUNDED

DIAL TUNED TO 540 KC.



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RCA MODEL 94BT6

Precautionary Lead Dress

1. Leads on C16 and C20, and lead from R16 to terminal board, must be short. C22 and C4 are soldered direct (no leads).

2. Dress L10 away from chassis. Dress T1 secondary leads (brown and green) away from base and free of other leads (same applies to R17 and C27). Dress T1 secondary midtap (brown-black) free of other leads and close to chassis.

3. Maintain original ground points.

4. Antenna and ground leads 36 inches long, twisted, and arranged as shown in top view.

5. I.F. plate lead (blue) dressed close to and along edge of chassis.

Battery Charger Connections. The positive side of the 6-volt "A" circuit is connected to the receiver chassis, and the chassis is normally grounded. If the charger has a ground on the negative side, the ground should be removed, or changed to the positive side.

Do not change the length of leads from the receiver to the battery.

Alignment Procedure

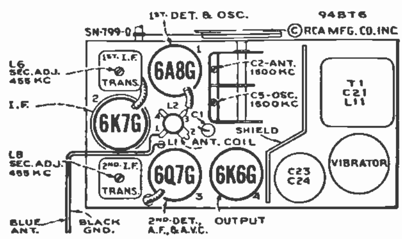
Cathode-ray Alignment is the preferable method. Connections for the oscillograph are shown in the chassis drawing.

Output Meter Alignment. If this method is used, connect the meter across the voice coil, and turn the receiver volume control to maximum.

Test-oscillator. For all alignment operations, connect the low side of the test-oscillator to the receiver chassis, and keep the output as low as possible to avoid a.v.c. action.

Presetting Dial. With gang condenser in full mesh, the pointer should be horizontal.

Resealing I.F. Adjustment Screws. After completion of alignment, seal the I.F. magnetite-core adjustment screws with a few drops of household cement.

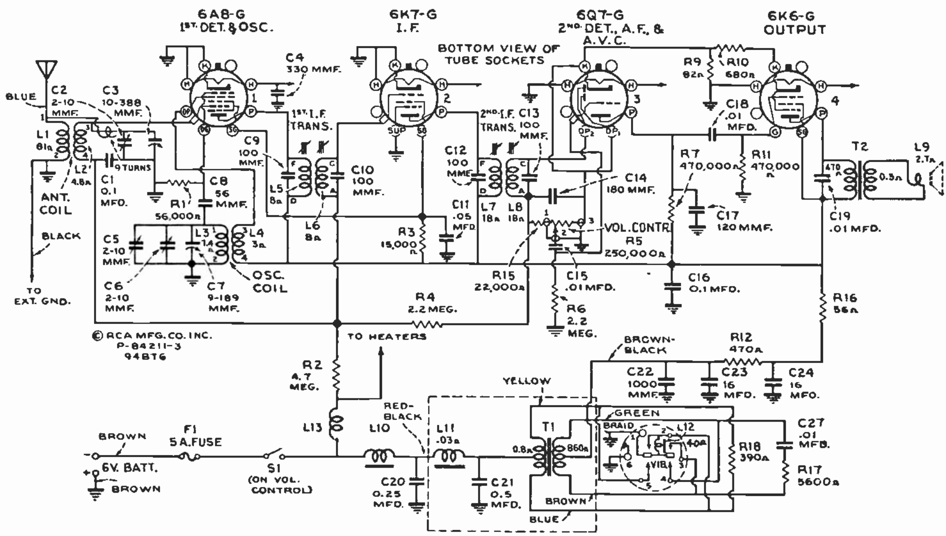


Radiotron and Trimmer Locations

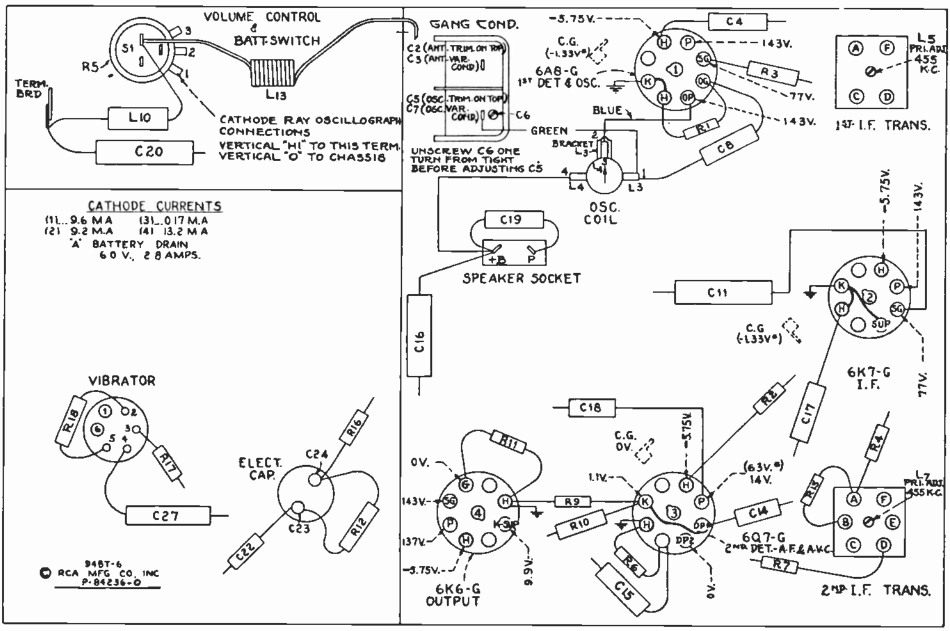
Alignment Table

Steps	Connect the high side of test-oscillator to—	Tune test-osc. to—	Turn radio dial to—	Adjust the following for max. peak output
No. 1	6K7-G I.-F. grid cap, in series with .001 mfd.	455 kc.	Quiet point between 550-750 kc.	L7 and L8 (2nd I.-F. transformer)
No. 2	6A8-G 1st-det. grid cap, in series with .001 mfd.	455 kc.		L5 and L6 (first I.-F. transformer)
No. 3	Antenna lead, in series with 200 mmfd.	1,500 kc.	1,500 kc.	C5* (oscillator) C2 (antenna)

*Adjust C6 on gang condenser to one complete turn from tight, before adjusting C5.



Schematic Circuit Diagram



Bottom view—rear of chassis. Radiotron Socket Voltages, and Location of parts

*Note: Values with star (*) are operating voltages. Values not starred are actual measured voltages. Measurements made to chassis unless otherwise indicated. Measurements made with set tuned to quiet point, volume control at minimum.

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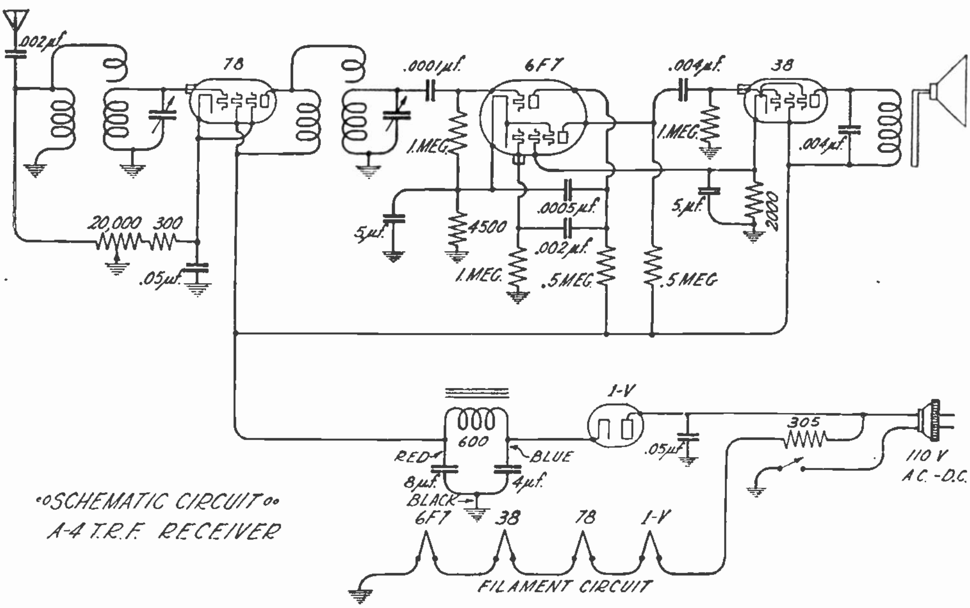
EMERSON RADIO & PHONOGRAPH CORP N.Y.

EMERSON "MICKEY MOUSE" UNIVERSAL FOUR-TUBE RADIO RECEIVER MODELS 409-410-411-414

The Emerson "Mickey Mouse" Radio is a Universal Compact All-Electric Receiver specially designed to operate on direct current or alternating current, 105-130 volts. It may also be used on 200 volts by attaching the extra ballast resistor.



TUBES

The tubes employed are as follows: 1—78 R. F. Pentode as first Radio frequency amplifier; 1—6F7 Triode-Pentode as detector and first audio amplifier; 1—38 Power Pentode as output-power tube; 1—1V Rectifier as rectifier.

VOLTAGE READING

All readings were made with a voltmeter having a resistance of 1,000 ohms per volt, and are subject to slight variations. Line voltage, 115 A. C.

	Plate	Screen	Cathode	Suppressor
78	105	105	2.5	2.5
6F7 Triode	15	...	1.5	..
6F7 Pentode	35	11	1.5	..
38	103	105	11.	..

All above voltages measured to chassis.

EMERSON MODEL L-AC-4 AND SL

The L-AC-4 is a four-tube receiver, employing the following tubes:

1 type 58 Pentode R. F. Amplifier Tube
1 type 57 Pentode Detector Tube
1 type 47 Pentode Power Tube
1 type Rectifier Tube

The set is designed to operate on from 110 to 120 volt, 60 cycle A. C., and to cover the regular broadcast band of 200 to 500 meters.

DO NOT CONNECT TO DIRECT CURRENT (D. C.).

VOLTAGE READINGS

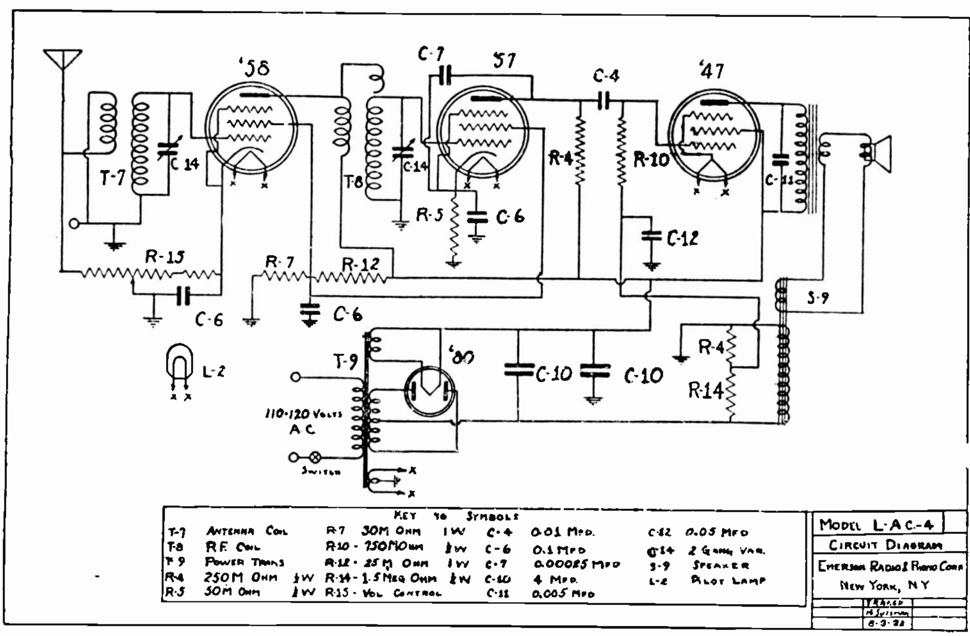
Readings should be taken with volume control all the way on and tuning control set for high wave length stations. Use a 250-volt D. C. meter having a resistance of 1,000 ohms per volt.

	Plate	Screen	Cathode
47 Tube—ground to	215	237	none
57 Tube—ground to	115	92	4.5
58 Tube—ground to	237	92	2

Line voltage, 119

The bias on the pentode cannot be read on the voltmeter.

These readings are approximate and will vary slightly with sets, tubes, etc.



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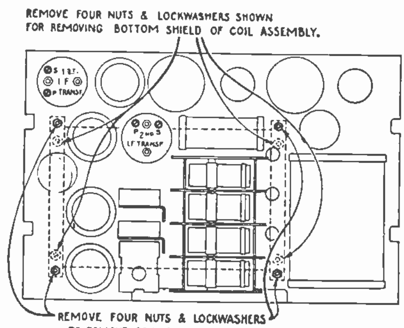
RCA-VICTOR MODELS 140, 141, 141-E AND 240; GENERAL ELECTRIC K-80, K-80X, K-85; WESTINGHOUSE WR-30, WR-31; CANADIAN RCA-VICTOR 140; CANADIAN G. E. K-80, K-85; CANADIAN WESTINGHOUSE W83AW.

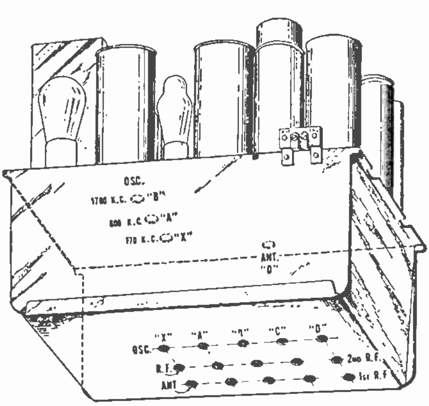
LINE-UP CAPACITOR ADJUSTMENTS

This receiver is aligned in a similar manner to that of a standard broadcast band receiver. That is, the three main tuning capacitors are aligned by means of three trimmers in each band and, on the three lowest frequency bands, a series trimmer is adjusted for aligning the oscillator circuit. The other two bands do not require this low-frequency trimmer, it being fixed in value. In the case of band D, it is necessary to adjust four trimmers, due to the additional R. F. stage used.

The chart one the right gives the details of all line-up adjustments. The receiver should be lined up in the order of the adjustments given on the chart. Refer to the diagrams below for the location of the line-up capacitors.



Location of nuts and lockwashers holding

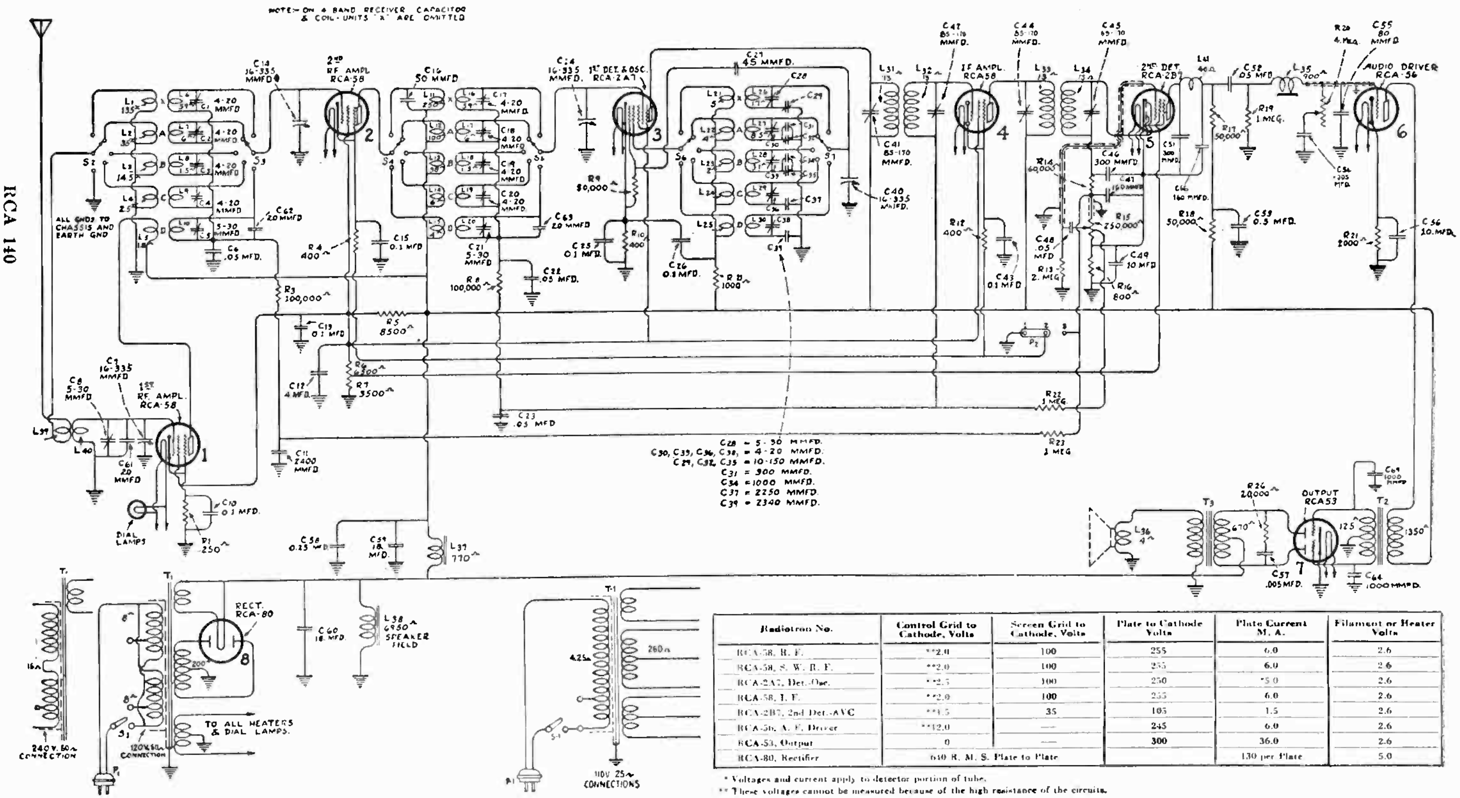


Location of line-up capacities

External Oscillator Frequency	Dial Setting	Location of Line-Up Capacitors	Position of Selector Switch	Adjust for	Number of Adjustments To be Made
445 K. C.	Any setting that does not bring in station.	At rear of chassis.	Any position that does not bring in station.	Maximum output.	4
370 K. C.	370 K. C.	Bottom of chassis.	X	Maximum output.	3
175 K. C.	Set for signal.	Top of chassis.	X	Maximum output while rocking dial back and forth.	1
1400 K. C.	1400 K. C.	Bottom of chassis.	A	Maximum output.	3
600 K. C.	Set for signal.	Top of chassis.	A	Maximum output while rocking dial back and forth.	1
3900 K. C.	3900 K. C.	Bottom of chassis.	B	Maximum output.	3
1710 K. C.	Set for signal.	Top of chassis.	B	Maximum output while rocking dial back and forth.	1
10 M. C.	10 M. C.	Bottom of chassis.	C	Maximum output. (See Note.)	3
15 or 18 M. C.	15 or 18 M. C.	Bottom and top.	D	Maximum output. (See Note.)	4

NOTE—It is important to note, when aligning bands C and D, that two peaks will be observed on the trimmers for the oscillator and for the first detector. The correct oscillator peak is the one obtained using the lower trimmer capacitance, whereas the correct detector peak is the one obtained with the greater capacitance. It is essential that the proper peak be chosen, as otherwise tracking and sensitivity will be very poor at other frequencies. When adjusting the detector trimmer, the tuning capacitor should be rocked, since there is a reaction on the oscillator tuning.

RCA 140



Radiotron No.	Control Grid to Cathode, Volts	Screen Grid to Cathode, Volts	Plate to Cathode Volts	Plate Current M. A.	Filament or Heater Volts
RCA-58, R. F.	**2.0	100	255	6.0	2.6
RCA-58, S. W. R. F.	**2.0	100	255	6.0	2.6
RCA-2A7, Det.-Osc.	**2.5	100	250	*5.0	2.6
RCA-58, I. F.	**2.0	100	255	6.0	2.6
RCA-2B7, 2nd Det.-AVC	**1.5	35	105	1.5	2.6
RCA-56, A. F. Driver	**12.0	—	245	6.0	2.6
RCA-53, Output	0	—	300	36.0	2.6
RCA-80, Rectifier	610 R. M. S. Plate to Plate			130 per Plate	5.0

* Voltages and current apply to detector portion of tube.
** These voltages cannot be measured because of the high resistance of the circuits.

BROAD TUNING on broadcast band is a normal condition. The same tuning condenser gang is used on short wave bands and because of wide band of frequencies covered is so designed that tuning of high frequencies will not be too critical.

LOW HUM increasing as set is tuned to resonance is sometimes caused by the 2B7 second detector. Try another one as trouble will not show up on tube checker.

CODE INTERFERENCE can often be eliminated by connecting the secondary of a 456 k.c. I.F. transformer in series with the antenna as close as possible to the receiver. Tune the secondary to the frequency of the interfering signal.

NOISY AND INTERMITTENT RECEPTION is sometimes caused by the 2A7 tube. Try a new tube as this trouble may not show up on tube checker.

A CARRIER HUM can often be eliminated by inter-changing the position of all the 58 tubes, or substituting one or more new ones.

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RCA MODEL 95X1

ALIGNMENT PROCEDURE

Remove Chassis from Cabinet

Reel up the antenna wire, and connect the high side of test-oscillator through an 80-mmfd. capacitor to the antenna terminal on the antenna transformer. Connect low side of oscillator to receiver chassis through an .01-mfd. capacitor. Turn gang condenser to minimum (full out), push in the manual-tuning (right-hand) button, tune oscillator to 1,560 kc., connect an output meter across the voice coil, and turn volume control to maximum.

Keep antenna roll and lead clear of chassis during all adjustments.

Adjust the two trimmers (C3 and C6) on side of gang condenser for maximum output, using lowest possible output from test-oscillator.

Turn pointer, so that it is horizontal and pointing to low-frequency end when the gang condenser is at maximum. Check pointer adjustment on a station.

Adjustment of Tuning Capacitors

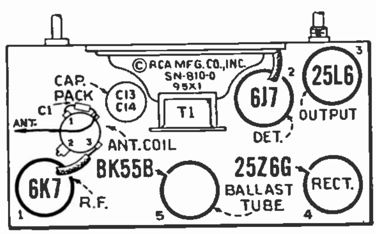
The preferable and quickest method of adjusting the tuning capacitors for five different stations is to employ a test-oscillator, as described below:

1. Make a list of the desired five stations, arranged in order from low to high frequencies.

2. Determine the correct settings of the test-oscillator for these five frequencies. This is accomplished as follows: Tune in each of the five stations on any standard receiver; zero-beat the test-oscillator against each station, and note the exact setting of the oscillator in each case.

3. Reel up the antenna wire. Connect the high side of test-oscillator through an 80-mmfd. fixed capacitor to the end of the antenna wire. Clip the low side of the oscillator through a 0.1-mfd. capacitor to one of the chassis-mounting screws on the bottom of the cabinet. Tune the oscillator to the previously-determined point for the lowest-frequency station, and adjust for a strong output.

4. Turn the volume control of the push-button receiver full clockwise, and push in the left-hand end button. Using an insulated screwdriver, peak capacitors C20 and C26, at the same time reducing the output of the oscillator in order to secure a sharp peak. (Clockwise adjustment of the capacitors tunes the circuits to lower frequencies, and counter-clockwise adjustment tunes the circuits to higher frequencies. The range of each trimmer is three full counter-clockwise turns from the tight position. Do not unscrew more than three turns.)

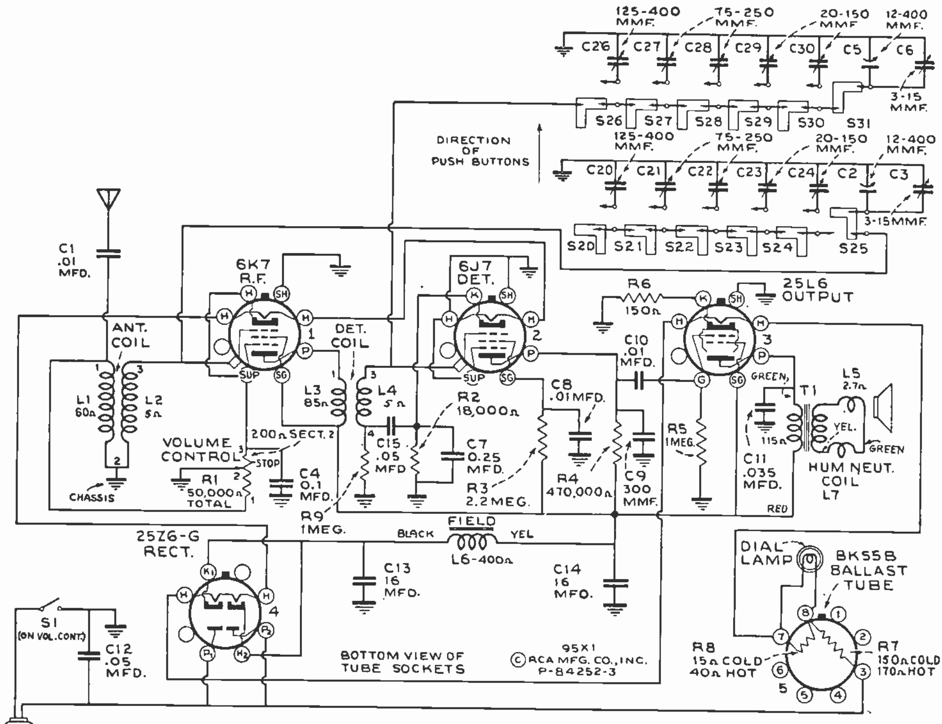


Radiotron Location

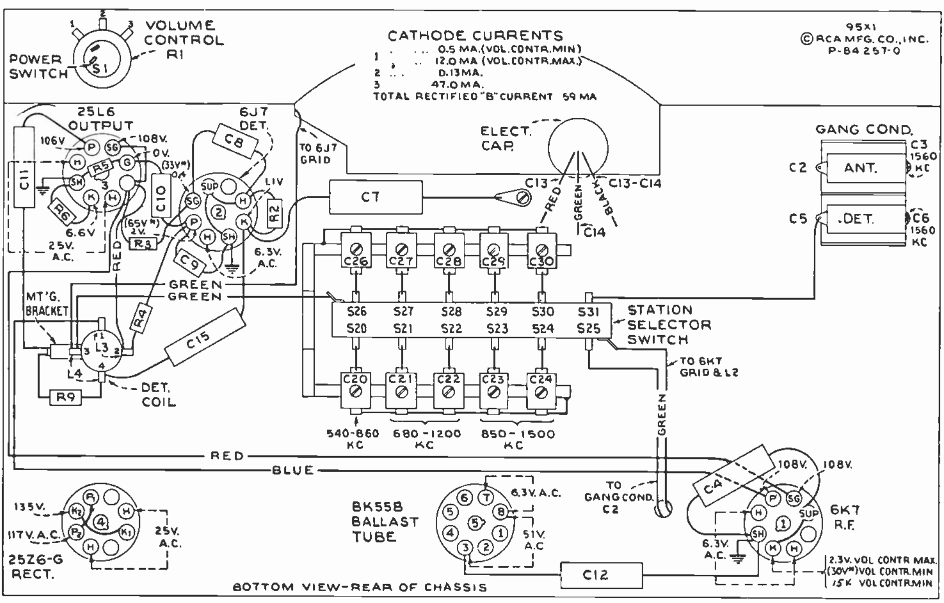
5. Push in the second button from left, and adjust C21 and C27 for peak output with the oscillator tuned to the frequency of the second station.

6. Proceed in this manner to adjust each pair of capacitors for the desired frequencies.

7. Final adjustment may be made in actual reception of the stations.



Schematic Circuit Diagram. The line by-pass, C12, is changed to .25 mfd. (Stock No. 12484) in some sets.



RADIOTRON SOCKET VOLTAGES, AND LOCATION OF PARTS

Measurements made to chassis unless otherwise indicated. Manual tuning button pushed in and set tuned to a quiet point, volume control at minimum.

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GRUNOW CHASSIS TYPE 4NB—RECEIVER MODELS 410 AND 411

The Grunow Chassis 4NB is a 4 tube, 6 volt battery operated superheterodyne receiver using 1-1A6 1st Detector and Oscillator, 1-1A4 I.F. Amplifier, 1-75 2nd Detector, A.V.C. and Audio Amplifier and 1-41 Power Output. The tuning range covers the Broadcast Band from 550 K.C. to 1850 K.C.

REPAIRS

When servicing this chassis it is IMPERATIVE that all parts replacements are made in EXACTLY the same way as the original parts were located and connected; this applies particularly to ground points. All parts replacements in the R.F. end of the circuit must be exact duplicates of the originals, especially so in the case of coils, R.F. by-pass or coupling condensers. Any repairs in the R.F. circuit will make a complete realignment of the tuned circuit necessary.

BIAS CELL

This chassis uses a "C" bias cell unit in the control grid of the 75 tube. This type bias cell has an exceedingly long life but occasionally may have to be replaced. When replacing the cell, note that the carbon or (+) side is connected to the ground side of the terminal clip. To check the bias cell, a new cell or a 1½ volt battery must be substituted as the cell voltage cannot be measured with an ordinary voltmeter due to its low current rating.

POWER UNIT

The power or "B" voltage in this receiver is supplied by a six volt "plug-in" type synchronous vibrator and conventional transformer and filter combination. All ground connections in this unit are located at one point in order to eliminate vibrator noise, and UNDER NO CONDITIONS SHALL THE COMMON GROUND POINT BE CHANGED.

CIRCUIT ALIGNMENT EQUIPMENT

1—Signal Generator.
A modulating oscillator capable of delivering frequencies from 465 K.C. to 1750 K.C.

2—Alignment Tool.
A non-metallic screw driver.

3—Dummy Antenna.
.05 Mfd. Condenser (I.F. Alignment).
200 Mfd. Condenser (Broadcast Alignment).

4—Output Meter.
A meter of sufficient sensitivity to give a good deflection at very low signal input.

Note: The receiver should be aligned in a location free from local interference. A screen room is recommended.

1. HEATING

(A) Allow the receiver to heat up for a period of at least 15 minutes. This is necessary in order to eliminate possible alignment variations due to the thermal expansion and contraction of the capacitors and inductances.

(B) Allow the signal generator to warm up in order to prevent frequency drift during alignment.

2. DIAL CALIBRATION

(A) Turn the tuning condenser until fully meshed and set the dial pointer to the horizontal line on the dial chart.

3. SIGNAL GENERATOR ADJUSTMENT

During the entire alignment procedure the signal input from the generator to the receiver must be continually attenuated at the generator as the various trimmers are brought into resonance. This is necessary in order to hold the signal at the lowest intensity so that the A.V.C. circuit will remain at its most sensitive point.

4. I.F. ALIGNMENT

(A) Set the generator to 465 K.C. and connect the output lead to the control grid of the 1A6 tube through the .05 Mfd. dummy and the generator ground to the chassis ground post.

(B) Set the receiver dial pointer to 600 K.C., turn the volume control full on.

(C) Connect the output meter across the two primary terminals on the output transformer.

(D) Adjust the I.F. Trimmers A1, A2, A3 and A4, to maximum output.

5. 1500 K.C. ALIGNMENT

(A) Set the generator to 1500 K.C. and connect the output to the antenna post on the chassis through the 200 Mmfd. dummy.

(B) Set the receiver dial pointer to 1500 K.C.

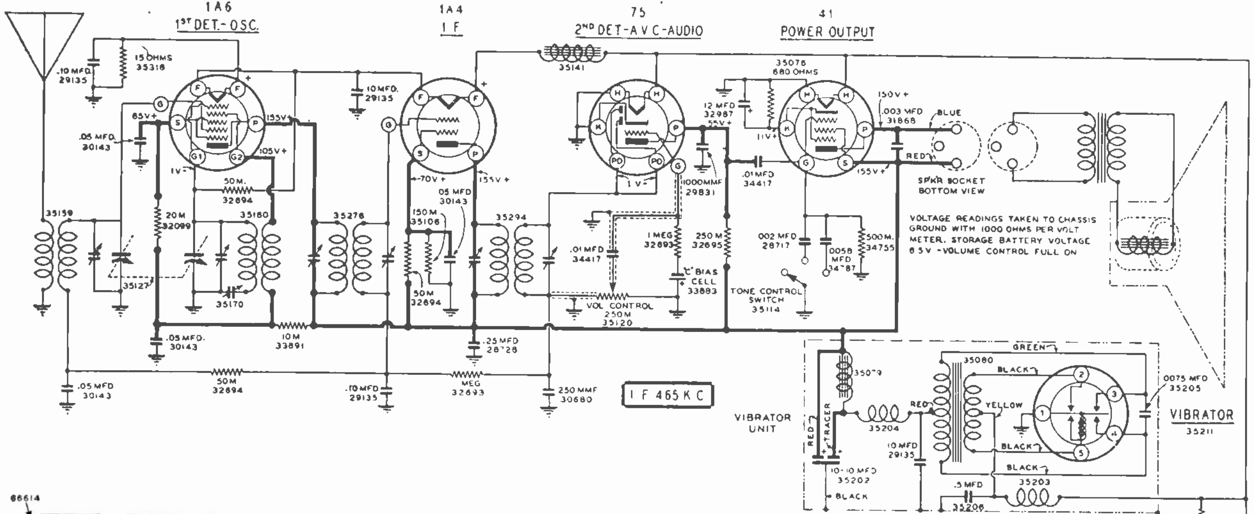
(C) Adjust the Oscillator trimmer A5 and the Antenna trimmer A6 to maximum output.

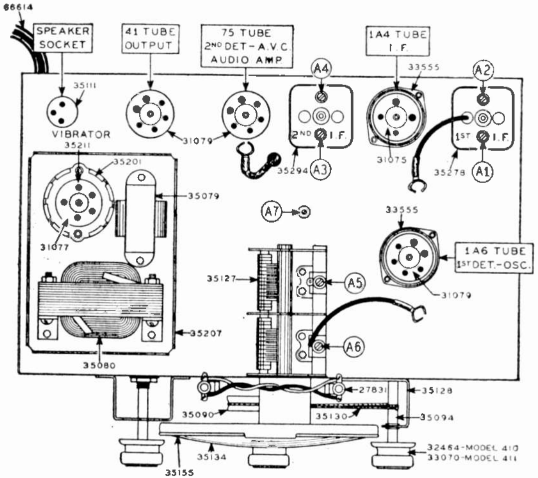
6. 600 K.C. ALIGNMENT

(A) Set the generator to 600 K.C.

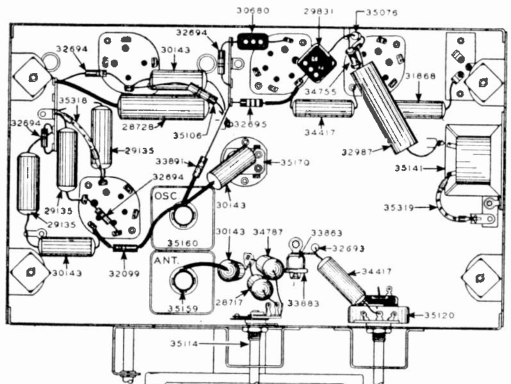
(B) Set the receiver to 600 K.C.

(C) Adjust the trimmer A7 in the direction of signal increase and at the same time slowly rock the tuning condenser back and forth until the exact resonant point is determined.

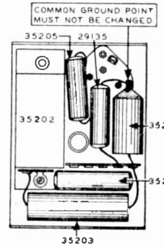




CHASSIS TOP VIEW



CHASSIS BOTTOM VIEW



VIBRATOR-UNIT
BOTTOM VIEW

COMPLETE VIBRATOR UNIT MAY NOT BE RETURNED FOR CREDIT

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Service Sheet

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NATIONAL RADIO INSTITUTE, WASHINGTON, D.C.

PHILCO MODEL 16

The Philco Radio Model 16 is an eleven-tube superheterodyne broadcast and short-wave receiver, operating upon alternating current and employing the high-efficiency 6.3 volt tubes, automatic inter-station noise suppression, and a frequency (wave-band) coverage that permits reception of the short-wave (high-frequency) broadcast programs. The same superheterodyne circuit is used for all reception. The Receiver is equipped with a five-point wave-band switch. The ranges are—

(1) 520 K.C. to 1500 K.C. (3) 3.2 M.C. to 6.0 M.C.
(2) 1.5 M.C. to 4.0 M.C. (4) 5.8 M.C. to 12.0 M.C.
(5) 11.0 M.C. to 23.0 M.C.

The Receiver employs a Philco Type 77 tube for first detector, a Type 76 for oscillator, a Type 78 for first I. F., a Type 78 for second I. F., and a Type 37 for second detector. The automatic interstation noise suppression circuit uses a Type 78, the first A. F., a Type 77. The driver (second A. F.) is a Type 42; the class "A" amplification is accomplished with two Type 42 tubes as triodes; the rectifier is a Type 5-Z-3. The intermediate frequency is 460 kilocycles. The power consumption of Model 16-122 is 130 watts; of Model 16-121, 120 watts.

Table 1—Tube Socket Data*—A. C. Line Voltage 115 Volts

Circuit	1st Det.	Osc.	1st. I. F.	2nd I. F.	2nd Det.	Inter-Station Noise Supr. Circuit	1st A. F.	2nd A. F. (Driver)	Output		Rectifier
Type Tube	77	76	78	78	37	78	77	42	42	42	5-Z-3
Filament Volts—F to F........	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	4.7
Plate Volts—P to K...........	220	53	225	230	0	1.8	130	220	340	340	400
Screen Grid Volts—SG to K....	80	—	80	80	—	1.8	1.8	220	340	340	—
Control Grid Volts—CG to K...	1.6	6.4	0	0	.2	1.6	.4	.6	34	34	—
Cathode Volts—K to F........	4.2	1.9	2.2	2.5	0	0	0	0	0	0	—

* All of the above readings were taken from the underside of the chassis, using test prods and leads, with a suitable A. C. voltmeter for filament voltages, and a high-resistance multi-range D. C. voltmeter for other readings. The *Philco Model 048 All-Purpose Set Tester* is highly recommended for this use. Volume control set at maximum and station selector turned to low frequency end; interstation noise suppression circuit potentiometer turned all the way to the right; and toggle switch (interstation noise suppression circuit) in "ON" ("S") position. Readings taken with a plug-in adapter will NOT be satisfactory.

Note—These values are for Model 16-122. Model 16-121 uses a Type 80 Rectifier Tube.

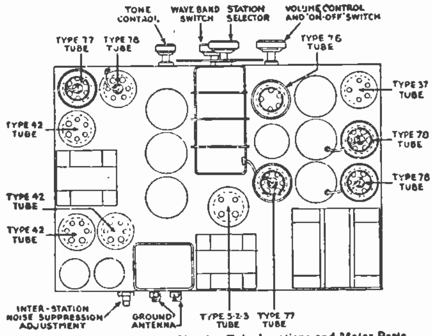
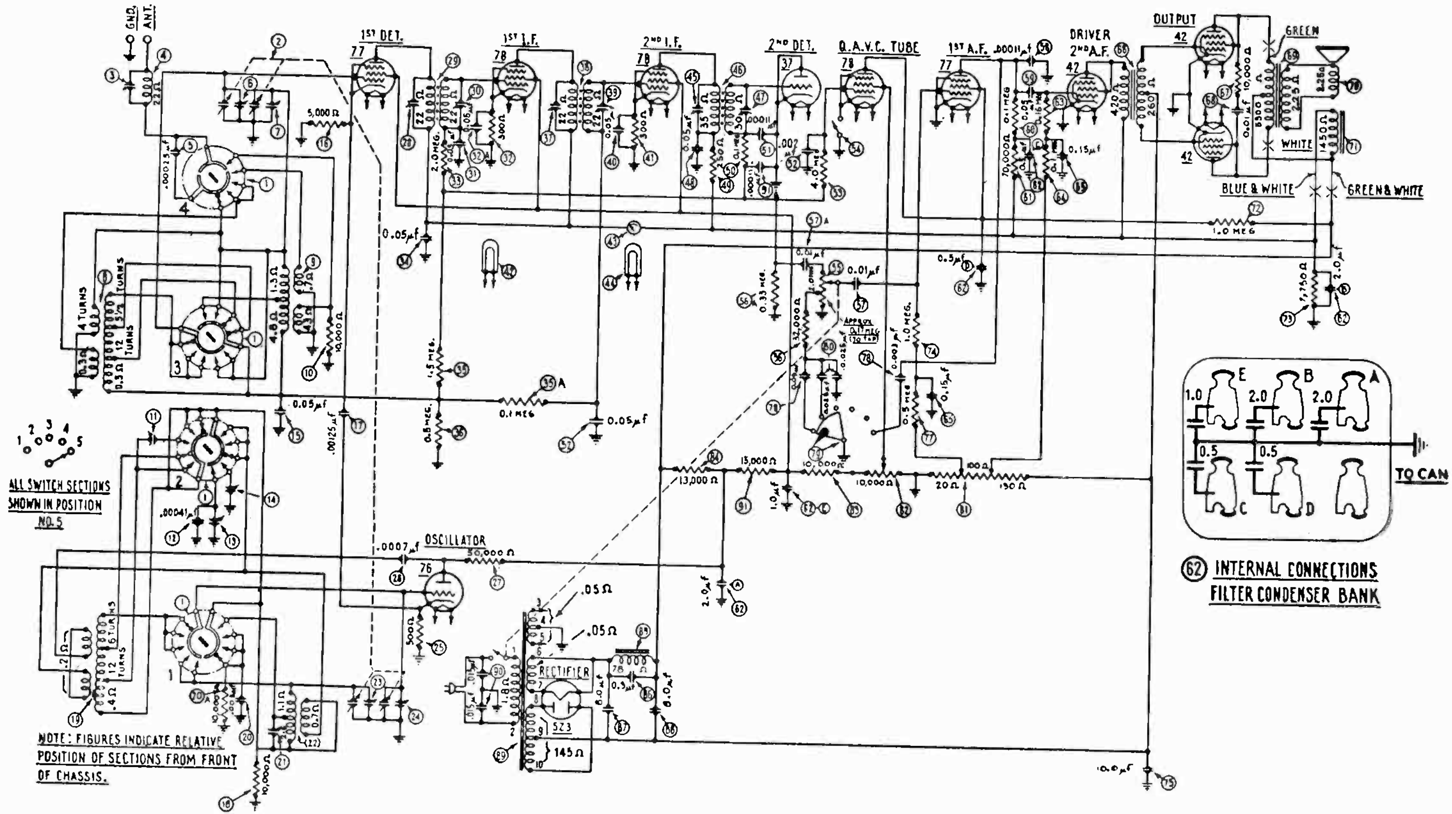


Fig. 1—Top View of Chassis, Showing Tube Locations and Major Parts

Table 2—Power Transformer Data

Terminal	A. C. Volts	Circuit	Color
1—2	105—125	Primary	White
3—5	6.3	Filament	Black
6—7	5.0	Filament of 5-Z-3	Blue
8—10	800	Plates of 5-Z-3	Yellow
4	—	Center Tap of 3—5	Black—Yellow Tracer
9	—	Center Tap of 8—10	Yellow—Green Tracer

Terminal Arrangement of Tube Sockets Viewed from Underside of Chassis



GND.
ANT.
1ST DET.
77
1ST I.F.
78
2ND I.F.
78
2ND DET.
37
Q.A.V.C. TUBE
78
1ST A.F.
77
DRIVER
2ND A.F.
42
OUTPUT
42
42
GREEN
WHITE
BLUE & WHITE
GREEN & WHITE
OSCILLATOR
76
RECTIFIER
5Z3
ALL SWITCH SECTIONS SHOWN IN POSITION NO. 5
NOTE: FIGURES INDICATE RELATIVE POSITION OF SECTIONS FROM FRONT OF CHASSIS.
TO CAN
62 INTERNAL CONNECTIONS FILTER CONDENSER BANK

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SILVERTONE MODELS 1700—7062

GENERAL NOTES: The A.V.C. action can be rendered inoperative, when peaking the I.F. transformers, by shortening Resistors R3 and R4. A preferable method is to use an oscillator with variable output power. The output should be made no greater than is necessary to obtain a satisfactory signal or output meter reading.

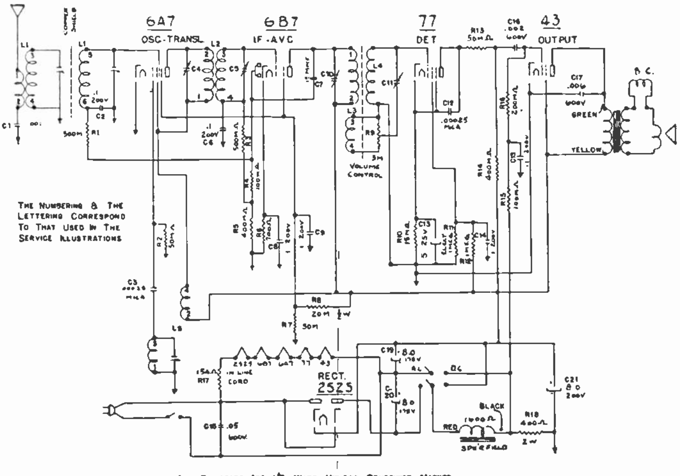
The four tuning condenser adjustments for the I.F. transformers are accessible from the front of the chassis. The I.F. frequency is 175 Kc.

The loudspeaker can be removed for replacement by taking off the 6B7 tube shield and removing the three speaker mounting screws. Be certain that the speaker leads color code, indicated in the schematic, is followed. Improper connection will cause excessive hum due to the hum bucking coil's increasing hum instead of cancelling it out.

Speaker rattle may be due to the cone's being off center. Loosen the center adjusting screw, insert four 1/8 inch wide strips of heavy writing paper between the pole piece and the inside of the voice coil, retighten the adjusting screw, and remove the paper spacing strips.

Increased pickup can be had by splicing the antenna lead to an additional length of wire or to a regular antenna if available.

All metal parts of the chassis (including the AC-DC Switch) are at high potential to ground. DO NOT touch chassis while the line cord is plugged into an outlet.



ALL RESISTORS ARE 1/3 WATT UNLESS OTHERWISE MARKED

TUBE VOLTAGE AND CURRENT CHART

MODELS 1700 - 7062

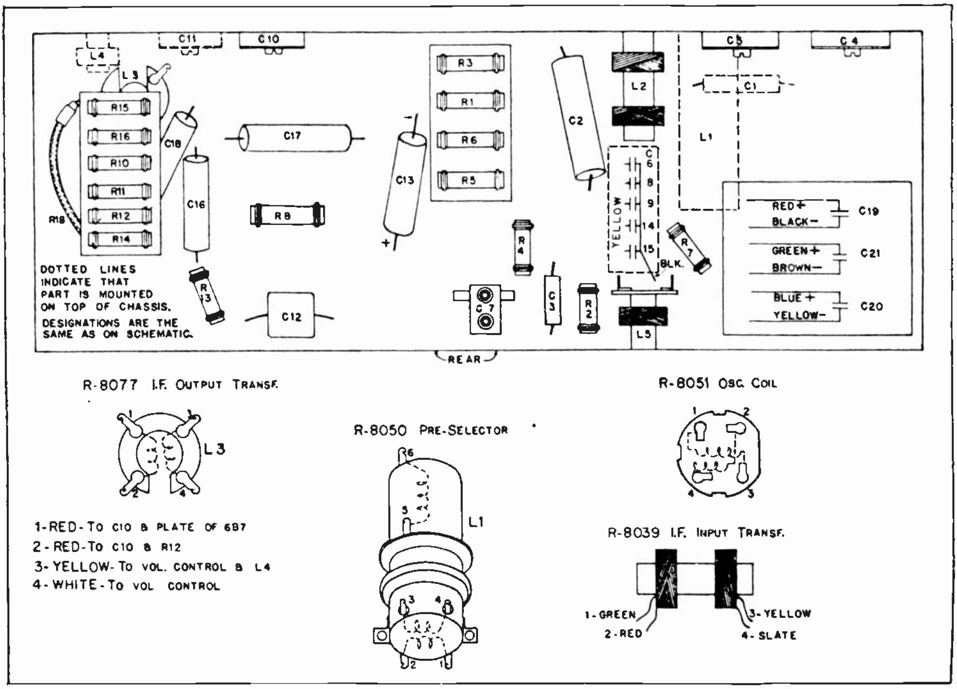
TUBE	PLATE VOLTS	SCREEN VOLTS	GRID VOLTS	PLATE MA	SCREEN MA
6B7 IF-AVC	110	55	-7*	.4	.2
77 Detector	50	22	-1.5	.1	.04
43 Output	100	120	-10*	26	5
6A7 Osc-Transl	Ep=105v EG#4=*	EG#1=-5v Ip=2ma	EG#2=105v Ig#2=1.3ma	EG#3 and 5=55v Ig-#3&5=1.2ma	
25Z5 Rectifier	Plate Current - 40 M.A.per plate				

Speaker Field Voltage = 70 v

Eg=Grid Voltage Ip=Plate Current
Ep=Plate Voltage Ig=Grid Current

* Indicates high series resistor

Tube heaters are in series so that if one burns out, none will light. These measurements were made with a 500 volt, 1000 ohms per volt meter. Power supply 118 volts A.C. Measurements made with set detuned, and speaker field hot. Care should be used when taking readings with a set analyzer as the capacity of the cables may cause circuits to oscillate, giving rise to erratic readings. Usually, touching the finger to grid or plate is sufficient to stop oscillation.



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FADA MODEL 1462 SERIES

VOLTAGE READINGS

No Signal Input—Wave Band Switch—Right

Type of Tube	*Position*	*Plate Volts*	*Plate MA Current*	*Cathode Volts*	*Screen Grid Volts*
6A7	1st Det.-Osc.	121	2.4	3	70
6D6	Int. Freq.	117	5.3	7	117
75	1st Aud.	58*	.1	1	...
	2nd Det.	...	..	..	...
43	2nd Aud.	99	22.0	17	107
37	Spk. Rectifier	...	26.0	..	...
25Z5	"B" Rectifier	...	42.0 TOTAL	..	...

6A7 Osc. Anode Voltage—100 and Current—3.3 ma.

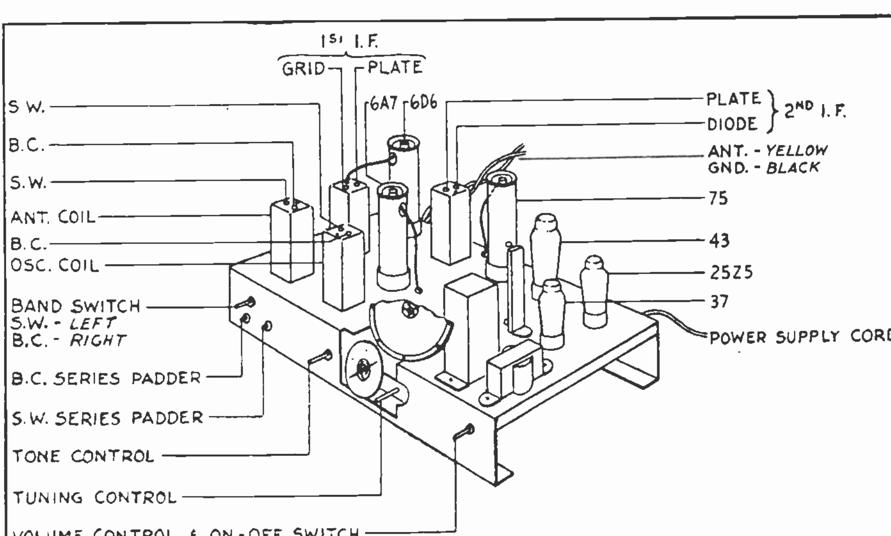
*Readings taken with 1,000 ohm per volt meter; not indicative of effective voltages.

* * * * *

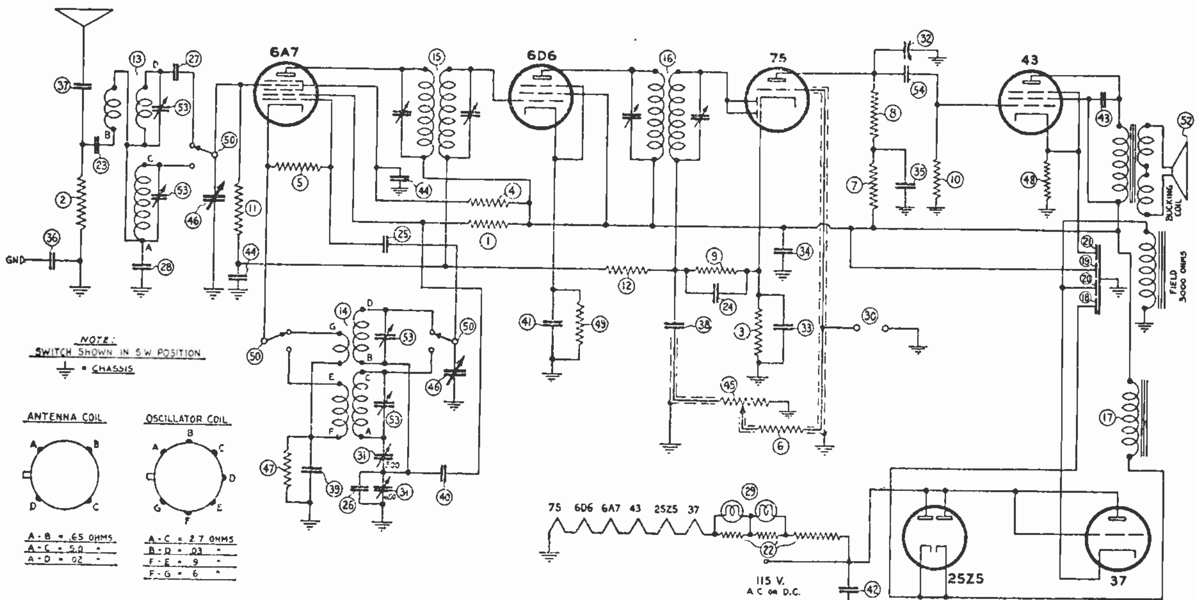
Voltage Across Electrolytic Condenser: 1st Section 139; 2nd Section 124.
Voltage across speaker field 80 volts; voltage across filter choke 15 volts.

D. C. Resistance Values

Speaker input transformer; Primary 330. ohms; Secondary .42 ohms.
Speaker field coil; Primary 3,000. ohms.
Speaker voice coil; Primary 3. ohms.
Speaker bucking coil; Primary .38 ohms.



FA-1462



REF No	PART No	DESCRIPTION	REF No	PART No	DESCRIPTION	REF No	PART No	DESCRIPTION
1	30.1	CARB RES - 5,000 OHMS - ½ W ± 10%	23	15.2	MICA COND - .0005 MF. ± 10%	45	50.1	VOLUME CONTROL - ½ MEG.
2	30.31	" " 10,000 " " " 20%	24	15.2	" " .0005 " "	46	25.2	VARIABLE COND
3	30.31	" " 10,000 " " " "	25	15.3	" " .0001 " "	47	130.2	WIRE RES. - 350 OHMS ½ W. FX
4	30.7	" " 15,000 " " " 10%	26	15.19	" " .0015 " "	48	130.1	" " 625 " " " "
5	30.3	" " 50,000 " " " "	27	15.5	" " .002 " 3%	49	130.3	" " " 1000 " " " "
6	30.26	" " 50,000 " " " 20%	28	15.6	" " .0025 " "	50	45.1	BAND SWITCH
7	30.26	" " 50,000 " " " "	29	120.1	PILOT LIGHTS 6-8 V .25 A.	51		ON-OFF SW ON VOL CONT (45)
8	30.20	" " 250,000 " " " "	30	125.1	PHONO JACK	52	105.1	SPEAKER - 3,000 OHMS
9	30.23	" " 500,000 " " " "	31	25.1	PADDING COND - 650 - 500 MMF	53		MIN. ADJ. ON COILS
10	30.23	" " 500,000 " " " "	32	55.1	TONE CONTROL	54	10.4	TUBULAR COND - .01 MF. - 200 V
11	30.22	" " 1 MEG " " "	33	10.12	TUBULAR COND - 1.0 MF. - 200 V			
12	30.22	" " 1 " " " "	34	10.2	" " .1 " " "			
13	2026	ANTENNA COIL	35	10.2	" " .1 " " "			
14	3116	OSCILLATOR "	36	10.3	" " .006 " 400 "			
15	3379	1ST I F "	37	10.4	" " .01 " 200 "			
16	3880	2ND I F "	38	10.4	" " .01 " " "			
17	40.1	CHOKE - 300 OHMS	39	10.5	" " .05 " " "			
18	20.1	ELECTRO COND BLOCK - 16 MF 400 V	40	10.5	" " .05 " " "			
19	20.1	" " " 16 " 100 "	41	10.5	" .05 " " "			
20	20.1	" " " " 4 " 100 "	42	10.5	" " .05 " " "			
21	20.1	" " " 4 " 25 "	43	10.10	" " .01 " 400 "			
22	115.1	LINE RESISTOR - 180 - 38 - 36 OHMS	44	10.6	" " DUAL .05 " 200 "			

1ST I.F. TRANS

PRI. - 14.5 OHMS
SEC. - 14.5 "

2ND I.F. TRANS

PRI. - 14.5 OHMS
SEC. - 14.5 "

I.F. = 456 K.C.

FADA RADIO & ELECTRIC CO
LONG ISLAND CITY, N.Y.

MODEL 1462

DRAWN BY: CD
DATE: 7-17-35
CHECKED BY:
NO. RFS

14 CIRCUIT DIAGRAMS EACH WITH TESTING INFORMATION

23SS

SERVICE MANUAL

NATIONAL RADIO INSTITUTE
EST. 1914
WASHINGTON, D.C.

FOREWORD

This booklet is one of a series of service manuals which contain service sheets giving typical information on radio receivers. Each service sheet shows the circuit diagram in the usual symbolic form for that radio receiver. Many of the service sheets will contain such special service information as space will permit.

By studying each service sheet, you will gradually develop the ability to read any diagram or manufacturer's service manual and learn the usual methods of set adjustment. Enough typical receivers have been selected to give you quickly a good insight to the entire radio problem.

In reading a circuit diagram, learn to trace independently the power supply and the signal circuits. Then locate the special control circuits, such as the automatic volume controls, tuning indicators, manual volume controls, etc. Detailed information on power, supply, signal and control circuits, as well as set servicing, is given in the course, to which reference should be made.

J. E. SMITH

FM3M341

Printed in U. S. A.

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Service Sheet
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Arvin Model 44C, Chassis RE46

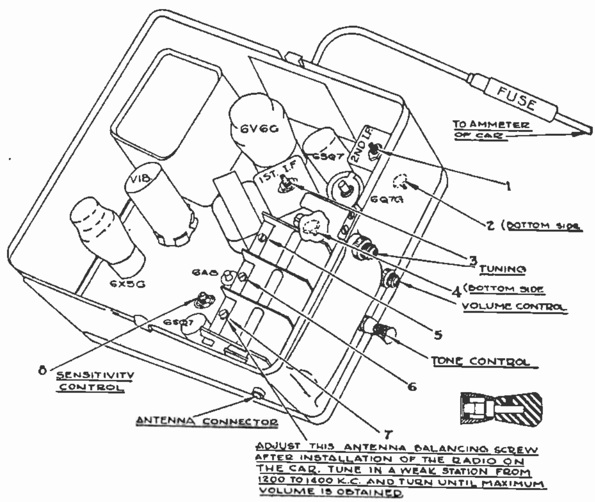
BALANCING INSTRUCTIONS

All sensitivities are given for 1 watt output=1.73 V across speaker voice coil.

SPECIAL NOTE: The intermediate frequency transformers in this receiver are coupled so as to secure flat top characteristics and provide semi-high fidelity reception of radio stations. These transformers may be balanced with a standard signal generator and output meter as follows:

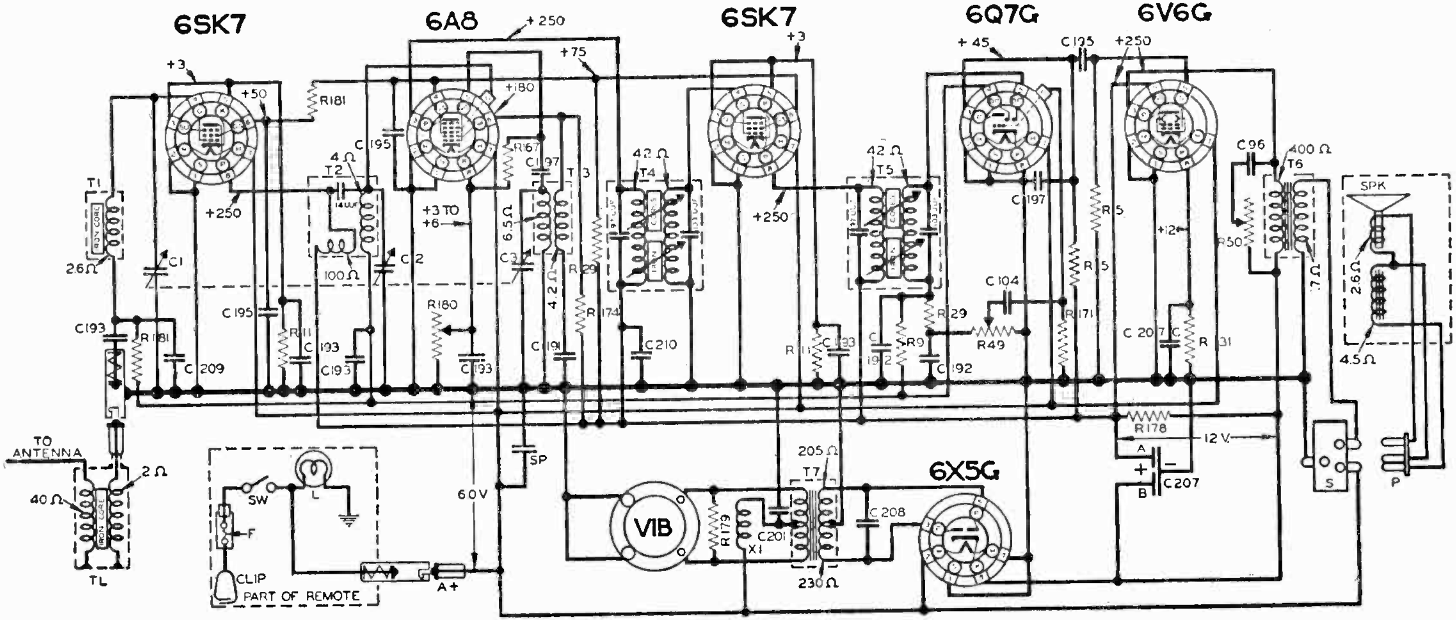
Feed a signal of 170 kc into the grid of the 6A8 tube through .002 mfd. capacity, connect a 30,000 ohm resistor across the primary of the second I.F. transformer (P to B+) and adjust screw No. 1 for maximum output. Disconnect the resistor and place it across the secondary of the same transformer and adjust screw No. 2.

Then connect the resistor across the primary of the 1st I.F. transformer and adjust screw No. 3 and then after placing the resistor across the secondary, adjust screw No. 4.



Operation No.	Connect Bal. Oscillator To	Bal. Oscillator Frenquency	Adjust Padder No.	Dial Setting	Sensitivity
1 (See note above)	6A8 Grid	170 kc	1, 2, 3 & 4	Condenser Closed	700 uv
2	Ant. Coupler Through 20 uuf	1570 kc	5	Condenser Open	—
3	Through 20 uuf	1400 kc	6 & 7	1400 kc	5 uv
*4	Through 20 uuf	600 kc	8	600 kc	3.5 uv

*Operation No. 4 adjust bias on 6A8 to obtain 5 uv. sensitivity; for metropolitan areas this sensitivity may be set as low as 10 uv. and in mountainous areas as high as 1 uv. to secure the most satisfactory reception.



RESISTORS

R5	500,000 ohm, 1/4 watt
R9	1,000 ohm, 1/4 watt
R11	2,000 ohm, 1/4 watt
R29	50,000 ohm, 1/4 watt
R31	260 ohm, 1/2 watt
R49	500,000 ohm
R50	100,000 ohm
R167	60,000 ohm, 1/4 watt
R171	15,000 ohm, 1/4 watt
R174	30,000 ohm, 1/4 watt
R178	1200 ohm, 1 watt
R179	100 ohm, 1/4 watt
R180	2000 ohm
R181	100,000 ohm, 1/4 watt

CONDENSERS

C96	.05 mfd. 600 v
C104	.01 mfd. 200 v
C191	.01 mfd. 400 v
C192	.00025 mfd. 600 v
C193	.05 mfd. 200 v
C195	.05 mfd. 400 v
C197	.0001 mfd. 600 v
C201	.5 mfd. 150 v
C207A	10 mfd. 400 v
C207B	10 mfd. 400 v
C207C	20 mfd. 25 v
C208	.005 mfd. 1,600 v
C209	.001725 mfd. 600 v
C210	.1 mfd. 400 v

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Arvin Model 89 and 91, Chassis RE27

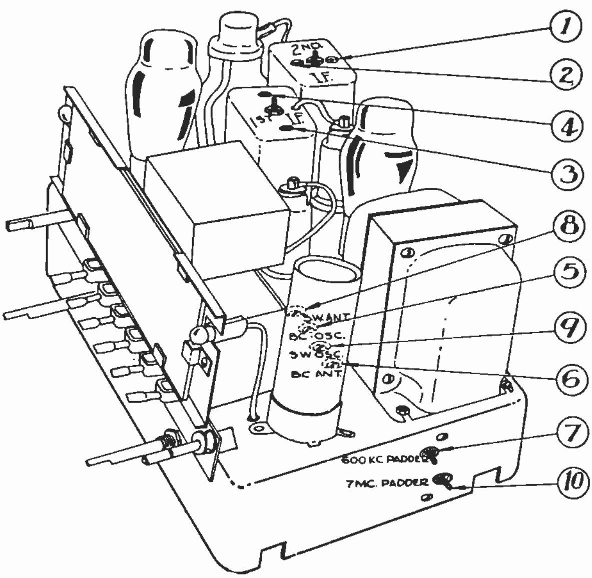
Balancing Instructions

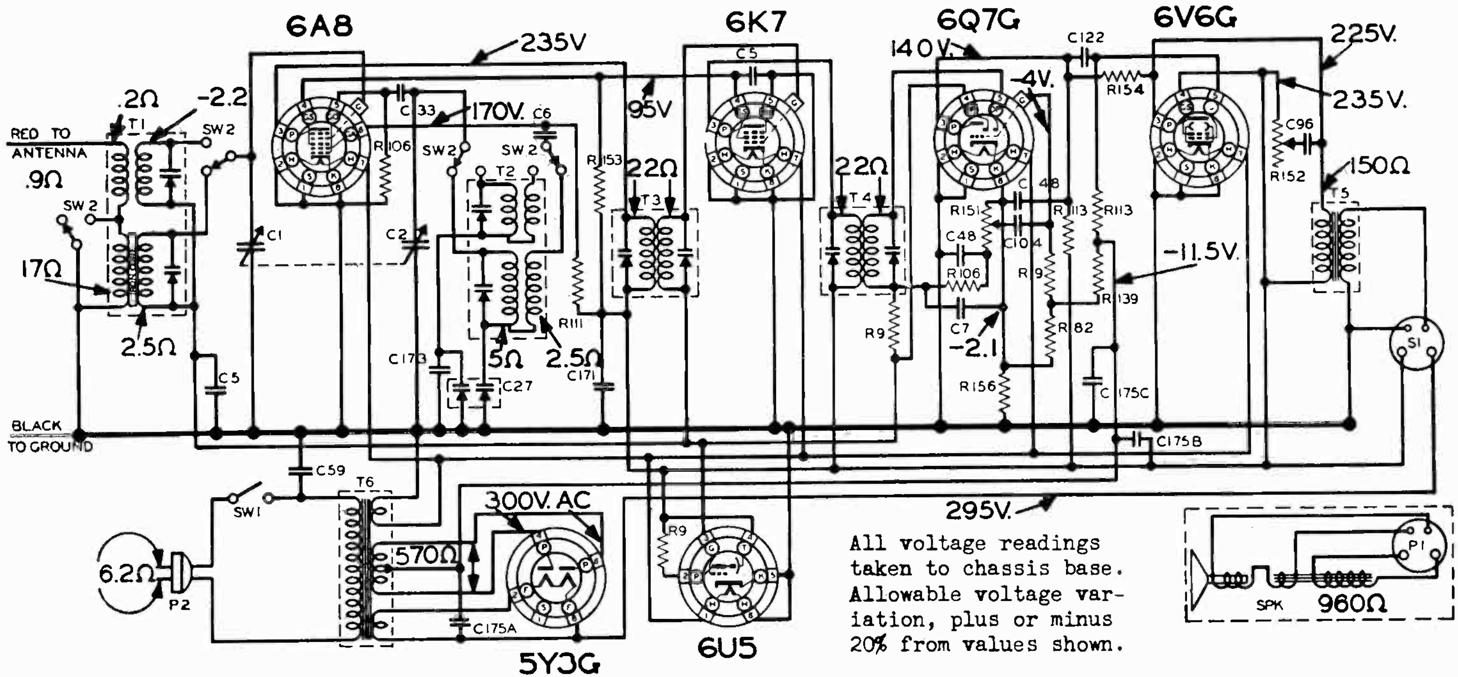
All sensitivities given for 200 milliwatts output—.78 V across voice coil

Operation No.	Connect Sig. Generator To	Input Frequency	Adjust Padder No.	Dial Setting	Band Switch Position	Sensitivity
1	6A8 Grid	455 KC	1, 2, 3, & 4	600 KC	Broadcast	70 uv
*2	Antenna Wire	1400 KC	5	1400 KC	Broadcast	.....
3	Antenna Wire	1400 KC	6	1400 KC	Broadcast	25 uv
**4	Antenna Wire	600 KC	7	600 KC	Broadcast	40 uv
5	Antenna Wire	15 MC	8	15 MC	Short Wave	.....
6	Antenna Wire	15 MC	9	15 MC	Short Wave	120 uv
7	Antenna Wire	7 MC	10	7 MC	Short Wave	150 uv

* Dial pointer should be parallel with horizontal line across center of dial with tuning condenser in closed position (maximum capacity) before proceeding with adjustments.

** After balancing 600 KC padder, return and recheck the adjustments of padders 5 & 6.





All voltage readings taken to chassis base. Allowable voltage variation, plus or minus 20% from values shown.

RESISTORS

R9	1,000,000 ohm, 1/4 watt
R82	30 ohm, 1/4 watt
R106	50,000 ohm, 1/4 watt
R111	20,000 ohm, 1/4 watt
R113	250,000 ohm, 1/4 watt
R139	100 ohm, 1 watt
R153	30,000 ohm, 1/2 watt
R154	1,500,000 ohm, 1/4 watt
R156	35 ohm, 1/4 watt

CONDENSERS

C6	.002 mfd. 600 v
C7	.0001 mfd. 600 v
C122	.01 mfd. 400 v
C104	.01 mfd. 200 v
C48	.00025 mfd. 600 v
C27	Series Padder
C5	.05 mfd. 200 v
C33	.00005 mfd. 600 v.
C96	.05 mfd. 600 v
C171	.1 mfd. 400 v
C173	.003 mfd. 600 v
C175 A, B & C	10-10 mfd. 450 v 20 mfd. 25 v
C59	.01 mfd. 400 v

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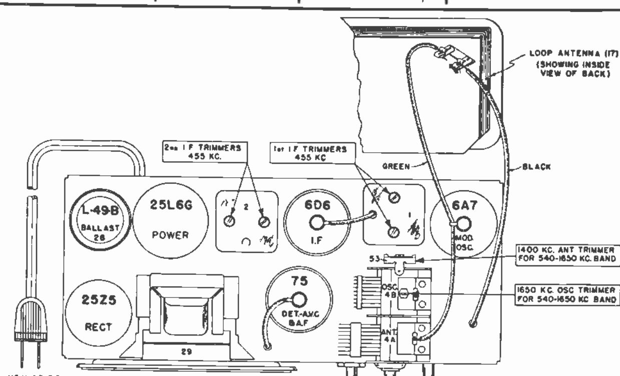
SENTINEL MODEL 163UL
Alignment Procedure In Tabulated Form

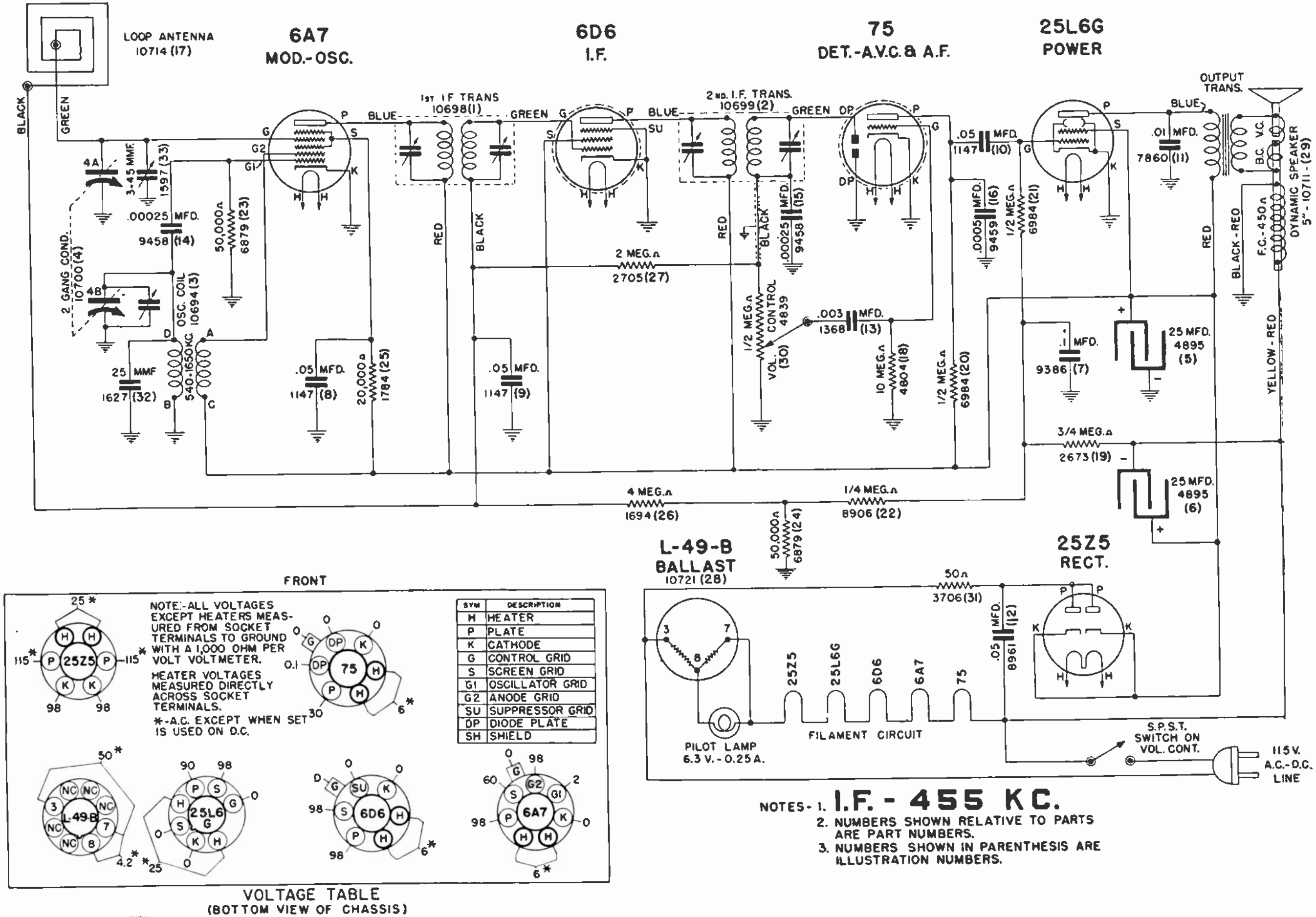
IMPORTANT: BEFORE ALIGNING, PLACE LOOP ANTENNA IN SAME APPROXIMATE POSITION IT WILL BE IN WHEN SET IS IN CABINET AND BACK ATTACHED.

When adjusting 1650 K.C. oscillator trimmer and 1400 K.C. antenna trimmer, couple test oscillator to set loop by placing lead from high side of test oscillator on top of or near set loop. Be sure that neither the loop or test oscillator lead moves during alignment.

DO NOT ATTACH LOW SIDE OF TEST OSCILLATOR TO RECEIVER—LEAVE UNCONNECTED.

Set receiver dial to:	TEST OSCILLATOR: Adjust test oscillator frequency to:	TEST OSCILLATOR: Use dummy antenna in series with output of test oscillator consisting of:	TEST OSCILLATOR: Attach output of test oscillator to:	Refer to parts layout diagram for location of trimmers mentioned below—and:
Any point where no interfering signal is received	455 K. C.	.02 MFD condenser	High side to grid terminal of 6A7 tube DO NOT REMOVE CAP.	Adjust each of the second I. F. transformer trimmers for maximum output—then adjust each of the first I. F. trimmers for maximum output.
Exactly **(1)** 1650 K. C.	Exactly 1650 K. C.	None	Lay lead on top of or close to loop	Adjust 1650 K. C. oscillator trimmer for maximum output.
Approx. **(2)** 1400 K. C.	Exactly 1400 K. C.	None	Lay lead on top of or close to loop	Adjust 1400 K. C. antenna trimmer for maximum output.





SYM	DESCRIPTION
H	HEATER
P	PLATE
K	CATHODE
G	CONTROL GRID
S	SCREEN GRID
G1	OSCILLATOR GRID
G2	ANODE GRID
SU	SUPPRESSOR GRID
DP	DIODE PLATE
SH	SHIELD

NOTES- 1. I.F. - 455 KC.
2. NUMBERS SHOWN RELATIVE TO PARTS ARE PART NUMBERS.
3. NUMBERS SHOWN IN PARENTHESIS ARE ILLUSTRATION NUMBERS.

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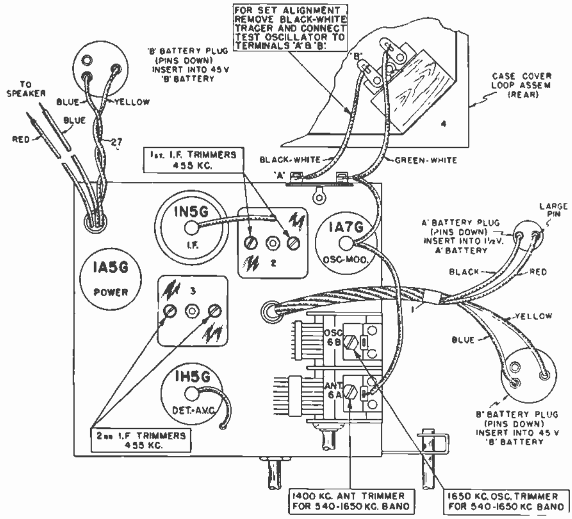
SENTINEL MODEL 178BL

Alignment Procedure In Tabulated Form

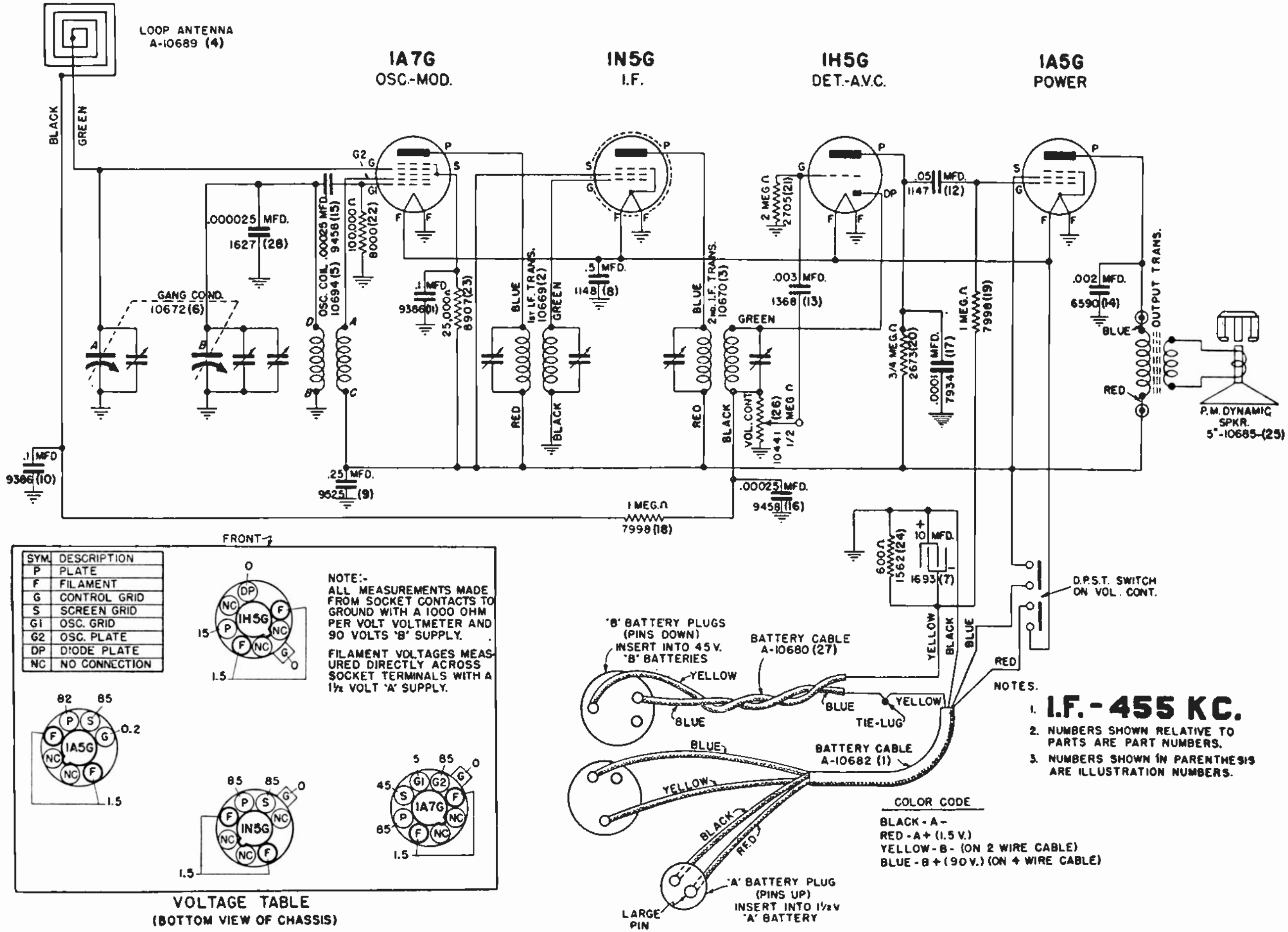
BEFORE ALIGNING, PLACE LOOP ANTENNA AND "A" AND "B" BATTERIES IN SAME APPROXIMATE POSITION THAT THEY WILL BE IN WHEN SET IS IN CABINET AND BACK CLOSED.

When adjusting 1650 kilocycle oscillator trimmer and 1400 kilocycle antenna trimmer, place test oscillator in series with set loop by:

1. Remove black with white tracer wire used to connect loop antenna to chassis.
2. Attach test oscillator to terminals marked "A" and "B" on parts layout diagram.



Set receiver dial to:	TEST OSCILLATOR: Adjust test oscillator frequency to:	TEST OSCILLATOR: Use dummy antenna in series with output of test oscillator consisting of:	TEST OSCILLATOR: Attach output of test oscillator to:	Refer to parts layout diagram for location of trimmers mentioned below—and:
Any point where no interfering signal is received	455 K. C.	.02 MFD condenser	High side to grid terminal of IA7G tube Low side to chassis DO NOT REMOVE CAP.	Adjust each of the second I. F. transformer trimmers for maximum output—then adjust each of the first I. F. trimmers for maximum output.
(1) Exactly 1650 K. C.	Exactly 1650 K. C.	None	Attach in series with "A" and "B" Loop Terminals	Adjust 1650 K. C. oscillator trimmer for maximum output.
(2) Approx. 1400 K. C.	Exactly 1400 K. C.	None	Attach in series with "A" and "B" Loop Terminals	Adjust 1400 K. C. antenna trimmer for maximum output.



SYM.	DESCRIPTION
P	PLATE
F	FILAMENT
G	CONTROL GRID
S	SCREEN GRID
G1	OSC. GRID
G2	OSC. PLATE
DP	DIODE PLATE
NC	NO CONNECTION

NOTE:-
ALL MEASUREMENTS MADE FROM SOCKET CONTACTS TO GROUND WITH A 1000 OHM PER VOLT VOLTMETER AND 90 VOLTS 'B' SUPPLY.

FILAMENT VOLTAGES MEASURED DIRECTLY ACROSS SOCKET TERMINALS WITH A 1½ VOLT 'A' SUPPLY.

VOLTAGE TABLE
(BOTTOM VIEW OF CHASSIS)

NOTES.

1. **I.F. - 455 KC.**
2. NUMBERS SHOWN RELATIVE TO PARTS ARE PART NUMBERS.
3. NUMBERS SHOWN IN PARENTHESIS ARE ILLUSTRATION NUMBERS.

COLOR CODE

BLACK - A -
RED - A + (1.5 V.)
YELLOW - B - (ON 2 WIRE CABLE)
BLUE - B + (90 V.) (ON 4 WIRE CABLE)

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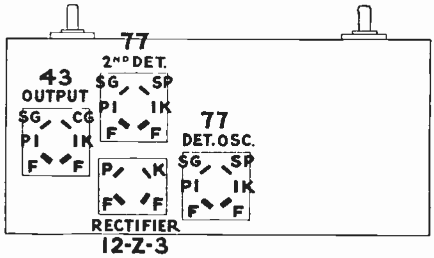
NATIONAL RADIO INSTITUTE, WASHINGTON, D.C.

PHILCO MODEL 53

The Philco Radio Model 53 is a four tube superheterodyne, employing the new Philco high efficiency tubes with pentode output and a permanent Field Dynamic Speaker. The set uses a Philco Type 77 tube as a first detector and oscillator, a Type 77 tube as second detector, a Type 43 tube as output, and a Type 12-Z-3 as a rectifier. The set will operate universally on either alternating or direct current, 105-125 Volts. The intermediate frequency for tuning the I.F. transformer is 450 kilocycles. The power consumption on both A. C. and D. C. is approximately 45 watts.



F	Filament	SG	Screen Grid	K	Cathode
P	Plate	CG	Control Grid	SP	Suppressor Grid

Fig. 1—Tube Sockets, Under Side of Chassis

Table 1—Tube Socket Data*—A.C. Line Voltage 115 Volts

Circuit	Det. Osc.	2nd Det.	Out-put	Recti-fier
Type Tube	77	77	43	12-Z-3
Filament—Total 49.9 Volts A.C. Refer to Note.				
Plate Volts—P to K.........	95	15	94	112
Screen Grid Volts—SG to K...	94	34	102	....
Control Grid Volts—CG to K..	7	4	4	...
Cathode Volts—K to F... ...	18	12	10	112

NOTE:—Refer to Fig. 3. Due to filaments in series, test with suitable A. C. voltmeter across the two points indicated.

*All of the readings above in Table 1 were taken from the under side of chassis, using test prods and leads with a suitable A. C. voltmeter for filament voltage and a high resistance, multi-range D. C. voltmeter for all other readings. Volume control at maximum and station selector set for 550 KC. Readings taken with a radio set tester and plug-in adapter will not be satisfactory.

Table 2—Tube Socket Data*—D.C. Line Voltage 120 Volts

Circuit	Det. Osc.	2nd Det.	Out-put	Recti-fier
Type Tube	77	77	43	12-Z-3
Filament—Total 51 Volts D.C.—Refer to Note.				
Plate Volts—P to K...	95	14	94	10
Screen Grid Volts—SG to K...	93	34	100	....
Control Grid Volts—CG to K.	8	3	4	....
Cathode Volts—K to F.......	7-14	6-12	3-26	58-73

NOTE:—Refer to Fig. 3. Due to filaments in series, test with suitable D.C. Voltmeter across the two points indicated.

*All of the readings above in Table 2 were taken from the under side of chassis, using test prods and leads with a suitable high resistance, multi-range D. C. voltmeter for all readings. Volume control at maximum and station selector set for 550 KC. Readings taken with a radio set tester and plug-in adapter will not be satisfactory.

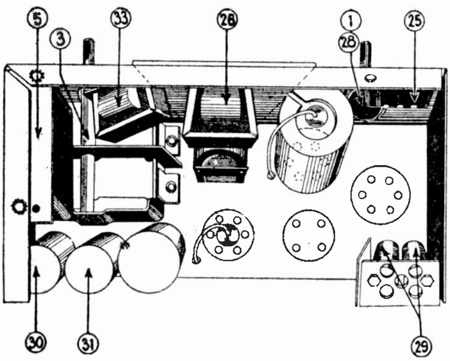


Fig. 2—Top View of Chassis, Showing Parts

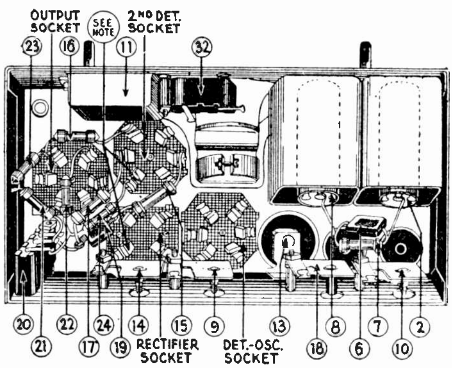


Fig. 3—Bottom View of Chassis, Showing Parts
NOTE:—Place test prods across the two points indicated to test filament voltage.

Model 53

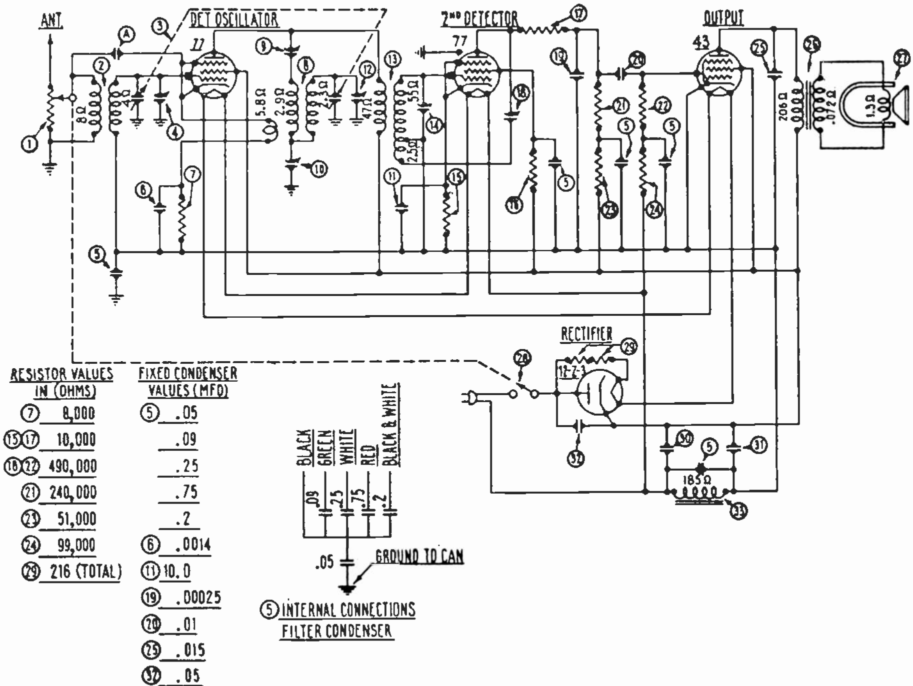


Figure 4—Schematic Wiring Diagram
NOTE Ⓐ—This capacity obtained by pair twisted wires

Replacement Parts for Model 53

No. on Figs. 2, 3 and 4	Description	Part No.
①	Volume Control	33-5001
②	Antenna Transformer	32-1000
③	Tuning Condenser Assembly	31-1000
④	Compensating Condenser (Part of Tuning Condenser Assembly)	
⑤	Filter Condenser Block (.05-.09-.25-.75-.2 Mfd.)	30-4000
⑥	Condenser (.0014 Mfd.)	7007
⑦	Resistor (8,000 ohms) Gray–Black–Red	5838
⑧	Oscillator Transformer	32-1001
⑨	Compensating Condenser (I.F. Primary)	04000-A
⑩	Compensating Cond. (Low Frequency)	04000-S
⑪	Condenser (10.0 Mfd.)	7440
⑫	Compensating Condenser (Part of Tuning Condenser Assembly)	
⑬	I.F. Transformer	32-1002
⑭	Compensating Cond. (I.F. Secondary)	04000-A
⑮	Resistor (10,000 ohms) Brown–Black–Orange	4412
⑯	Resistor (490,000 ohms) Yellow–White–Yellow	4517
⑰	Resistor (10,000 ohms) Brown–Black–Orange	4412
⑱	Compensating Condenser (Regeneration)	04000
⑲	Condenser (.00025 Mfd.)	3082
⑳	Condenser (.01 Mfd.)	3903-AM
㉑	Resistor (240,000 ohms) Red–Yellow–Yellow	4410
㉒	Resistor (490,000 ohms) Yellow–White–Yellow	4517
㉓	Resistor (51,000 ohms) Green–Brown–Orange	4518
㉔	Resistor (99,000 ohms) White–White–Orange	4411
㉕	Condenser (.015 Mfd.)	3793-S
㉖	Output Transformer	32-7000
㉗	Voice Coil and Cone Assembly	36-3000
㉘	A. C. Switch (Part of Volume Control Assembly)	33-5001
㉙	Resistors (2 Wire Wound–108 ohms each)	33-3000, 33-3001
㉚	Electrolytic Condenser (8 Mfd.)	30-2000
㉛	Electrolytic Condenser (8 Mfd.)	30-2000
㉜	Condenser (.05 Mfd.)	3615-E
㉝	Filter Choke	32-7000
	Tube Shield	7172
	Knobs (Both Controls)	03064
	Four Prong Socket	7544
	Six Prong Socket	7547
	Pointer for Station Selector	28-1019
	Dial	28-1021

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NATIONAL RADIO INSTITUTE, WASHINGTON, D.C.

PHILCO MODEL 81

The Philco Radio Model 81 is a four tube superheterodyne receiver combining Standard broadcast and police reception and employs the new Philco high efficiency tubes with pentode output and electro dynamic speaker. The same superheterodyne circuit is used for Standard broadcast and police reception. The intermediate frequency for tuning the I. F. transformer is 460 kilocycles. The power consumption of the Model 81 is 46 watts.

Table 1—Tube Socket Data*
Power Line Voltage 115 Volts

Circuit	Det. Osc.	2nd Det.	Output	Rectifier
Type Tube	77	77	42	80
Filament Volts–F to K	6.3	6.3	6.3	5.0
Plate Volts–P to K	240	75	240	425
Screen Grid Volts–SG to K	85	40	250	..
Control Grid Volts–CG to K	5.6	.6	2.3	..
Cathode Volts–K to F	24.5	16	16.2	..

Table 2—Power Transformer Data

Terminal	A. C. Volts	Circuit	Color
1–2	105–125	Primary	White
3–5	6.3	Filament	Black
6–7	5.0	Filament of 80	Blue
8–10	630	Plates of 80	Yellow
4	..	Center Tap of 3-5	Black-Yellow Tracer
9	..	Center Tap of 8-10	Yellow-Green Tracer

*All of the above readings were taken from the underside of the chassis, using test prods and leads with a suitable A. C. voltmeter for filament voltages and a high resistance multirange D. C. voltmeter for all other readings. Volume control at maximum and station selector turned to low frequency end. Readings taken with a radio set tester and plug in adapter will not be satisfactory.

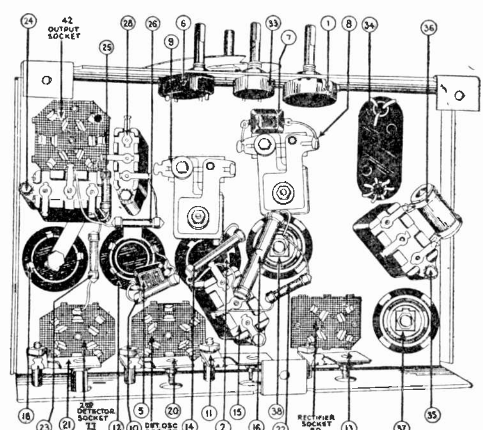
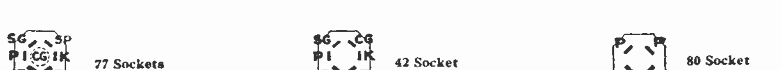


Fig. 1—Parts Diagram



Terminal Arrangement of Tube Sockets Viewed from Under Side of Chassis.

PHILCO MODEL 81

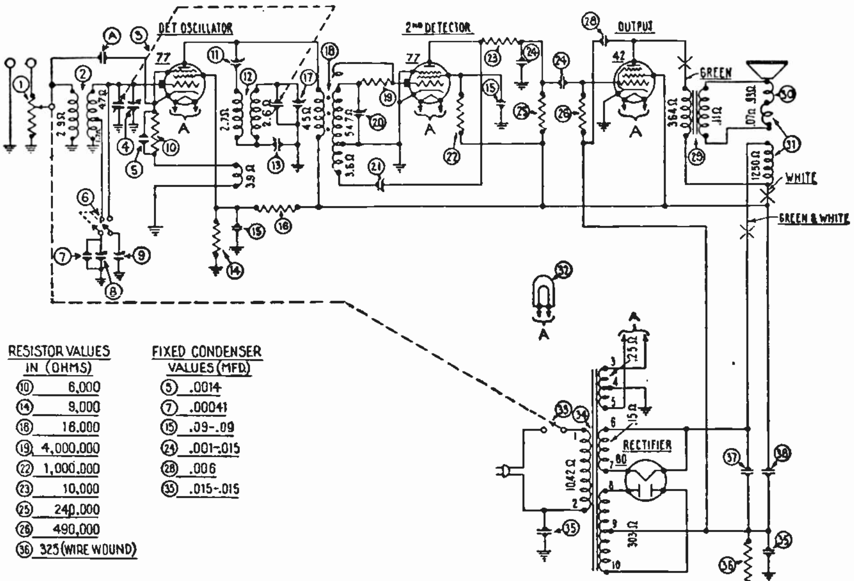


Fig. 2—Schematic Wiring Diagram

Note (A)—This capacity obtained by pair twisted wires.

REPLACEMENT PARTS MODEL 81

No. on Figs.	Description	Part No.	List Price
(1)	Volume Control*	33-5002	.75
(2)	Antenna Transformer	32-1030	.50
(3)	Tuning Cond. Assembly	31-1006	
(4)	Compensating Condenser (Part of (3))		
(5)	Cond. (Red and Black)	7007	.25
(6)	Frequency Switch	42-1000	
(7)	Cond. (Orange and Yellow)	30-1000	.20
(8)	Compensating Condenser	04000-S	.25
(9)	Compensating Condenser	04000-X	.16
(10)	Resistor (Blue-Black-Red)	7352	.25
(11)	Compensating Condenser (I.F. Primary)	04000-A	.12
(12)	Oscillator Coil	32-1031	.75
(13)	Compensating Condenser (Low Frequency)	04000-S	.25
(14)	Resistor (White-Black-Red)	7501	.25
(15)	Condenser	4989-B	.22
(16)	Resistor (Brown-Blue-Orange)	7500	.40
(17)	Compensating Condenser (Part of (3))		
(18)	I.F. Transformer	06100	1.25
(19)	Resistor (Mounted on I.F. Transformer)	6010	.25
(20)	Compensating Condenser (I.F. Secondary)	04000-D	.10
(21)	Compensating Condenser	04000	.16
(22)	Resistor (Brown-Black-Green)	4409	.25
(23)	Resistor (Brown-Black-Orange)	4412	.25
(24)	Condenser (Double)	7762-B	.20
(25)	Resistor (Red-Yellow-Yellow)	4410	.25
(26)	Resistor (Yellow-White-Yellow)	4517	.25
(28)	Condenser	7625-B	.12
(29)	Output Transformer	2660	1.25
(30)	Voice Coil and Cone Assembly	02861	.60
(31)	Speaker Field and Bucking Coil (with Pot)	02667	2.00
(32)	Pilot Light	6608	.14
(33)	"On-Off" Switch*	6416-W	.40
(34)	Power Transformer—50-60 Cycles	7421	2.75
	Power Transformer—25-40 Cycles	7422	4.00
	Power Transformer—50-60 Cycles, 250 Volts	7423	2.75
(35)	Condenser (Double)	3793-R	.25
(36)	Resistor (Wire Wound)	7465	.12
(37)	Electrolytic Condenser (8 Mfd.)	7558	1.25
(38)	Electrolytic Condenser (4 Mfd.)	7467	1.25
	Bezel	7417	
	Tube Shield	7172	.12
	Knob (Large)	03063	.08
	Knob (Small)	03064	.06
	Knob Spring	5262	.35 per C
	Grid Clip	4897	.30 per C
	Four Prong Socket Assembly	5026	.08
	Six Prong Socket Assembly	6417	.10
	Chassis Mounting Screw	W-567	2.40 per C
	Chassis Mounting Washer	W-315	.40 per C
	Pilot Lamp Shield	5760	

*On later production (run No. 3 and above, rubber stamped in a star on back of chassis) volume control (1) and on-off switch (33) was combined. This new volume control and on-off switch is Part Number 7439.

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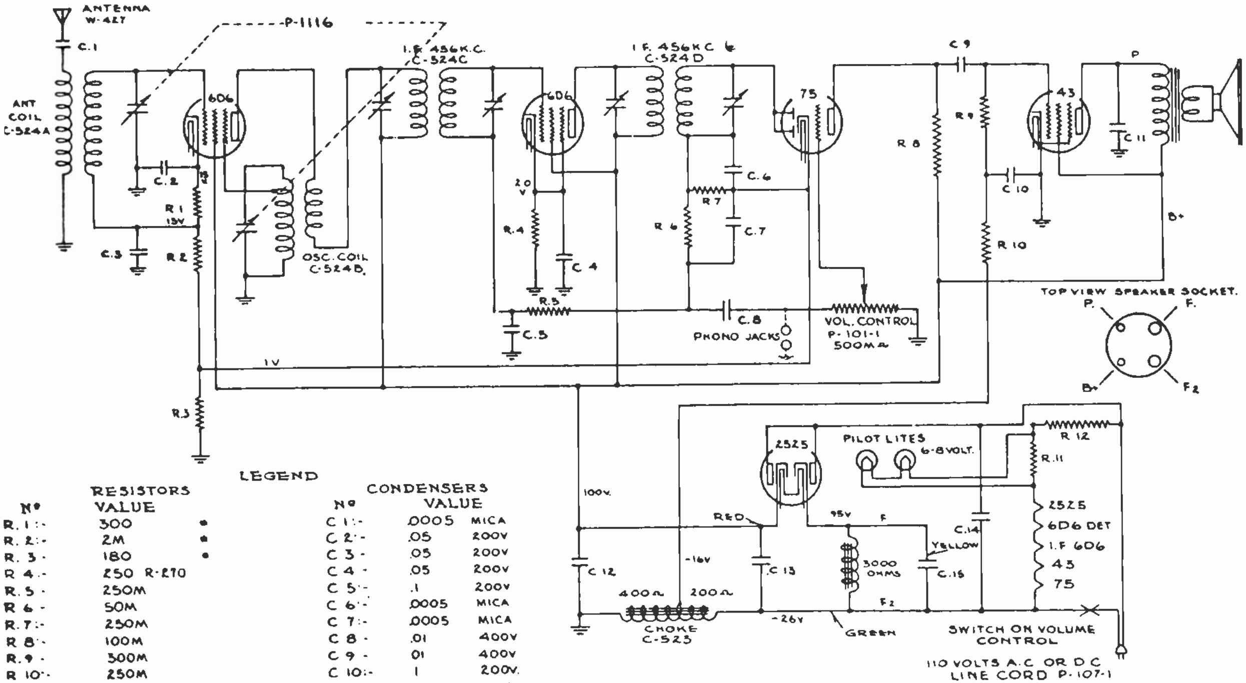
ZENITH MODEL 801



LEGEND

RESISTORS

Nº	VALUE	
R. 1	300	*
R. 2	2M	*
R. 3	180	*
R 4	250 R-270	
R. 5	250M	
R 6	50M	
R. 7	250M	
R 8	100M	
R. 9	300M	
R 10	250M	
R 11	40 500M A. 0 36W P-106-1	
R 12	126 IN CORD P107-1	

CONDENSERS

Nº	VALUE	
C 1	.0005	MICA
C 2	.05	200V
C 3	.05	200V
C 4	.05	200V
C 5	.1	200V
C 6	.0005	MICA
C 7	.0005	MICA
C 8	.01	400V
C 9	.01	400V
C 10	.1	200V.
C 11	.025	300
C 12	5.0 MFD.	C-525D
C 13	25.0 MFD.	*
C 14	.1	400V.
C 15	5.0 MFD	*

NOTE

* R 1, R. 2 & R 3 IN ONE UNIT PART NUMBER R-268.
* C. 13 AND C. 15 IN ONE UNIT PART NUMBER C-525-C

NUMBERS PREFIXED BY LETTERS ARE PARTS.
VOLTAGES TAKEN FROM POINTS INDICATED TO CHASSIS GROUND. VOLUME CONTROL ON FULL MEASURED ON A C CURRENT.

SERVICE NOTES

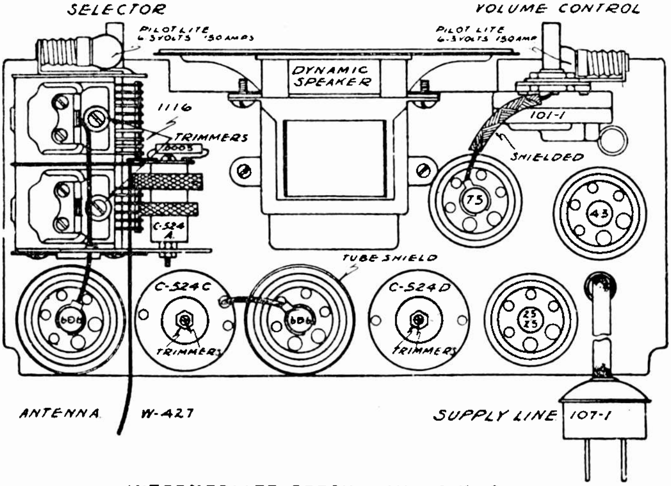
Should it be at any time necessary to rebalance this set, the correct procedure is as follows:

1. Volume control on full during all alignment.
2. Variable condenser in minimum capacity position, plates open, at start of all aligning.

I.F. ALIGNMENT.

1. To peak I.F. transformers, connect oscillator set at 456 kilocycles to the grid of the 6D6 tube directly in back of the variable condenser and adjust the trimming condensers of the I.F. transformers to resonance (Maximum deflection on an output meter connected across the primary of the speaker input transformer).

Each I.F. trimmer has two adjustments, one nut and one screw, both of which are adjustable from the top.



INTERMEDIATE FREQUENCY 456 K. C.

SERVICE SUGGESTIONS:

NOTE—CONNECTING CORD OF SET GETS WARM IN NORMAL OPERATION. DO NOT BECOME ALARMED.

Make sure that all tubes are pushed firmly in their proper sockets and that the clips are securely fastened to the caps on the tops of the tubes.

That the aerial is stretched out and that the connections to an outdoor antenna (if used) are good.

If necessary to change tubes or service chassis, UNDER NO CIRCUMSTANCES REMOVE BACK OR CHASSIS WITHOUT FIRST REMOVING PLUG FROM LIGHT SOCKET.

To remove chassis from cabinet, pull off knobs from front, remove back (held with screws to case). Remove four mounting screws, then chassis can be slipped out of case.

BROADCAST BAND ALIGNMENT.

1. Disconnect antenna wire and connect oscillator in series with a 75 mmfd. condenser to the antenna coil. With the variable condenser set at its minimum capacity position, at the extreme right of its rotation, and with an oscillator output adjusted to 1720 kilocycles, adjust trimmer of oscillator section of variable condenser (rear section) to resonance (maximum deflection on an output meter connected across the primary of the speaker input transformer). Next adjust the trimmer condenser of the front section of the variable condenser to resonance.
2. Check alignment at 1400-1200-1000-800-600-530 kilocycles, bending the slotted plates of the front section of the variable condenser only if absolutely necessary.

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NATIONAL RADIO INSTITUTE, WASHINGTON, D.C.

CROSLEY MODEL 1055

TUBE VOLTAGES—MODEL 1055

Type	Where Used	H	P	S	Su	G	K	Go	Ga
6K7	R. F. Amp.	6.2	250	103	6	0	6	—	—
6A8	Mod.	6.2	250	103	—	0	6	-1 To -30	107
6C5	Osc.	6.2	75	—	—	—	0	—	—
6K7	I. F. Amp.	6.2	250	103	3	0	3	—	—
6H6	Det. & AVC.	6.2	—	—	—	—	0	—	—
6C5	1st A. F. Amp.	6.2	70	—	—	0	3	—	—
6F6	2nd A. F. Amp.	6.2	218	218	—	0	18	—	—
6F6	Push Pull	6.2	355	245	—	0	18	—	—
6F6	Class A. B. Output	6.2	355	245	—	0	18	—	—
5Z4	Rect.	4.9	365	—	—	—	—	—	—

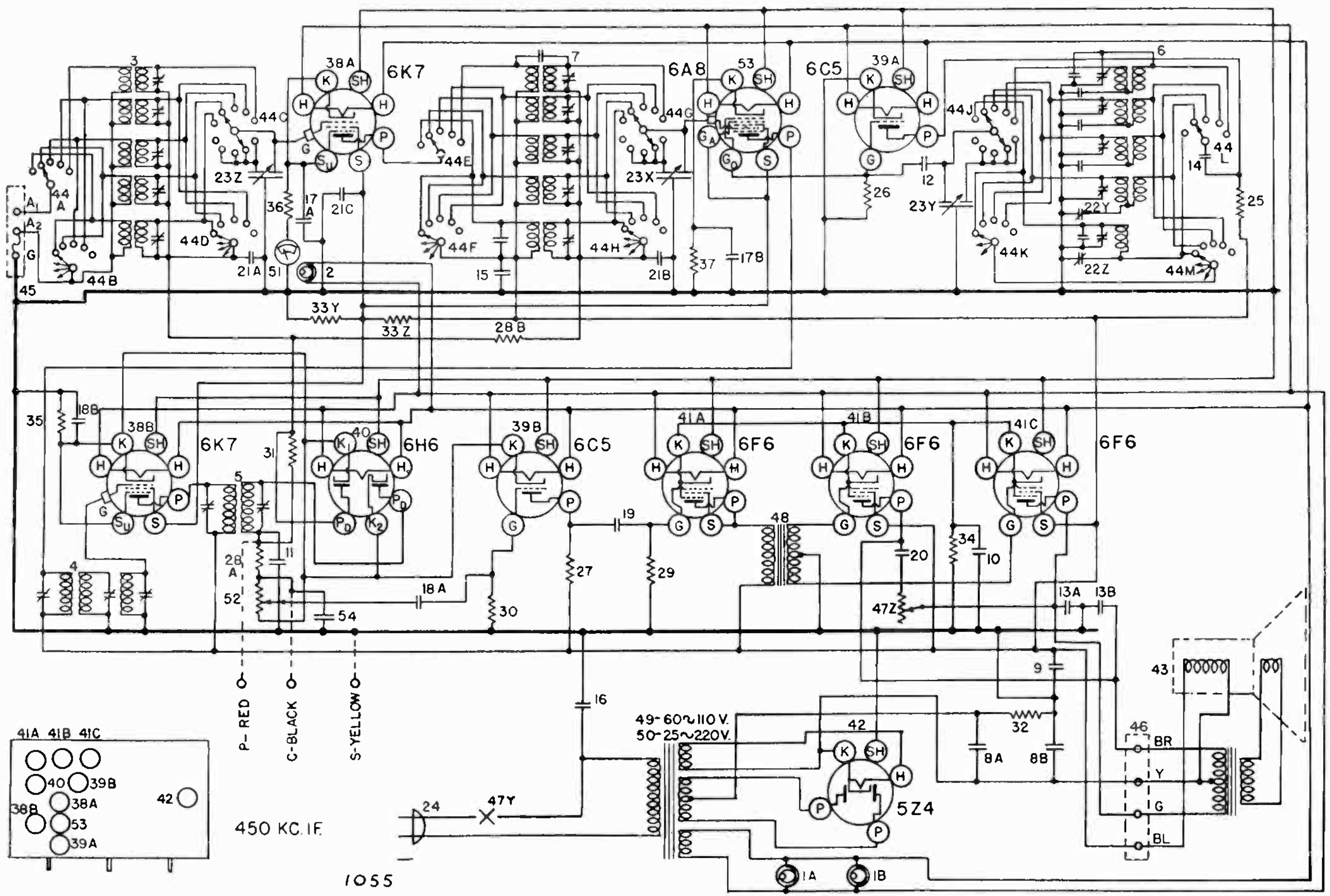
ALL D.C. VOLTAGES MEASURED TO CHASSIS WITH 500 VOLT, 1000 OHMS PER VOLT VOLTMETER ALL VOLTAGE PLUS OR MINUS 10% AT 117.5 LINE VOLTAGE.—POWER CONSUMPTION APPROXIMATELY 123 WATTS.

PARTS LIST—MODEL 1055

Figures in first column refer to parts in Diagram

Item No.	Part No.	Description
1A	36504	Dial Light Socket Assm.
1B	36504	Dial Light Socket Assm.
2	W —36557	Tuning Meter Bulb.
3	G63 —32000	Ant. Coil Assm. Complete
	G64 —32000	Ant. Coil only 150-400 Kc. (W. B.)
	G68 —32000	Ant. Coil only 540-1500 Kc. (B. B.)
	G65 —32000	Ant. Coil only 1500-4000 Kc. (P.B.)
	G67 —32000	Ant. Coil only 4-10 Mc. (S. W. B.)
	G66 —32000	Ant. Coil only 10-22 Mc. (S. W. B.)
	MG26—36542	Coil Support Base.
	W —36028	5 Section Trimmer Cond. Assm.
	MG9 —36168	Shield.
4	G66 —32004	1st I. F. Trans. Assm.
5	G67 —32004	2nd I. F. Trans. Assm.
6	G54 —32002	Osc. Coil Assm. Complete
	G55 —32002	Osc. Coil only 150-400 Kc.
	G56 —32002	Osc. Coil only 540-1500 Kc.
	G57 —32002	Osc. Coil only 1500-4000 Kc.
	G59 —32002	Osc. Coil only 4-10 Mc.
	G58 —32002	Osc. Coil only 10-22 Mc.
	MG26—36542	Coil Support Base.
	W —36028	5 Section Trimmer Cond. Assm.
	G7 —34007	Condenser 1750 mmf.
	G8 —34007	Condenser 4350 mmf. (2)
	G6 —34002	Condenser 25 mmf. (2)
	MG9 —36168	Shield.
7	G39 —32001	R. F. Coil Assm. Complete
	G40 —32001	R. F. Coil only 150-400 Kc.
	G44 —32001	R. F. Coil only 540-1500 Kc.
	G41 —32001	R. F. Coil only 1500-4000 Kc.
	G43 —32001	R. F. Coil only 4-10 Mc.
	G42 —32001	R. F. Coil only 10-22 Mc.
	MG27—36542	Coil Support Base.
	W —36028	5 Section Trimmer Cond. Assm.
	MG9 —36168	Shield.
8A	W —36055	Condenser 35 mfd. 400 Volts.
8B	W —36055	Condenser 35 mfd. 400 V.
9	W —36057	Condenser 40 mfd. 300 V.
10	W —36548	Condenser 25 mfd. 25 V.
11	G2 —34002	Condenser 0.0001 mfd. 200 V.
12	G1 —34002	Condenser 0.00025 mfd. 200 V.
13A	W —35758	Condenser 0.008 mfd. 400 V.
13B	W —35758	Condenser 0.008 mfd. 400 V.
14	W —35647	Condenser 0.006 mfd. 400 V.
15	W —32378	Condenser 0.01 mfd. 400 V.
16	W —30805	Condenser 0.01 mfd. 400 V.
17A	W —36541	Condenser 0.02 mfd. 160 V.
17B	W —36541	Condenser 0.02 mfd. 160 V.
18A	W —28621	Condenser 0.02 mfd. 200 V.
18B	W —28621	Condenser 0.02 mfd. 200 V.
19	W —32780	Condenser 0.05 mfd. 400 V.
20	W —23615	Condenser 0.05 mfd. 400 V.
21A	W —35936	Condenser 0.05 mfd. 200 V.
21B	W —35936	Condenser 0.05 mfd. 200 V.
21C	W —35936	Condenser 0.05 mfd. 200 V.
22Z 22Y	G27 —33006	Condenser-trimmer.

Item No.	Part No.	Description
23 Z 23Y 23X	G37 —33002	Var. Tuning Condenser Gang.
	—37376	Dial Drive Assembly
	—37375A	Dial Face only.
	—37551	Dial Hand.
	—37554	Second Hand.
	—37484	Dial Hand Screw.
	—37543	Dial Hand Washer.
24	B —33906A	A. C. Cord & Plug.
25	W —36545	Resistor 30,000 Ohm.
26	—22196	Resistor 20,000 Ohm.
27	—23403	Resistor 150,000 Ohm.
28A	—21455	Resistor 300,000 Ohm.
28B	—21455	Resistor 300,000 Ohm.
29	—23785	Resistor 500,000 Ohm.
30	—35927	Resistor 2 Megohm.
31	—36688	Resistor 3 Megohm.
32	W —36549	Resistor 200 Ohm 6 Watt.
33Z 33Y	W —32301	Resistor 10,000 Ohm. 15,000 Ohm.
34	W —22873	Resistor 220 Ohm (Flex.)
35	W —25937	Resistor 275 Ohm (Flex.)
36	W —21964	Resistor 165 Ohm (Flex.)
37	W —22514	Resistor 750 Ohm (Flex.)
38A	G151—36400	Socket, 6K7.
38B	G151—36400	Socket, 6K7.
39A	G152—36400	Socket, 6C5.
39B	G152—36400	Socket, 6C5.
40	G155—36400	Socket, 6H6.
41A	G153—36400	Socket, 6F6.
41B	G153—36400	Socket, 6F6.
41C	G153—36400	Socket, 6F6.
42	G154—36400	Socket, 5Z4.
43	427CL—22	Speaker, Table Model.
	627CL—27	Speaker, Console.
44	—36547A	Band Change Switch.
45	G27 —26719	Ant.-Grnd. Terminal.
46	G5 —31128	Speaker Terminal.
	W —34627	Terminal Board Insulator
	W —34628	Terminal Board Cover.
47Z 47Y	—32063	Tone Control. On-Off Switch.
48	G22 —24628	A. F. Transformer.
49	G42 —25669	Power Transformer 60 Cy. 110 V.
50	B —35007B	Universal Power Transformer.
51	W —36500	Tuning Meter.
	W —36501	Tuning Meter Bracket.
52	—32062	Volume Control.
53	G156—36400	Socket, 6A8.
54	G6 —34402	Condenser 0.000025 mfd.
	B —36515	Escutcheon.
	W —36564	Escutcheon indicator
	W —36311	Band Change Escutcheon.
	W —36519	Knob, Tuning.
	W —36520A	Knob, Vernier.
	W —36518	Knob (Tail) Band Change.
	W —36521	Knob (2)



WIRING DIAGRAM—MODEL 1055

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CROSLEY MODEL 6625

TUBE SOCKET VOLTAGE READINGS

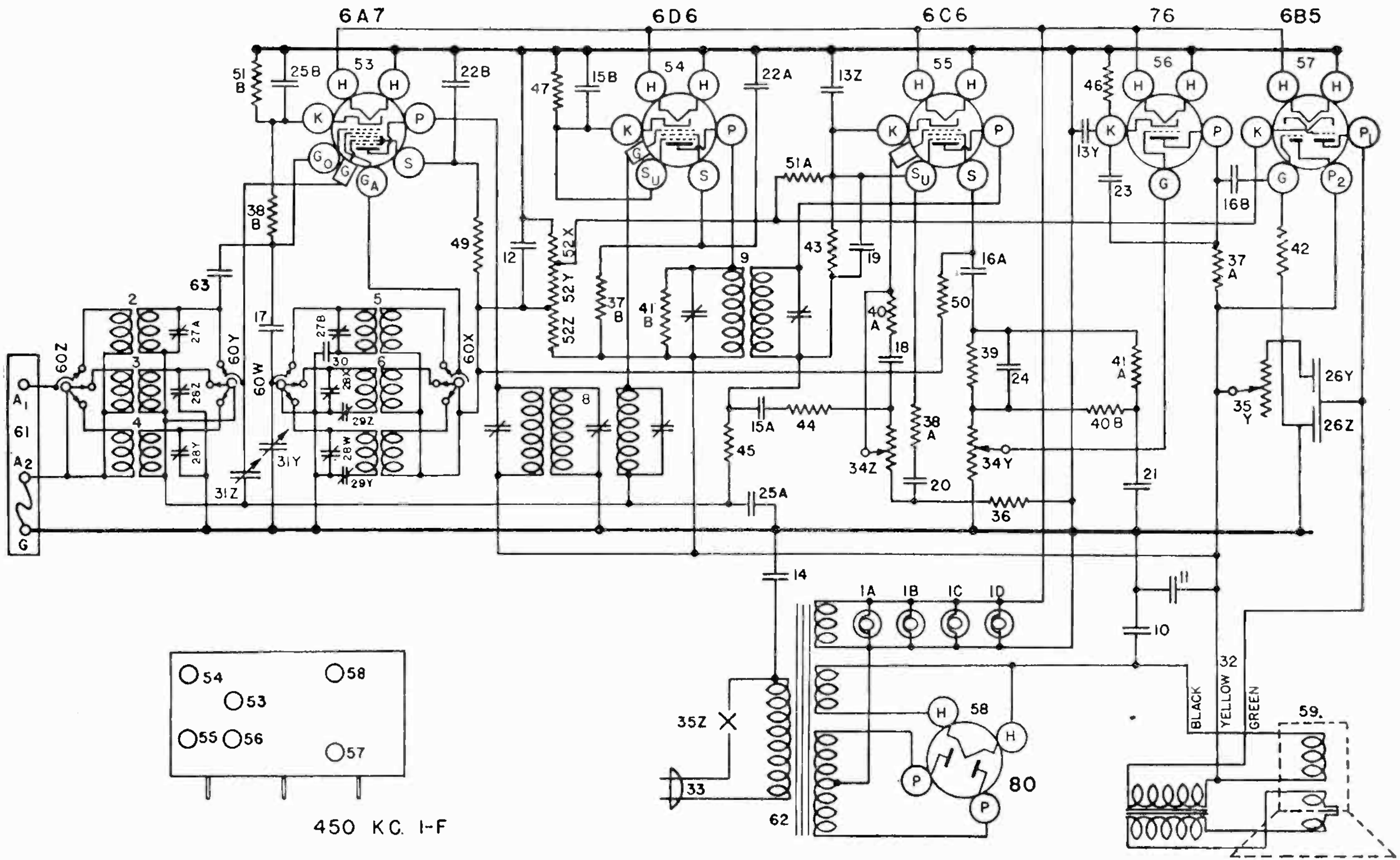
Tube	Function	H	P	P2	S	Su	G	K	Go	Ga
6A7	Osc.-Modulator	6.3	265	—	100	—	0	5.0	0	140
6D6	I-F Amplifier	6.3	265	—	120	6.2	0	6.2	—	—
6C6	Det. & A-F Amplifier	6.3	0	—	75	2.6	0	2.6	—	—
76	2nd. A-F Amplifier	6.3	140	—	—	—	0	10.0	—	—
6B5	Output	6.3	270	255	—	—	0	2.3	—	—
80	Rectifier	4.9	350	—	—	—	—	—	—	—

MEASURED ON 117.5 VOLT—60 CYCLE POWER SUPPLY
POWER CONSUMPTION APPROXIMATELY 80 WATTS.
POWER OUTPUT APPROXIMATELY 3 WATTS.

PARTS LIST—MODEL 6625

Figures in first column refer to parts in Diagram

Item	Part No.	Name Description
1A	W —37922	Bulb, Dial Light
1B	W —37922	Bulb, Dial Light
1C	W —37922	Bulb, Dial Light
1D	W —37922	Bulb, Indicator Light
2	G92—32000	Coil, Ant. 6000-18000 Kc.
3	G90—32000	Coil, Ant. 1800-6000 Kc.
4	G91—32000	Coil, Ant. 540-1800 Kc.
5	G84—32002	Coil, Osc. 6000-18000 Kc.
6	G83—32002	Coil, Osc. 1800-6000 Kc.
7	G82—32002	Coil, Osc. 540-1800 Kc.
8	G94—32004	Coil, 1st I-F Assm.
9	G93—32004	Coil, 2nd I-F Assm.
10	W —36055	Condenser, 35 mfd., 400 V.
11	W —36057	Condenser, 40 mfd., 300 V.
12	W —40325	Condenser, 50 mfd., 150 V.
13Z	W —37778	Condenser, 12 mfd., 25 V.
13Y		Condenser, 12 mfd., 25 V.
14	W —30805	Condenser, .01 mfd., 400 V
15A	W —36541	Condenser, .02 mfd., 160 V.
15B	W —36541	Condenser, .02 mfd., 160 V.
16A	W —32780B	Condenser, .05 mfd., 400 V.
16B	W —32780B	Condenser, .05 mfd., 400 V.
17	G1 —34002	Condenser, .00025 mfd., (molded)
18	G6 —34002	Condenser, .000025 mfd., (molded)
19	G2 —34002	Condenser, .0001 mfd., (molded)
20	W —30323	Condenser, .01 mfd., 200 V.
21	W —37988	Condenser, .017 mfd., 200 V.
22A	W —23142	Condenser, .02 mfd., 400 V.
22B		Condenser, .02 mfd., 400 V.
23	W —27540	Condenser, .0005 mfd., 400 V.
24	G5 —34002	Condenser, .00005 mfd., (molded)
25A	W —35936	Condenser, .05 mfd., 200 V.
25B	W —35936	Condenser, .05 mfd., 200 V.
26Z	W —31052	Condenser, .004 mfd., 400 V.
26Y		Condenser, .05 mfd., 400 V.
27A	W —37954	Condenser, H-F Ant Shunt Trim.
27B	W —37954	Condenser, H-F Ant Shunt Trim.
28Z	W —37822A	Condenser, Pol. Ant. Shunt Trim.
28Y		Condenser, B-C Ant. Shunt Trim.
28X		Condenser, Pol. Osc. Shunt Trim.
28W		Condenser, B-C Osc. Shunt Trim.
29Z	G31—33006	Condenser, Pol. Osc. Series Trim.
29Y		Condenser, B-C Osc. Series Trim.
30	G17—34000	Condenser, .0053 mfd. H-F Osc.
31Z	G19—33001	Condenser, Var. Tuning Gang
31Y		
32	G4 —35696	Cable, Speaker
33	B —33906A	Cable & Plug, Power Supply
34Z	37907	Vol. Cont., 1st A-F Control, 3 Meg
34Y		2nd A-F Control, 1 Meg
35Y	—37908	Control, Tone
35Z		Switch, On-Off
36	—21455	Resistor, 300,000 Ohm, ¼ W.
37A	—5469A	Resistor, 100,000 Ohm, 1 W.
37B	—5469A	Resistor, 100,000 Ohm, 1 W.
38A	—36761	Resistor 40,000 Ohm, ¼ W., Insul.
38B	—36761	Resistor 40,000 Ohm, ¼ W., Insul.
39	—21454	Resistor, 1 Megohm, ¼ W.
40A	—34020	Resistor 250,000 Ohm, ¼ W.
40B	—34020	Resistor 250,000 Ohm, ¼ W.
41A	—37590	Resistor, 750,000 Ohm, ¼ W.
41B	—37590	Resistor, 750,000 Ohm, ¼ W.
42	—36322	Resistor, 500,000 Ohm, ¼ W.
43	—33344	Resistor, 400,000 Ohm, ¼ W.
44	—23403	Resistor, 150,000 Ohm, ¼ W.
45	—37245	Resistor, 1.5 Megohm, ¼ W.
46	—21876	Resistor, 10,000 Ohm, ¼ W.
47	W —22514	Resistor, 750 Ohm, ½ W., Flex.
48	W —24537	Resistor, 60 Ohm, ½ W., Flex.
49	—22831	Resistor, 15,000 Ohm, ¼ W.
50	—21875	Resistor, 100,000 Ohm, ¼ W.
51A	W —28106	Resistor, 500 Ohm, ½ W. Flex.
51B	W —28106	Resistor, 500 Ohm, ½ W. Flex
52Z	—37829	Resistor, 10,000 Ohm — Candohm
52Y		Resistor, 25,000 Ohm — Candohm
52X		Resistor, 65 Ohm — Candohm
53	G47—28807	Socket, 6A7 Type
54	G75—28807	Socket, 6D6 Type
55	G74—28807	Socket, 6C6 Type
56	G80—28807	Socket, 76 Type
57	G90—28807	Socket, 6B5 Type
58	G6 —28807	Socket, 80 Type
59	—37916	Speaker, Spec. 532—BJ—3
60	B —37906	Switch, 2 Sec. Band Selector
61	G27—26719	Terminal Board, Ant. & Grnd.
62	G15—28500	Transformer, Power 110-60 Cy.
	G16—28500	Transformer, Power 110-25 Cy.
	G17—28500	Transformer, Power 220-25 Cy.
	W —35774	Base, Tube Shield
	—40531	Belt, Drive
	W —22334	Cable, Indicator Control
	W —35773	Cap, Tube Shield
	—40537	Coupling, Flexible Drive
	—37947	Dial Assy., Complete
	W —40545	Diffuser, Light
	C —37894	Escutcheon, Cabinet
	C —37969	Face, Celluloid Dial
	C —37968	Face, Glass Dial
	W —40365	Gasket, Escutcheon Felt
	—40485	Hand, Long
	—40484	Hand, Short
	W —37339	Knob, 3 required
	W —40192	Knob, 1 required
	B —37898	Lens, Dial
	W —37909	Pulley, Indicator Cable
	W —35772	Shield, Tube (Half)
	W —37814	Shield, Dial Light
	G2 —37965	Socket, Dial Light
	G3 —37965	Socket, Indicator Light
	B —37896	Spring, Escutcheon Retaining
	B —37897	Spring, Dial Lens Retaining



WIRING DIAGRAM—MODEL 6625

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CROSLEY MODEL NO. 597-5597

Alignment Procedure

The chassis of this receiver is connected to one side of the power supply and for this reason all test equipment should be thoroughly insulated in order that the power supply will not become short circuited while aligning the receiver.

Connecting Output Meter

Connect one terminal of the output meter to the plate and the other terminal to the screen of the 25A6 output tube. Be certain that the meter is protected from DC by connecting a condenser (.1 mfd. or larger—not electrolytic) in series with one of the leads.

Tuning the I-F Amplifier to 455 Kilocycles

(a) Disconnect the antenna roll from the receiver and connect the output of the signal generator through a 50 mmf. condenser to the antenna connection on the receiver. Do not use a ground return from the signal generator unless it is found to be absolutely necessary. If it is found to be necessary, a small condenser (approximately .001 mfd.) should be connected in series with the ground terminal of the signal generator and the receiver chassis. KEEP THE GENERATOR LEADS AS FAR AS POSSIBLE FROM THE GRID LEADS OF THE OTHER SCREEN GRID TUBES.

(b) Set the station selector so that the plates of the condenser gang are completely out of mesh and turn the volume control to the right (ON).

(c) Set the signal generator to 455 kilocycles.

(d) Adjust the 2nd I-F trimmer condenser, Item 14, located beneath the edge of speaker field, for maximum reading on the output meter.

(e) Adjust the 1st I-F trimmer condensers, located on back flange of the chassis, for maximum output.

(f) Repeat operations (d) and (e) for more accurate adjustments.

ALWAYS USE THE LOWEST SIGNAL GENERATOR OUTPUT THAT WILL GIVE A REASONABLE READING ON THE OUTPUT METER.

Aligning the R-F Amplifier

(a) Set the signal generator to 1725 kilocycles.

(b) With the condenser gang turned to the minimum capacity position, adjust the trimmer condenser on the "OSC" section of the gang so that the 1725 kilocycle signal is heard. It is not necessary that the receiver tune through this signal.

(c) Set the signal generator to 1400 kilocycles.

(d) Tune-in the 1400 kilocycle signal in the region of 140 on the dial for maximum output.

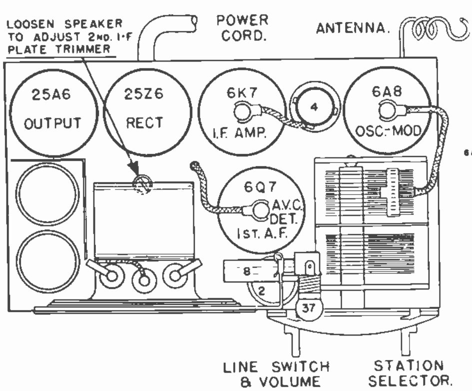
(e) Adjust the trimmer condenser located on the "ANT" section of the gang for maximum output.

Note: Do not readjust the "OSC" trimmer.

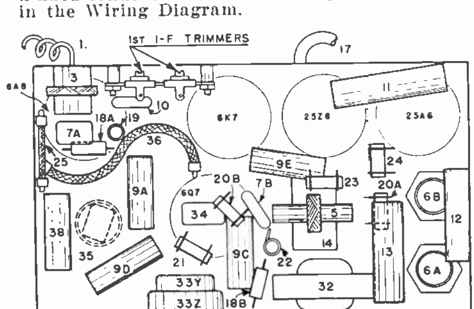
(f) Repeat operations (d) and (e) for more accurate adjustments.

Wave Trap

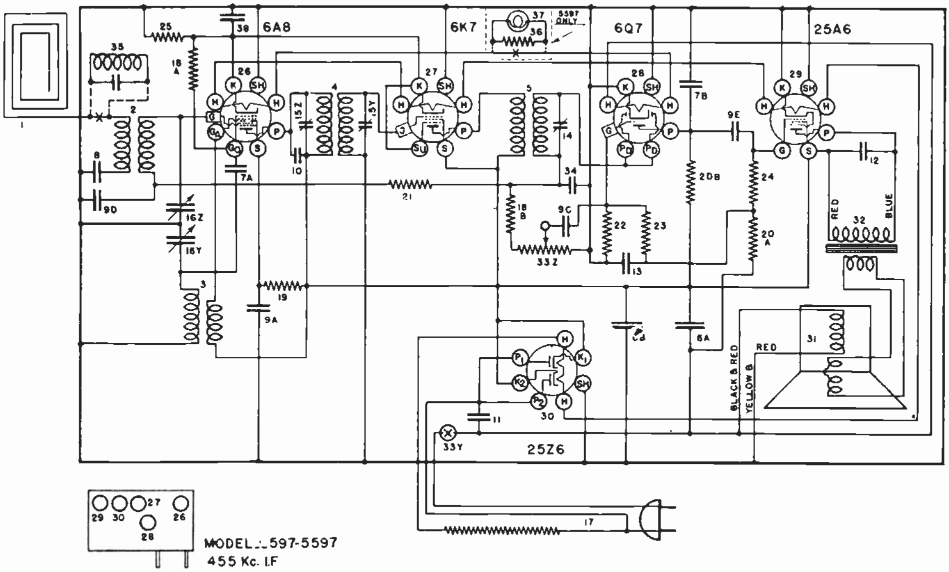
Some chassis of this model are equipped with a wave trap for the purpose of eliminating interference from code stations which operate on a frequency of approximately 455 kilocycles. This assembly is located on the underneath side of the chassis and consists of a coil and a fixed condenser as illustrated by dotted lines in the Wiring Diagram.



Top View Model 597 and 5597



Bottom View Model 597 and 5597



WIRING DIAGRAM—CROSLEY MODEL 597-5597

PARTS LIST

Item	Description	Item	Description
6A	Condenser, 30 Mf. 125 V.	18B	Resistor, 60,000 Ohm ¼ W. Ins.
6B	Condenser, 30 Mf. 125 V.	19	Resistor, 15,000 Ohm 1/3 W. Ins.
7A	Condenser, .0001 Mf. Molded	20A	Resistor, 300,000 Ohm 1/3 W. Carb.
7B	Condenser, .0001 Mf. Molded	20B	See Item 39
8	Condenser, .0005 Mf. 200 V.	21	Resistor, 3 Megohm 1/3 W. Carb.
9A	Condenser, .02 Mf. 200 V.	22	Resistor, 1 Megohm 1/3 W. Carb.
9C	Condenser, .02 Mf. 200 V.	23	Resistor, 11 Megohm 1/3 W. Carb.
9D	Condenser, .02 Mf. 200 V.	24	Resistor, 250,000 Ohm 1/3 W. Carb.
9E	Condenser, .02 Mf. 200 V.	25	Resistor, 75 Ohm ¾ W. Flex.
10	Condenser, .00005 Mf. Molded	33	Vol. Cont. (1 Meg.) and Line Switch
11	Condenser, .05 Mf. 400 V.	34	Condenser, .00025 Mf. Molded
12	Condenser, .006 Mf. 200 V.	36	Resistor 40 Ohm 3½ W. Flex. 5597
13	Condenser, .1 Mf. 200 V.	37	Bulb 6-8 V. Dial Light 5597
17	Power Cord and Plug (160 Ohm) 597 Only	38	Condenser, .05 Mf. 200 V.
	Power Cord and Plug (140 Ohm) 5597 Only	39	Resistor, 150,000 Ohm 1/3 W. Carb.
18A	Resistor, 60,000 Ohm ¼ W. Ins.		

TUBE SOCKET VOLTAGE READINGS

Tube	Function	H	P	S	Su	K	Go	Ga
6A8	Oscillator-Modulator	6.3	105	65	—	3	—10	105
6K7	I-F Amplifier	6.3	105	105	0	3	—	—
6Q7	Det, AVC, A-F Amplifier	6.3	50	—	—	0	—	—
25A6	Output	25.1	100	105	—	0	—	—
25Z6	Rectifier	25.1	117.5	—	—	110	—	—

Power output approximately 1 watt.
Power consumption approximately 55 watts.
Voltage drop across speaker field 18 volts.
All voltages except filament will be approximately 10% lower if measured on 117.5 volts DC power supply.

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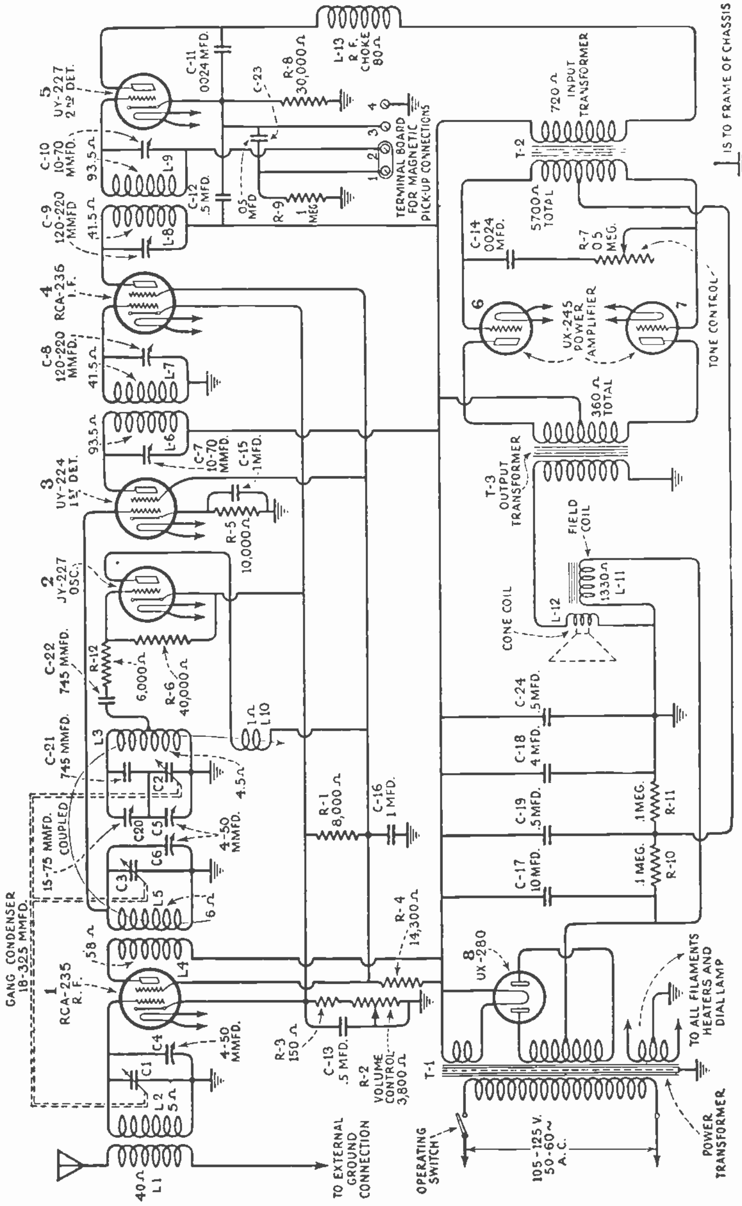
GENERAL ELECTRIC S-22 AND VICTOR-RADIOLA SUPERETTE



Schematic Wiring Diagram

The wiring diagram is also used in the following receivers: Graybar No. 8 Midget; Westinghouse No. WR-10 Columnette; and General Electric Models G. E. Jr. No. S-22, G. E. Jr., with clock, No. S-22-N and G. E. Jr. Console S-42.

VOLTAGE READING SERVICE DATA CHART

VOLUME CONTROL AT MAXIMUM

VOLTAGE CHARACTERISTICS	1 R. F.				2 OSC.			3 1st DET.				4 I. F.				5 2nd DET.			6 PWR. A. F.			7 PWR. A. F.			CAUSE OF INCORRECT READING
	C.G. Volts	S.G. Volts	Plate Volts	Plate M.A.	Grid Volts	Plate Volts	Plate M.A.	C.G. Volts	S.G. Volts	Plate Volts	Plate M.A.	C.G. Volts	S.G. Volts	Plate Volts	Plate M.A.	Grid Volts	Plate Volts	Plate M.A.	Grid Volts	Plate Volts	Plate M.A.	Grid Volts	Plate Volts	Plate M.A.	
Normal	3.5	70	240	5.0	0	65	5.5	5.0	70	235	0.5	3.5	70	240	5.0	5.0	220	0.5	30	245	25	30	245	25	
No C. G. Voltage on Tube No. 1	0	70	240	9.0																					Open Secondary of R. F. Transformer L-2
No C. G. Voltage on Tube No. 3								0	70	235	1.5														Open 1st Det. Grid Coil L-5
No C. G. Voltage on Tube No. 4												0	70	240	9.0										Open Secondary of 1st I. F. Transformer L-7
No C. G. and Low Plate Voltage on Tube No. 5																0	70	5.5							Open Sec. of 2nd I. F. Trans. L-9 or 1 Meg. Res. R-9
Low Voltages on All Tubes	2.0	35	150	2.5	0	35	3.0	3.0	35	140	0.5	2.0	35	150	2.5	5.0	100	0.25	0	140	80	30	150	0	Open One-Half Secondary of Interstage Transformer T-2
Low Voltages on All Tubes	2.0	35	150	2.5	0	35	3.0	3.0	35	140	0.5	2.0	35	150	2.5	5.0	100	0.25	30	150	0	0	140	80	Open One-Half Secondary of Interstage Transformer T-2
No Voltages on Tube No. 2					0	0	0																		Open Oscillator Plate Coil L-10
No Plate Voltage on Tube No. 1	3.5	60	0	0																					Open R. F. Plate Coil L-4
No Plate Voltage on Tube No. 3								4.0	70	0	0														Open Primary of 1st I. F. Transformer L-6
No Plate Voltage on Tube No. 4												3.5	60	0	0										Open Primary of 2nd I. F. Transformer L-8
No Voltages on Tube No. 5																0	0	0							Open R. F. Choke L-13 or Primary of Transformer T-2
No Plate Voltage on Tube No. 6																			20	0	0				Open One-Half Primary of Output Transformer T-3
No Plate Voltage on Tube No. 7																						20	0	0	Open One-Half Primary of Output Transformer T-3
No C. G. Voltage on Tubes Nos. 1 and 4	0	70	240	9.0								0	70	240	9.0										Shorted 0.5 Mfd. Condenser C-13
No C. G. Voltage on Tube No. 3								0	70	240	4.0														Shorted 0.1 Mfd. Condenser C-15
No C. G. or S. G. Voltages on Tubes Nos. 1, 2, 3 or 4	0	0	240	0	0	0	0	0	0	235	0	0	0	240	0										Shorted 1.0 Mfd. Condenser C-16
Low Voltages on All Tubes	1.0	20	100	1.0	0	20	1.5	1.0	20	100	0.25	1.0	20	100	1.0	5	60	0.5	+8	80	50	+8	80	50	Shorted 0.5 Mfd. Condenser C-24
No. C. G. Voltage on Tube No. 5																0	180	30							Shorted 0.5 Mfd. Condenser C-12
Low Plate Voltage on Tube No. 5																0	60	1.5							Shorted 0.05 Mfd. Condenser C-23
No Plate Voltage on Tube No. 5																25	0	0							Shorted .0024 Mfd. Condenser C-11
Low Plate M. A. on Tubes Nos. 6 and 7																			50	260	10.0	50	260	10.0	Shorted 100,000 Ohm Resistor R-10
Low Voltages on All Tubes	1.5	25	100	0.25	0	25	0.5	1.5	25	100	0.25	1.5	25	100	0.5	5.0	100	0.25	0	100	40	0	100	40	Shorted 100,000 Ohm Resistor R-11
High C. G. Voltage on Tubes Nos. 1 and 4	200	0	0	0	0	0	0	20	200	215	0	200	0	0	0										Open Volume Control R-2 or 150 Ohm Resistor R-3
High S. G. Voltages	7.0	160	210	25	0	100	12	14	160	200	2.0	7.0	160	210	25										Open 8,000 Ohm Resistor R-1
No C. G. or S. G. Voltage on Tubes Nos. 1, 2, 3 and 4	0	0	250	0	0	0	0	0	0	240	0	0	0	250	0										Open 14,300 Ohm Resistor R-4
No Voltages on Tube No. 3								0	0	0	0														Open 10,000 Ohm Resistor R-5
No Plate Voltage on Tube No. 5																20	0	0							Open 30,000 Ohm Resistor R-8

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NATIONAL RADIO INSTITUTE, WASHINGTON, D.C.

EMERSON MODEL Q157

Chassis Model Q

Four-Tube A.C.-D.C. T.R.F. Receiver

Voltage rating ....105 to 125 volts a-c or d-c.
Power consumption ....45 watts.
Frequency range ....540 to 1725 kc.

TUBE DATA

The tube complement is as follows:

1—6D6, r-f amplifier.
1—6C6, biased detector.
1—25L6, beam power output.
1—25Z5, dual half-wave rectifier.

VOLTAGE ANALYSIS

Readings should be taken with a 1000 ohms-per-volt meter. Voltages listed below are from point indicated to ground (chassis) with volume control turned on full and no signal. The line voltage for these readings was 117.5 volts, 60 cycles, a-c.

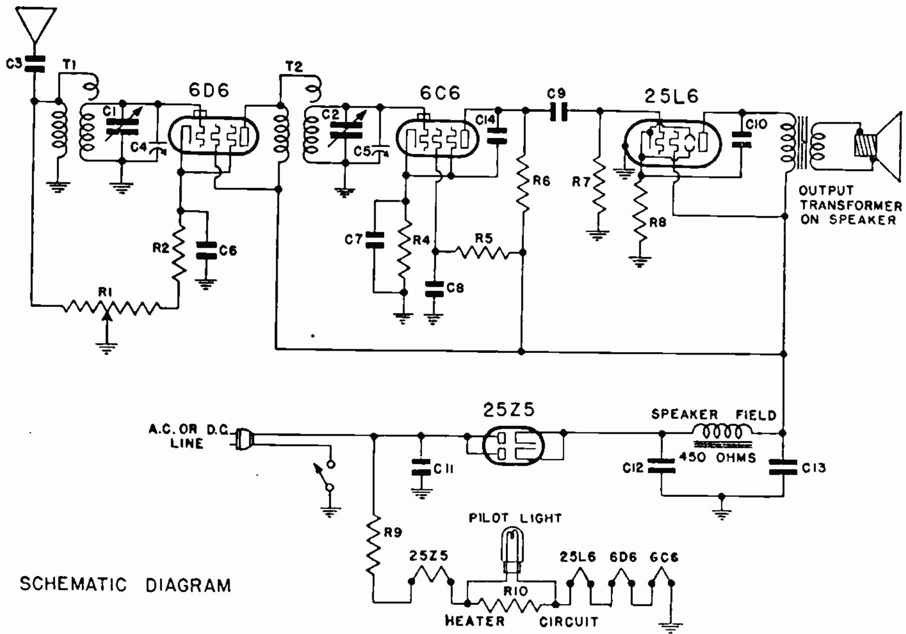
Tube	Plate	Screen	Cathode	Fil.
6D6	100	100	2.8	6.3
6C6	30	15	1.4	6.3
25L6	93	100	5.7	25.0

Voltage across speaker field—30 volts.
25Z5 cathode to ground—130 volts.

ALIGNMENT PROCEDURE

An oscillator with a frequency of 1400 kc. is required.
Use as weak a test signal as possible. An output meter should be used across the voice coil or output transformer for observing maximum response.
Rotate variable condenser to the maximum capacity position and set the pointer at the next calibration mark beyond 55. Then rotate the variable condenser until the pointer is at 140 and feed 1400 kc. to the antenna through a .0001 mf mica condenser and adjust both trimmer condensers on the variable condenser for maximum response.

EMERSON MODEL Q157



SCHEMATIC DIAGRAM

REPLACEMENT PARTS

ITEM	DESCRIPTION	ITEM	DESCRIPTION
T1	Broadcast antenna coil	R9	185 ohm 17 watt resistor in line cord
T2	Broadcast detector coil	R10	40 ohm metal clad wire-wound resistor
R1	Volume control—75,000 ohms	C1, C2	Two gang variable condenser
R2	310 ohm ½ watt wire-wound molded resistor	C3	0.001 mf roll type condenser
R4	250,000 ohm ¼ watt carbon resistor	C4, C5	Trimmer part of variable condenser
R5	2 megohm ¼ watt carbon resistor	C6, C8	0.1 mf, 200 volt roll type condenser
R6	500,000 ohm ¼ watt carbon resistor	C7	0.25 mf, 200 volt roll type condenser
R7	500,000 ohm ¼ watt carbon resistor	C9	0.02 mf, 400 volt roll type condenser
R8	110 ohm ½ watt wire-wound resistor	C10	0.03 mf, 400 volt roll type condenser
		C11	0.1 mf, 400 volt molded type paper condenser
		C12, C13	Dual 16 mf, 100 volt dry electrolytic condenser
		C14	0.001 mf mica condenser

PRODUCTION CHANGES

In receivers bearing serial numbers below 1,109,445.

(a) C10 was returned to B plus instead of the 25L6 cathode as shown on the schematic diagram.

(b) A 250,000 ohm ¼ watt carbon resistor was connected from the cathode of the 6D6 to B plus.

(c) C14 was connected from the 25L6 grid to ground.

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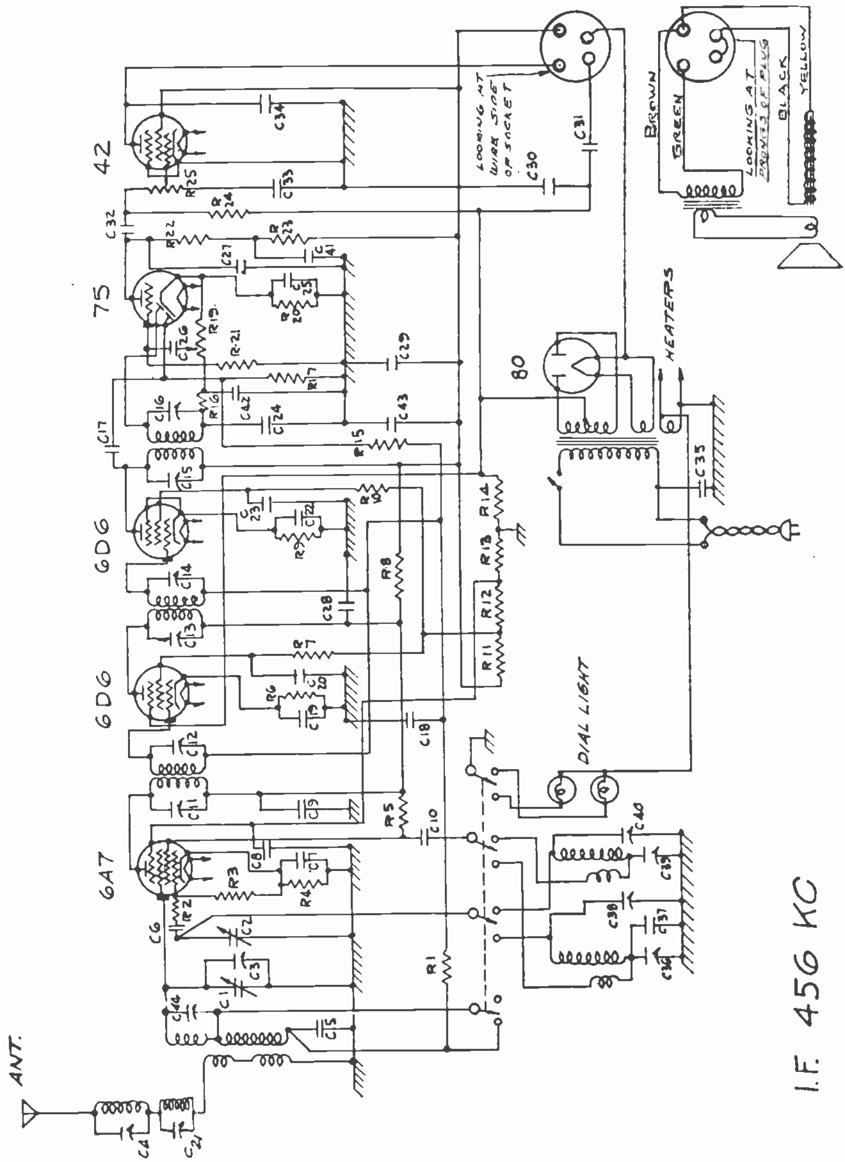
WESTINGHOUSE DUAL-WAVE RECEIVERS MODELS WR-28-29



WESTINGHOUSE DUAL-WAVE RECEIVERS MODELS WR-28-29

Symbol Number	Description	Part Number
C-1, C-2, C-3	Variable gang with trimmer	WR-07256
C-4	600 mmf. variable	WR-07238
C-5	.05 mf - 2 ply	WR-06386
C-6	.0001 mf - mica	WR-06417
C-7	.05 mf - 2 ply	WR-06386
C-8	.05 mf - 2 ply	WR-02493
C-9	.05 mf - 3 ply	WR-02492
C-10	.02 mf - 3 ply	WR-02504
C-11, C-12	Part of I.F. coil	WR-07247
C-13, C-14	Part of I.F. coil	WR-07248
C-15, C-16	Part of I.F. coil	WR-07249
C-17	.001 - mica	WR-06417
C-18	.05 mf - 2 ply	WR-06386
C-19	.05 mf - 2 ply	WR-06386
C-20	.05 mf - 2 ply	WR-06386
C-21	10 to 55 mmfd	WR-07842
C-22	.05 mf - 2 ply	WR-06386
C-23	.05 - 2 ply	WR-06386
C-24	.0001 mica ...... part of	WR-07249
C-25	.5 mf - 2 ply	WR-02499
C-26	.005 mf - 3 ply	WR-03659
C-27	.001 mf - 4 ply	WR-06403
C-28	8 mf - electrolytic	WR-07239
C-29	4 mf - electrolytic	WR-06665
C-30	20 mf - electrolytic	WR-06665
C-31	8 mf - electrolytic	WR-06665
C-32	.005 mf - 3 ply	WR-03659
C-33	.001 mf - 4 ply	WR-06403
C-34	.01 mf - 4 ply	WR-03695

Symbol Number	Description	Part Number
C-35	.01 mf - 4 ply	WR-05931
C-36	425 mmf. variable	WR-07241
C-37	1500 mmf. mica	WR-07422
C-38	Trimmer condenser	WR-07237
C-39	425 mmf. variable	WR-07241
C-40	Trimmer condenser	WR-07237
C-41	.05 mf - 3 ply	WR-02492
C-42	.001 mica	WR-06417
C-43	.05 mf - 3 ply	WR-02492
C-44	4-40 mmf. variable ... part of	WR-07246
R-1	.1 meg. 1/4 watt	WR-05278
R-2	50 ohms 1/4 watt	WR-05255
R-3	50,000 ohms 1/4 watt	WR-05275
R-4	500 ohms 1/4 watt	WR-05264
R-5	20,000 ohms 1/2 watt	WR-00813
R-6	1,000 ohms 1/4 watt	WR-05267
R-7	5,000 ohms 1/4 watt	WR-05249
R-8	1,000 ohms 1/4 watt	WR-05267
R-9	1,000 ohms 1/4 watt	WR-05267
R-10	5,000 ohms 1/4 watt	WR-05249
R-11	11,200 ohms	WR-07236
R-12	1,800 ohms	
R-13	12,000 ohms	
R-14	300 ohms	
R-15	1 meg. 1/4 watt	WR-05281
R-16	50,000 ohms 1/4 watt .. part of	WR-07249
R-17	1 meg. 1/4 watt	WR-05281
R-19	.5 meg. variable	WR-05562
R-20	2,000 ohms 1/4 watt	WR-05245
R-21	1 meg. 1/4 watt	WR-05281
R-22	75,000 ohms 1/4 watt	WR-05277
R-23	50,000 ohms 1/4 watt	WR-05276
R-24	.25 meg. 1/4 watt	WR-05279
R-25	.25 meg variable	WR-07250

Stage	Tube	Filament	Plate	Screen	Cathode
Rectifier	80	4.85	382		
Power Output	42	6.1	234	245	18
2nd Detector	75	6.1	126		0.87
1st I. F.	6D6	6.1	236	99	5.6
2nd I. F.	6D6	6.1	245	96	5.6
Oscillator	6A7	6.1	236-136	87	4.7

Note: These values are readings of a high resistance voltmeter from each socket terminal to ground, with the exception of the filament voltages.

RADIO-TRICIAN
REG. U.S. PAT. OFF.
Service Sheet
Compiled Solely for Students and Graduates

NATIONAL RADIO INSTITUTE, WASHINGTON, D.C.

ZENITH MODELS 811-862-865-866-1162

SOCKET VOLTAGE READINGS

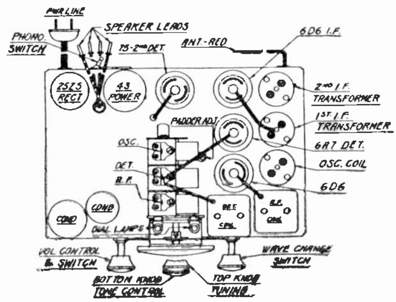
TUBE	POSITION	Ef	Ek	Eg1	Eg2	Eg3	Ep
6D6	R.F.	5.8	3		98	3	98
6A7	1st Det.	5.8	2.5		60	-	98
	Osc.			-1	-	-	90
6D6	I.F.	5.8	3		98	3	98
75	2nd Det. A.V.C 1st Aud.	5.8	.5		-	-	30
43	PWR.	26	13.5	0	98	-	90
25Z5	Rect.	26	-30 -28	-	-	-	-

Line Voltage 112 — Antenna and Ground Disconnected

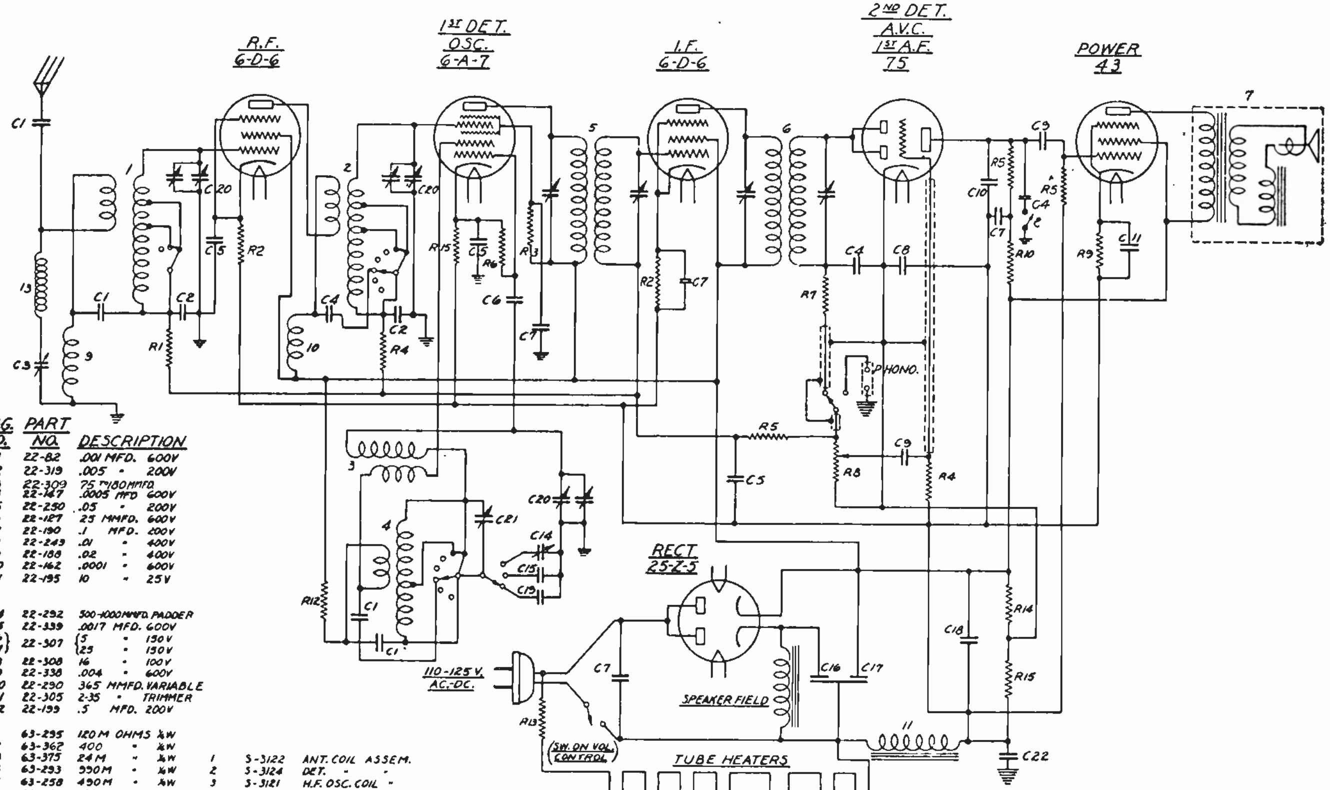
F - Filament; K - Cathode; g1 - Control Grid; g2 - Screen Grid; g3 - Suppressor Grid; p - Plate

Alignment

1. Balance intermediate transformers at 252.5 K.C. with service oscillator connected to grid of 6A7 and chassis ground.
2. Adjust wave trap padder (located underneath chassis at rear right side) for weakest signal with 252.5 K.C. service oscillator connected to antenna and ground.
3. Turn wave-band switch clockwise to the highest frequency band. Set service oscillator at 15 M.C. - still connected to aerial and ground. Balance oscillator trimmer on gang condenser for correct dial reading at this frequency.
4. Turn wave-band switch counter clockwise to standard broadcast position. Adjust broadcast oscillator trimmer (located underneath chassis at right - center) for correct dial reading at 1400 K.C. and adjust R.F. and first detector trimmers on gang condenser for loudest signal.
5. Set service oscillator at 600 K.C. Adjust oscillator broadcast padder through hole in top of chassis, simultaneously rocking the dial back and forth for loudest signal.



Tube Position



DIAG. NO.	PART NO.	DESCRIPTION
C1	22-82	.001 MFD. 600V
C2	22-319	.005 " 200V
C3	22-309	75 ~ 180 MMFD.
C4	22-147	.0005 MFD 600V
C5	22-250	.05 " 200V
C6	22-127	25 MMFD. 600V
C7	22-190	.1 MFD. 200V
C8	22-249	.01 " 400V
C9	22-188	.02 " 400V
C10	22-162	.0001 " 600V
C11	22-195	10 " 25V
C14	22-292	500-1000 MMFD. PADDER
C15	22-339	.0017 MFD. 600V
C16	22-307	5 " 150V
C17	22-307	25 " 150V
C18	22-308	16 " 100V
C19	22-338	.004 " 600V
C20	22-290	365 MMFD. VARIABLE
C21	22-305	2-35 " TRIMMER
C22	22-199	.5 MFD. 200V
R1	63-295	120 M OHMS ¼W
R2	63-362	400 " ¼W
R3	63-375	24 M " ¼W
R4	63-293	990 M " ¼W
R5	63-258	490 M " ¼W
R6	63-260	100 M " ¼W
R7	63-280	49 M " ¼W
R8	63-366	200 M OHM VOL. CONT.
R9	63-287	700 OHMS ½W
R10	63-278	99 M " ¼W
R12	63-326	4 M " ¼W
R13	11-9	90 OHM RES. CORD
R14	63-372	50 M OHMS ¼W
R15	63-244	500 " ¼W
R16	63-374	50 " 2W

1	S-3122	ANT. COIL ASSEM.
2	S-3124	DET. " "
3	S-3121	H.F. OSC. COIL "
4	S-3123	B'DC'ST OSC. COIL ASSEM.
5	95-247	1ST I.F. TRANSF.
6	95-248	2ND I.F. "
7	49-93	SPEAKER 3000 ~ FIELD
8	85-48	TONE CONTROL SWITCH
9	20-71	ANT. CHOKE
10	20-76	R.F. PLATE IMPEDANCE COIL
11	95-249	POWER FILTER CHOKE
12	85-57	BAND CHANGE SWITCH
13	20-75	WAVE TRAP

I.F. FREQUENCY 252.5 K.C.
6 TUBE SUPERHETERODYNE
CHASSIS NO. 5609 A.C.-D.C.

ZENITH RADIO CORP.
CHICAGO ILL.

MODELS 811-862-865-866-1162

INSTRUCTIONS FOR PERFORMING RADIO EXPERIMENTS 1 TO 10

1 RK

NATIONAL RADIO INSTITUTE

ESTABLISHED 1914

WASHINGTON, D. C.

A COURSE IN PRACTICAL DEMONSTRATIONS OF RADIO FUNDAMENTALS

THE VALUE OF BEING NEAT

Neatness is a valuable habit for you to acquire, because it is a virtue which everyone can see and appreciate. Dress neatly, as befits the professional man you aspire to be. Keep your living quarters in order at all times, so that chance visitors will be just as favorably impressed as expected guests.

Keep your workbench and working quarters neat and orderly, for the average customer unconsciously associates neatness with technical ability. When performing an experiment, keep your tools, parts, and study materials arranged around you for maximum convenience, instead of letting them be scattered all over the bench.

A professional radio man takes pride in keeping his tools in shape. Keep your tools clean and bright by wiping occasionally with a cloth on which you have placed a few drops of fine oil or a bit of vaseline. Keep your soldering iron tip clean and well tinned. Keep your pocket knife sharp. Keep your radio parts in neatly labeled containers when not in use; empty cigar boxes are fine for this purpose.

J. E. SMITH.

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

1941 Edition

THIS EXPERIMENTAL MANUAL IS A PART OF THE N. R. I. COURSE WHICH TRAINS YOU TO BECOME A

RADIOTRICIAN & TELETRICIAN

(REGISTERED U. S. PATENT OFFICE) (REGISTERED U. S. PATENT OFFICE)

NCP3M341 Printed in U. S. A.

Instructions for Performing Radio Experiments 1 to 10

Bringing Lecture Room Demonstrations to Your Home

MASTERY of an important radio or electrical principle which you study in your regular N. R. I. course becomes much easier if you can actually demonstrate that principle for yourself. Seeing is believing; when you carry out an experiment, you impress indelibly upon your mind the principle involved.

The N. R. I. course of training in radio is a well-balanced combination of radio theory and practical instruction, *supplemented by the practical demonstrations* given in this and the following experimental manuals. By doing these experiments yourself, you get actual experience in handling radio parts and making radio measurements, and you acquire the ability to understand explanations of more advanced circuit actions. This experience *is even more valuable to you* than demonstrations by an instructor in a lecture room.

These practical N. R. I. radio experiments will develop confidence in your own ability, and will provide exactly what you need to develop yourself into a practical radio technician—a real *Radiotrician and Teletrician.* You will encounter and master technical problems, one by one. You will learn to connect radio parts together in a professional manner. You will see for yourself what happens when a particular part in a radio circuit is removed or made defective. You will learn how to detect and correct errors in connecting parts together, and will learn how to adjust and align practical radio circuits.

This N. R. I. practical demonstration course will be equally valuable regardless of whether you plan to follow radio servicing, radio communications, or one of the specialized branches of these two main radio fields. The basic principles underlying all branches of radio are essentially the same, and all require practical experience with radio parts and radio circuits.

Every single experiment is important, so do not pass over any one of them hurriedly even though you may already know what the results will be.

Importance of Mastering the Art of Soldering

If you examine the chassis of any modern radio receiver or public address amplifier, you will find that the parts are connected together by means of soldered connections. These are the most reliable connections it is possible to make in commercial production; a good soldered connection will not deteriorate appreciably during the entire life of a piece of radio equipment.

When repairing a defective receiver, you must first locate the defective part. But the ability to determine what is wrong with a radio device is of little value unless you also know how to remove the defective part and how to solder the connections for the new part. Furthermore, it will often be necessary to *unsolder* one or more connections in order to make tests which will reveal the defective part.

This first manual in your practical demonstration course is devoted entirely to soldering. You study the fundamentals of radio soldering, then learn how to make each of the common types of soldered connections used in radio work. The soldering iron, solder, hook-up wire and radio parts included with Radio Kit 1RK for these first ten experiments are all standard, just like those you would work with when servicing radio receivers.

Contents of Radio Kit 1RK

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

> **IMPORTANT: If any part in your Radio Kit 1RK is obviously defective or has been damaged during shipment, please return *the defective part* to the Institute *immediately* for replacement.**

Tools Needed

For the experiments in your practical demonstration course, you will need the tools which are shown in Fig. *2* and listed in the caption underneath. These tools are *not* supplied in Radio Kit 1RK, but you undoubtedly have at least some of them already since they are common home tools. Those which you do not have are readily obtainable at local hardware stores, dime stores, mail order firms, or radio supply firms. All of the tools will be needed for radio servicing work and for later experiments in your practical demonstration course, so they are a really worthwhile investment.

Theory of Soldering

Any art or technique is easier to master if you first study the fundamental principles and theories which are involved. For this reason, we will consider now what solder actually is, why it adheres to certain metals under certain conditions, and why solder is so essential for permanent connections in radio circuits.

Molecular Attraction. When two ordinary solid objects are pressed together, nothing happens. Thus, we cannot make a block of solder stick to a block of copper merely by pressing the two blocks together.

It is perfectly possible to grind two metal surfaces so perfectly flat and smooth that they will adhere to each other when pressed together with a twisting force. The Johansson gage blocks used by machinists for precision measurements are an example of this phenomenon. When these blocks are pressed together hard enough to force air out from between the adjoining surfaces, the molecules of steel get close enough to attract each other with tremendous force. *Molecular attraction* thus explains why Johansson gage blocks stick together.

Why Solder Adheres. In soldering, it is unnecessary to have perfectly flat surfaces on the objects which are to be joined together. When both metal objects, even though irregular, are made perfectly clean (free of foreign materials such as chemical oxides, grease and dirt) and are heated to the proper temperature, molten solder will adhere to the two cleaned surfaces and will bridge the gaps between them. Now, when the solder has cooled and hardened, its surface molecules will be just as close to the molecules in the adjoining cleaned but irregular surfaces as are the molecules in gage blocks. *Molecular attraction* thus makes solder adhere to certain metals.

Once a metallic surface has been *tinned* by making a layer of solder adhere to it, additional solder can very easily be *fused* to that already on the metal. (Two pieces of solder

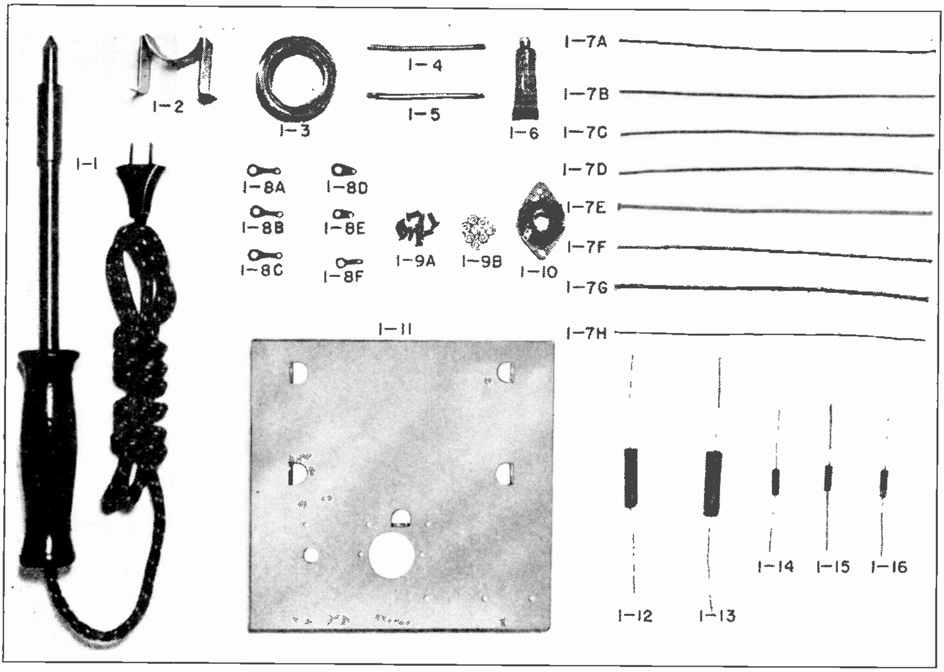


FIG. 1. The parts included in Radio Kit 1RK are pictured above, and identified in the list below. The first numeral in a part number is that of the kit in which the part is supplied; thus, parts supplied with Radio Kit 2RK will be numbered *2-1*, *2-2*, etc., and parts supplied with 3RK will be numbered *3-1*, *3-2*, etc. With this system, therefore, the first numeral tells you at a glance the number of the kit in which a particular part was supplied.

PART NO.	DESCRIPTION
1-1	One 55-watt electric soldering iron.*
1-2	One soldering iron holder.
1-3	One roll of ribbon-type rosin-core solder.
1-4	Three-inch length of round-type plain solder (no markings).
1-5	Three-inch length of round-type acid-core solder (*marked with indented dots*).
1-6	One tube of paste flux.
1-7A	*Red* 8-inch length of No. 20 solid tinned push-back wire.
1-7B	*Red* 8-inch length of No. 20 solid tinned push-back wire.
1-7C	*Red* 8-inch length of No. 20 solid tinned push-back wire. (Parts *1-7A*, *1-7B* and *1-7C* are identical, and are numbered differently merely for convenience.)
1-7D	*Black* 8-inch length of No. 20 stranded tinned push-back wire.
1-7E	*Green* 8-inch length of No. 18 solid untinned rubber and cotton insulated wire.
1-7F	*Yellow* 8-inch length of No. 20 stranded tinned rubber and cotton insulated wire.
1-7G	*Yellow and green* 8-inch length of stranded untinned No. 18 lamp cord.
1-7H	Eight-inch length of 7-strand No. 26 enameled aerial wire.
1-8A	13/16-inch tinned soldering lug.
1-8B	13/16-inch tinned soldering lug
1-8C	13/16-inch tinned soldering lug. (Parts *1-8A*, *1-8B* and *1-8C* are identical, and are numbered differently merely for convenience.)
1-8D	5/8-inch untinned soldering lug.
1-8E	1/2-inch untinned soldering lug.
1-8F	11/16-inch untinned soldering lug.
1-9A	Eight 1/4-inch long, 6-32 cadmium-plated binder-head machine screws.
1-9B	Eight cadmium-plated hexagonal nuts for 6-32 screws.
1-10	One octal-type tube socket with six terminal lugs. (Slots 2, 3, 4, 5, 6 and 7 should have lugs, as shown in Figs. *36* and *37*. Some lugs may seem loose, but they will tighten automatically when a tube is plugged into the socket.)
1-11	One steel chassis bent to shape, with all holes already punched out for future use.
1-12	One .03-mfd., 400-volt tubular paper condenser.
1-13	One .05-mfd., 400-volt tubular paper condenser.
1-14	One .25-megohm, 1/2-watt resistor with 10% tolerance (color-coded red, green, yellow, silver).
1-15	One .1-megohm, 1/2-watt resistor with 10% tolerance (color-coded brown, black, yellow, silver).
1-16	One 18,000-ohm, ½-watt resistor with 10% tolerance (color-coded brown, gray, orange, silver).
1-17	One metal-marking crayon (not shown above).

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* If you have previously notified the Institute that you do not have 115-volt power available, Part *1-1* will be missing, and you will receive Part *1-1A* instead; this is a plain soldering iron like that illustrated in Fig. *4*.

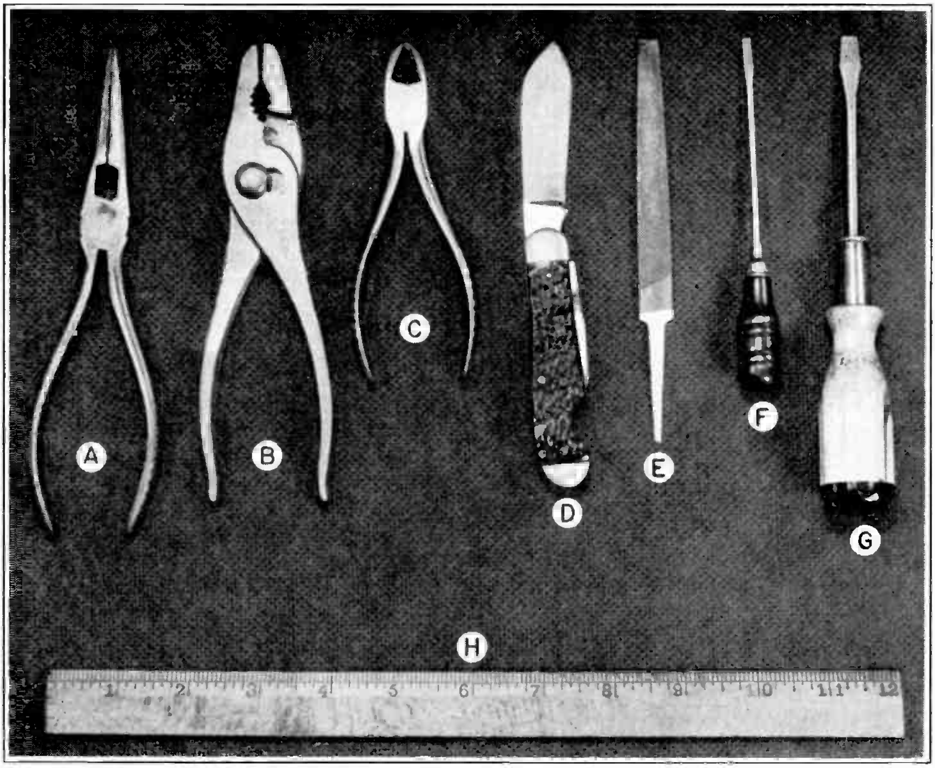


FIG. 2. The essential tools which you will need for the experiments in your practical demonstration course are pictured here and identified below. Get the best side-cutting pliers and long-nose pliers you can afford, for you will use these tools continually throughout your practical demonstration course and in actual radio work of all kinds.

A—One pair long-nose pliers (5 to 7 inches long). These usually have side-cutting jaws, but this feature is not essential.
B—One pair ordinary all-purpose pliers (6 to 7 inches long); the thin type is handiest for radio work.
C—One pair side-cutting pliers (5 to 6 inches long).
D—One ordinary pocket knife (jack-knife).
E—One medium-size flat metal-cutting file (about 7 inches long).
F—One small screwdriver (about 5 inches long).
G—One medium-size screwdriver (about 7 inches long).
H—One 12-inch ruler of any type.

can be combined or fused simply by placing one in contact with the other and applying heat.)

What Solder Is. Solder is a general term applied to *any mixture or alloy of metals which is used to provide a good bond between two or more metal objects.* Solder used for radio work contains only lead and tin. The ratio of lead to tin determines the hardness, strength and melting point of the solder.

Radio solder will adhere to iron, steel, brass, copper, cadmium and phosphor bronze when these metals are properly cleaned. Radio men have no need for soldering to aluminum, which requires a special aluminum solder.

Importance of Heating the Work. Solder will *adhere* to a metal surface only when that metal surface is clean and sufficiently hot to melt the solder. *Molten solder will not adhere to a cold surface.* One requirement for successful soldering is *heating the work sufficiently so that the solder will melt readily when applied directly to the work.*

The two types of soldering irons

used by radio men for heating a metal object preparatory to soldering will now be considered.

Soldering Irons

Electric Soldering Iron. An electric soldering iron like that shown in Fig. *3* is used in the radio industry far more than any other type for bringing electrical joints to soldering temperature. This is a true professional soldering iron, and is the one you now have in Radio Kit 1RK if you previously indicated that 115-volt electric power was available for your home demonstration course.

heating element consists of nichrome wire (like that used in electric stoves) wound into a coil and covered by a heat-resistant insulating material.

Never unscrew the copper barrel and tip of the N. R. I. electric soldering iron; the heating element inside is fragile, and is easily damaged when exposed. If the copper barrel becomes loose during normal use, tighten it while the iron is cold. Avoid dropping your soldering iron or swinging it carelessly against a hard object; more important yet, *never use your soldering iron as a hammer,* for that will surely damage the heating element.

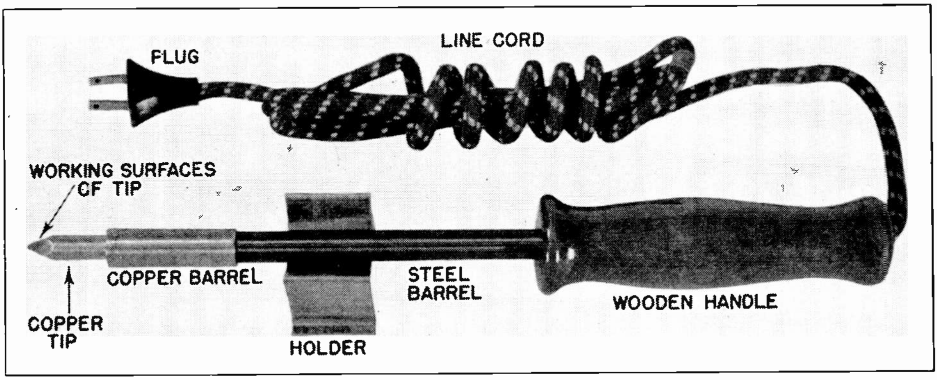


FIG. 3. Typical electric soldering iron for radio work. This is the soldering iron which is supplied to you as Part *1-1* in Radio Kit 1RK if you have access to 115-volt electric power. The correct way to use your soldering iron holder (Part *1-2*) is also shown; the holder should be near to the copper barrel but should not touch it.

Electric soldering irons of various makes may differ slightly in size and appearance, but all are constructed in essentially the same manner. In the electric soldering iron we supply, there is a hollow copper barrel mounted at one end of a hollow steel barrel, with the heating element fitting snugly inside both the copper and steel barrels. A pointed copper tip projects from the end of the copper barrel. At the other end of the steel barrel is a wooden handle. The line cord passes through the wooden handle and the iron barrel, and connects to the terminals of the heating element. This

Electric soldering irons are usually built for 115-volt operation,* and can be used with either a.c. or d.c. power. For ordinary radio servicing work, the heating element has a wattage rating of from 50 to 60 watts; the N. R. I. electric soldering iron will draw about 55 watts when plugged into either a 115-volt a.c. or 115-volt d.c. power source. Allow about three minutes for the iron to heat up after plugging it into a power source.

*Power line voltages may vary between 110 volts and 120 volts. Up to a few years ago, line voltages at homes were around 110 volts, but today most homes have voltages approaching 120 volts. An electric soldering iron built for 115-volt operation can be used on any voltage between 100 volts and 125 volts.

Since heat tends to rise (travel upward), the copper tip of an electric soldering iron will heat up fastest when the iron is held vertically with the tip uppermost. Remember this simple fact when you want to heat your iron in a hurry. Normally, however, an electric soldering iron supported horizontally in its holder will heat up fast enough for all practical purposes; this is the position you should use. Do not allow the iron to hang downward by its cord while heating, for in this position the heat will travel upward through the iron and make the wooden handle uncomfortably hot.

It is quite all right to plug in your electric soldering iron when you start experimental work, and leave the iron plugged in until you are through for the day. The iron is then ready for use instantly when needed, even though you may be studying the instructions more than half of the time.

Plain Soldering Iron. When electric power is not available, a plain soldering iron like that shown in Fig. *4* is used. In this iron which we supply if you do not have 115-volt power, a pointed copper tip projects from a solid copper barrel which is in turn screwed onto a hollow steel barrel. A wooden handle is fitted over the other end of the steel barrel. This iron is heated by placing the copper barrel in the flame of an alcohol burner or gasoline blow torch. Once heated to the proper temperature, a plain soldering iron holds its heat long enough to make a number of soldered joints. It is then reheated for additional work.

In an emergency, you can heat the copper barrel of any electric soldering iron in the flame of an alcohol burner. Radiotricians who get occasional calls from suburban or rural homes not equipped with electricity often carry along in their tool kit a can of special heating fuel called "canned heat," or an alcohol burner like that described later in this manual.

Purpose of Soldering Iron Holder. A heated soldering iron should always be returned to its metal holder when not in use. Figures *3* and *4* both illustrate the correct position of an iron in its holder. It is best not to let the hot copper portion touch the holder. The copper barrel is the hottest part of the iron; heat conducted from the barrel through the metal holder may scorch the workbench or other surface on which the holder is resting, and heat conducted away from the barrel by the holder will tend to cool the tip.

The soldering iron holder should be kept conveniently close to your work, but never in a position where you might accidentally knock the iron out of the holder. A heated soldering iron is hot enough to do considerable dam-

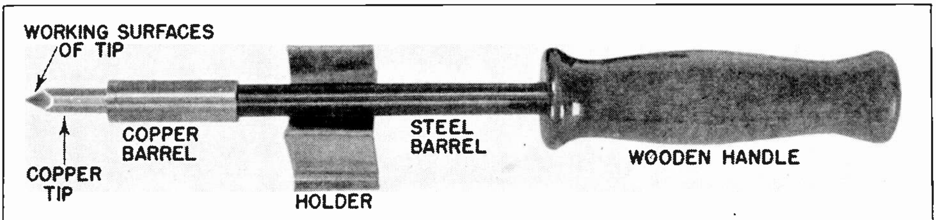


FIG. 4. Plain soldering iron for radio work. This can be used anywhere, for it simply requires a source of heat such as a torch or alcohol burner. You have this soldering iron in Radio Kit 1RK (identified as Part *1-1A*) if you previously indicated that electric power would not be available for your practical demonstration course. The correct position of your soldering iron holder (Part *1-2*) is also shown; this holder should be close to the copper barrel but should not touch it.

age to your hands, to your clothes, or to wooden table tops, so be careful.

Soldering Flux

When plain solder is applied to a heated piece of uncleaned brass or copper, the solder melts but rolls off immediately, without adhering. This is to be expected, for ordinary uncleaned metal is covered with a film of grease, dirt and metal oxides which prevent the molecules of solder from getting sufficiently close to the molecules of brass or copper. Filing the surface of the brass or copper makes it appear clean, but ordinarily does little good because oxides form very rapidly on a heated metal surface. The oxygen in the air combines with the metal to form the oxide film, and heat accelerates this combining action.

If solder is to be applied successfully to a metal, the oxides must be removed from the heated metal surface as fast as they form. This can be accomplished by applying, along with the solder, an additional material called a *flux*. For good radio work, this flux is always rosin (an amber-colored substance which remains after oil of turpentine is distilled out of crude turpentine). Sheet metal workers generally use an acid flux (usually some form of hydrochloric acid); this is more effective than rosin, but has a corrosive action which makes it unsuitable for radio work.

A flux can be applied either in the form of a liquid or a paste, but it is more convenient to use a special radio solder having a core of the desired flux. In this way, both the solder and the flux are applied at the same time.

Disadvantages of Acid Flux. Although it is a well-known fact that acid flux or acid-core solder is easy to use, it is unfortunate that some of the acid *always* remains on the work and *creeps* over to unsoldered portions. In time, this acid will eat away the copper or brass around the joint, causing failure of the joint. The slightest presence of moisture in the air will speed up the creeping movement of acid flux. The acid may travel through the insulation between radio parts, thereby forming leakage paths for electric currents and impairing the efficiency of the circuit.

Because of its strongly corrosive action, acid flux should never be used for radio work.

Rosin Flux. Rosin is a solidified material when at normal room temperatures, but becomes liquid when heated by a soldering iron. Rosin is a fairly good insulator and has no corrosive action on metals, hence surplus rosin flux does no harm to a properly soldered connection. Rosin flux is considerably harder to use successfully than acid flux, but because of its superior insulating and non-corrosive qualities, rosin is by far the best flux for radio connections. It is generally used in the form of rosin-core solder.

Paste Fluxes. Both rosin and acid fluxes are available in the form of pastes which can be applied to the joint with a knife or a wooden splinter. A paste flux is fairly easy to use, but it is difficult to determine whether a particular paste includes corrosive ingredients which can ruin a radio connection. Even pastes which are advertised as being non-corrosive will sometimes cause enough corrosion to ruin a delicate radio joint. For this reason *the use of paste flux should be avoided in radio work.*

How Fluxes Work. Acid and rosin fluxes both act in the same manner in making a lead-tin mixture (solder) adhere to another metal. These fluxes dissolve some of the oxides which are always present on a metal surface. The oxides then flow off the metal in liquid form, carrying along dirt, grease and other oxides so as to leave a clean metal surface to which solder can adhere.

Making an Alcohol Burner for Heating a Plain Soldering Iron

If you have a plain soldering iron (Part *1-1A*) in place of the electric soldering iron (Part *1-1*), you will need a convenient source of heat. A small alcohol burner is ideal for this purpose, as it is easy to make and safe to use. Furthermore, this burner provides an alcohol flame which is ideal for removing enamel insulation from wires.

Parts Needed. The only parts needed for the alcohol burner are a plain medium-sized oil can of the type sold for about ten cents in most dime stores and hardware stores, a lamp wick of the type used in kerosene lamps, and about a pint of denatured alcohol, wood alcohol, grain alcohol, Paco Solvent, or an equivalent alcohol product. These parts are pictured in Fig. *5*.

Unscrew the spout of the oil can. With a hacksaw, cut off the spout about 3/8 inch above the base, as indicated by the dotted line in Fig. *5*. You can clamp the small end of the spout in a vise while sawing, for this end will be discarded. Use a fine-tooth hacksaw blade and take light strokes to prevent excessive chattering. Smooth the saw cut with your file, and scrape off all metal burrs.

Roll the lamp wick together lengthwise at one end, and push it through the stub of the spout from the bottom. Let the wick project about 1/2 inch above the top of the spout.

Fill the can about half full of alcohol, then replace the spout and tighten it. Tip the can upside down for a few seconds so the entire wick becomes saturated with alcohol, then set the can upright and apply a lighted match to the wick. The flame should extend 2 to 4 inches above the wick. The color of the flame depends upon the type of alcohol used; pure grain alcohol will give an almost invisible blue flame, while commercial alcohols give a predominantly yellow flame, with only a small blue portion.

The height and size of the flame can be adjusted by pushing the wick in or out of the spout. The more wick there is exposed and the more the wick ends are spread out, the larger will be the flame. If the flame decreases gradually in size or flickers excessively when the burner is used for some time, loosen the cap about half a turn so that air can get in around its threads. Even a slight breeze or draft in a room will make the flame flicker; if the draft cannot conveniently be eliminated by closing windows and doors, set up boxes or boards around the burner to shield it from the air currents.

The flame can be extinguished simply by blowing it out, or by placing a thimble or small tin can momentarily over the flame to cut off its air supply.

Alcohol evaporates rapidly, so if a considerable amount is left in the can after work is finished, you can pour it back into the bottle or can in which the alcohol was sold. Keep your supply of alcohol tightly capped or corked to minimize evaporation. As an alternative to emptying the burner, you can place a small thimble over the wick.

Holder for Plain Soldering Iron. The soldering iron should always be placed so that the copper barrel is in the upper third portion of the flame. Soot will sometimes be deposited by the flame, so do not allow the flame to touch the copper tip of the iron. The iron should be in a horizontal position, or the handle should be lower than the tip during heating. Heat always travels upward; if the handle

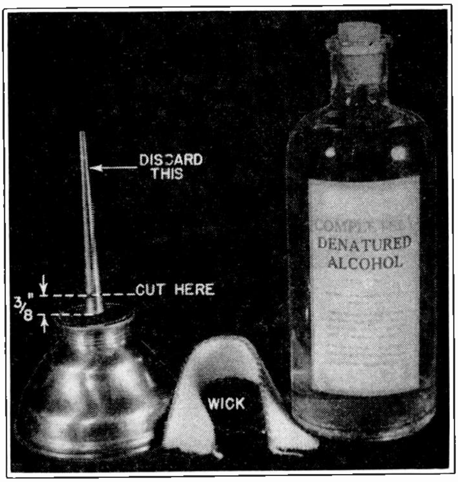


FIG. 5. Parts needed for making an alcohol lamp which can be used for heating a plain soldering iron, for removing enamel from wires, and for heating an electric soldering iron in locations where power is not available.

were higher than the tip, heat would travel up to the handle and make it uncomfortably hot.

A suitable holder in which the plain soldering iron can be placed *while heating* is illustrated in Fig. *6*. (This holder is used only for heating the iron; the ordinary metal holder shown in Fig. *4* is used to support the heated iron when tinning wires or lugs.) You can make this yourself very easily, using a large tin can, a scrap piece of wood and a few nails, or you can design an equivalent holder from other materials which you may have at hand. Keep in mind that the two purposes of the holder are to prevent the alcohol burner from tipping and to hold the copper barrel of the soldering iron in the upper third portion of the flame.

How to Tell When the Iron Is Heated Sufficiently. An alcohol burner like that described here will ordinarily bring your soldering iron to the correct working temperature in from three to five minutes. After heating for three minutes, apply solder momentarily to a flat surface of the tip; if the solder melts readily, the iron is ready for use. If the solder melts slowly, continue heating for a while and then repeat the test. Ordinarily, it is best to heat the iron for about one minute after solder first begins to melt on the tip; extra heat is then stored in the copper barrel and tip, and a number of joints can be soldered before the iron needs reheating.

Do not overheat the iron; above all, never allow a soldering iron to become red hot. *Too hot* an iron is just as bad as *too cold* an iron insofar as good soldering is concerned, and an excessively hot iron quickly becomes corroded.

Starting the Experiments

Choosing a Place to Work. The experiments in your practical demonstration course can be performed on almost any type of table or workbench which does *not* have a metal top. Students living in city apartments will find that an ordinary folding card table serves nicely. If you will be using the plain soldering iron and alcohol burner, choose a location well away from curtains and other highly inflammable materials. If you will be using the electric soldering iron, you can either place the table near a wall electric outlet, or use an extension cord to

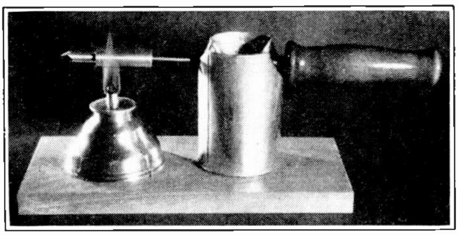


FIG. 6. Completed alcohol burner in use. The base is a wooden board of any convenient size. Three finishing nails hold the oil can in position on the base and prevent accidental tipping. A large empty tin can with notches cut in opposite sides can be used as a holder for the soldering iron, or you can cut a holder out of sheet metal for this purpose. The holder can be fastened to the base with two wood screws, in a position such that the copper barrel will be in the upper third portion of the flame.

bring electric power to your table.

Performing the Experiments. Develop the correct experimental habits right from the start by following a logical procedure for each experiment. Whenever you start a new manual, always study first the introductory discussions at the beginning of the book. After this, perform the experiments *one at a time*, in the correct order, by observing the following procedures:

1. Read through the instructions and discussions for the entire experiment once very slowly, and study any parts which are not immediately clear to you. Do not touch a single tool or radio part until you make this preliminary study.

2. Lay out on your work table the parts and tools needed for the experiment which is to be performed.

3. Carry out the experiment, one step at a time. Record your results whenever spaces are provided in the manual for this purpose. Additional observations and comments can be written in the margins of the pages, for future reference.

4. Study the discussion at the end of the experiment very carefully, and analyze your results. After finishing an experiment, you should be able to tell in your own words exactly what you proved and how you did it.

5. Fill out the report statement for the experiment just completed. This statement will always be on the inside of the back cover of the manual, and will be numbered the same as the experiment.

6. When you have completed all ten experiments in a manual and have answered all of the report statements, cut off the last page of the manual on the dotted line according to the instructions on that page, and mail the report statement to N. R. I. for grading. *Do not send in the entire manual.*

IMPORTANT NOTICE: In order to build the N. R. I. Tester with the parts furnished in Radio Kits 1RK and 2RK, it is absolutely necessary that you perform every step in each of the ten soldering experiments in this manual. There are about twenty-five soldered joints in the N. R. I. Tester, and these must be made exactly in accordance with the professional soldering techniques presented in this manual. Furthermore, the ability to make good soldered joints is required in all later experiments as well as in practical radio work. DO NOT SKIP ANY STEPS.

EXPERIMENT 1

***Purpose:* To tin the working tip of your soldering iron.**

Step 1. To determine if plain solder alone (without flux) can be used for tinning a soldering iron, hold the heated iron horizontally in one hand, and melt a small amount (it will be sufficient to use up about ½ inch of your length of plain solder) of plain solder (Part *1-4,* with no markings) by rubbing lightly over the flat surface of the tip in the manner shown in Fig. 7. Wipe off the heated solder with quick strokes of a piece of cloth, and note whether any of the solder clings to the tip. Use several thicknesses of cloth so as not to burn your fingers. If you prefer, you can tack this cloth to a small board and use it like a brush for wiping the iron.

Now file this heated flat surface until it is uniformly clean, using for this purpose the flat file specified in Fig. 2. Usually the Radiotrician will rest the tip of the soldering iron against a non-inflammable solid object such as a brick or a stove while filing. *Never squeeze an electric soldering iron tightly in a vise.* Note how the heated copper surface changes color soon after being filed. Apply plain solder to the freshly filed surface, wipe off with the cloth, and note how much solder adheres to the tip.

In the case of a plain soldering iron, reheat the soldering iron just before filing, and file rapidly so that the iron will still be hot enough to melt solder after you have finished filing one surface.

Step 2. To determine if rosin-core solder can be used for tinning a soldering iron, file a different surface from that used in Step 1, then rub a small amount (about ½ inch) of rosin-core solder (Part *1-3,* marked with printed letters) lightly over this entire surface. Wipe off surplus solder with the piece of cloth to see if any solder remains on the tip.

Step 3. To determine if acid-core solder can be used for tinning a soldering iron, file a different flat surface of the tip from those used in Steps 1 and 2, and rub a small amount (about ½ inch) of acid-core solder (Part *1-5,* marked with indented dots) lightly over the entire brightly filed surface. Do not let the heated acid splatter on your hands or clothes. Wipe off surplus solder with the cloth to see if any solder remains as a desired coating.

Step 4. To complete the tinning of your soldering iron, file the remaining flat surface of the heated soldering iron tip until bright. Apply a small amount of paste flux (Part *1-6*) to this surface with a toothpick or match, then rub plain solder (Part *1-4*) over the surface. Wipe off surplus solder with a cloth, then apply additional paste flux to those parts of the surface where solder did not adhere, and rub on plain solder again. Repeat until this surface is completely tinned, then do the same for any other surfaces which are not completely tinned. Your soldering iron should now be completely tinned on all four surfaces as shown in Fig. *8.*

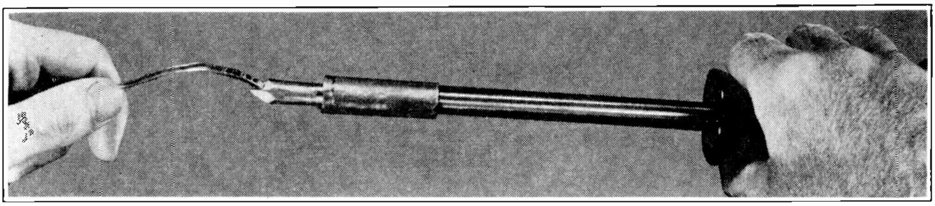


FIG. 7. Correct way to hold the soldering iron while applying solder to one flat surface of the tip for tinning purposes. By keeping the flat surface approximately level, the tendency of the molten solder to roll off the tip is minimized.

Step 5. To learn the radio expert's technique for shaking surplus solder off the tip of a soldering iron, apply a small extra amount (about ¼ inch) of rosin-core solder to the heated tip. Now hold the iron firmly by its handle and shake it downward over a box, a board, or newspapers. Practice this several times, until you can flip off surplus solder without getting it on your clothes or scattering it all over the room. Apply more rosin-core solder to the heated tip, but this time wipe it off with quick strokes of a cloth.

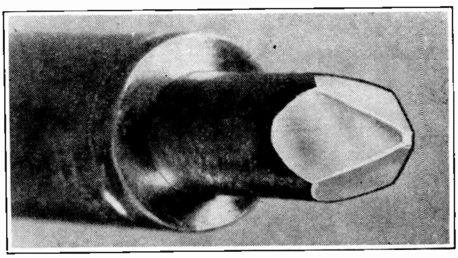


FIG. 8. Close-up photograph showing a properly tinned soldering iron tip. Note that only the flat surfaces of the copper tip are tinned.

Discussion: Plain solder without

flux will not ordinarily adhere to a copper surface. You proved this in Step 1 by applying the solder to the heated tip of the soldering iron both before and after filing the tip. You would secure the same results with copper wire or any other heated copper surface.

The change in the color of the copper surface soon after filing was due to the formation of oxides of copper on the surface. These oxides, along with any other foreign matter which may be on the tip, prevent you from tinning the soldering iron with plain solder. There is no danger of destroying the temper of the file, for an electric soldering iron never gets hot enough to affect the hardness of steel.

In Step 2, you proved that rosin-core solder will adhere to a properly cleaned and properly heated copper surface. Only the surplus solder can be removed with the cloth; the bright silvery surface layer of solder adheres to the clean copper, and cannot be wiped off. In this step, therefore, you tinned one of the four working surfaces of the tip.

Acid-core solder splatters and sizzles when applied to a heated copper tip as in Step 3, but adheres more readily and tins faster than does rosin-core solder. Wiping off surplus solder leaves the same desired tinned surface obtained with rosin-core solder. Acid-core solder can be used occasionally for tinning your soldering iron, but should never be used for radio joints because of its corrosive action.

Paste flux and plain solder provide a tinned surface very nearly as quickly as does acid-core solder, but here again there is always the danger that the flux may corrode your work. Avoid using paste or acid flux for radio work; these were included in your radio kit *only for tinning your iron to make you familiar with all of the common fluxes.*

Surplus solder often accumulates on a soldering iron during radio work. Rosin flux evaporates quickly from hot solder, so it is usually best to discard this solder. When radio men are in a hurry, they just give the iron an expert flip as described in Step 5, so as to shake off the solder. When the iron is also a bit corroded, however, wiping off the surplus solder with a cloth will usually remove the oxides too, leaving a clean tinned tip. Wiping off the tip in Step 5 also serves to remove any acid flux which may have been left on the tip after the first four steps.

Tinning serves the dual purpose of *keeping the tip of your soldering iron clean and aiding in the transfer of heat* from the iron to the work. The solder fills small irregularities in the tip and in the work, thus increasing the area of contact between the tip and the work.

A soldering iron which is untinned or only partially tinned on its flat working surfaces quickly becomes pitted and covered with crusts of copper oxide. An iron in this condition is difficult to use, for the oxide has heat-insulating characteristics and thus hinders the transfer of heat.

A certain amount of copper oxide will form even on a properly tinned iron which is used continuously for several hours. This can usually be removed by applying rosin-core solder to the spots, then wiping off the surplus solder with a cloth. The tip should be filed only when a considerable quantity of oxide has formed and cannot be removed by retinning.

In filing the tip of your soldering iron, always hold the file flat against the surface so as not to change the angle of the tip too much. The tip of your iron has been cut at the angle which has proved most satisfactory for radio work.

A long, slim tip cools too rapidly when in contact with the object being heated, so avoid making the tip more pointed than it now is. A blunter tip holds its heat well, but is awkward to use because this type of tip often blocks your view of the work.

Instructions for Report Statement No. 1. The report question which checks your work on this experiment is on the last page of this manual. After you have completed the experiment and studied the discussion, read Report Statement No. 1 carefully. You are asked to specify *the type of solder* (plain, rosin-core or acid-core) *with which it was the most difficult to tin your soldering iron.* Either the observations which you made during this experiment or the analysis of results in the discussion can give you the answer, but if you prefer, you can wipe off surplus solder, file your tip, and repeat Steps 1, 2 and 3 again on your iron.

EXPERIMENT 2

Purpose: **To recognize when solder has hardened, and to see what happens when a joint is moved before the solder has hardened.**

Step 1. To demonstrate how solder changes color as it hardens, hold your heated and tinned soldering iron over a scrap piece of wood with the tip downward, and apply rosin-core solder just above the point of the tip until a solder globule about ⅛ inch in diameter drips down onto the board (the drop is shown actual size in Fig. *9*). Watch this globule for about a minute, noting the change in color as it hardens.

Drop another globule of solder on the board in this same way, then apply the tip of the iron to the globule and apply additional solder to the tip until this second globule is about twice the size of the first globule. In the same way, place on the board a third globule which is about three times the size of the first one. As each globule cools, study the changing colors of the hardening solder.

Step 2. To find whether larger amounts of molten solder take longer to cool, reheat all three globules of solder on the board one after another as quickly as you can, by applying the heated tip of your soldering iron first to the largest globule, then to the medium-sized one, and finally to the smallest one. Jerk the tip of the iron away from each globule as soon as the solder takes on a silvery molten appearance. While the three globules are cooling together, watch them carefully to determine which ones harden first.

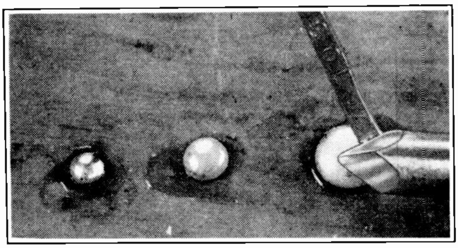


FIG. 9. Method of increasing the size of a molten globule of solder by feeding rosin-core solder to the soldering iron tip while it is in contact with the globule. The three globules used in Experiment 2 are shown clearly in this view. The darker rings on the board around each globule are formed by the surplus rosin flux, which is a yellowish liquid when heated.

If you look closely, you will see your own image in the surface of a molten solder globule, just as if it were a tiny curved mirror. The image vanishes gradually as the solder hardens.

Step 3. To determine by actual test the instant when solder hardens, reheat the largest globule with the soldering iron, then remove the iron and allow the globule to cool. Take the length of stranded enameled aerial wire (Part *1-7H*) and occasionally touch the *top* of the globule gently with it to determine when the solder hardens, while watching the changes in color. Repeat this test a few times if necessary, until you are familiar with the color corresponding to complete hardening of the solder.

Step 4. To see what happens to solder which is disturbed while it is cooling, reheat the largest globule with the soldering iron, and hold the wire in the center of the globule while it cools. *Just before the globule turns white,* tilt the wire sideways and twist it slightly so as to crack the globule apart.

Discussion: Step 1 showed you that solder has a bright, silvery color (much like mercury) when in a molten condition, and changes gradually in color as it hardens. This change in color serves as a "thermometer" to the Radiotrician, for it tells him when the solder has melted on a joint being unsoldered, and tells him when the solder has hardened sufficiently on a joint being soldered.

Step 2 showed clearly that a large globule of molten solder takes longer to cool than does a small globule. Likewise, you found that the larger globules took longer to heat up.

In the first two steps, we assumed that the solder was hard when it stopped changing color. In Step 3, you probe the solder with the wire, and you prove for yourself that a globule of solder has completely hardened when it changes all over to the characteristic color of hardened solder.

Step 4 demonstrates conclusively a highly important requirement of good soldering: *A soldered joint should not be moved until the solder has completely hardened.* Premature movement cracks the solder, for it is very brittle at the instant of hardening. Solder which is cracked gives very poor electrical contact between the parts of a joint. Provision for holding wires rigid while solder cools is an important part of the preliminary soldering procedure.

Instructions for Report Statement No. 2. The test question for this experiment is a simple check of your ability to observe how solder changes in color as it hardens. A correct answer means that you have mastered one important requirement of good soldering, for these color changes tell

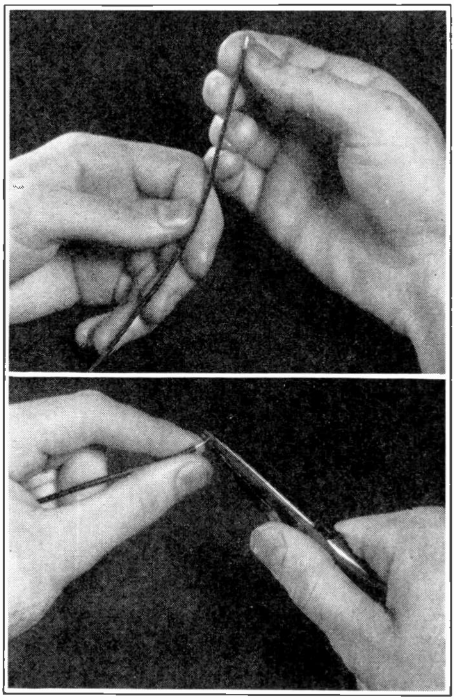


FIG. 10. The correct method of pushing back the insulation of solid push-back insulated wire with the fingers preparatory to soldering is shown in the upper view. The same method is used for stranded wire of this type. When the insulation cannot readily be pushed back far enough with the fingers, it will be easier to grasp the bare end of the wire with your long-nose pliers, as illustrated in the lower view. When holding the wire with pliers in this manner, it is a simple matter to push the insulation back with the fingers as much as desired.

you when solder has hardened enough to withstand movement.

After you have completed this experiment and studied the discussion, read Report Statement No. 2 on the last page of this manual carefully, and place a check mark in the box which follows the answer you consider correct.

EXPERIMENT 3

Purpose: **To remove insulation from wires and clean the wires preparatory to soldering.**

Step 1. To remove insulation from push-back insulated hook-up wire, grasp in one hand a length of *red* wire (Part *1-7A*, which is *solid* tinned push-back insulated wire), and push the insulation back from the end with the thumb and first finger of your other hand, as shown in the upper view in Fig. *10*. Push the insulation back far enough to expose about ¾ inch of wire. To show that the insulation can be pushed forward again after a joint is made if too much wire was originally exposed, push the insulation forward until only about ¼ inch of wire is exposed. Push back again until the full ¾ inch is exposed. Now push back the insulation on the other end of this wire the same amount (¾ inch); use long-nose pliers this time to hold the end of the wire, as illustrated in the lower view in Fig. *10*.

Push back the insulation for ¾ inch from both ends of the *black* wire (Part *1-7D*), which is *stranded* tinned push-back insulated wire). Use long-nose pliers to hold the wire, as illustrated in Fig. *10*.

Step 2. To remove insulation from ordinary insulated hook-up wire by squeezing with long-nose pliers, grasp in one hand the length of *green* wire (Part *1-7E*, which is solid untinned No. 18 wire insulated with rubber and cotton braid) and use your long-nose pliers to squeeze the insulation for a distance of ¾ inch from one end. Figure *11* illustrates how this is done. You will have to apply enough pressure with the long-nose pliers to split the insulation lengthwise, so that you can pull off the strips of insulation with the pliers. Loose threads of insulation can then be clipped off with side-cutting pliers or a pocket knife. Remove ¾ inch of insulation from the other end of the wire in the same way. Scrape the exposed copper wire lightly with the blade of a pocket knife as shown in Fig. *12*, to remove oxides and dirt.

Now remove ¾ inch of insulation from each end of the length of *yellow*

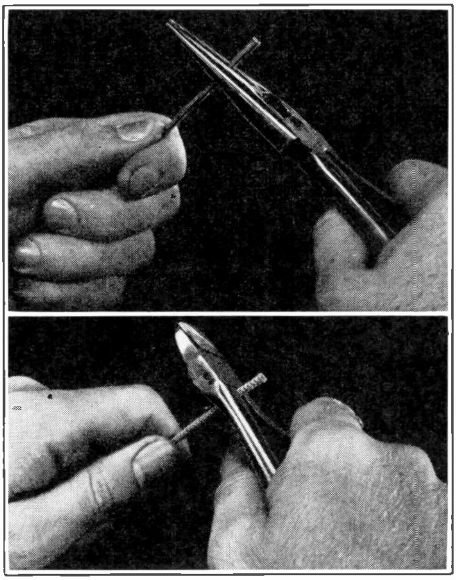


FIG. 11. A method of using long-nose pliers to squeeze off the insulation from ordinary (not push-back) hook-up wire preparatory to soldering is shown above. Try placing the wire at different positions along the jaws of the pliers, for there is always one position at which you can exert the greatest pressure on the wire. Usually this position will be close to the pivot. Some long-nose and side-cutting pliers are designed so that insulation can be squeezed between the handles, as illustrated below for side-cutting pliers.

wire (Part *1-7F*, which is stranded tinned No. 20 wire insulated with rubber and cotton braid) in this same manner.

If you are unable to break the insulation by squeezing, omit this step and apply to this same wire one of the alternative methods given in the next step.

Step 3. To remove insulation from ordinary insulated wire with a pocket *knife,* hold the length of *green and yellow* wire (Part *1-7G*, which is No. 18 stranded lamp cord) flat upon your workbench or on a block of wood. Cut through the insulation all around the wire at a point ¾ inch from one end by moving the blade of a sharp pocket knife across the insulation with a sawing motion while rotating the wire slowly with your fingers. This is illustrated in Fig. *13*. Continue until the outer covering of woven cotton thread has been cut through all around, then slide this covering off over the end of the wire with your fingers or by pulling with long-nose pliers. Be careful not to cut through the inner rubber layer to the copper strands. Once the inner rubber insulation is partly cut through, peel it off with your fingers or a knife.

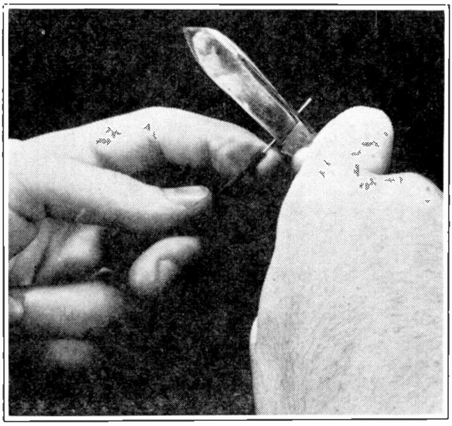


FIG. 12. Always use the portion of your pocket knife blade closest to the handle for scraping oxides and dirt from exposed copper wire preparatory to soldering. This preserves the main part of the blade for purposes where sharpness is required, such as when cutting through braided cotton insulation.

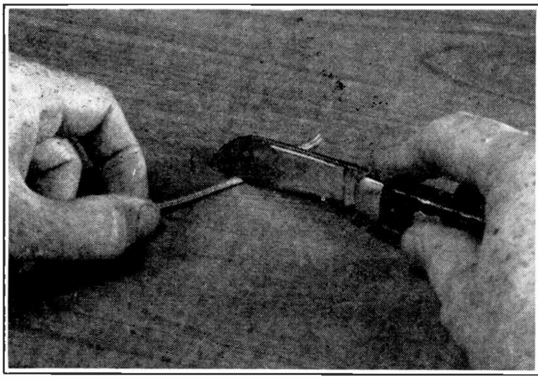
Scrape the exposed wire lightly with your knife blade if the copper appears corroded or dirty; do this several times, spreading out the strands each time so as to expose a different part of each strand to the knife.

Now take the other end of the lamp cord wire, hold it in your hands as shown in Fig. *14*, and slice off the outer braided cotton covering for a distance of ¾ inch from the end. Peel away the remaining rubber insulation with your knife and fingers, and trim off loose threads. Be careful not to cut or nick any of the copper strands. Scrape the strands with the knife blade until all are clean and shiny.

Step 4. To remove enamel insulation from a wire, take the length of enameled aerial wire (Part *1-7H*) and untwist the wires for about 1½ inches at one end. Using your knife blade, scrape off the enamel from each of the seven strands of wire, one at a time, for a distance of ¾ inch from the end. Do this carefully and thoroughly, to give clean copper surfaces without nicking any of the wires. Leave the wires like this for a future experiment.

If you have an alcohol burner, use it to burn off the enamel at the other end of the aerial wire. Untwist the strands for about 1½ inches, and spread them out just enough so that none touch each other. Light the alcohol burner, and hold the spread-out strands just within the tip of the inner cone of flame, as shown in Fig. *15*, until the wires are red hot for about ¾ inch from the end. Now immerse the heated wires quickly in a little pan of alcohol. Repeat if any enamel remains on the ends of the wires and can't be rubbed off with a cloth. If you do not have an alcohol burner, use the scraping technique for both ends of this wire.

Discussion: Tinned push-back insulated hook-up wire, either solid or stranded, is the most popular type of wire used by radio men. The copper wire is tinned during manufacture so that insulation slides along it readily,



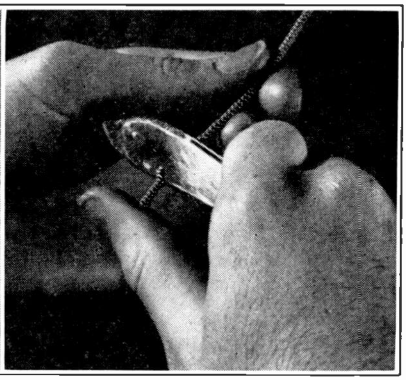


FIG. 13. When the insulation on a wire is too tough to be broken by squeezing with pliers, the pocket knife technique illustrated here is employed by some radio men for cutting through the outer braided covering on the wire. *The knife must be sharp,* and must be held lightly so as to avoid cutting too far and nicking or breaking the copper wire.

FIG. 14. This method is employed by radio men for cutting away the insulation from a wire which is anchored at its other end. The knife must be sharp, and extreme care must be used to avoid nicking solid copper wire or cutting strands in the case of stranded wire.

and the insulating cotton covering has a special weave which permits compressing the insulation. Solid push-back hook-up wire is supplied in your next radio kit for use in hooking up practical radio circuits for demonstration purposes, so you will get plenty of experience with this type of wire.

Ordinary insulated wire (not of the push-back type) is used for the power line cords of radio receivers, and is occasionally used for receiver wiring as well. A highly convenient way to remove insulation from wire of this type is by squeezing with pliers as explained in Step 2, but there will be times when you will have to cut away the insulation with a pocket knife as explained in Step 3. Whenever you use a knife for removing insulation or scraping wire, however, *try to avoid cutting or nicking the wire.* Even the slightest nick will weaken the wire enough to cause a break eventually at that point, if the wire is subject to considerable bending or vibration.

Scraping with a knife blade as described in Step 4 is the method used most often by radio men for removing enamel insulation from a wire. Use only a small portion of the knife blade near the handle for scraping wires, as this dulls the blade quickly. The main part of the blade should be kept as sharp as possible, for cutting purposes.

A small piece of fine sandpaper can be used for removing enamel insulation with no danger of nicking the wire. Simply fold the sandpaper over the wire, then pull the wire out from the sandpaper. Repeat as many times as necessary to remove

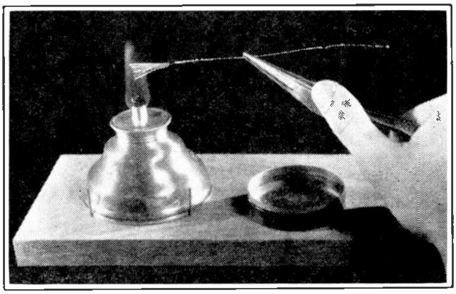


FIG. 15. If enamel-covered wire is held just inside the tip of the *inner cone* of an alcohol burner flame as illustrated here, the wire will become red hot and the enamel will burn off. The inner cone appears darker in color than the outer cone. If the room is drafty due to air currents, the flame will flicker and make heating difficult; a few boxes or boards set up around the flame will prevent this flickering. Some experimentation may be necessary to find the portion of the inner cone which will heat the wires red hot, for other portions of the flame will not remove the enamel and oxides.

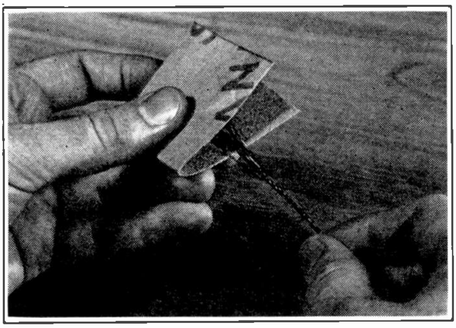


FIG. 16. Method of using fine sandpaper (about Number 00) to remove enamel from stranded wire. Press the folded sandpaper (about one inch wide and two inches long) together with the wire in between as indicated, then draw out the wire. Repeat until the enamel is entirely removed from the portion of wire which is to be soldered.

all enamel. A few trials will tell you how hard to press the sandpaper between your fingers while drawing out the wire. Stranded enameled wire can be cleaned in this same way if the wires are spread out and are turned a little each time so as to expose all of their surfaces to the sandpaper; this is illustrated in Fig. *16*.

Burning off enamel with an alcohol burner gives a better job than scraping, and eliminates the possibility of damaging the copper wire. The tip of the inner cone in the flame is hot enough to make the wire red hot and remove the enamel and oxides. Plunging the hot wire quickly into alcohol prevents the cleaned wire from tarnishing while cooling. The same alcohol used for the burner can serve for this purpose; the alcohol can be poured back in the bottle after you have finished with it.

The samples of wire supplied you for the experiments in this manual are long enough so that you can cut off an inch or so of wire from an end and repeat the experiment in case you accidentally damage the wire. Do not cut the wires any shorter than 5 inches, however, for you will need these wires later for practicing actual radio connections.

Instructions for Report Statement No. 3. After completing this experiment and studying the discussion, turn to the last page of this manual and read Report Statement No. 3 carefully. Place a check mark in the box following *the type of wire which you found easiest to prepare for soldering.*

EXPERIMENT 4

Purpose: **To tin hook-up wire.**

Step 1. To learn how to tin solid wire properly, practice by using the *green* untinned wire (Part *1-7E*) from which you have already removed the insulation at the ends and cleaned the exposed copper. Leave the heated soldering iron in its holder with the tip facing you. Hold the wire in one hand with one end resting on a flat surface of the soldering iron tip, then apply solder to the *wire* with the other

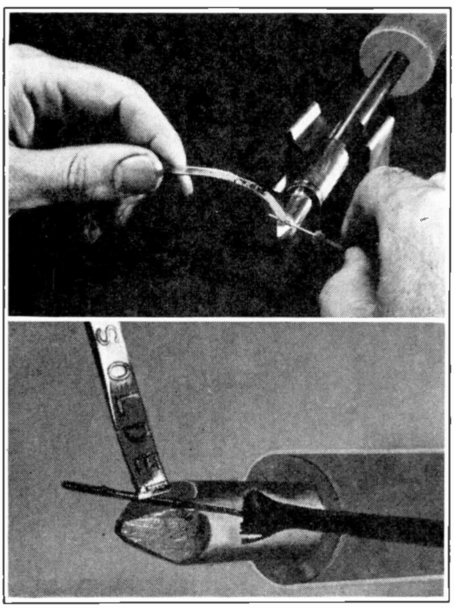


FIG. 17. Method of holding the solder and wire when tinning either solid or stranded wire. The heated soldering iron is left in its holder. The close-up photo shows a partly tinned wire. Slide the wire back and forth between the soldering iron tip and the solder until it is completely tinned for about half an inch from the end.

hand, as illustrated in Fig. *17*. Slide and rotate the wire slowly between the iron and the solder until the wire is completely tinned. Shake off surplus solder from the wire. Tin the other end of this wire in the same way.

Step 2. To learn how to tin stranded wire properly, untwist the exposed and cleaned strands at one end of the *yellow and green* lamp cord wire (Part *1-7G*) so that the strands are separated from each other for a distance of about ½ inch from the end, as shown in Fig. *18C*. Tin this wire by applying solder to one side of the strands while heating them from the other side with the soldering iron, just as you did in Step 1. When all strands have been tinned for ½ inch from the ends, shake off surplus solder from the strands while the solder is still in molten form, or simply tap the strands with the heated soldering iron. After the wire has cooled, twist the strands together again. Stranded wire at various stages of this tinning process is illustrated in Fig. *18*. Tin one end of the 7-strand enameled aerial wire (Part *1-7H*) in this same manner.

Now tin the untinned end of the lamp cord wire (Part *1-7G*) with the strands twisted together, by following the tinning procedure given in Step 1. Tin the untinned end of the enameled aerial wire (Part *1-7H*) in this same way (with the strands twisted together).

Discussion: Solid wire is remarkably easy to tin if clean. New wire can usually be tinned without cleaning, but old wire should be scraped clean first. It is usually sufficient to tin the wire up to about ¼ inch from the insulation; if you go much closer than this with the soldering iron, there is danger of burning the insulation.

Untinned stranded wire is often difficult to tin properly unless the strands are individually cleaned and the procedure given in Step 2 is followed completely. If properly done, the tinned wire can be twisted together again. Difficulty in tinning stranded wire means that additional careful scraping is necessary.

With new and fairly clean stranded wire, it is possible to tin the wire without untwisting, just as if it were a solid wire. There are two drawbacks to this short-cut method; the inside strands may not be thoroughly tinned, and the wire after tinning will be so stiff that bending to form a joint will be difficult.

Instructions for Report Statement No. 4. After completing this experiment and studying the discussion, read Report statement No. 4 (on the last page) carefully, then place a check mark in the box following the

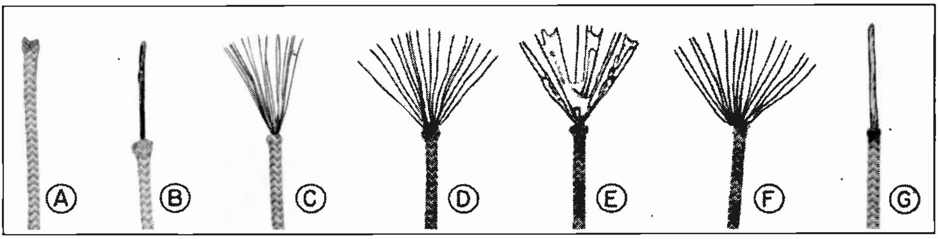


FIG. 18. Steps in preparing one end of the No. 18 stranded untinned lamp cord (Part *1-7G*) which has rubber insulation covered with cotton braid. *A*—Original wire; *B*—wire with insulation removed from end; *C*—Strands spread out for cleaning; *D*—Cleaned strands ready to be tinned; *E*—Completely tinned strands; *F*—Tinned strands after surplus solder has been removed; *G*—Tinned strands twisted together again.

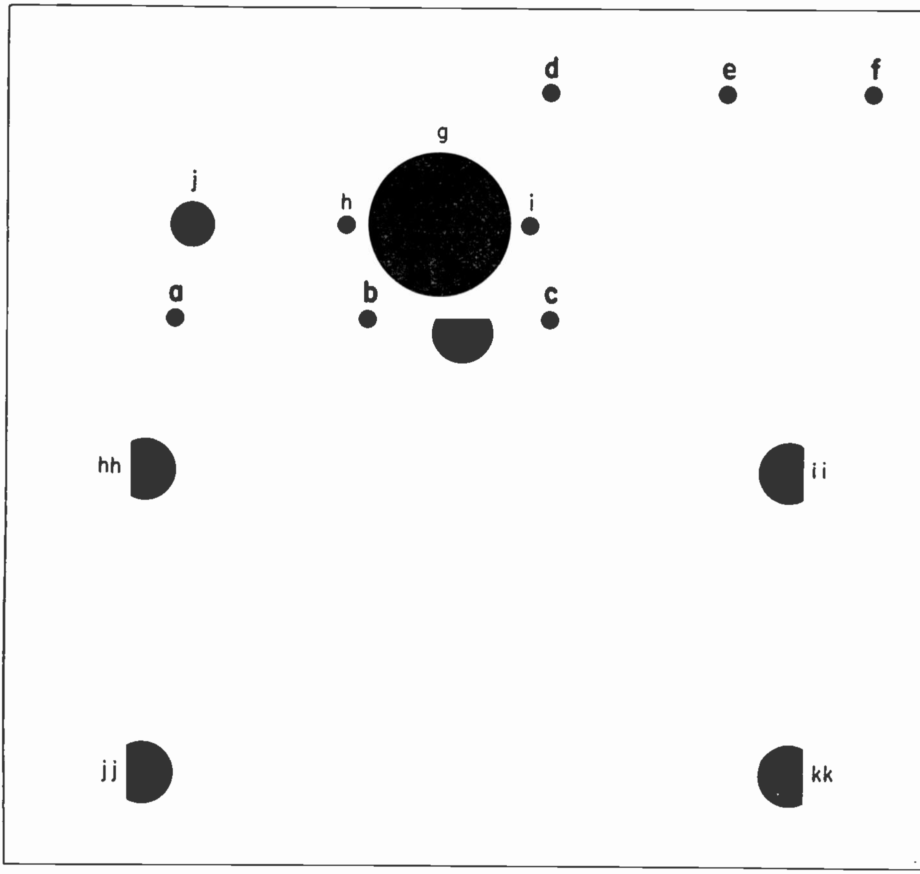


FIG. 19. Bottom view of metal chassis (supplied to you with Radio Kit 1RK, as Part *1-11*). The front edge of the chassis has three holes and is bent in the same direction as the sides. The back edge of the chassis has no holes, and is bent in the opposite direction from the other three edges. The large letters *a, b, c, d, e* and *f* can be placed alongside the holes with a metal-marking crayon, ordinary soft lead pencil, or with pen and ink.

answer which you believe will give *more thorough tinning of stranded wire.*

EXPERIMENT 5

***Purpose:* To mount soldering lugs on a metal chassis and prepare them for soldering.**

Step 1. Mount the three tinned soldering lugs (Parts *1-8A, 1-8B* and *1-8C*) *in holes d, e and f respectively on the bottom of the metal chassis* (Part *1-11*), in the following manner. Place the chassis on your table, bottom up, locate the six holes which are to be used for lugs in this experiment, and mark them with a metal-marking crayon as indicated in Fig. *19.*

Now bend a tinned lug (*1-8A*) at an angle of about 45°, using long-nose pliers as shown in Fig. *20.* Insert a machine screw (Part *1-9A*) in hole *d* from the top of the chassis, and hold the head of the screw in place with a finger. Place lug *1-8A* over the screw from the bottom of the chassis, with the bent part of the lug away from the chassis, then place a nut (Part *1-9B*) on the screw and tighten with your fingers.

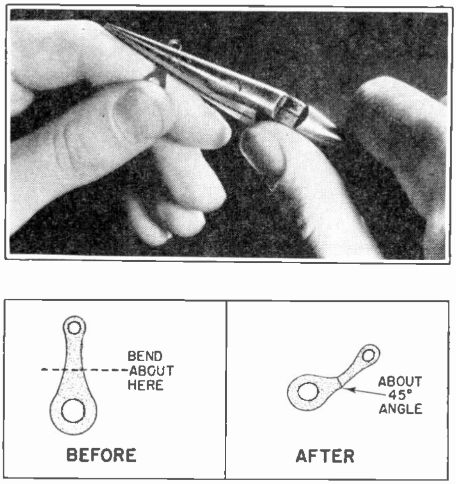


FIG. 20. Method of bending a soldering lug with long-nose pliers. Bending should be done *before* the lug is bolted to the chassis; once a flat lug is bolted to a chassis, it is difficult to pry the lug upward to a convenient soldering position.

Hold the nut and lug with ordinary all-purpose pliers in the manner shown in Fig. *21A,* so that the lug points toward the back of the chassis, and tighten the bolt head from the top of the chassis with a medium-sized screwdriver as shown in Fig. *21B.* Now bend the other two tinned lugs (*1-8B* and *1-8C*) and fasten them in holes *e* and *f* respectively with screws and nuts in exactly the same way. These three tinned lugs are now ready for use.

Step 2. To get experience in tinning untinned lugs before they are mounted, take untinned lug *1-8D* and file both sides of the lug at the end having the smaller hole, until the copper shows clean and bright at this end of the lug. Scraping the lug with your pocket knife blade is an alternative cleaning method. Now hold the cleaned part of the lug against a flat face of the heated soldering iron tip with long-nose pliers, and rub *a small amount* (less than ¼ inch) of rosin-core solder over the uppermost cleaned surface as shown in Fig. *22.* Turn the lug over and apply solder to the other side. Rub the lug back and forth over the iron to spread the solder and make it adhere to the cleaned surfaces.

To remove surplus solder after tinning, hold the lug with the pliers in one hand, heat the lug with the solder-

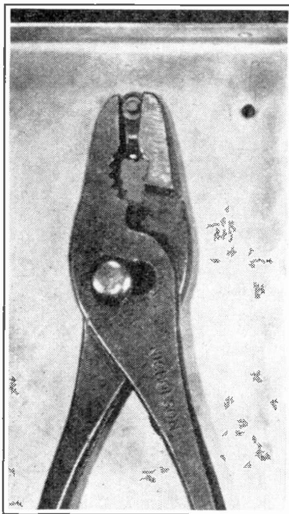


FIG. 21A. One method of using ordinary all-purpose pliers to prevent the soldering nut and lug from turning as screw is tightened.

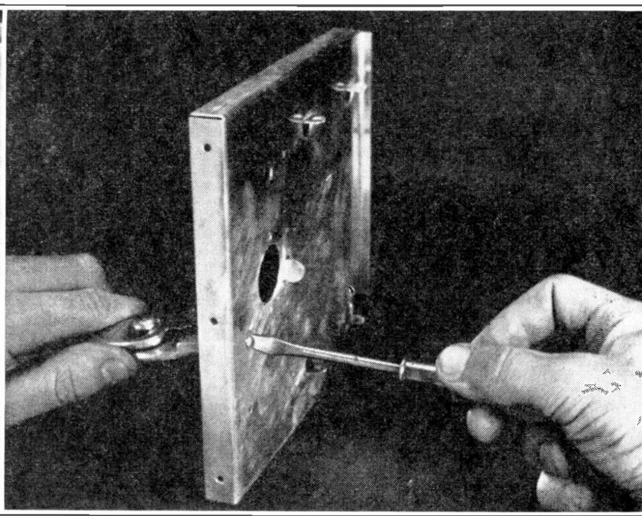


FIG. 21B. Another method of holding a nut with ordinary pliers while tightening a machine screw which is being used for mounting a soldering lug underneath the chassis. The screw should be tightened enough so that the lug cannot readily be moved with the finger.

ing iron held in the other hand, then tap the lug gently against the tip of the iron to shake off surplus molten solder. (Sometimes it is more convenient to wipe off the surplus molten solder from the lug with a cloth.) Bend the lug approximately at its center, using pliers and fingers as shown in Fig. *20*, then mount this lug in hole *a* on the bottom of the chassis as shown in Fig. *23*.

Using the same methods, clean lug *1-8E* by filing or scraping, then proceed to tin the lug and remove surplus solder. Bend the lug at a 45° angle solder directly to the top of the lug, and rub the solder over the lug by sliding the iron back and forth. Apply additional solder if some parts of the lug near the small hole are untinned, but use as little solder as possible in order to avoid having surplus solder roll down the lug to the nut.

Step 4. To practice removing surplus solder from a mounted soldering lug, use a cloth to wipe as much surplus solder as possible from the tip of the heated soldering iron, then apply the iron to lug *1-8F* so as to pick up some of the surplus solder on the lug.

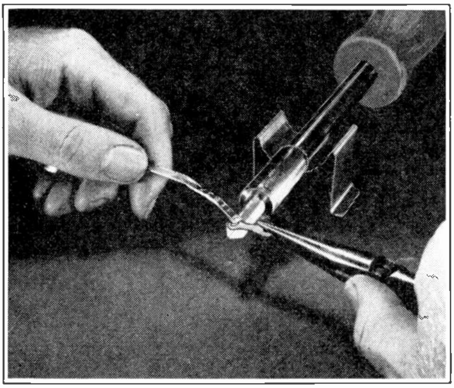


FIG. 22. Method of tinning a lug prior to mounting it on a chassis. This technique is used only for untinned lugs, or for tinned lugs which have become coated with oxides and dirt.

just as you did for the other lugs, then mount this lug in hole *b* on the chassis.

Step 3. To get experience in tinning an untinned lug which is already mounted on a chassis, bend lug *1-8F* in its center about half as much as you bent the other lugs, then mount this lug in hole *c* on the bottom of the chassis. Scrape the exposed upper half of the lug with the knife blade until clean, then hold the heated soldering iron against the top of the lug for a few seconds. Now slide the soldering iron down along the lug far enough so you can apply rosin-core Wipe this solder from the iron, then repeat the process as many times as are necessary to get the solder out of the small hole in the lug. Sometimes solder can be poked out of the hole by inserting the cleaned tip of the soldering iron in the hole. The six lugs should now appear as shown in Fig. *23*.

Discussion: Separate soldering lugs like those supplied in Radio Kit 1RK are used chiefly for making connections to a metal chassis. Wire could be soldered directly to the chassis in some cases, but chassis metals are usually difficult to tin, and require more heat than can be supplied by the average radio soldering iron. Furthermore, a soldered connection to a flat metal surface is usually messy in appearance. Remember that tinned soldering lugs similar to those you mounted in Step 1, or lugs which you have previously tinned, should be used for making soldered connections to a chassis or any other large metal surface.

It is generally easier to bend soldering lugs before they are mounted. Bending a lug away from the chassis makes it easier for you to attach wires to the lug. As a general rule, bend a lug approximately in its center. Hold the small end of the lug with the pliers, for you can bend the large end more readily with your fingers.

When using a soldering lug, solder is ordinarily applied only to the bent-up half of the lug, hence only this portion need be cleaned and tinned. When the lug is unmounted, it is best to clean and tin both sides in the vicinity of the smaller hole. When a lug is mounted on a chassis, only the uppermost surface is cleaned and tinned, for it is difficult to work on the underneath surface.

Some soldering lugs which appear to be tinned are actually coated with nickel, a metal to which rosin-core solder does not readily adhere. With lugs like this, scrape or file away the nickel surface so as to expose the brass or copper underneath.

The secret of tinning a soldering lug properly lies in applying the rosin-core solder directly to the lug, a small distance away from the soldering iron tip. The rosin flux can then act on the lug. If the solder rolls off, the lug is too hot and should be allowed to cool for a few seconds. Insufficient cleaning and tinning is indicated when you can wipe off solder completely from parts of the lug. Rubbing the soldering iron tip back and forth over the top of the lug helps to make the solder adhere.

When a soldering lug is being tinned, the hole in its small end usually fills with solder. This hole must be opened to permit looping the connecting wire through the hole. Brushing out the solder is bad practice, for it scatters molten solder in all directions and may result in short circuits. One technique for getting out this solder is given in Step 4; practice this several times by filling the holes again with solder after

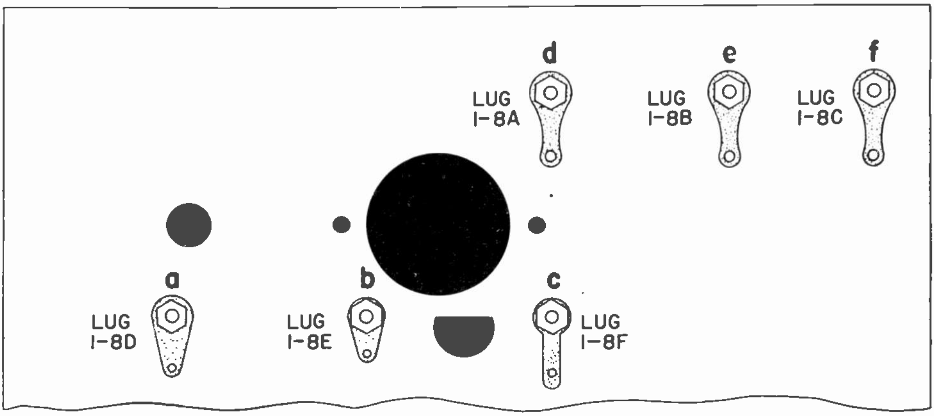


FIG. 23. Upon completion of Experiment 5, you should have the six soldering lugs, all tinned, mounted on the chassis exactly as shown here, with the ends of the lugs bent upward as shown in Fig. 20.

you have cleaned them out, and you will soon find yourself lifting off surplus solder just as speedily as does an experienced serviceman. Incidentally, some servicemen do not bother to remove surplus solder from the hole; when ready to make a connection, they simply apply the soldering iron to melt the solder, then poke the wire through the hole. Shake surplus solder

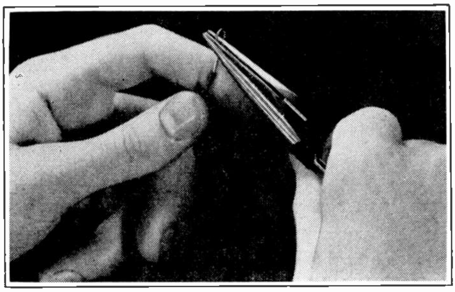


FIG. 24. Forming a hook on solid wire with long-nose pliers, preparatory to making a soldered hook joint.

from the iron whenever necessary, and wipe the soldering iron frequently with a cloth. The less solder on the iron, the more solder you can pick up.

Instructions for Report Statement No. 5. After completing this experiment and studying the discussion, read Report Statement No. 5 (on the last page) carefully, then place a check mark in the box following *the correct method of connecting a hook-up wire to the metal chassis of a radio receiver.*

EXPERIMENT 6

Purpose: **To secure practical experience in making temporary and permanent soldered connections to lugs.**

Step 1. To make a temporary hook joint to a soldering lug with solid wire, bend one end of a length of *red* solid push-back wire (we will designate this as Part *1-7A*) into a hook by using long-nose pliers, as illustrated in Fig. *24*. Insert this hook in the hole in lug *1-8D,* starting from the bottom of the lug as shown in Fig. *25A*. Bend the hook a little more after inserting, if there is any tendency for the wire to fall out, but do not pinch the hook together for this temporary joint.

Now apply your heated soldering iron to the top of the lug, on one side of the wire, and apply rosin-core solder to the other side of the wire and to the lug, as in Fig. *25B*. Apply just enough solder to fill the gap between the lug and the upper part of the hooked wire, then remove the soldering iron. Do not move the wire until the solder has hardened. The finished temporary hook joint is shown in Fig. *25C*.

IMPORTANT: The soldering tip must make good contact with both the lug and the wire, so as to heat and solder both parts of the joint.

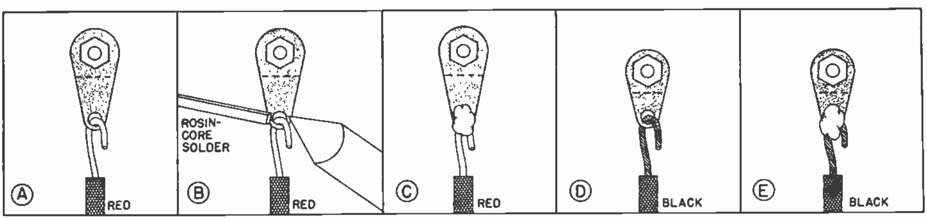


FIG. 25. Temporary connections to soldering lugs. *A*—Temporary hook joint to a soldering lug with solid wire, before soldering; *B*—Method of soldering a hook joint on a soldering lug. Note that the soldering iron is held on top of the lug, on one side of the wire, and solder is applied to the other side of the wire; *C*—Your temporary hook joint with solid wire should appear like this after soldering; *D*—Temporary hook joint with stranded wire, before soldering; *E*—Temporary hook joint with stranded wire, after soldering.

Step 2. To make a temporary hook joint to a soldering lug with stranded wire, take the *black* stranded push-back wire (Part *1-7D*), twist the strands together with your fingers if they have become unraveled, bend the end into a hook, insert the hook in lug *1-8E* from underneath as shown in Fig. *25D,* and solder the joint exactly as instructed in Step. 1. The soldered joint should appear as in Fig. *25E.*

Step 3. To make a permanent hook joint to a soldering lug with solid wire, take another length of *red* solid push-back wire (we will designate this as Part *1-7C*), bend a hook in one end with long-nose pliers, and insert the hook in lug *1-8F* from underneath just make the same type of permanent hook joint to lug *1-8B,* using that end of the wire which was tinned *without untwisting the strands.*

Finally, take the stranded enameled aerial wire (Part *1-7H*) and make a permanent hook joint with either end of it to lug *1-8C*, then solder it.

Step 5. To make a temporary hook joint to a soldering lug which already has one connecting wire, take the remaining length of *red* solid push-back wire (this will be designated as Part *1-7B*) and form a hook at one end with long-nose pliers. Apply the heated soldering iron to the solder at the top of lug *1-8D* so as to melt the solder, then insert the hook of your wire in

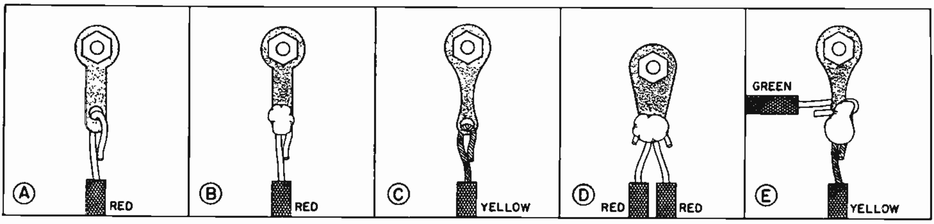


FIG. 26. These illustrations show essential features of various soldering lug connections. *A*—Permanent hook joint with solid wire, before soldering; *B*—Permanent hook joint with solid wire, after soldering; *C*—Permanent hook joint with stranded wire, before soldering; *D*—Two temporary hook joints to a lug with solid wire, after soldering; *E*—Two permanent hook joints to a lug, after soldering.

as you did in Step 1. Squeeze the hook together with long-nose pliers so that it resembles Fig. *26A,* then solder the joint according to the instructions in Step 1. The final soldered joint is shown in Fig. *26B.*

Step 4. To make a permanent hook joint to a soldering lug with stranded wire, take the *yellow* stranded hook-up wire (Part *1-7F*), twist the strands together with the fingers if necessary, bend the end into a hook, insert the hook in lug *1-8A* from underneath, squeeze the hook together tightly with long-nose pliers as illustrated in Fig. *26C,* and solder the joint as instructed in Step 1.

Now take the *yellow and green* stranded lamp cord (Part *1-7G*) and this hole from underneath while holding the soldering iron on the top or side of the lug so as to keep the solder in a molten state. When both wires are hooked through the hole in the lug as shown in Fig. *26D,* remove the soldering iron and allow the joint to cool.

Step 6. To make a permanent hook joint around a soldering lug instead of through the hole in the lug, take the length of *green* solid wire (Part *1-7E*), form a hook at one end with long-nose pliers, loop this hook around lug *1-8A* just behind the existing connection to this lug, as shown in Fig. *26E,* squeeze the hook tightly over the lug with long-nose pliers, then apply rosin-core solder to one side of the hook and to the lug while holding the heated soldering iron on the other side of the hook.

Step 7. To secure practice in "dressing" wires neatly, first compare your work carefully with the illustration in Fig. *27* to make sure that your wires

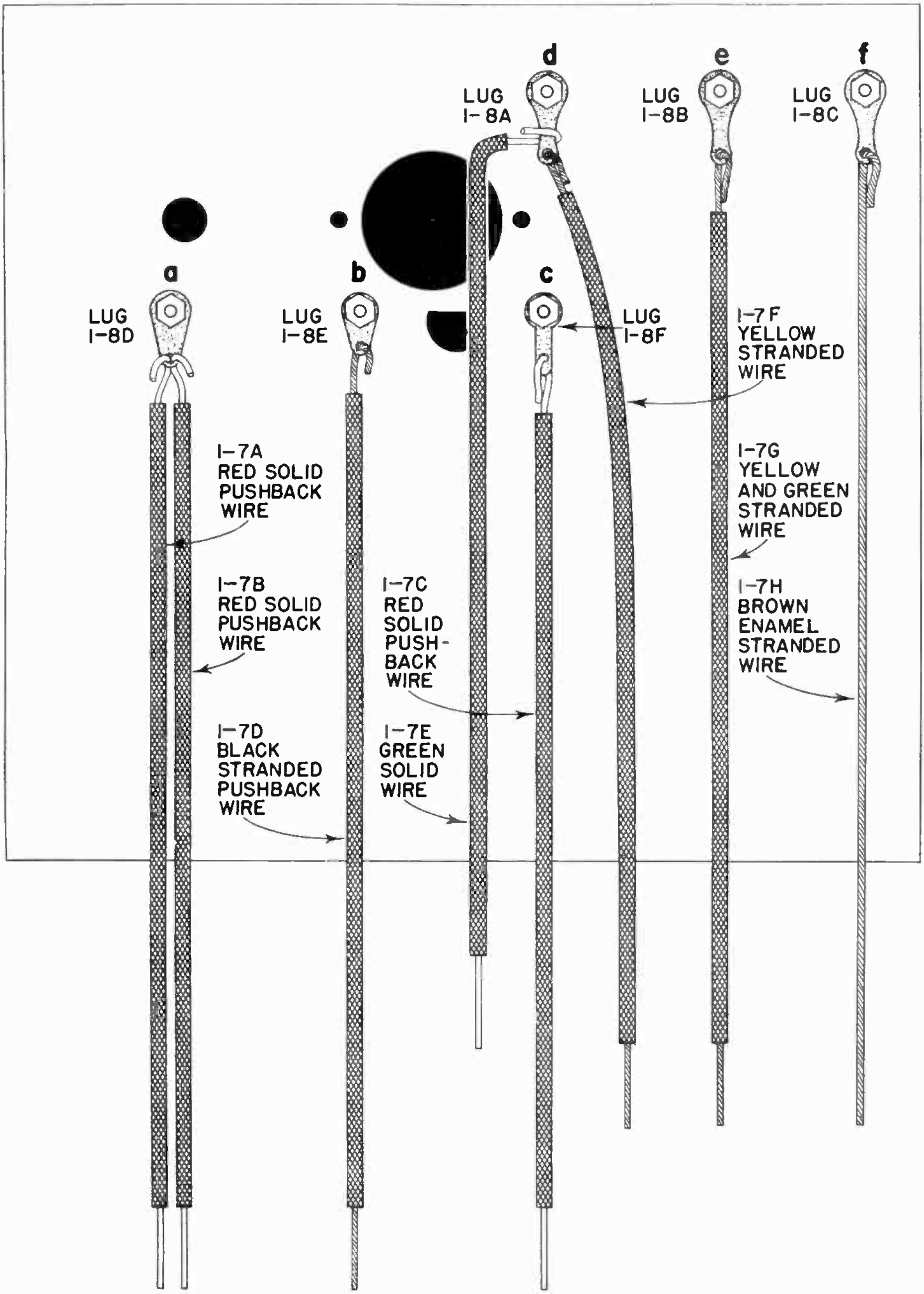


FIG. 27. Appearance of bottom of chassis after completion of Experiment 6. Each of the soldering lug connections commonly used by radio men is included in this experiment.

are on the correct lugs, then straighten out each wire with your fingers and arrange them all neatly in the manner shown in Fig. *27*, so they will be ready for the next experiment.

Now apply the heated soldering iron to lug *1-8A* so as to melt the solder on *yellow* wire *1-7F*, then grasp this wire with long-nose pliers and hold it rigidly in position at the angle shown in Fig. *27*, while the solder is hardening. Rest either your hand or the pliers on the chassis while doing this.

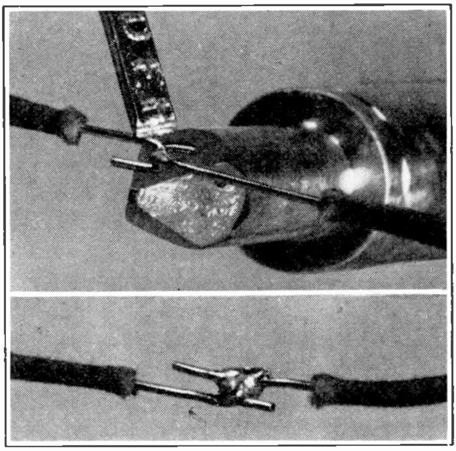


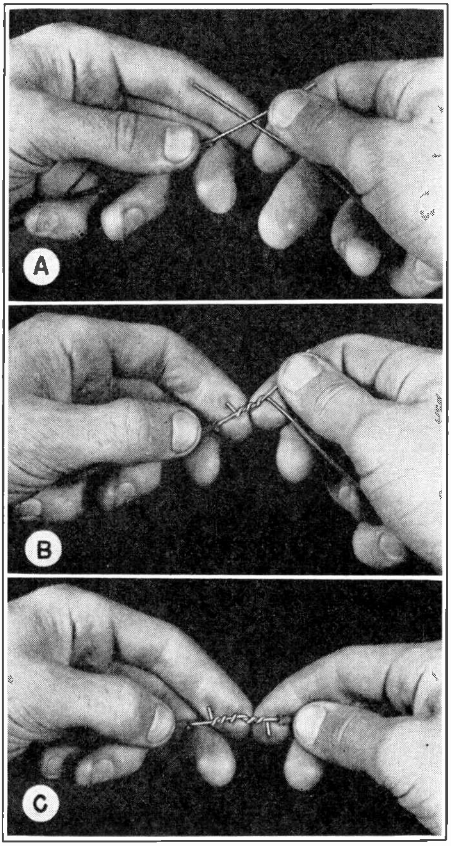
FIG. 28A (above). Correct way to solder a temporary hook joint. The tip of the iron is held under the joint, and the solder is applied to the wire from above.
FIG. 28B (below). Completely soldered temporary hook joint.

Discussion: Soldered connections to soldering lugs are among the most common which you will make in your radio work. In this experiment, you make such a wide variety of connections to soldering lugs that you are prepared for just about any type of soldering lug connection you may require in professional radio work.

A temporary connection is made only when you are reasonably sure that you will have to remove the wire in the near future. A permanent joint differs from a temporary joint only in the squeezing of the hook prior to soldering. A permanent connection is always more satisfactory, and should be used whenever there is any chance at all that the joint may be in use for some time. The permanent connection possesses mechanical strength as well as good electrical contact; thus, a good permanent connection will withstand pulling and will serve its electrical purpose even before it is soldered.

To avoid burning the insulation on a wire when soldering, it is best to bend the hook in such a way that all insulation will be at least ⅛ inch away from the lug when the wire is in soldering position. In the case of push-back wire, this insulation can be pushed right up to the lug after the joint is soldered; with other types of wire, the insulation cannot be moved.

Remember that a joint must not be disturbed while the solder is hardening. If the wire will not remain in position by itself during this time, hold it rigid with your hand. If you rest your hand on the chassis when doing this, you will have no difficulty in



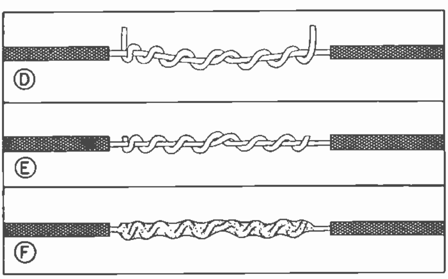


FIG. 29. Steps in connecting two wires together permanently by means of a Western Union soldered splice.

holding a wire without appreciable movement for the few seconds required for the solder to harden. Joints must often be remelted to change the positions of wires, so the experience you secure in the last part of Step 7 is particularly valuable.

Solder which is on a lug or wire hardens far more rapidly than a globule of solder on a board, because lugs and wires conduct heat away from the solder and thereby speed up the cooling.

Instructions for Report Statement No. 6. After completing this experiment and studying the discussion, read Report Statement No. 6 (on the last page) carefully, then place a check mark in the box following *the correct method of making a temporary soldered connection to a soldering lug.*

EXPERIMENT 7

***Purpose:* To secure practical experience in soldering two wires together temporarily and permanently.**

Step 1. To make a temporary hook joint between two wires, locate *red* wire *1-7B* and *green* wire *1-7E* on the chassis (by referring to Fig. *27*) and bend a hook in the free end of each with long-nose pliers. Hook together the free ends of the two wires as indicated in Fig. *28A*. If you first spread out the two wires, they will not fall apart when hooked together. Hold the heated soldering iron on one side of the joint for a few seconds, then apply rosin-core solder to the wires, starting at the soldering iron and then moving the solder away from it along the wires (see Fig. *28A*). Remove the solder and the iron, and allow the joint to cool without disturbing it. The completed joint should resemble that shown in Figs. *28B* and *34*.

Step 2. To connect together two wires by means of a professional Western Union splice, locate *red* wire *1-7A* and *red* wire *1-7C*, and push back the insulation far enough to expose at least 1½ inches of wire at each free end (if the insulation cannot readily be pushed back this amount, remove the required amount of insulation by squeezing with pliers or by cutting with a pocket knife).

Grasp wire *1-7A* in your left hand, grasp wire *1-7C* in your right hand, and cross them in the manner shown in Fig. *29A*. The wires and the positions of the hands in this illustration are exactly as you would see them when looking at your work. Observe that wire *1-7A* is between you and wire *1-7C*.

Holding both wires between the thumb and forefinger of your right hand as shown in Fig. *29B*, twist the end of wire *1-7C* around the other wire with the thumb and forefinger of your left hand. Leave a little space between the turns so solder will flow readily between the wires. Continue twisting until only about ¼ inch of wire *1-7C* is left.

Now grasp the twisted part in your left hand and proceed to twist the free end of wire *1-7A* over the other wire in the *opposite* direction with your right hand, as illustrated in Fig. *29C*. Again allow about ¼ inch of wire to remain untwisted, so that the splice appears as shown in Fig. *29D*.

Cut off the projecting ends of the wires with your side-cutting pliers, and straighten up the splice with the fingers so that it appears as shown in Fig. *29E*. Now hold the heated soldering iron alongside the splice just as you did in Step 1, and apply rosin-core solder first between the splice and the tip of the iron, then over all parts of the splice. Slide both the solder and the soldering iron along the splice to speed up the process, until the entire twisted portion of the splice is covered with solder. The completed splice should appear as shown in Figs. *29F* and *34*.

Step 3. To connect two wires together by means of a permanent Bell splice, locate *yellow* stranded wire *1-7F* and *yellow and green* stranded wire *1-7G* on the chassis, cross the bare ends of the wires as shown in Fig. *30A*, then proceed to twist the wires together *with the fingers* so that the result appears as shown in Fig. *30B*. Cut off about 1/16 inch from the end of the splice with side-cutting pliers to give a neat joint, then solder the splice as instructed in Step 1.

Step 4. To make a permanent T type joint to some point on *red* wire *1-7C*, take your pocket knife and cut through the insulation at a point near the center of this wire, being careful not to damage the wire itself. Now

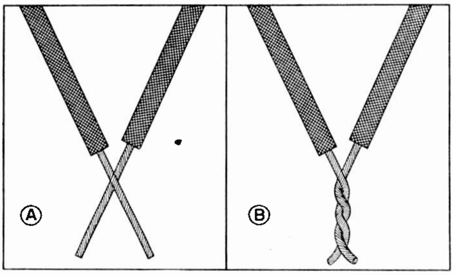


FIG. 30. Steps in making a common twist splice. This permanent joint is also known as a *Bell splice*, since it is used extensively by Bell Telephone linemen and switchboard men for connecting telephone wires together. When making this joint with solid wire, remove insulation for about 1 1/2 inches from the end of each wire, twist up to about 1/4 inch from the ends, then cut off the surplus wire with your side-cutting pliers.

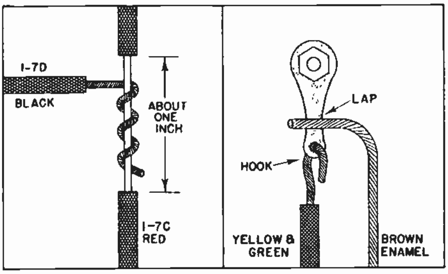


FIG. 31. Permanent T type joint between two insulated wires.

FIG. 32. Temporary lap joint on top of a soldering lug.

push the insulation apart at this point so as to expose about 1 inch of wire. (Do not discard the wire if you accidentally nick it, for the soldered joint will bridge across the nick in the wire.) Take *black* stranded wire *1-7D*, shorten it as shown in Fig. *34* by winding the wire a few times around a pencil, then twist together the strands at its free end, and wind this end around *red* wire *1-7C* with your fingers. Space the turns apart a small amount as shown in Fig. *31*. Trim off the ends of the strands with side-cutting pliers, then solder the joint as instructed in Step 1. Now push the insulation on *red* wire *1-7C* up to this T joint on both sides.

Step 5. To make a temporary lap joint between one wire and a lug or between two wires, take enameled wire *1-7H* and apply additional solder to its free end by employing the same technique used for tinning solid wires. Next, apply a small amount of solder to the top of lug *1-8B,* just behind the joint already on this lug. Now hold the free end of the wire over the lug just behind the joint, as shown in Fig. *32,* press your heated soldering iron over rosin-core solder so it will pick up some solder on its lower face, then apply the soldering iron to the top of wire *1-7H* so as to fuse together the solder on the wire and on the lug. Remove the soldering iron when fusion occurs, but continue holding wire *1-7H* rigid until the solder has hardened. The completed joint is shown in Fig. *34*.

Discussion: Radio servicemen probably use the temporary hook joint more often than any other joint for connecting together two wires. The reason is simply that this joint can be unsoldered and separated very easily. The joint can be made more permanent, yet still be unsoldered fairly

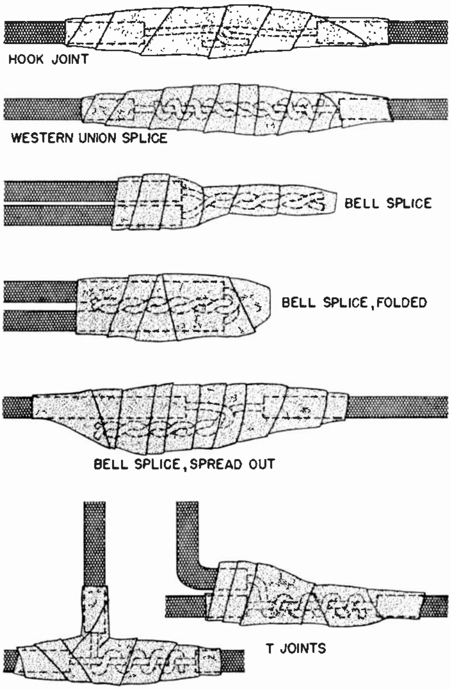


FIG. 33. Methods of taping the various types of soldered joints taken up in this manual. These diagrams are presented for future reference only, since you do not have to tape any of the joints used in your practical demonstration course.

easily, by squeezing the two hooks together with long-nosed pliers just before soldering.

As a general rule, a joint between two wires should always be covered with friction tape when left permanently in a radio receiver. Radio men prefer to use a special narrow type of friction tape, obtainable in 3/8-inch wide rolls at radio supply houses, for the standard ¾-inch wide tape is awkward to use on small joints.

When a joint is taped, all exposed wires are covered with at least two thicknesses of the friction tape, and the surrounding insulation is also covered with friction tape for about ½ inch on each side of the joint. Typical taped joints are shown in Fig. 33.

Figure 34 is presented for reference purposes, to show you how your chassis should look after completing this experiment. Whenever you are in doubt as to the position in which a particular joint is to be made, refer to this illustration.

The hook joint is not suitable for use where considerable force may be applied to the wires. The Western Union splice described in Step 2 is

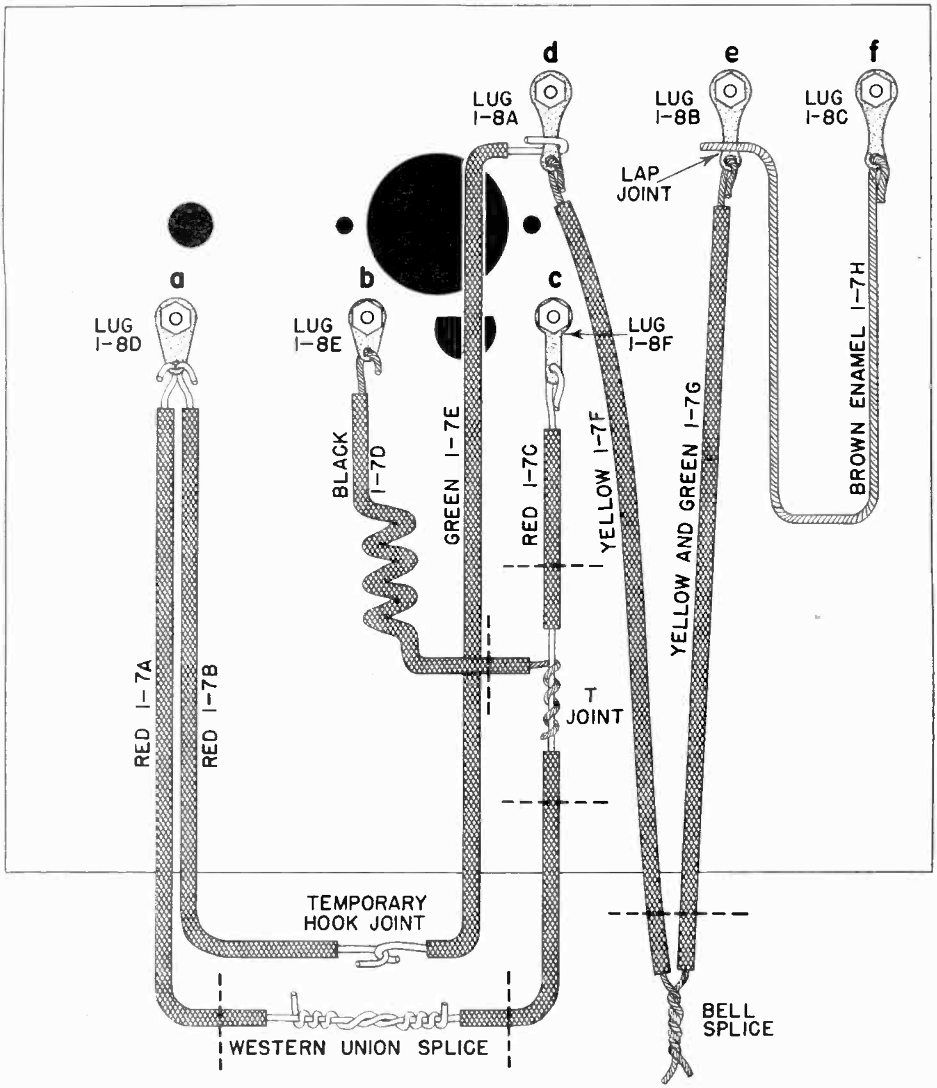


FIG. 34. Your chassis should appear like this after you have completed each of the joints called for in this experiment. The dotted lines indicate the approximate positions at which cuts should be made after completing this experiment so you can remove and save the T joint and the two splices.

preferred by radio men when mechanical strength is required, such as in antenna systems. Telegraph lines on poles are joined together by means of this splice.

The Bell splice described in Step 3 is usually easier to make in a crowded radio chassis than is the Western Union splice. When made with stranded wire, the Bell splice is readily formed with the fingers; with solid wire, it can either be twisted with the fingers up to about 1/4 inch from the end, and the surplus wire then cut off, or the twisting can be completed with long-nosed pliers. It is best not to twist a splice so tightly that solder cannot flow between its turns; there should always be a little room between the wires. Study the illustrations carefully, to determine just how much of a twist each type of splice should have.

The permanent T joint described in Step 4 is occasionally required in radio work, for it permits connecting one wire to any point along another wire. The important factor in this joint is the removal of the insulation along the wire without damaging the wire itself. With push-back wire, only a single cut need be made, for the insulation can then be pushed apart. With other types of insulation, however, the insulation must be sliced off carefully with a knife, or squeezed with pliers and then trimmed off.

The temporary lap joint covered in Step 5 is widely used by radio men for test purposes. You will use it extensively in future experiments in your demonstration course. This joint can be made just as well to another soldered connection or to a wire; it was made to a soldering lug in this step merely for convenience. The secrets of a good lap joint are applying the solder to the individual parts *before* placing them together, and holding the wire perfectly rigid while the solder is hardening.

In soldering any joint, be sure that the solder flows in between the turns or twists of the wire. If the wire has previously been tinned properly, there should be no difficulty in accomplishing this.

Any connection which depends upon solder for adequate mechanical strength and electrical conductivity is known as a *joint.* A connection between two wires which gives adequate mechanical strength and electrical conductivity initially without solder is known as a *splice.* Solder is used on a true splice chiefly to prevent corrosion with age from affecting the original electrical conductivity.

The only two splices which are used to any extent in radio work are the Western Union splice and the Bell splice, both of which you made in this experiment. All other radio connections can be considered as joints. You thus see that the great majority of joints made by professional radio men require soldering for effectiveness.

Instructions for Report Statement No. 7. After completing this experiment and studying the discussion, read Report Statement No. 7 (on the last page) carefully, then place a check mark in the box following the answer which you believe *will give the greatest mechanical strength,* when used to connect wires together end to end in an antenna system.

EXPERIMENT 8

***Purpose:* To secure experience in unsoldering the various types of temporary and permanent connections encountered in radio work.**

Step 1. To secure experience in disconnecting splices and permanent *joints between two wires,* try unsoldering the Western Union splice by any means you desire. Yes, this joint is very difficult to unsolder; in fact, radio men never bother unsoldering it. Therefore, proceed to cut out this joint with your side-cutting pliers as indicated by the dotted lines in Fig. *34*. Remove the Bell splice in the same manner, cutting far enough back to remove any damaged insulation near the splice. Finally, cut out the T joint by making three cuts with your side-cutting pliers as indicated by the dotted lines in Fig. *34*. Place this joint in an envelope along with the two splices, and keep the envelope with other N. R. I. material.

Slide the wire off the lug as soon as the hook has opened sufficiently for this purpose.

Now open the hook in *yellow* wire *1-7F* (on this same lug) with long-nose pliers while heating with the soldering iron, and unhook the wire. This professional unsoldering procedure is illustrated in Fig. *35*.

To practice the technique employed by radio men for unsoldering wires which are difficult to bend open, melt the solder on lug *1-8B* with the soldering iron, then wiggle the *yellow and green* wire *1-7G* vigorously while the wire is cooling. Spread out the hook as much as possible with long-nose pliers after the joint has cooled,

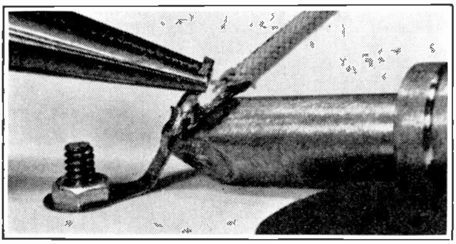


FIG. 35. Method of unsoldering a permanent hook joint on a soldered lug. Spread open the hook with long-nose pliers while keeping the solder molten by holding the soldering iron under the lug.

Step 2. To secure experience in unsoldering temporary joints, unsolder the temporary hook joint between *red* wire *1-7B* and *green* wire *1-7E,* by applying the heated soldering iron to the joint and unhooking the wires as soon as the solder has melted. Using this same procedure of holding the soldering iron against a joint to melt the solder, proceed to unhook the wires from lugs *1-8D* and *1-8E*. Next, unsolder the lap joint on lug *1-8B*.

Step 3. To secure experience in unsoldering permanent joints, hold your heated soldering iron in one hand and apply it to lug *1-8A* while pulling open the hook at the end of *green* wire *1-7E* with your long-nose pliers.

then repeat the heating and wiggling procedure until the wire is separated from the lug.

Use this same wiggling and unbending procedure for enamel wire *1-7H* on lug *1-8C* and for *red* wire *1-7C* on lug *1-8F*.

Finally, lift off surplus solder from the lugs on the chassis with the cleaned, heated soldering iron, as instructed in Step 4 of Experiment 5. When there is a great deal of solder on a lug, you can speed up this step by holding the soldering iron tip alongside or under the lug so as to keep the solder molten, and wiping off this solder with quick strokes of a cloth.

Discussion: As you learned by actual trial in Step 1, it is very difficult to unsolder a properly formed splice. In an emergency, you could untwist the splice bit by bit with long-nose pliers while keeping the solder molten with the soldering iron, but this tedious procedure is required only where the wires must be used again and would be too short if cut off. The Radiotrician invariably snips off splices and T joints with the side-cutting pliers, just as you did in this step.

Be sure to save the two splices and the T joint which you cut off in Step 1. If you encounter difficulty in assembling any of the equipment used in future experiments, we may ask you to send these joints to N. R. I. so we can see the type of soldering work you are doing. We will then be in a better position to help you. *Do not send in these joints,* however, until you are asked to do so.

Step 2 demonstrated to you that a temporary soldered joint can be disconnected simply by applying the heated soldering iron to melt the solder, then unhooking the joint. Only when working in awkward and crowded positions is it necessary to spread apart the hook in a temporary joint. Lap joints are the easiest to unsolder of all joints.

When working on radio receivers, most of the joints which you unsolder will be of the type you practiced with in Step 3. These invariably must be spread apart with long-nose pliers before the wire can be unhooked from the lug. Sometimes it will be necessary to remove surplus solder from the joint before you can grip the end of the wire with long-nose pliers.

During unsoldering, surplus solder will accumulate on the soldering iron. Shake this off from time to time, but remember that a *little* extra solder on the iron will speed up transfer of heat to the joint being unsoldered. Sliding the soldering iron back and forth a bit over the joint also speeds up unsolder-

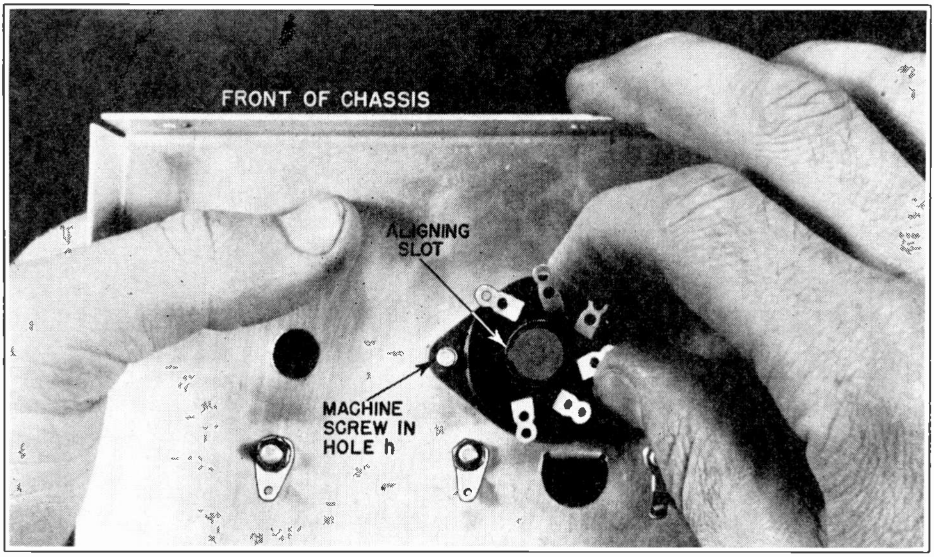


FIG. 36. Method of mounting the tube socket on the chassis. The terminal lugs of the socket should be underneath the chassis, and the aligning slot should be at the left (near hole *h*) when the chassis is held as shown in this illustration. Hold the machine screw in position with a finger of your left hand.

ing, for this tends to break through the coating of oxide and dirt on old solder.

Instructions for Report Statement No. 8. After completing this experiment and studying the discussion, read Report Statement No. 8 (on the last page) carefully, then place a check mark in the box following *the type of joint which you found easiest to unsolder* when you unsoldered these *three* joints in Steps 2 and 3.

the socket is next to this screw. After pushing the metal mounting flange of the socket over the screw, place a hexagonal nut (Part *1-9B*) on the screw and tighten partially with the fingers. Now take another machine screw, insert it through hole *i* from the top of the chassis and through the other mounting hole of the tube socket, then place a hexagonal nut on this screw. Hold this nut with long-nose pliers, then tighten the screw from the other

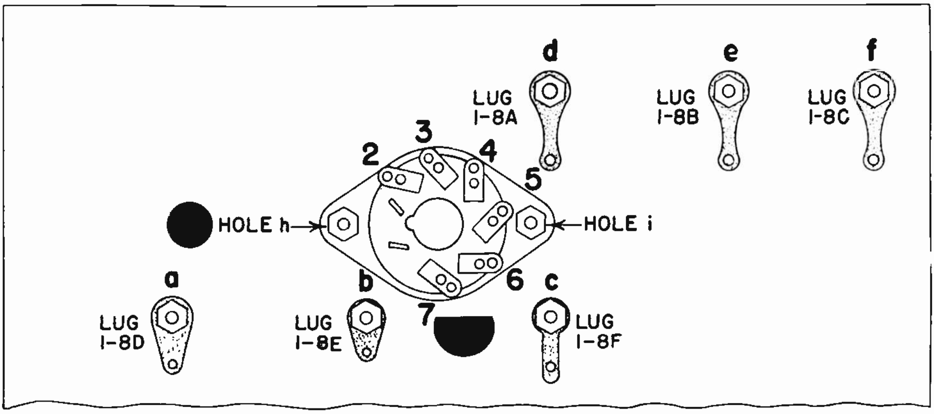


FIG. 37. Your chassis should appear exactly like this after you complete Step 1 in Experiment 9.

EXPERIMENT 9

***Purpose:* To secure practical experience in connecting actual radio parts to soldering lugs by means of temporary and permanent soldered connections, just as you would do when servicing radio receivers.**

Step 1. To mount the tube socket (Part *1-10*) *on the chassis* in preparation for this experiment, take one machine screw (Part *1-9A*) and insert it in hole *h* (Fig. *36*) from the top of the chassis. Holding one finger on the head of this screw to keep it in the hole, turn the chassis over and place the tube socket in position in the manner illustrated in Fig. *36*, so that the aligning slot in the center hole of

side of the chassis with a medium-sized screwdriver. Tighten the other socket mounting screw in the same manner.

The tube socket has six terminal lugs, each identified by a number molded into the bakelite base alongside the lug. The numbers are *2*, *3*, *4*, *5*, *6* and *7*. To speed up future work on this socket, take a crayon or pencil and mark the number of each lug clearly, directly alongside the lug on the bottom of the chassis. The portion of the chassis on which you will work in this experiment should now appear as shown in Fig. *37*.

Step 2. To connect a condenser temporarily between two soldering lugs, take the .05-mfd. condenser (Part *1-13*) and bend an open hook in the end of each lead with long-nose pliers. Bend the condenser leads with your fingers approximately to the shape shown for Part *1-13* in Fig. *38*. Now hook the condenser leads into the holes in lugs *1-8C* and *1-8E* from the bottom and allow the condenser to rest on the chassis, as in Fig. *38*.

Solder each condenser lead by applying the heated soldering iron to the top of the lug on one side of the wire, and applying rosin-core solder to the other side of the wire and to the lug.

IMPORTANT: The soldering iron tip must make good contact with both the lug and the wire, so as to heat and solder both parts of the joint.

Step 3. To connect a condenser permanently between two lugs of a tube socket, take the .03-mfd. condenser (Part *1-12*), bend an open hook in the end of each lead, then bend the leads themselves approximately to the shapes indicated for Part *1-12* in Fig. *38*. Hook the condenser leads through the outermost holes in lugs *2* and *7* of the tube socket, by inserting the ends of the leads through the holes in the lugs from underneath, and squeeze each hook together with long-nose pliers, as indicated in Fig. *38*.

Solder the condenser lead which is on lug *7* of the tube socket. Leave the lead on lug *2* unsoldered.

Step 4. To connect a resistor temporarily between two lugs, take the .1-megohm resistor (Part *1-15*) and bend a hook in the end of one lead with long-nose pliers. With your fingers, bend the leads for this resistor approximately as indicated for Part *1-15* in Fig. *38*, then insert the hook into the outermost hole in socket lug *4* from underneath. Push the other resistor lead into the hole in soldering lug *1-8B* from above, then bend the end of the lead up with long-nose pliers to form a hook, as shown on lug *1-8B* in Fig. *38*. Now solder both of the joints for resistor *1-15*.

In the same manner, bend one lead of 18,000-ohm resistor *1-16* into a hook and insert it in lug *1-8D* from underneath as indicated in Fig. *38*, then bend the other lead (as shown in the illustration), push it through the outermost hole in tube socket lug *6* from underneath, then bend the end of the lead back with long-nose pliers to form a hook. Solder both of the joints now for resistor *1-16*.

Step 5. To connect a resistor permanently between two tube socket lugs, take .25-megohm resistor *1-14*, bend its leads approximately as shown in Fig. *38*, form a hook in the end of each lead, then hook the leads through the holes in tube socket lugs *2* and *3* from underneath. This places two leads in lug *2*. If you have difficulty in inserting the lead in the outermost hole of tube socket lug *2* even though this lug has not yet been soldered, use the other hole in this lug. Squeeze the hooks together tightly with long-nose pliers, then proceed to solder lugs *2* and *3*.

Discussion: With radio parts like the condensers and resistors included in this radio kit, the bending of the leads to their proper shapes is an important part of the connecting process. Do not intentionally make sharp-cornered bends in leads by means of pliers, however, for this may weaken the wire. Make the bends with your fingers, and use pliers only when forming hooks in the ends of wires. Bends in leads should always start at least ¼ inch away from a resistor or condenser for the same reason.

Bend each lead carefully, checking your work continually by fitting the leads to the correct lugs on the chassis. Additional bending may be done after the leads have been soldered; in fact, the leads should always

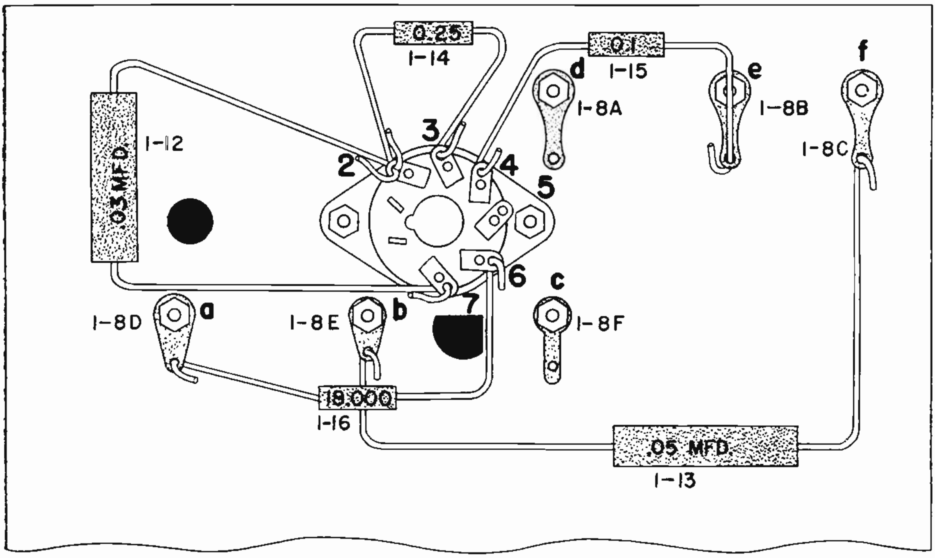


FIG. 38. The five radio parts which you connect to lugs in Experiment 9 are shown here ready for soldering. If you prefer, you can prepare all the parts in this manner, and then solder all the joints at once instead of soldering each part separately as called for in the experiment. WARNING: Bends in resistor and condenser leads should be *gradual* (not sharp), and should begin at least one-quarter inch away from the body of the part; otherwise, the leads will break off.

be bent away from the chassis after this is done, to minimize the possibility of bare wires shorting to the chassis. The leads to these condensers and resistors are stiff enough to support the parts in air.

A permanent joint differs from a temporary joint only in the squeezing of the hook with long-nose pliers prior to soldering. You will find that this little extra step makes a great deal of difference as regards the ease with which a joint can be unsoldered.

In this experiment, you have connected radio parts exactly as they would be connected by professional radio servicemen. With the repeated practice in soldering which you will secure in future experiments, you will soon find yourself able to make soldered connections with professional skill, speed and efficiency.

Instructions for Report Statement No. 9. After completing this experiment and studying the discussion, read Report Statement No. 9 (on the last page) carefully, then place a check mark in the box following *the splice or joint which is most often used in radio work for connecting the leads of radio parts to soldering lugs.*

EXPERIMENT 10

Purpose: **To secure experience in unsoldering connections like those encountered in radio receivers, just as you would do when removing a defective part from a receiver.**

Step 1. To remove .1-megohm resistor 1-15 from your chassis, apply the heated soldering iron to one side of lug *1-8B,* unbend the hook with long-nose pliers while the solder is molten, then pull this lead out of the lug by pulling on the lead with long-nose pliers. Now apply the soldering iron to tube socket lug *4,* and unhook the other resistor lead from this lug.

Step 2. To remove 18,000-ohm resistor 1-16 from your chassis, use your long-nose pliers to open up the hook in lug *1-8D* while applying the soldering iron to this lug so as to melt the solder. When the end of the lead is straight up and down, pull the wire out of the hole in the lug with your long-nose pliers while keeping the solder molten with the soldering iron. Now apply the soldering iron to lug *6*, and unhook the resistor lead going to this lug.

Step 3. To remove .05-mfd. condenser 1-13 from your chassis, apply the soldering iron to lug *1-8E* while grasping with long-nose pliers the lead going to this lug. Unhook the lead from this lug. This will undoubtedly cause bends in both condenser leads, but you can readily straighten these out after the part has been removed. Now melt the solder on lug *1-8C* and unhook the lead from this lug in the same manner.

Step 4. To remove .03-mfd. condenser 1-12 and .25-megohm resistor 1-14 from your chassis, first apply the heated soldering iron to lug *7*, and pry open the hook in the condenser lead going to this lug. Do not expect to do this in one trial, for it is usually quite difficult to get a good grip upon the end of the wire with pliers. Continue unbending the hook until you can push the wire out of the lug. The other lead of this condenser will be somewhat more difficult to unsolder, since it goes to a lug *(2)* which has two connections; use exactly the same technique, however.

Part *1-14* also has permanent connections, so unsolder its leads from lugs *2* and *3* in the same manner.

Step 5. Remove surplus solder from all six soldering lugs and from the lugs on the tube socket, either by wiping off the molten solder with a cloth or by lifting it off with the clean soldering iron. Melt and shake off surplus solder from the leads of the five radio parts used in this experiment, then straighten out the leads with your fingers as best you can. If the ends of any leads have been damaged by the long-nose pliers, cut off about ¼ inch from each end. Simply straighten out the hooks in the remaining leads if the wires themselves are in good condition, so that all parts are clean and ready for use again in future experiments. Now remove the six soldering lugs *(1-8A, 1-8B, 1-8C, 1-8D, 1-8E* and *1-8F)* from the chassis by loosening the mounting screws with your screwdriver and long-nose pliers, then spinning off the nuts. Leave the tube socket on the chassis.

Discussion: In this experiment, you demonstrated for yourself the fact that hook joints which are not squeezed prior to soldering are fairly easy to unsolder. You found that sometimes the leads can be removed from a lug without unbending the hook, while in other cases it was necessary to unbend the hook somewhat with long-nose pliers before the lead could be pulled away from the lug.

You also found that permanent soldered connections can be unsoldered fairly easily once you get the knack of prying open the hook with long-nose pliers. As you undoubtedly realize now, it is quite a trick to hold a heated soldering iron against one part of a lug while prying open a wire on that lug with long-nose pliers. You will become quite proficient in this work, however, by the time you have completed your home demonstration course.

Whenever a permanent hook joint has been squeezed so tightly that it is very difficult to get a grip on the end of the wire with long-nose pliers, servicemen will usually snip off the wire as close as possible to the soldering lug with side-cutting pliers. The portion of the wire remaining in the lug can either be pushed out with the tip of the soldering iron after this is done, or can be cut again with side-cutting pliers so it will fall out when the soldering iron is applied. You may use this procedure if you have difficulty in unsoldering any of the joints.

Sometimes the wire will come out after only a part of the hook is cut off. Then again, it may be possible to spread the hook apart with a small screwdriver or with the blade of a pocket knife.

viewed in convenient reference form in Fig. *39*. If you understand and follow each of these requirements, you should have no difficulty in making professional soldered joints once you have practiced as instructed in your home demonstration course.

In the case of plain soldering irons, which must be heated by an alcohol burner, we have the additional requirement that the soldering iron be at the correct temperature. (This re-

REQUIREMENTS OF A GOOD SOLDERED JOINT

1. KEEP YOUR SOLDERING IRON CLEAN AND WELL TINNED.
2. REMOVE INSULATION FROM WIRES, AND SCRAPE OFF EXCESSIVE DIRT. AVOID NICKING THE WIRE WITH THE SCRAPING TOOL.
3. USE ONLY ROSIN-CORE SOLDER FOR RADIO WORK.
4. TIN EACH PART SEPARATELY IF ORIGINALLY UNTINNED.
5. MAKE GOOD MECHANICAL CONTACT BETWEEN THE PARTS BEING SOLDERED.
6. APPLY THE SOLDER TO THE LUG OR WIRE, NOT TO THE SOLDERING IRON.
7. DO NOT MOVE THE JOINT UNTIL THE SOLDER HARDENS.

FIG. 39. Observance of these seven basic requirements is the secret of making professional soldered joints for radio equipment.

Instructions for Report Statement No. 10. After completing this experiment and studying the discussion, read Report Statement No. 10 (on the last page) carefully, then place a check mark in the box following *the condition of solder* (hard or molten) *which made disconnecting of a permanent hook joint easier.*

Requirements of a Good Soldered Joint

The seven important requirements of a good soldered radio joint are re-quirement is taken care of automatically in an electric soldering iron by the original design of the heating element.) If the soldering iron is too cold, a joint made with it may look good but be mechanically and electrically weak because hardened rosin is the chief bonding material. The resulting "rosin" joint (one in which there is little or no solder connecting the two parts together) is unsatisfactory and can actually be an open connection. In any event, a rosin joint will eventually break apart and cause trouble.

Too hot a soldering iron is equally unsatisfactory, for excessive heat will evaporate the rosin flux before it has a chance to act upon the work, and will make the solder flow too rapidly away from the joint. Furthermore, excessive heat will travel around the joint through the copper wire and burn insulation or loosen adjacent soldered joints.

Looking Forward

Having mastered professional soldering techniques, you are ready to set up real radio circuits with soldered joints, and demonstrate basic radio principles for yourself. In your next radio kit will be another fascinating collection of actual radio parts, including a milliammeter and a vacuum tube. With these additional parts you will assemble simple electrical and radio circuits and trace electron flow through them. You will make measurements of current and voltage in these circuits, and see for yourself that current, voltage and resistance in a circuit always have values which agree with Ohm's Law.

Finally, after completing Experiment 20, you will assemble the N. R. I. Tester on its attractively designed panel and chassis. This is a specially designed measuring instrument which is equivalent to eighteen separate ordinary meters. You will use the N. R. I. Tester a great deal in future experiments.

IMPORTANT: Do not discard any of the parts supplied to you in N. R. I. radio kits until you have completed your course. The parts supplied to you in Radio Kit 1RK will be used again in later experiments.

Detach by Cutting Along This Line. Do Not Tear Off.

INSTRUCTIONS FOR PERFORMING RADIO EXPERIMENTS 11 TO 20

2 RK

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Youth is eager and impatient. It seeks to achieve success at a single bound. But older people know from cruel experience that success is not acquired in a minute, nor a week, nor a month. If it were that easy to secure, every one would be a President, a Supreme Court Justice, or a millionaire captain of industry, and the world would be like a navy in which every sailor is a captain!

"Learn to walk before you run" is good grandmotherly advice. The worst type of ignorance is *not knowing how much there is to know*. Just because you have attained the first step in your climb to success, don't get the idea you can skip all the other steps.

Build gradually that ladder of knowledge and experience by which you will rise in radio. Be like the postage stamp, which sticks to one thing until it gets there, and you'll be able to stay at the top when you do arrive.

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WASHINGTON, D.C.

1941 Edition

THIS EXPERIMENTAL MANUAL IS A PART OF THE N. R. I. COURSE WHICH TRAINS YOU TO BECOME A RADIOTRICIAN & TELETRICIAN

(REGISTERED U. S. PATENT OFFICE) (REGISTERED U. S. PATENT OFFICE)

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Instructions for Performing Radio Experiments 11 to 20

Introduction

IN THE design, construction and repair of radio apparatus, circuits are highly important. You have already studied many different types of circuits in your regular course, and have learned that every circuit must have three things: *1. A source of voltage; 2. A load; 3. A transmission system* (either two simple wires or a complex arrangement of radio parts) *which connects together the source and load.*

In the next ten experiments, you will work with real radio circuits and actually demonstrate for yourself their characteristics. In one experiment, you will prove that electrons flow in a definite direction between the source and the load in a d.c. circuit. In another experiment, you will increase the source voltage and see that this makes the current increase. You will also increase the resistance in a circuit, and prove that the current decreases exactly as Ohm's Law says it will.

Four entire experiments in this manual are devoted to vacuum tube circuits. You will actually see for yourself that current can flow through the vacuum inside a tube when one electrode is heated and another electrode is positively charged with respect to the heated electrode. You will also perform an experiment which shows how a vacuum tube can control the flow of electrons in a circuit. By working with vacuum tube circuits right from the start, you will become accustomed to thinking in terms of electron flow, and will soon find yourself using vacuum tubes as guides to tell the direction of electron flow in any circuit.

Contents of Radio Kit 2RK

The parts included in Radio Kit 2RK are illustrated in Fig. *1* and listed in the caption underneath. Check against this list the parts which you received, to be sure you have all of them.

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

Batteries Needed

The batteries needed for the ten experiments in this manual and for construction of the N. R. I. Tester are pictured in Fig. *2A*, and an optional battery arrangement is shown in Fig. *2B*. Instructions for ordering these batteries have already been sent to you.

Batteries are required for every experiment in this second manual of your practical demonstration course, so order your batteries immediately (either from N. R. I. or from a radio supply firm) if you have not already done so.

RMA Color Code for Resistors

Most of the fixed resistors included with N. R. I. radio kits are marked according to the standard Radio Manufacturers' Association (RMA) color code, in addition to having the ohmic value printed on the body of the resistor. Furthermore, resistors used in commercial radio equipment are often identified only by these

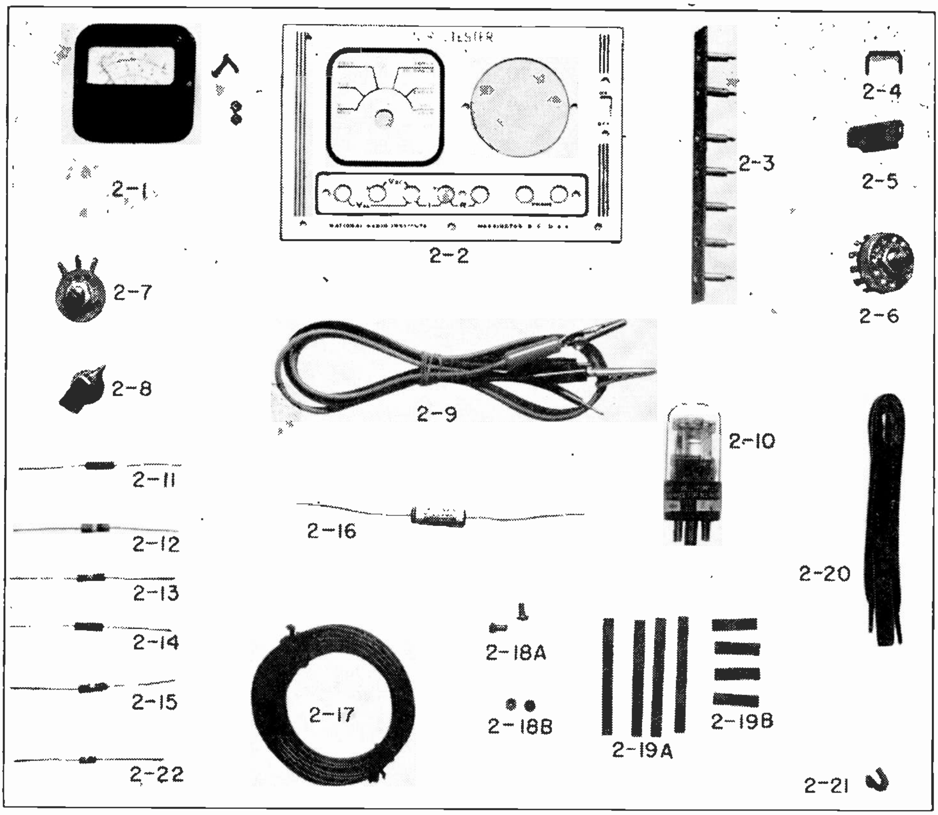


FIG. 1. The parts included in Radio Kit 2RK are pictured above, and are identified in the list below. Note that the first numeral in each part number is 2; this enables you to identify these parts immediately as having been supplied to you in Radio Kit 2RK, when the parts are specified for use in future experiments. When an experiment calls for a part having 1 as its first numeral, you know immediately that the part was supplied to you in Radio Kit 1RK. Some resistors may have a better tolerance (a lower percentage tolerance) than that indicated here.

Part No.	*Description*
2-1	One 0-3-ma. milliammeter with special scale and zero-adjusting knob at rear. Two mounting screws and two nuts are included with the meter.
2-2	Front panel for N. R. I. Tester.
2-3	One 7-jack strip.
2-4	One U-shaped shorting piece for phone jacks.
2-5	One slide-type ON-OFF power switch.
2-6	One 6-position rotary selector switch.
2-7	One 1,000-ohm wire-wound potentiometer.
2-8	One bar knob for the selector switch.
2-9	One pair of test leads (one red lead and one black lead) with probes and alligator clips.
2-10	One type 1C5GT vacuum tube. (This tube is sometimes marked 1C5G or 1C5GT/G.)
2-11	One 6.7-megohm, ½-watt resistor with 10% tolerance (color-coded blue, violet, green, silver).
2-12	One 3-megohm, ½-watt resistor with 10% tolerance (color-coded orange, black, green, silver).
2-13	One .25-megohm, ½-watt resistor with 10% tolerance (color-coded red, green, yellow, silver). (This is exactly the same as Part *1-14*, so you can use either *2-13* or *1-14* when a .25-megohm resistor is specified.)
2-14	One 900-ohm, ½-watt resistor with 10% tolerance (color-coded white, black, brown, silver).
2-15	One 100-ohm, ½-watt resistor with 10% tolerance (color-coded brown, black, brown, silver.)
2-16	One .005-mfd., 600-volt paper condenser.
2-17	One 25-foot roll of push-back hook-up wire, with red insulation.
2-18A	Two ¼-inch long, 6-32 cadmium-plated binder-head machine screws.
2-18B	Two cadmium-plated hexagonal nuts for 6/32 screws.
2-19A	Four ¼-inch wide, 2½-inch long tinned copper strips.
2-19B	Four ¼-inch wide, 1-inch long tinned copper strips.
2-20	One 45-inch length of black lace for fastening tester battery to chassis.
2-21	One grid clip.
2-22	One .2-megohm, 1/3-watt resistor with 20% tolerance (color-coded red, black and yellow).

color code markings. (Some radio set manufacturers used private color codes for resistors. These resistors must be checked by actual measurement. The RMA color code is presented in Fig. *3* for your convenience in referring to it while carrying out experiments.

Tolerances. The standard tolerance observed by manufacturers of carbon or metallized resistors is 20%. This means that the actual value of a resistor may be as much as 20% higher or 20% lower than the rated value. For example, in the case of a 1,000-ohm resistor, the standard 20% tolerance comes to 200 ohms, and the resistor may therefore have a value anywhere between 800 ohms and 1,200 ohms. No special tolerance markings are used when a resistor has standard 20% tolerance.

In some radio circuits, better accuracy is required for resistors. With 10% tolerance, a 1,000-ohm resistor would be somewhere between 900 ohms and 1,100 ohms. When resistors with 10% tolerance are marked according to Method *I* in Fig. *3,* they will have a *silver* band at *D*.

With 5% tolerance, the range of variation would be between 950 ohms and 1,050 ohms for a rated 1,000-ohm resistor. When resistors with 5% tolerance are marked according to Method *I* in Fig. *3,* they will have a *gold* band at *D*.

Radio servicemen are rarely concerned with resistor tolerances because the standard tolerance of 20% is entirely satisfactory for the great majority of circuits. In the N. R. I. Tester which you will soon build, however, you will use some resistors having 10% tolerance.

Insulated Resistors. When the outer covering of a resistor is an insulating material, we have what is known as

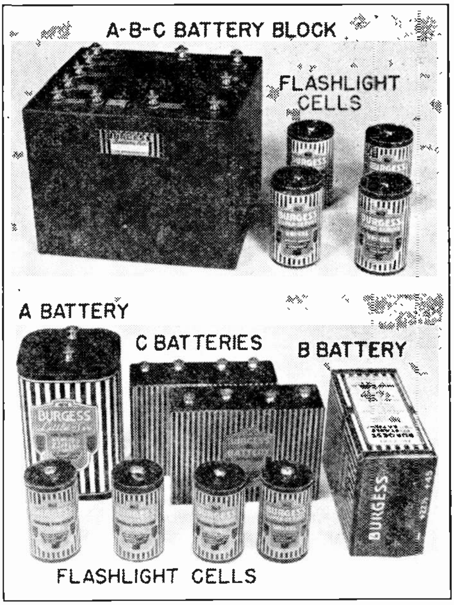


FIG. 2A (above). The only batteries you need for Experiments 11 to 20 in this manual and for the N. R. I. Tester are the four standard No. 2 (large size) flashlight cells and the special Burgess A-B-C battery block shown in this illustration. The A-B-C block contains a 1½-volt A battery, a 45-volt B battery tapped at 22½ volts, and a 9-volt C battery tapped at − 3, − 4½, − 6 and − 7½ volts.

Note: This special A-B-C battery block can be purchased only through National Radio Institute. It is not sold in stores anywhere. Write to us for a price quotation if you did not get a battery folder.

If you followed the instructions given in the battery folder accompanying your first radio kit (1RK), you will already have this set of batteries or the equivalent set of individual units shown in Fig. *2B*. If for any reason you have not yet obtained your batteries, *order them immediately* because you will need them for the experiments in this manual.

FIG. 2B (below). Students who purchased their batteries from a local radio parts distributor or from a mail order firm handling radio parts will have this set of individual Burgess batteries or their Eveready equivalents, for the special A-B-C battery block is available only through N. R. I. The individual battery assortment includes the following units:

One Burgess type 4FH 1½-volt A battery (or Eveready type 742, in which case the correct plug adapter for this battery must also be ordered).

Two Burgess type 2370 (or Eveready type 761T) 4½-volt C batteries.

One Burgess type Z3ON 45-volt B battery (or Eveready type 738, in which case the correct plug adapter for this battery must also be ordered).

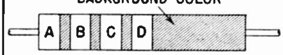
Four Burgess standard No. 2 flashlight unicells (or four Eveready type 950 flashlight cells).

an *insulated resistor.* When marked according to Method *I* in Fig. *3,* you can identify these by the fact that they have a *tan* background color. These resistors may safely be used in contact with the chassis or other parts.

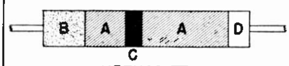
allowed to touch other parts or wires.

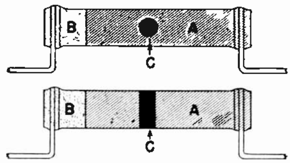
Most of the resistors furnished to you in N. R. I. radio kits are of the insulated type, but nevertheless it is always good practice to position resistors so that they do not touch other parts.

RMA COLOR CODE FOR RESISTORS



METHOD I
COLOR BANDS A,B,AND C GIVE VALUE.
GOLD OR SILVER BAND D, USUALLY OMITTED, INDICATES TOLERANCE.
BLACK BACKGROUND — UNINSULATED.
TAN BACKGROUND — INSULATED.





METHOD II
BODY COLOR (A), END COLOR (B), AND DOT OR BAND COLOR (C) GIVE VALUE.
GOLD OR SILVER BAND D, USUALLY OMITTED, INDICATES TOLERANCE.

Color	Figure
BLACK	0
BROWN	1
RED	2
ORANGE	3
YELLOW	4
GREEN	5
BLUE	6
VIOLET	7
GRAY	8
WHITE	9

COLOR A GIVES FIRST FIGURE OF RESISTOR VALUE.

COLOR B GIVES SECOND FIGURE OF RESISTOR VALUE.

COLOR C GIVES NUMBER OF CIPHERS FOLLOWING THE FIRST TWO FIGURES.

COLOR D: GOLD BAND INDICATES ± 5% TOLERANCE.
SILVER BAND INDICATES ± 10% TOLERANCE.
NO BAND INDICATES STANDARD ± 20% TOLERANCE.

FIG. 3. The two methods being used for marking resistors according to the standard R.M.A. Color Code are given here.

When a color band is missing in non-insulated (black background) resistors marked according to Method I, assume that the color of the missing band is black.

When end color B, or dot or band C, is missing in a resistor marked by Method II, the missing marking is the same as body color *A;* thus, an all-red color-coded resistor would be 2,200 ohms.

Note that with Method I markings the color bands are all equal in width, while with Method II marking on resistors having leads coming straight out from the ends, the color bands are of different widths; this serves as a clue for telling which method of marking is employed.

When there is no insulating covering on a ceramic fixed resistor, we have what is known as a *non-insulated* resistor. When marked according to Method *I* in Fig. *3,* these have a *black* background color. Non-insulated resistors should not be

INSTRUCTIONS FOR EACH EXPERIMENT

1. **Read the entire experiment, giving particular attention to the discussion.**
2. **Perform each step of the experiment and record your results.**
3. **Study the discussion and analyze your results.**
4. **Answer the report statement for the experiment. It will always be on the last page of the manual.**

EXPERIMENT 11

***Purpose:* To demonstrate that a d.c. voltage source has polarity.**

Step 1. To provide convenient soldering terminals for the four flashlight cells, take one of the $2\frac{1}{2}$-inch long tinned copper strips (Part *2-19A*), and make a rounded right-angle bend $\frac{3}{4}$ inch from one end with long-nose pliers. Now hold one of the cells in your left hand and push the zinc container almost entirely out of the cardboard cylinder with the thumb of your right hand, as shown in Fig. *4A.* Insert the long end of the bent strip between the cardboard housing and the zinc case of the cell, as shown in Fig. *4B.* This can be

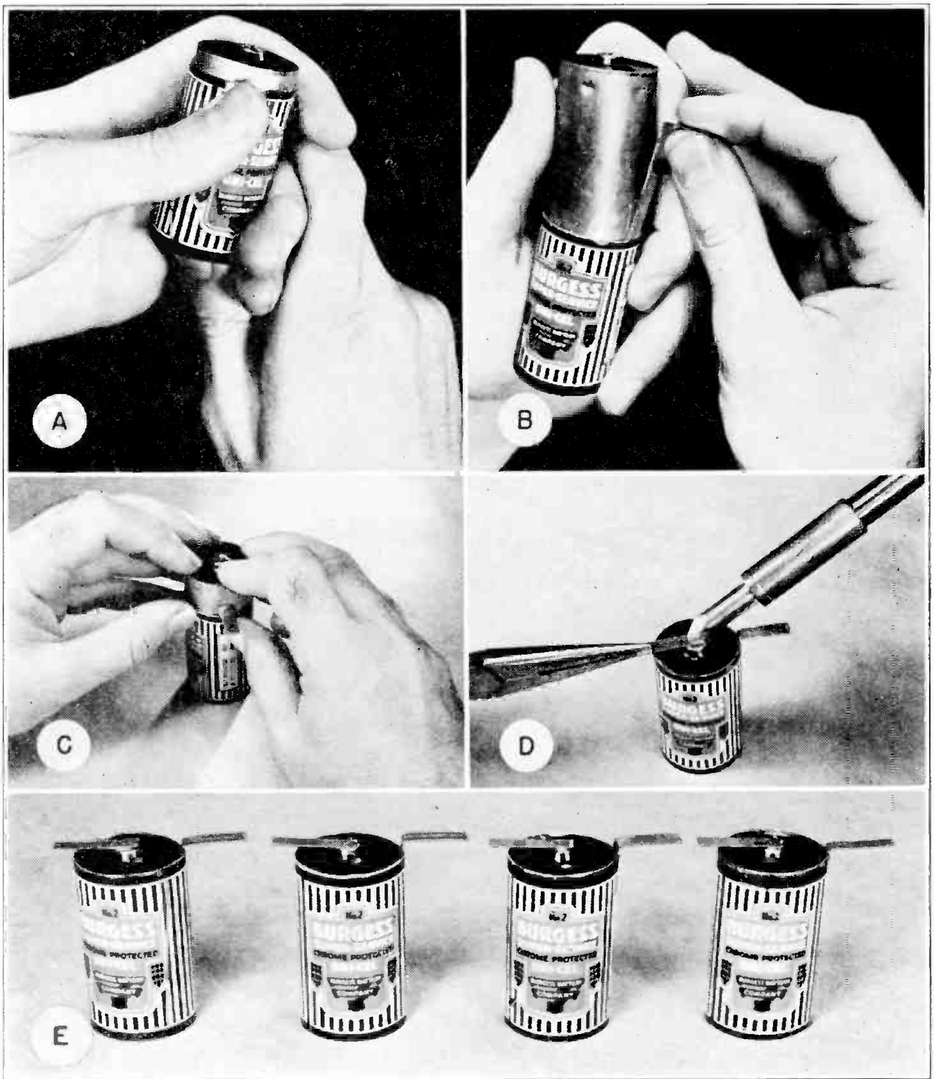


FIG. 4. Steps in providing the four $1\frac{1}{2}$-volt flashlight cells with convenient soldering terminals.

done most easily when the zinc can is just about ready to come out of the cardboard cylinder. Be sure the strip is against the zinc can, not between layers of paper. Push the strip down until the horizontal part of the strip is about $\frac{1}{8}$ inch above the top of the cardboard cylinder, then push the zinc can carefully back into its housing by pressing evenly with the fingers of both hands as shown in Fig. *4C*.

In the same way, bend each of the other $2\frac{1}{2}$-inch long tinned copper strips, and insert one against the zinc can of each of the other three cells.

Although the copper strips are tinned during manufacture, this original coating of solder is quite thin and is sometimes covered with grease or oxides. Additional tinning of areas to which connections will be made takes only a few minutes, and greatly simplifies future work with the strips.

Tin each of the 1-inch long strips (Part *2-19B*) on one side for about ¼ inch from one end, by grasping a strip with long-nose pliers and holding it over a flat face of the heated soldering iron in its holder, then rubbing rosin-core solder over the uppermost surface of the strip at one end.

Tin the center terminal of a flashlight cell by filing the top surface until bright (be careful not to let the file touch the exposed rim of the zinc can, for that would short-circuit the cell). The center terminals of some cells are chromium plated; solder will not readily adhere to chromium, so file away the chromium layer until a bright brass or copper color shows. Apply the heated soldering iron and rosin-core solder to the cleaned surface of the center terminal. Slide the iron back and forth over the surface to tin all parts of it uniformly with a minimum amount of solder. Do not hold the soldering iron on the terminal any longer than necessary, for excessive heat can shorten the life of a dry cell. In the same way, clean and tin the center terminals of the other three cells, one at a time.

Solder a tinned 1-inch strip to the center terminal of a cell in the following manner: Hold the strip over the center terminal with long-nose pliers in the manner shown in Fig. *4D*, so that the freshly tinned area on the strip is in contact with the center terminal and the strip lines up with the 2½-inch strip already on this cell. The two strips then project on opposite sides of the cell. Apply the heated soldering iron to the strip just long enough to fuse together the solder on the strip and the terminal. Hold the strip rigid until the solder hardens. *Do not let either the pliers or the tinned copper strip touch the metal rim of the cell;* bend the strip upward if necessary.

Solder a 1-inch strip to the center terminals of each of the other three cells in the same way. Your four cells should now appear as shown in Fig. *4E*. If you desire, you can round off the sharp corners of these terminal strips with your file.

Step 2. To assemble the chassis and panel for future use, take the N. R. I. Tester front panel (Part *2-2*) and bolt it to the chassis (Part *1-11* from Radio Kit 1RK) with three screws (Part *1-9A* or *2-18A*) and three nuts (Part *1-9B* or *2-18B*) *exactly* in the manner shown in Fig. *5*.

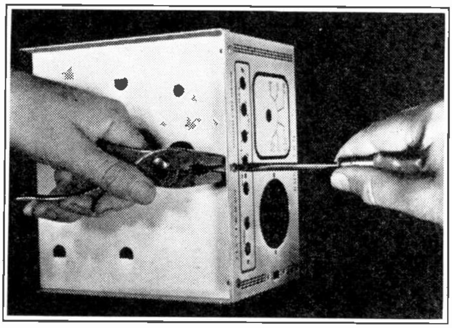


FIG. 5. Fasten the front panel to the chassis exactly as shown here. Use a medium-size screwdriver to tighten each screw while holding its nut with ordinary pliers.

Step 3. To mount the meter (Part *2-1*) *on the panel for convenience in making measurements,* place the meter in hole *q* (see Fig. *6*) from the front, and adjust its position until the holes in the meter frame coincide with panel holes *r* and *s*. Now take the meter mounting screws (these are in the small envelope in the meter box), insert them in meter mounting holes *r* and *s* from the front of the panel, then place the nuts on these screws at the back of the panel. Tighten first with the fingers, then with long-nose pliers and a screwdriver. When looking at the back of the panel now, the meter will appear as shown in Fig. *6*.

Step 4. To mount the 7-jack strip (Part *2-3*) *on the panel,* wipe dust off both sides of the strip, hold the strip against the back of the panel in the position shown in Fig. *6* and fasten the strip to the panel with three screws (*1-9A* or *2-18A*), inserted from the front of the panel, and three nuts (*1-9B* or *2-18B*). There is only one position of the strip in which the three mounting holes on the strip and panel will coincide. Shift the strip sideways slightly, if necessary, so that the jacks are centered as well as possible in the panel holes.

On the back of the panel, directly above each jack, write its terminal number with a metal-marking crayon, exactly as shown in Fig. *6*. Keep the point of the crayon sharp by trimming it off with a pocket knife or by rubbing the crayon on scrap paper to reshape the point.

Step 5. To connect the meter to two of the jacks on the panel with temporary soldered joints for convenience in making tests, remove *one* of the nuts from the positive meter terminal (this terminal is identified by a small plus sign stamped into the meter case near the terminal), place a 13/16-inch long soldering lug (Part *1-8A*) on the meter terminal after first straightening out the lug with long-nose pliers, then replace the nut and tighten with fingers and pliers while holding the lug straight down. Mark the number *15* above this lug on the meter case with crayon. In the same way, straighten another lug (Part *1-8B*), place it on the other meter terminal (this is the negative terminal of the meter and has no marking), and mark the number *16* above this lug on the meter case.

Now cut off a 3¼-inch length from the roll of red push-back wire supplied you as Part *2-17*, push the insulation back ½ inch from each end, then form a hook in one end with long-nose pliers and hook this through the + terminal lug of the meter (lug *15* in Fig. *6*). Push the other end of the wire through the hole in the soldering lug of jack *27* and bend the wire back on itself to form a hook. In the same way, cut a 2½-inch

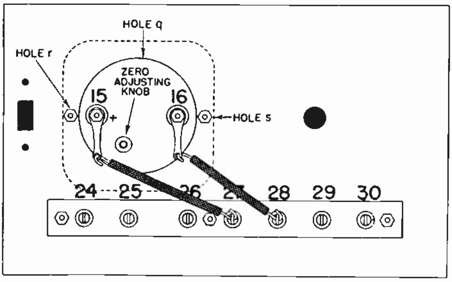


FIG. 6. ***Rear*** **view of front panel, showing how the meter and jack strip are mounted and connected together for the experiments which are to be made before assembling the N. R. I. Tester. The chassis is not shown in this view, but should be attached to the bottom of the panel according to instructions given in Step 2 of Experiment 11.**

length of red push-back wire and use it to connect lug *16* (on the — terminal of the meter) to the lug on jack *28*. Solder all four of these temporary joints now with rosin-core solder.

Step 6. To set the meter pointer at zero, locate the knurled zero-adjusting knob at the back of the meter (the position of this knob is indicated in Fig. *6*). With your fingers, rotate this knob first in one direction as far as it will go, then in the other direction while watching the front of the meter, to get a general idea of how the knob controls the pointer position. After this, adjust the knob carefully while tapping the meter lightly with one finger, until the pointer is exactly at the zero line on the lowest scale of the meter (this scale is marked I_M).

Step 7. To show that the meter will read up-scale when properly connected to a voltage source, first secure the pair of test leads furnished you as Part *2-9,* and plug these into the two jacks marked *I* on the front panel; plug the red-handled probe into the *I* jack marked +, and plug the black-handled probe in the *I* jack marked —, as shown in Fig. 7. If difficulty is encountered in inserting a probe in a jack the first time, twist and wiggle the probe slightly while pushing on it, so as to loosen the spring contacts in the jack. Hold the back of the jack with one hand while doing this, to minimize the pressure exerted on the fiber jack strip.

Now attach the alligator clip of the red lead to the positive (center) terminal strip of one of the flashlight cells which you previously prepared, and watch the meter pointer while you attach the alligator clip of the black test lead to the tinned copper strip which serves as the negative terminal of this flashlight cell. As soon as you have noted the direction in which the pointer moves, open the circuit by removing one of the alligator clips, so as to avoid unnecessary drain on the cell. It is only necessary now to observe the direction in which the pointer moves; do not try to read the meter yet.

Step 8. To demonstrate that the meter will read down-scale (off-scale to the left of zero) *when improperly connected to a d.c. voltage source,* leave the test leads plugged into the panel jacks just as before, but now place the red alligator clip on the — cell terminal, and place the black clip on the + cell terminal. Note the direction in which the meter pointer moves, then break the circuit by removing both alligator clips.

Discussion: The four flashlight cells which you were instructed to obtain for your practical demonstration course will be connected together in various ways to provide a variety of d.c. voltage values. The terminal strips which you place on these cells in Step 1 will greatly simplify the connecting of these cells into experimental circuits.

The important thing for you to remember in connection with these cells is that the center terminal of each cell is + (positive). The 1-inch long strip which you soldered to this center terminal thus becomes the + terminal of the cell. If you wish, you may mark a + sign on the center strip with a metal-marking crayon. The 2½-inch long strip which you inserted between the cardboard housing and the zinc case therefore becomes the — (negative) terminal.

In Steps 3, 4 and 5, you prepare the meter for use by mounting it on a vertical panel and connecting it to two of the jacks which are also mounted on this panel. When this is done, you can make connections to the meter simply by plugging your test leads into the two jacks marked *I* on the front panel. You will find that this preliminary work greatly simplifies the use of the meter during the next ten experiments.

Step 6 is intended to familiarize you with the use of the zero-adjusting knob at the back of your meter. Always tap the top of the meter lightly with the finger while adjusting the zero position of the pointer or reading low current and voltage values; the resulting slight vibration overcomes any friction which may exist at the bearings of the meter pointer.

Your meter is highly sensitive to the presence of iron, steel or any magnetic field in its vicinity. You can demonstrate this for yourself by watching the pointer while moving a pair of pliers in front of the meter.

If the meter pointer refuses to return to zero at any time even with tapping, there may be a magnetic field or magnetic material somewhere in the vicinity.* You can either readjust the zero-adjusting knob to compensate for this condition, or remove the offending material. When conducting experiments, keep all iron or steel tools at least 6 inches away from the meter. This seemingly peculiar behavior of your meter is entirely normal, and is an inherent characteristic of all magnetic vane type meters such as yours.

In Step 7 you connected the + terminal of the meter to the + terminal of the flashlight cell, and connected the — meter terminal to the — terminal of the flashlight cell. This is the correct polarity for connecting a meter to a d.c. voltage source, and you therefore obtained an up-scale movement of the meter pointer.

Now, since you know that the meter reads up-scale whenever the + meter terminal is connected to the + terminal of a voltage source, you can determine the polarity of any d.c. voltage source within the range of your meter. Simply connect the meter to the voltage source and note the direction in which the pointer moves. If the pointer moves up-scale, you then know that the red test lead (the + terminal of the meter) is on the + terminal of the voltage source. If the meter pointer reads down-scale, as it did when you reversed the meter connections in Step 8, you know that the meter is improperly connected. When this occurs (when the meter reads down-scale), reverse the positions of the test clips immediately.

Do not leave the meter connected to the flashlight cell any longer than is necessary to observe the movement of the meter pointer. The meter draws a certain amount of current from the flashlight cell, and naturally you want to conserve the life of the cell.

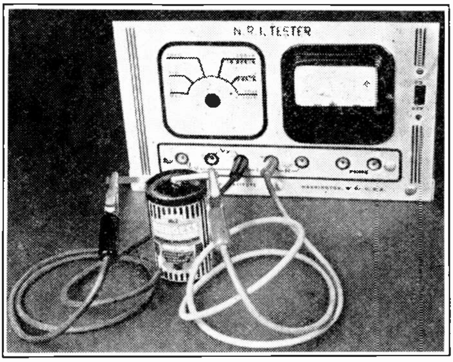


FIG. 7. Using the meter to demonstrate that a d.c. voltage source (the flashlight cell) has polarity. The meter pointer moves up-scale only when the cell is connected to the meter with proper polarity. The test leads were coiled merely to simplify taking the photograph; you will not have to bother with arranging the test leads in any particular position during experiments.

In your fundamental course, you learned that electrons always flow *out of* the negative terminal of a d.c. voltage source, and flow *into* the positive terminal of the d.c. voltage source after they have traveled around the external circuit. You also learned that a *d.c.* meter should be connected *so electrons enter the negative terminal of the meter.* With these fundamental facts in mind, you can very easily trace electron flow in your sim-

* Overloading of the meter can also cause a shift in the zero position of the pointer. This condition will usually correct itself in a short time, but you will receive instructions later for correcting the shift immediately.

ple circuit consisting of the meter connected across the flashlight cell. The electrons leave the — terminal of the cell, go through the black test lead, the — *I* jack and one length of hook-up wire to the meter. The electrons then enter the — terminal of the meter (marked *16*), flow through the coil of wire inside the meter, emerge from the + meter terminal (marked *15*), travel through the other length of hook-up wire to the + *I* jack, then go through the red test lead to the + terminal of the flashlight cell.

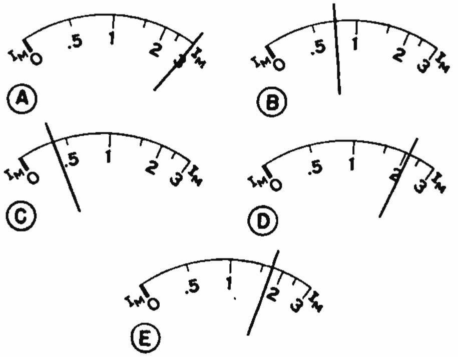


FIG. 8. Examples illustrating how to read scale I_M of your meter. The reading for *A* is 3 ma.; *B* is .75 ma.; *C* is .4 ma.; *D* is 2.1 ma.; *E* is to be read by you and the reading recorded in Report Statement No. 12. This scale indicates the current in milliamperes which is passing through the meter. These scales are reproduced here for instruction purposes; the scale on your meter may not be exactly like these, but the same scale-reading methods will apply. Disregard the other three scales on your meter for the present; they will be taken up later.

Instructions for Report Statement No. 11. The report question which checks your work on this experiment is extremely important, because knowledge of the correct answer will enable you to trace electron flow in any d.c. circuit having a meter, even when there are no vacuum tubes present to indicate the direction of flow.

Using your actual observations and the discussion material as guides, *figure out the terminal at which electrons will enter your d.c. meter when it is connected in a d.c. circuit with correct polarity so as to give an up-scale deflection.* Three answers are given in Report Statement No. 11 on the last page: *at the positive terminal; at the negative terminal; at both the positive and negative terminals.* Only one of these answers is correct; figure out which one it is, and make a check mark in the box following that answer.

EXPERIMENT 12

***Purpose:* To demonstrate that the current which flows in a circuit will increase when the voltage is increased.**

Step 1. To learn how to read the lowest scale (marked I_M) *on your meter,* study the exact-size reproductions of this scale in Fig. *8*. Observe that the scale reads from 0 to 3; these scale values represent milliamperes of current flowing through the meter, for your instrument is basically a milliammeter having a range of from 0 to 3 milliamperes.

When the maximum permissible current of 3 ma. is flowing through the meter, the pointer will be at *3* on scale I_M, as shown in Fig. *8A;* you would read this as 3 ma. When the pointer is on any other numbered line on this scale, the number below the line indicates the current in milliamperes.

When the pointer is on a short unnumbered line between two numbered lines, the meter reading is a value halfway between the values of the two adjacent numbered lines. Thus, you would read 1.5 ma. when the pointer is on the short line between *1* and *2,* and you would read 2.5 ma. when the pointer is on the short line between *2* and *3*.

Whenever the pointer is in between two lines on this scale, mentally di-

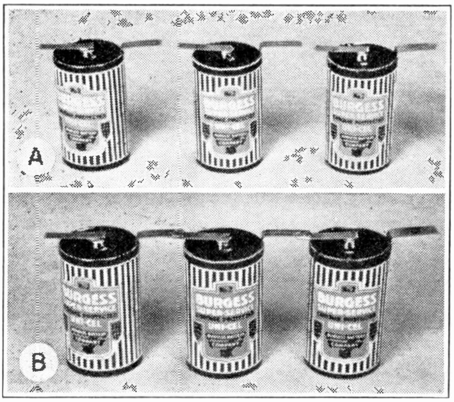


FIG. 9. Method of connecting three flashlight cells together in series aiding to permit obtaining three different values of d.c. voltage (1.5 volts, 3 volts and 4.5 volts).

vide the space between the two lines into equal smaller spaces and estimate the meter reading. For example, if the pointer is about halfway between lines marked *.5* and *1*, as in Fig. *8B*, you would estimate the meter reading to be .75 ma. If the pointer is as shown in Fig. *8C*, where it is closer to *.5* than to *0*, you might estimate the reading to be .4 ma. Finally, if the pointer is as shown in Fig. *8D*, you would estimate the reading to be about 2.1 ma.

Step 2. To secure 1.5, 3 and 4.5-volt d.c. voltage sources for this experiment, first take each cell in turn and tin the upper surface of its positive terminal strip for about one-fourth inch from the free end, then tin the under surface of its negative terminal in the same manner so as to secure surplus solder at these points. Now arrange three of your previously prepared flashlight cells exactly in the manner shown in Fig. *9A*, so that the — terminal strip of one cell is over the + terminal strip of the adjacent cell. Bend the terminal strips so that they will touch each other when they are overlapping about ¼ inch in this manner, then apply the heated soldering iron tip to each region in turn where the strips overlap. Hold the soldering iron over each of these lap joints only long enough to melt and fuse together the solder in between the strips. Fig. *9B* shows the cells connected together.

Step 3. To secure practical experience in measuring the current in a circuit, attach the alligator clip of the black test lead to the — terminal at one end of your cell group. (The probes should be plugged into the panel jacks exactly as they were for Experiment 11, with red in +*I* jack and black in —*I*.) Now attach the red alligator clip to the + terminal of this same cell as shown in Fig. *10A*, so as to secure a voltage of 1.5 volts. Read on scale I_M of your meter the amount of current flowing, discon-

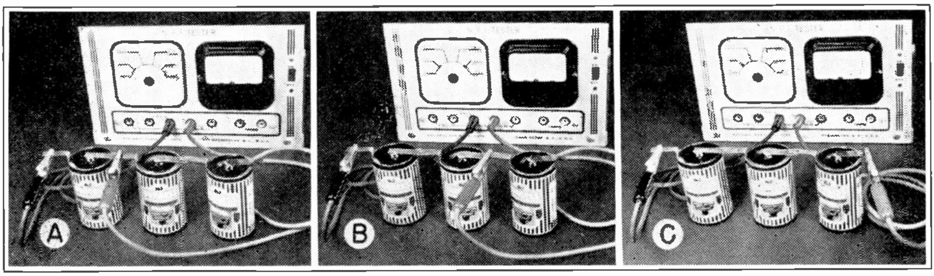


FIG. 10. These illustrations show you how to set up the three circuits in which you make current measurements as a part of Experiment 12. Note that the red probe is plugged into the +*I* jack, and the black probe is plugged into the —*I* jack. Leave the test probes in these jacks until you are told to remove them in Experiment 16.

nect the red clip, and record your reading in the first line of Table *12*.

Now attach the red clip to the + terminal of the middle cell as shown in Fig. *10B*, so as to secure a voltage of 3 volts. Read the meter on scale I_M just as before, disconnect the red clip, and record your result in the second line of Table *12*.

Finally, attach the red clip to the + terminal of the last cell as shown in Fig. *10C*, so as to secure a voltage of 4.5 volts. Read the meter, disconnect the red clip, and record your result in the last line of Table *12*.

CAUTION: Do not leave the meter connected to a flashlight cell or battery for more than a few minutes at a time; it is always better to disconnect one lead of the meter as soon as you take a reading, and leave it disconnected until you are ready for the next reading.

Look squarely at the meter when reading it, to secure consistently accurate readings; in other words, your eyes should be directly in front of the meter scale whenever you take a reading.

Discussion: The meter which is furnished you in Radio Kit 2RK has four distinct scales. The only one which applies directly to the meter is the lowest scale, marked I_M, covering a range of from 0 to 3 ma. Ordinarily, this would be the only scale you would find on a meter of this type; the other three scales are provided for the N. R. I. Tester in which you will use this meter after completing Experiment 20. For the present, therefore, it is entirely sufficient for you to know how to read only the lowest meter scale.

Do not worry too much about reading the meter accurately at this time. In the first place, accurate readings are seldom required in radio work. Furthermore, you will automatically acquire the ability to estimate meter readings as you secure experience with your meter. Just remember that a meter scale is like an ordinary ruler, and is read in much the same manner.

When you have a number of separate voltage sources and want to connect them together in such a way that the voltages add, you always connect them in the manner described in Step 2. This connection is known as *series aiding* (or simply as a *series connection*), for the voltage sources (flashlight cells) are connected in series in such a way that their voltages aid each other. Thus, if one cell gives 1.5 volts, two cells connected in series aiding will give 3 volts, and three cells will give 4.5 volts.

A comparison of the three meter readings which you obtained in Step 3 will show you that the current increases when you increase the source voltage from 1.5 volts to 4.5 volts. This experiment which you perform therefore proves the basic radio rule that the current in a circuit will increase when the voltage is increased. Conversely, it proves that the circuit current will decrease when the voltage is reduced.

Two factors determine the amount of current which will flow in a circuit; *the value of the source voltage, and the amount of opposition or resistance which the circuit offers to current flow.* In the three circuits which you set up in Step 3, the flashlight cells serve as d.c. voltage sources. As to resistance, we can say definitely that every electrical part has resistance. Sometimes this resistance is very large, so that electron flow is almost completely blocked, while in other cases the resistance is so small that it can be neglected.

In the circuits of Step 3, each 1.5-volt dry cell has a resistance of about .5 ohm. The terminal strips, the test leads, the alligator clips, the jacks on the panel and the lengths of hook-up wire also have resistance, but in each case this resistance is lower than .5 ohm. The milliammeter has a resistance of about 2,000 ohms; this is so much higher than the resistance of the other parts in the circuit that we can call it the predominant resistance and neglect all other resistances. We thus have voltages of 1.5, 3 and 4.5 volts respectively, acting in a simple circuit having an effective total resistance of about 2,000 ohms.

Computing Circuit Current. Let us see what the value of circuit current will be when computed according to Ohm's Law for our first circuit, in which a d.c. voltage source of 1.5 volts is sending electrons through a circuit having a resistance of 2,000 ohms.

As you learned in your regular lessons, Ohm's Law says that the current in amperes is equal to the voltage in volts divided by the resistance in ohms. In our case, then, the current in amperes will be equal to 1.5 divided by 2,000, which is .00075 ampere. To convert this current value into milliamperes, we multiply by 1,000, and get .75 ma. as the computed value of circuit current. This computed value is listed in Table *12*, for convenience in comparing it with your own reading and with the reading of .7 ma. which we obtained in the N. R. I. laboratory.

If the reading which you obtained is fairly close to the computed value (any reading between .5 ma. and 1.0 ma. can be considered as sufficiently close for all practical purposes in this particular experiment), you can consider that you have proved the validity of Ohm's Law in your d.c. circuit.

Whenever you double the source voltage value, as you did by adding another dry cell to your circuit, you would naturally expect that the current would double also. According to Ohm's Law, 3 volts acting on 2,000 ohms gives a current of 3 divided by 2,000, or .0015 ampere. This corresponds to 1.5 milliamperes, a computed value of circuit current which is exactly twice the value you computed for a 1.5-volt d.c. source. Likewise, your own current reading for 3 volts should be approximately twice the reading which you obtained for 1.5 volts.

With a d.c. source voltage of 4.5 volts, you would expect the computed current value to be three times that obtained with 1.5 volts. Dividing 4.5 by 2,000 gives .00225 ampere, which is equal to 2.25 ma. This is exactly three times the value computed for 1.5 volts, as you expected. Compare your own current reading for 4.5 volts with the computed value; if your reading is somewhere between 2 and 3 ma., you can consider your work on this experiment to be entirely successful, and you can consider that you have demonstrated how Ohm's Law holds true in a simple d.c. circuit.

Extra Information. You could safely apply as high as 6 volts directly to your meter without damaging it, since the full-scale value is 3 ma. (6÷2,000 =.003, or 3 ma.). Your millammeter can thus be used as a 0-6 volt d.c. voltmeter simply by multiplying the readings on scale I_M by 2. When using your meter in circuits having voltages higher than 6 volts, however, special precautions must be observed; these will be taken up later. In other words, never connect your meter directly to the terminals of a 22.5-volt or 45-volt B battery.

D.C. SOURCE VOLTAGE IN VOLTS	YOUR CURRENT READING ON SCALE I_M IN MA.	N.R.I. CURRENT READING ON SCALE I_M IN MA.	COMPUTED CURRENT IN MA.
1.5	.9	.7	.75
3.0	1.7	1.6	1.50
4.5	2.6	2.3	2.25

TABLE 12. Record your results for Experiment 12 here.

Some milliammeters have very much lower resistance than the meter which you used in Step 3. For this reason, never connect *an unknown milliammeter* across a dry cell *or any other voltage source* until you know exactly what the characteristics of the meter are. In some cases you may burn out the meter when doing this, for even the 1.5-volt value of a single dry cell may send through the meter a larger current than that for which it was designed.

Instructions for Report Statement No. 12. The question for this experiment is a test of your ability to read the meter on scale I_M with reasonable accuracy for practical radio work. After you have completed this experiment and studied the discussion, turn to the exact-size reproduction of this meter scale in Fig. *8E* and figure out what the meter reading would be when the pointer is at the position shown. Now turn to Report Statement No. 12 on the last page, and place a check mark in the box following the meter reading which you consider to be correct for Fig. *8E*.

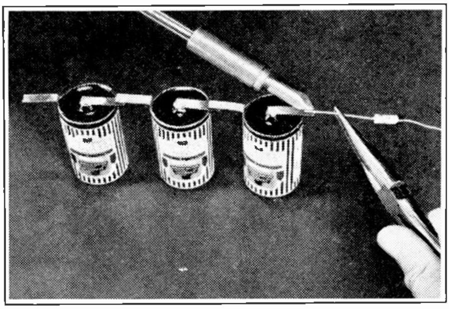


FIG. 11. To solder a resistor to a battery terminal strip by means of a lap joint, tin both the lead and the end of the strip, hold the resistor on the terminal strip with long-nose pliers as shown here, and apply the heated soldering iron.

EXPERIMENT 13

Purpose: **To demonstrate that the current flowing in a circuit will be reduced when the resistance in the circuit is increased, and to prove for yourself the basic fact that the current is the same at all points in a series circuit.**

Step 1. To measure the current before and after you insert a 900-ohm resistance into a simple d.c. circuit, connect your meter across the group of three flashlight cells just as you did for the final measurement in Experiment 12, read the meter on scale I_M, disconnect the red clip, and record the current value on the first line in Table *13*.

Now solder one lead of a 900-ohm resistor (Part *2-14*) to the + terminal at the end of the cell group, in the manner shown in Fig. *11*. To make this temporary soldered joint, simply tin the end of the resistor lead liberally with rosin-core solder, hold this lead over the positive terminal strip with long-nose pliers, apply the heated soldering iron tip to the lead, then remove the iron and hold the resistor rigid until the solder hardens. Now attach the red clip to the other lead of this resistor while still leaving the black clip on the — terminal of the cell group, read the meter on scale I_M, disconnect the red clip, and record the result on the second line in Table *13*.

Step 2. To prove that the same current flows through all parts of a series circuit, measure the current at three different points in a circuit with your milliammeter, in the following manner:

Cut off an 11-inch length of *red* push-back hook-up wire (Part *2-17*), push back the insulation for about ¾ inch from each end, then solder one end to negative cell terminal *1* in Fig. *12A* by means of a lap joint after first applying additional solder to the top surface of this terminal.

Now attach the red clip to resistor lead *8*, and attach the black clip to the other end of the hook-up wire (marked *9* in Fig. *12A*). Read the meter on scale I_M, disconnect both the red and black clips, and record the result in Table *13* as the current flowing at points *8-9* in your circuit.

Next, measure the current at points *6-7* by unsoldering resistor lead *7* from positive terminal *6*, then soldering end *9* of the hook-up wire to resistor lead *8* by means of a temporary hook joint as shown in Fig. *12B*. Attach the red clip to positive terminal *6*, and attach the black

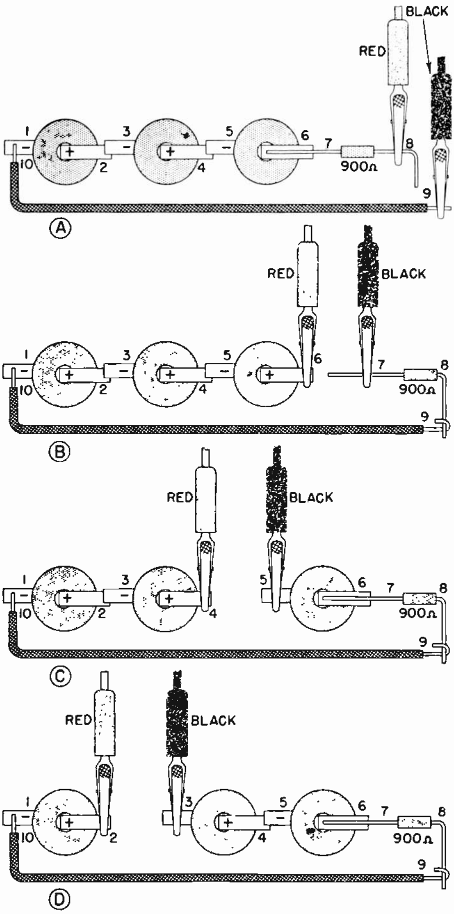


FIG. 12. Use these four milliammeter connections to prove for yourself that the same current value flows through all points in a series circuit.

STEP	NATURE OF MEASUREMENT	YOUR CURRENT READING ON SCALE I_M IN MA.	N.R.I. CURRENT READING ON SCALE I_M IN MA.	COMPUTED CIRCUIT CURRENT IN MA.
1	CURRENT THRU METER. (E = 4.5 V.)	2.5	2.3	2.25
	CURRENT THRU 900Ω AND METER (E = 4.5 V.)	1.7	1.6	1.55
2	CURRENT AT POINTS 8–9	1.7	1.6	1.55
	CURRENT AT POINTS 6–7	1.7	1.6	1.55
	CURRENT AT POINTS 4–5	1.7	1.6	1.55
	CURRENT AT POINTS 2–3	1.7	1.6	1.55

TABLE 13. Record your results for Experiment 13 here.

clip to resistor lead *7*. Read the meter on scale I_M, remove both clips, and record your result in Table *13* as the current flowing at points *6-7*.

Now separate terminal strips *4* and *5* by applying the heated soldering iron to the lap and moving the cells apart. Resolder resistor lead *7* to terminal *6*, as shown in Fig. *12C*. Attach the red clip to terminal *4*, and attach the black clip to terminal *5*. Read the meter on scale I_M, remove both clips, and record your result in Table *13* as the current flowing at points *4-5*.

Separate terminal *2* from terminal *3* by unsoldering. Resolder terminal *4* to terminal *5* as shown in Fig. *12D*. Place the red clip on terminal *2*, and place the black clip on terminal *3*. Read the meter on scale I_M, remove both clips, and record your result in Table *13* as the current flowing at points *2-3*. Do not disconnect this set-up yet, because you will make one more measurement with it for Report Statement No. 13 after studying the discussion.

Discussion: For your first measurement in Step 1, the meter reading should be essentially the same as for the last measurement you made in Experiment 12, since the circuits are identical. When you increase the circuit resistance by inserting a 900-ohm resistor in the circuit, as you did for the second measurement in Step 1, you are increasing from 2,000 ohms to 2,900 ohms the opposition which the circuit offers to electron flow. According to Ohm's Law, the current will decrease when the circuit resistance is increased, hence the second reading which you record in Table *13* should be smaller than the first reading. If you do obtain this smaller reading, you know that you have performed the experiment correctly and have verified Ohm's Law again.

Computing Circuit Current. With a circuit resistance of 2,900 ohms and a voltage of 4.5 volts, Ohm's Law tells us that the circuit current in amperes will be 4.5 divided by 2,900, or .00155 ampere. This is equivalent to 1.55 ma. The second value which you recorded in Table *13* should correspond approximately to this computed value.

If you measure essentially the same meter readings at the four points where you measure current in Step 2, you have proved the fundamental radio principle that *the current is the same at all points in a series circuit.* Remember to tap the top of the meter lightly each time before you take a reading when the pointer is near zero, so as to offset bearing friction. Remember to look squarely at the meter from a position directly in front of it when taking a reading. If you read the meter from an angle, you will obtain a different value than if you were reading it properly.

In any series circuit, the voltage source "feels" the total resistance of the circuit, regardless of where or how this resistance is distributed throughout the circuit. As a result, only the correct current (correct electron flow) for the total circuit resistance can flow, and this current will be the same value at all points in the series circuit.

Instructions for Report Statement No. 13. In order to answer this report statement and prove that you have mastered the measuring techniques involved, connect three dry cells, the meter, a 900-ohm resistor and an 18,000-ohm resistor all in se-

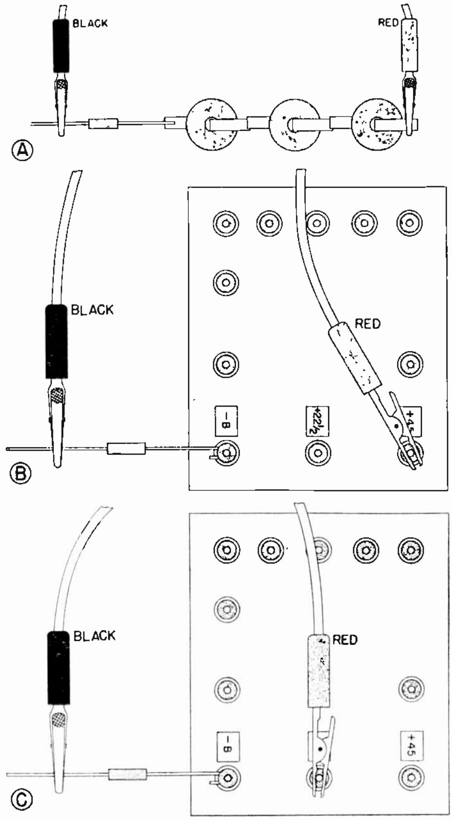


FIG. 13. The three circuits illustrated here all have the same total resistance (the meter with its resistance of 2,000 ohms is not shown, but is connected to the other ends of the two test leads in each case), but each circuit has a different voltage. In Experiment 14 you measure the current in each circuit and note its relationship to the circuit voltage, thereby demonstrating how a milliammeter can be used as a voltmeter.

ries and measure the current flowing in this circuit.

You can arrange these parts in any desired order as long as they are all in series; thus, you could have the meter connected to terminals *2* and *3* as shown in Fig. *12D*, and insert the 18,000-ohm resistor (Part *1-16*) be-

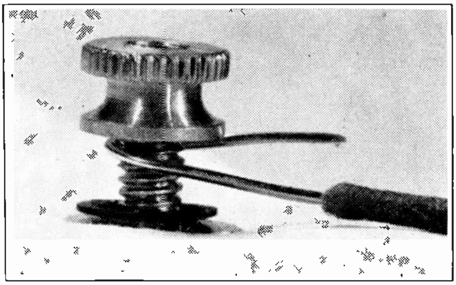


FIG. 14. Whenever you connect a wire or lead to a terminal screw, always bend the hook in a clockwise direction as shown here. This is the same direction in which you turn the nut when tightening it, and therefore the hook will tend to close rather than spread apart and come off when the nut is tightened. The lock washer helps to prevent the terminal nut and wire from loosening.

tween *1* and *10* after unsoldering the wire from terminal *1*. The total circuit resistance is now 2,000 + 900 + 18,000, which is 20,900 ohms.

Compare your measured current value in ma. for this circuit with the current obtained in Step 2 for a total circuit resistance of 2,900 ohms, then turn to the report statement on the last page and place a check mark in the box following the answer which describes your result.

EXPERIMENT 14

***Purpose:* To demonstrate that a milliammeter in series with a resistor can be used as a voltmeter.**

Step 1. To obtain a meter reading when a 4.5-volt d.c. source is connected in series with your meter and an 18,000-ohm resistor, take the 18,000-ohm resistor which was supplied you as Part *1-16* in Radio Kit 1RK and solder one lead of it to the — terminal of your 3-cell battery in the manner shown in Fig. *13A*. Now attach the black clip to the other lead of this resistor, and attach the red clip to the + terminal of your group of cells. Read the meter on scale I_M, remove both clips, and record your result in Table *14* as the current in ma. flowing through this circuit when the source voltage E is 4.5 volts. The meter reading will be very low, less than .25 ma., but estimate its value roughly.

Step 2. To secure a meter reading when a 45-volt battery is connected in series with your meter and an 18,000-ohm resistor, unsolder the 18,000-ohm resistor from the flashlight cell group, bend a large hook in a clockwise direction at the end of one resistor lead with long-nose pliers, then attach this lead to the —B ter-

STEP	NATURE OF MEASUREMENT	YOUR CURRENT READING ON SCALE I_M IN MA.	N.R.I. CURRENT READING ON SCALE I_M IN MA.	COMPUTED CIRCUIT CURRENT IN MA.
1	CURRENT THRU 18,000Ω AND METER. (E = 4.5 V.)	.2	.2	.225
2	CURRENT THRU 18,000Ω AND METER. (E = 45 V.)	2.1	2.1	2.25
3	CURRENT THRU 18,000Ω AND METER. (E = 22.5 V.)	1.1	1.0	1.13

TABLE 14. Record your results for Experiment 14 here.

minal of the A-B-C battery block as shown in Fig. *13B* (or to the —B terminal of your 45-volt B battery if you obtained individual batteries in place of the battery block), by loosening the knurled nut on the —B terminal, hooking the lead around the screw between the nut and the lock washer, then tightening the nut.

Whenever you make a temporary connection to a terminal screw or part with a wire or lead, bend the hook in a clockwise direction as indicated in Fig. *14*, so that the hook will close rather than spread apart when you tighten the nut.

Now attach the black clip to the other resistor lead, and attach the red clip to the +45 terminal of your battery block (or to the +45 terminal of your individual B battery). Read the meter on scale I_M, remove the red clip, and record your result in Table *14* as the current in ma. flowing through this circuit when the source voltage is 45 volts.

Step 3. To secure a meter reading when a 22.5-volt battery is connected in series with your meter and an 18,000-ohm resistor, place the red clip on the +22½ terminal of your battery block (or on the +22½-volt terminal of your individual B battery) without disturbing the black clip or changing any other part of the circuit. This arrangement is shown in Fig. *13C*. Read the meter on scale I_M, remove both test clips, and record your result in Table *14* as the current in ma. flowing through this circuit when the source voltage B is 22.5 volts. Finally, disconnect the resistor from the battery.

CAUTION: Do not connect a 22.5 or 45-volt battery directly to the meter terminals (without the 18,000-ohm current-limiting resistor). Any voltage higher than 6 volts may damage the meter if applied directly.

Discussion: With an 18,000-ohm resistor in series with the 2,000-ohm resistance of your meter, the total circuit resistance becomes 20,000 ohms. This is ten times the resistance of the circuit using the meter alone. According to Ohm's Law, the circuit current should be reduced ten times (to 1/10 of its original value) when the circuit resistance is increased ten times. In Step 1 of Experiment 13 you obtained a current value somewhere near 2.25 ma. for a circuit including only the meter and a 4.5-volt battery, so you would naturally expect the meter reading in Step 1 of this experiment to be about 1/10 of this value, or about .2 ma.

Computing Circuit Current. According to Ohm's Law, the circuit current in amperes for the circuit used in Step 1 will be 4.5 divided by 20,000, which is .000225 ampere, or .225 ma.

In Step 2, you increased the battery voltage to 45 volts, while still keeping the circuit resistance at 20,000 ohms. If Ohm's Law holds true, this ten-times increase in voltage will make the current increase ten times. The current reading which you obtain for Step 2 should therefore be approximately ten times the reading you obtained for Step 1.

Computation. According to Ohm's Law, the current for Step 2 will be 45 divided by 20,000, which comes out to be 2.25 ma. This is exactly ten times the computed current value obtained for Step 1.

When you use a 22.5-volt d.c. source in Step 3, you are cutting the voltage to half the value employed in Step 2. If the current you measure is likewise cut approximately in half, you have performed the third step correctly and have again checked Ohm's Law.

Computation. According to Ohm's Law, the computed current for Step 3 is 22.5 divided by 20,000, which comes out to be 1.13 ma.

Now study your results in Table 14 for a few minutes. Note that the current increases in proportion to increases in the voltage, and the current decreases likewise in proportion to decreases in the voltage. Thus, there is a definite relationship between the meter reading and the voltage employed in the circuit. In fact, if you marked 4.5 volts on your meter scale at the pointer position obtained in Step 1, marked 45 volts at the pointer position obtained in Step 2, and marked 22.5 volts at the pointer position for Step 3, then filled in the missing voltage values on the scale by repeating the experiment for other known voltages, *you could use your meter with its 18,000-ohm resistor to read voltages directly.*

In other words, this experiment has shown definitely that *any milliammeter can be used to measure higher voltages than could safely be applied to the meter alone, provided a series resistor of the proper value* (such as the 18,000-ohm resistor employed in this case) *is used to extend the voltage range,* and the meter scale is recalibrated to read in volts instead of in milliamperes.

A current of 3 ma. through your meter will give you a full-scale deflection on scale I_M. Since the meter has a resistance of 2,000 ohms, Ohm's Law tells us that the voltage needed for a full-scale deflection will be .003 times 2,000, or 6 volts. In other words, if you connected your meter *alone* to a 6-volt battery, you would secure approximately a full-scale deflection on scale I_M.

To measure voltages up to 6 volts with your meter, connect the meter directly to the voltage source with the proper polarity, read the meter on scale I_M, and multiply the scale reading by 2 to get the actual voltage in volts. Thus, a scale reading of 2.25 would correspond to 4.5 volts.

By placing an 18,000-ohm resistor in series with your meter, you can increase the total circuit resistance ten times, and can safely apply ten times as much voltage to the meter circuit without exceeding the safe current of 3 ma. To prove this, we again resort to Ohm's Law.

Computation. Let us say that we have the maximum safe meter current of 3 ma. flowing through the circuit resistance of 18,000 ohms + 2,000 ohms. According to Ohm's Law, the voltage required to send .003 ampere (3 ma.) through a total resistance of 20,000 ohms is .003 × 20,000, or 60 volts. Thus, the insertion of an 18,000-ohm resistor in series with your meter allows you to apply voltages up to 60 volts to your measuring circuit without making the meter read higher than *3* on scale I_M.

To measure d.c. voltages up to 60 volts, connect your meter in series with an 18,000-ohm resistor to the terminals of the voltage source (being sure to get the correct polarity), read the meter on scale I_M, and multiply the scale reading by 20 to get the actual voltage. in volts.

When a resistor is placed in series with a meter in this manner to increase the voltage range, the resistor is known as a *voltage multiplier.*

To make your meter read up to 600 volts, which is 100 times the voltage which gives full-scale deflection of the meter alone, the meter and voltage multiplier together must have a resistance of 100 times 2,000 ohms, or 200,000 ohms. Since the meter alone has a resistance of 2,000 ohms, the voltage multiplier should have a value of 198,000 ohms. With this 198,000-ohm series resistor or voltage multiplier, you could then read voltages directly up to 600 volts on your meter simply by multiplying the reading on scale I_M by 200.

Multimeter Circuit Arrangement. By providing a number of different series resistors of the proper values, along with a switch which permits inserting any one of them in series with the meter, a milliammeter like yours can be made to serve for a number of different voltage ranges. Many of the meters used in radio work, particularly in professional multimeters, are arranged in this manner.

Ohms-Per-Volt Rating. With the meter resistance of 2,000 ohms used alone, the maximum voltage range is 6 volts; with a series resistor being used to increase the meter circuit resistance to 20,000 ohms, the maximum voltage range is 60 volts; with a total meter circuit resistance of 200,000 ohms, the maximum voltage range is

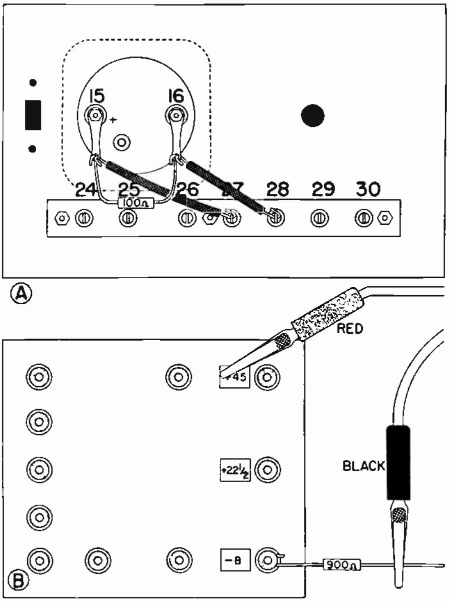


FIG. 15. By placing a 100-ohm shunt resistor across your meter in the manner shown at *A* here, you are able to measure (Experiment 15) the current in the circuit shown at *B*, even though this current is considerably higher than the 3-ma. maximum value which can be passed through the meter alone.

600 volts. When we divide the meter circuit resistance by the maximum voltage range in any one of these cases, we get 333 ohms. This value is known as the *ohms-per-volt rating* of your meter, and is an indication of its sensitivity when used as a voltmeter.

A common sensitivity rating for meters used in radio work is 1,000 ohms-per-volt. Some voltmeters have sensitivities of 5,000 ohms-per-volt, while a few even go as high as 20,000 ohms-per-volt. The vacuum tube voltmeter which you will build after completing this group of ten experiments has a full-scale sensitivity of over 2,000,000 ohms-per-volt on one range, and all of the other ranges are higher than 20,000 ohms-per-volt. This means that your instrument will be comparable with the best individual meters employed in radio work.

Voltage Multiplier Rule.* To find the correct value for a voltage multiplier resistor which is to give a desired voltage range, *multiply the ohms-per-volt rating of the meter by the maximum voltage range desired, then subtract from the resulting value the resistance of the meter itself.

Instructions for Report Statement No. 14. The question for this experiment checks your mastery of the discussion, so do not try to answer Report Statement No. 14 until you understand fully every single sentence in the discussion. You should realize that any d.c. milliammeter can be used as a d.c. voltmeter, and should have a general understanding of how voltage multiplier resistors can be used to increase the voltage range.

Here is the test problem: Suppose you are using your meter as a 0-60 volt d.c. voltmeter (by placing an 18,000-ohm voltage multiplier resistor in series with the meter) to measure an unknown d.c. voltage. You connect the meter and multiplier to the terminals of the voltage source with proper polarity and get a reading of 2 on scale I_M. What is the actual voltage of this source? Figure it out, referring to the discussion again if necessary, then place a check mark after the value which you consider to be correct in Report Statement No. 14 on the last page.

EXPERIMENT 15

Purpose: **To demonstrate the use of shunt resistors for increasing the current range of a milliammeter.**

Step 1. To secure experience in using your milliammeter with a 100-ohm shunt resistor for measuring higher current values, take a 100-ohm resistor (Part *2-15*) and connect it to the meter terminal lugs with temporary soldered joints as shown in Fig. *15A*.

Take a 900-ohm resistor (Part *2-14*) and connect one of its leads to the —B terminal of your battery block (or to the — terminal of a separate B battery), as shown in Fig. *15B*. With the test leads still in the *I* jacks exactly as shown in Fig. *7*, attach the black clip to the other lead of the 900-ohm resistor.

Now complete the circuit by attaching the red clip to the +45 battery terminal. Read the meter on scale I_M, remove the red clip immediately from the +45 terminal, then record your reading in Table *15*. Do not leave the red clip connected to the +45 terminal any longer than is necessary to secure the reading, for otherwise you will exhaust the B battery.

Discussion: In a circuit consisting of a 45-volt battery and a total resistance of 900 + 100 ohms, the current would be 45 ma. (45 divided by 1,000 = .045 ampere, or 45 ma.). This current cannot be measured directly with your meter, since the maximum current the meter can safely pass is 3 ma. In this experiment, we use a shunt resistor (100 ohms) to increase the range of the milliammeter enough to permit measurement of this high current.

In the circuit of Fig. *15*, the 100-ohm resistor is connected directly across the meter terminals. Let us see how this shunt resistor (usually called a *shunt*) limits the meter current to a safe value.

First of all, when a 2,000-ohm meter is connected across a 100-ohm resistor, the original total circuit resistance of 1,000 ohms (900 + 100) will be changed slightly. With 2,000 ohms in parallel with 100 ohms, the combined resistance is 95 ohms; 900 + 95 gives a total circuit resistance of 995 ohms. The change is so small, however, that for all practical purposes we can consider this total resistance to be still 1,000 ohms, and the circuit current still 45 ma. through the battery and the 900-ohm resistor.

When the 45-ma. circuit current reaches the parallel combination of the 100-ohm resistor and the meter, the current divides between these two parts. Naturally, most of the current goes through the 100-ohm resistor since it offers much lower opposition than does the 2,000-ohm resistance of the meter. Let us see exactly how the current divides.

STEP	NATURE OF MEASUREMENT	YOUR METER READING ON SCALE I_M	N.R.I. METER READING ON SCALE I_M	COMPUTED METER CURRENT IN MA.
1	CURRENT THRU 900Ω AND METER SHUNTED BY 100Ω (E = 45 V.)	2.5	2.2	2.14

TABLE 15. Record your results for Experiment 15 here.

Computation. Imagine that the 100-ohm resistor is replaced with twenty separate 2,000-ohm resistors connected in parallel. The combined resistance of this group of twenty resistors will be 100 ohms. (When resistors of equal value are connected in parallel, their combined resistance is equal to *the resistance of any one of them divided by the number of resistors* which are in parallel.)

When the meter is added in parallel with these twenty imaginary 2,000-ohm resistors, we will have twenty-one identical 2,000-ohm paths for current between the meter terminals. Each resistor will carry an equal amount of current, and the value of this current will be 1/21 of the total circuit current of 45 ma. In other words, the current through the 2,000-ohm meter (and through each imaginary 2,000-ohm resistor) will be 45 ma. divided by 21, or about 2.14 ma. Compare this computed value of meter current with the value you obtained and with the value of 2.2 ma which we obtained in the N. R. I. laboratory.

If the meter reads approximately 2.2 when used with its 100-ohm shunt in a circuit carrying 45 ma., we can determine the scale conversion number by dividing 45 by 2.2; this gives us 21 as the scale conversion number (also known as the *multiplying factor*). In other words, multiplying the meter reading on scale I_M by 21 will give us the actual circuit current when the meter is used with a 100-ohm shunt resistor. Multiplying the maximum meter reading of 3 ma. by 21 gives 63 ma. as the new full-scale range of the milliammeter when used with a 100-ohm shunt.

When using the meter with a 100-ohm shunt as a 0-63 ma. d.c. milliammeter, read the meter on scale I_M and multiply the scale reading by 21 to get the actual current value in ma.

Practical Extra Information on Meter Shunts. When the current range of a meter is to be increased a definite number of times, place across the meter terminals a shunt resistor having a resistance equal to *the meter resistance divided by "one less than the multiplication factor desired."* For example, if you wished to increase the range of your 2,000-ohm milliammeter to 30 ma., which is an increase of ten times, you would use a shunt resistor equal to 2,000 divided by 9, or 222 ohms.

When the resistance of a meter is not known and cannot conveniently be measured, the radio engineer prefers to use a somewhat different method for determining the required value for a shunt resistor. First of all, he determines the voltage required across the meter to give a full-scale deflection. This same voltage will act upon the shunt which is to be connected in parallel with the meter. He knows that the meter and shunt together must pass the new full-scale value of current, while the meter alone will pass its normal full-scale current value. Subtracting the meter current from the new full-scale value gives the current flowing through the shunt resistor at a full-scale deflection. The engineer then uses Ohm's Law, and divides the shunt resistor voltage by the shunt resistor current; this gives him the required value of shunt resistance.

Here is an example: The range of a 1-ma. milliammeter is to be in-

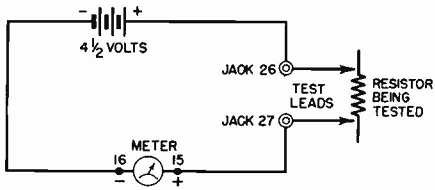


FIG. 16. Schematic circuit diagram for a series ohmmeter.

creased to 10 ma. by means of a shunt resistor. The engineer knows (or determines experimentally) that a voltage of .05 volt will send the normal full-scale value of current through the meter. This value of .05 volt is then the shunt voltage. The current flowing through the shunt at the new full-scale current value will be .01 ampere minus .001 ampere, or .009 ampere. The shunt resistance value will therefore be .05 divided by .009, which is 5.55 ohms.

Instructions for Report Statement No. 15. In order to supply the correct answer for this report statement, you will have to repeat Step 1 of this experiment with the red clip connected to the +22½ terminal of the battery instead of to the +45 terminal. Hold the clip on the $+22\frac{1}{2}$ terminal only long enough to read the meter on scale I_M. You will then be using your meter with its 100-ohm shunt as a 0-63 ma. milliammeter, and will be measuring the current flowing in a series circuit consisting of a 22.5-volt battery and a 900-ohm resistor. Record your meter reading in Report Statement No. 15 on the last page, along with the actual current value which you obtain by multiplying the reading by the multiplying factor of 21.

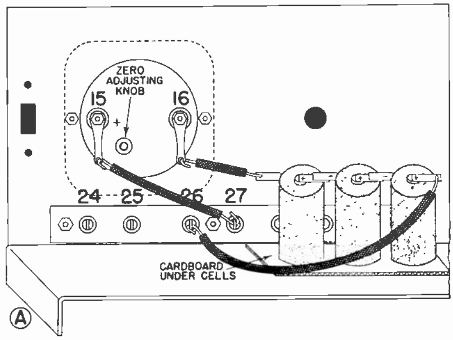
EXPERIMENT 16

Purpose: **To demonstrate that a milliammeter can be used to measure resistance.**

Step 1. To connect your meter into a series ohmmeter circuit like that shown in the circuit diagram of Fig. 16, and to secure experience in measuring resistance values with this series ohmmeter, first remove the red and black test leads from the *I* jacks on the panel. Now remove the 100-ohm shunt resistor from the meter terminals, and disconnect the hook joint on jack *28* at the back of the panel without disturbing the other end of this lead. Place a small piece of cardboard (about 3 inches by 6 inches in size) on top of the chassis for insulating purposes, then place the group of three flashlight cells on this cardboard in the manner shown in Fig. *17A*, with the — terminal of cell group near meter terminal *16*. Now solder the lead from terminal *16* to this — cell terminal by means of a lap joint.

With about a 6-inch length of red hook-up wire, connect the + terminal of the cell group to jack *26*, as shown in Fig. *17A*, making a lap joint at the cell and a hook joint at the jack.

Plug the test leads into the two *R* jacks on the front of the panel, as shown in Fig. *17B*. (The colors of the leads may be disregarded when



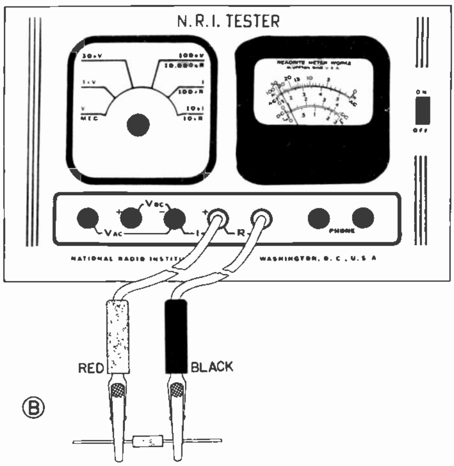


FIG. 17A (above). Rear view of panel, showing connections for the series ohmmeter which you set up in Step 1 of Experiment 16.

FIG. 17B (below). Method of connecting a resistor to the series ohmmeter.

making measurements of resistor values.) Your series ohmmeter is now ready for use.

Connect an 18,000-ohm resistor (Part *1-16*) to your ohmmeter by placing one test lead clip on each lead of the resistor, as shown in Fig. *17B*. Read the meter on scale I_M, record your result on the first line in Table *16*, then disconnect the 18,000-ohm resistor completely.

Connect a 900-ohm resistor (Part *2-14*) to your ohmmeter by placing one clip on each resistor lead. Read the meter on scale I_M, record your result in Table *16*, and disconnect the resistor.

Connect a 100-ohm resistor (Part *2-15*) to your ohmmeter by placing

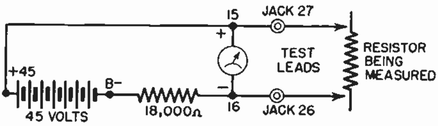


FIG. 18. Schematic circuit diagram for a shunt ohmmeter.

one clip on each resistor lead. Read the meter on scale I_M, record your result in Table *16*, and disconnect the resistor.

Finally, try your ohmmeter with essentially zero resistance, by attaching one test lead clip to the other clip. Read the meter on scale I_M, record your result in Table *16* (on the zero-resistance line), then separate the test clips.

Important: Before beginning Step 2, read the report statement instructions at the end of this experiment and make the additional series ohmmeter measurement which is required.

Step 2. To connect your meter into a shunt ohmmeter circuit like that shown in the circuit diagram of Fig. 18, and to secure experience in measuring resistances with a shunt ohmmeter, connect your parts in the manner shown in Fig. *19*, in the following order:

Unsolder the group of three cells used in the previous step.

Unsolder the joint at jack *26*, then connect one end of the unsoldered lead to meter terminal *15* by means of a temporary soldered hook joint. To do this, apply the heated soldering iron to this soldering lug to melt the solder, then hook the wire into the hole in this lug alongside the wire already there. Or, if you prefer, simply make a lap joint on the lug.

Solder to jack *26* the free end of the lead which is still on meter terminal *16*.

Solder a 3-inch length of hook-up wire to one lead of the 18,000-ohm resistor (Part *1-16*) by means of a temporary hook joint. Connect the other end of this wire to the lug on meter terminal *16* with a temporary soldered hook or lap joint.

Bend a large hook in the other end of the resistor lead, and connect this lead to the —B terminal of your A-B-C battery block.

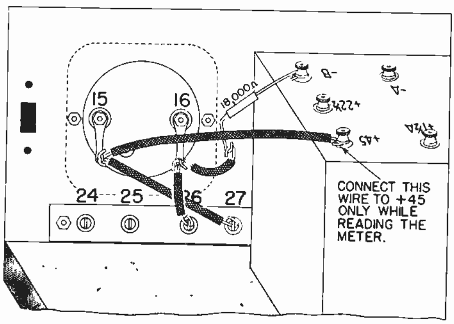


FIG. 19. Rear view of panel, showing connections for the shunt ohmmeter which you set up in Step 2 of Experiment 16.

Turn the chassis around, and connect the alligator clips to the leads of the 900-ohm resistor (Part *2-14*) while leaving the probes in the *R* jacks. Last of all, take the long lead from meter terminal *15* and connect its free end to the +45 terminal of your battery. Read the meter on scale I_M, disconnect the lead from the +45 terminal *immediately* to conserve battery life, and record your result in the fifth line of Table *16*.

Connect a 100-ohm resistor (Part *2-15*) to this shunt ohmmeter in place of the 900-ohm resistor, reconnect the lead to the +45 terminal, read the meter on scale I_M, disconnect the lead from the +45 terminal, and record your result in Table *16*.

Finally, place essentially zero resistance across your shunt ohmmeter by connecting one clip to the other, reconnect the lead to +45, read the meter on scale I_M, disconnect the lead from +45, separate the clips, and record your result on the last line in Table *16*. Disconnect the set-up completely now by unsoldering and removing the resistor and the four lengths of hook-up wire, but *do not* remove the meter, its soldering lugs, or the jack strip. Separate the flashlight cells.

Important: Be sure to save all pieces of hook-up wire, no matter how small, for they can be used over and over again in later experiments.

Discussion: When using the group of three dry cells as the voltage source for a series ohmmeter in Step 1, the wiring is simplest if you place the cells on the chassis as shown in Fig. *17A*. However, when you are doing this be sure to use the piece of cardboard under the cells, to prevent the exposed cell bottoms from shorting through the chassis and draining the cells.

A *series-type* ohmmeter is basically an instrument in which the resistor being measured is connected in series with a milliammeter and a d.c. voltage source. The two test leads, which are plugged into the *R* jacks, serve as the terminals of your series-type ohmmeter. When these terminals are separated, corresponding to an infinitely high resistance value, no current flows through the meter and consequently it reads zero. When a resistor is connected to the ohmmeter terminals, the current flow as indicated by the meter will depend upon the voltage being used and upon the total circuit resistance (the meter resistance plus the value of the resistance being measured).

Circuit Current Computation. By means of Ohm's Law, we can compute the current very easily in the ohmmeter circuit when an 18,000-ohm resistor is being measured (Step 1). Since the meter has a resistance of 2,000 ohms, the total circuit resistance in this case is 20,000 ohms. Dividing the circuit voltage of 4.5 volts by 20,000 ohms gives a current of .000225 ampere, or .225 ma

STEP	RESISTANCE BEING MEASURED IN OHMS	YOUR CURRENT READING ON SCALE I_M IN MA.	N.R.I. CURRENT READING ON SCALE I_M IN MA.	COMPUTED CIRCUIT CURRENT IN MA.
1	18,000	.2	.2	.225
	900	1.6	1.5	1.55
	100	2.3	2.2	2.14
	0	2 3	2.3	2.25
2	900	7.	.7	.74
	100	1.	.1	.12
	0	0	0	0

TABLE 16. Record your results for Experiment 16 here.

With a 900-ohm resistor, the computed current becomes 1.55 ma., while for a 100-ohm resistor the computed current is 2.14 ma. With zero resistance across the ohmmeter leads in Step 1, the computed circuit current is limited only by the meter resistance, and is therefore 2.25 ma., just as was calculated for the same condition in Experiment 12. You can thus see that as we decrease the ohmic value of the resistor in a series-type ohmmeter circuit, the meter current goes up. Conversely, *increasing* the resistance makes the meter current go down.

By using additional resistors of known values, or by computation, we can determine what the meter reading on scale I_M would be for any resistor value. A scale giving values in ohms rather than in milliamperes could then be marked on the meter, so that resistances could be measured directly whenever a 4.5-volt battery was used in series with the meter. This is the basic principle of the widely used series-type ohmmeter.

In an actual commercial series-type ohmmeter, the voltage employed is sufficient to give slightly higher than a full-scale meter reading, and a variable resistor is placed in series with the meter or shunted across the meter. This resistor can be adjusted to make the meter read exactly full-scale when the ohmmeter leads are clipped together. This scheme therefore permits compensation for the natural reduction in battery voltage with age. The variable resistor which is used with the meter for this purpose is sometimes called the *zero ohmmeter adjustment.*

Theoretically, every ohmmeter scale should cover all resistance values from zero to infinity. Actually, however, the most useful range of an ohmmeter is that near the middle of its calibrated scale. Resistance values are always indicated on the remaining portions of the scale, but readings in these portions cannot be estimated with reasonable accuracy. For this reason, it is often advisable to provide several different resistance ranges for use with one meter.

The useful range of an ohmmeter can be increased by providing means for employing either higher or lower d.c. voltages, and by providing for each voltage value a series resistor which will limit the circuit current to the full-scale meter value when the ohmmeter terminals are shorted.

In Step 2, you deal with the basic principle of what is called a *shunt-type ohmmeter.* In this circuit, the meter and the 18,000-ohm resistor are connected in series with the 45-volt d.c. source at all times, and the terminal leads for the ohmmeter go to the meter terminals. When the clips are disconnected, the circuit current is somewhere near the computed value of 2.25 ma. (This was calculated in connection with Step 2 of Experiment 14.)

When your shunt-type ohmmeter is connected to a 900-ohm resistor, the computed value of circuit current is .74 ma. The resistor provides an alternative path around the meter for current, and consequently we secure a lower meter reading than for the condition where no resistor is connected to the ohmmeter. With a 100-ohm resistor, the shunt path across the meter has even lower opposition to current flow, and consequently the meter reading drops still lower, to a value somewhere near the computed value of .12 ma. (Computations are not given since they are essentially the same as previous computations.)

Finally, when the ohmmeter clips are connected together to correspond to a zero-resistance condition, the meter is completely shorted and the reading drops to zero.

Thus, with a shunt-type ohmmeter the meter reading decreases as the value of the resistance being measured decreases. This is just exactly the opposite of the action observed for a series-type ohmmeter. Again, the meter could be calibrated and its scale marked to indicate directly the values of resistors being measured.

In commercial shunt-type ohmmeters, the scales are marked directly in ohms. Furthermore, the voltage source employed is high enough to give higher than full-scale deflection, and a variable resistance is inserted in series with the battery to permit compensation for natural aging of the battery.

As a general rule, series-type ohmmeters are employed for measuring high resistance values, and shunt-type ohmmeters are employed for measuring low resistance values. You can readily identify these types, for on a shunt-type ohmmeter the zero of the scale is always at the left, while with a series-type ohmmeter it is at the right.

Extra Information. When a series-type ohmmeter is properly adjusted, the insertion of a series resistor equal to the initial resistance of the circuit will cut the meter current in half, and consequently the meter pointer will take a mid-scale position.

When a shunt-type ohmmeter is properly adjusted, shunting the meter with a resistor equal in value to the meter resistance will cut the meter current in half, and the meter pointer will take a mid-scale position (assuming the meter resistance is negligibly low in comparison with the resistance value employed in series with the meter and battery).

To find the resistance of a d.c. milliammeter, connect the meter, a high-value variable resistance (about 50,000 ohms) and a voltage source all in series, choosing a voltage value which will give a full-scale meter reading when the variable resistance is adjusted. Now take another variable resistance of about the same value, shunt it *across* the meter, and adjust this second variable resistance until the meter reads exactly half of its full-scale current value. The ohmic value of the shunt variable resistance will now be exactly equal to the resistance of the meter, and can be measured with a conventional ohmmeter. This procedure is especially valuable when the resistance of a meter is so low that an ohmmeter battery would send an excessively large current through it during an ordinary resistance measurement.

Instructions for Report Statement No. 16. In order to supply the answer to this report statement, you must make one additional measurement with the series ohmmeter set-up described in Step 1 and shown in Fig. *16*. Secure a meter reading for a parallel combination of 900-ohm and 100-ohm resistors by placing one lead of each resistor in the jaws of the red clip, and placing the other resistor leads in the black clip. Read the meter on scale I_M, compare your reading with those you obtained in Step 1, then turn to the last page and make a check mark after the answer in Report Statement No. 16 which describes your result.

EXPERIMENT 17

***Purpose:* To demonstrate that electrons will flow from the cathode to the plate in a vacuum tube when the filament is heated and the plate is placed at a positive potential with respect to the cathode.**

Step 1. To connect your type 1C5GT pentode tube into the circuit shown in Fig. 20A, wherein it is used as a simple diode tube with a plate voltage of 22.5 volts and with your meter connected to measure the plate current, connect together the tube socket, the meter and the A-B-C battery block (or equivalent separate batteries) according to the circuit shown in Fig. *20B*, in the following manner: First of all, take a metal-marking crayon or pencil and identify on top of the chassis each of the six small holes which you previously marked *a, b, c, d, e, f* under the chassis. Do this carefully, one hole at a time, to make sure each hole is marked the same above the chassis as it is below the chassis. Recommended positions for these letters above the chassis can be seen in Fig. *21B*.

Turn the chassis upside-down, take a 1-inch length of red hook-up wire from which you have removed all insulation, and use it to connect together tube socket terminals *3* and *4* with temporary hook joints as shown in Fig. *21A*. Leave these joints unsoldered for the present.

Connect together tube socket terminals *5* and *7* with a 1¾-inch length of red hook-up wire; make temporary hook joints but leave them unsoldered.

Take a 10-inch length of red hook-up wire, push one end through hole *b* from the top of the chassis far enough to reach terminal *2*, then make a hook joint between the wire and terminal *2*, as shown in Fig. *21A*.

Take a 5-inch length of red hook-up wire, push it through hole *e* from the top of the chassis far enough to reach tube socket terminal *3*, then form a hook joint at this terminal.

Take a 7-inch length of red hook-up wire, push it through hole *c* from the top of the chassis far enough to reach terminal *7*, then form a hook joint at this terminal.

Now solder the connections to tube socket terminals *2, 3, 4, 5* and *7*.

Turn the chassis over, locate the wire which comes up through hole *e*, and connect it to the soldering lug of meter terminal *16* with a temporary soldered hook joint.

Take a 7½-inch length of red hook-up wire and connect one end of it to the soldering lug on meter terminal *15* by means of a temporary soldered hook joint.

Place your A-B-C battery block on the top of the chassis in the position shown in Fig. *21B*, so that it fits snugly in between the tabs provided for this purpose. Note that in this position, terminals —7½C, —9C, —A and —B are next to the front panel.

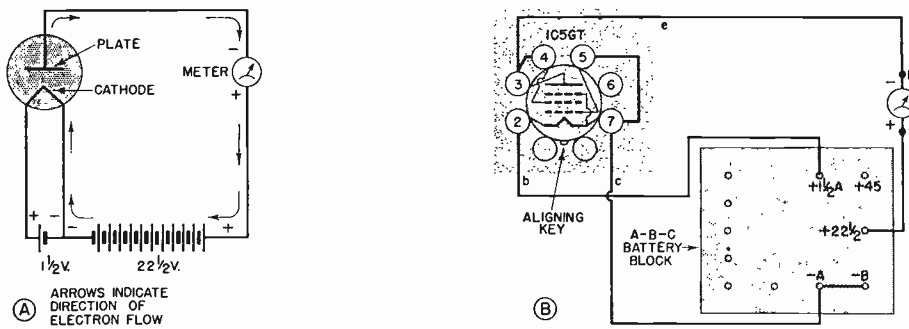


FIG. 20. Schematic circuit diagram *(A)* and semi-pictorial wiring diagram *(B)* for Step 1 of Experiment 17, in which you connect your type 1C5GT tube as a diode. The shaded area around the tube symbol in *B* indicates that connections to the tube socket are under the chassis. The letters *e, b* and *c* around this shaded area indicate the chassis holes through which the leads are run.

Important: If you are using individual batteries instead of an A-B-C block, it is recommended that you fasten them together at this time in exactly the manner specified for the N. R. I. Tester, then remark the terminals so they are the same as the terminals on the A-B-C block. Detailed in-

structions for doing this are given in Steps 50 through 54 (pages 65 and 66) of the N. R. I. Tester assembly instructions. Be sure to re-mark the battery terminals as instructed in Step 54. Now connect the —4½C terminal of the middle C battery to the *newly-marked* —4½C terminal of the other C battery with a short piece of wire, as shown in Fig. *46D*.

Take the wire which comes up through hole *c* and connect it to the —A terminal of the battery block, as shown in Fig. *21B*. Before tightening the nut on this terminal, take a 3¼-inch length of wire, bend a hook in each end, then hook one end of the wire around the —A terminal screw also. Connect the other end of this short wire to the —B terminal.

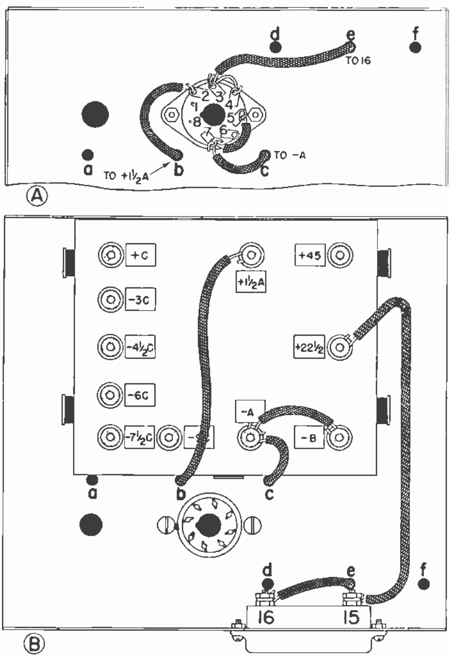


FIG. 21. Under-chassis *(A)* and above-chassis *(B)* connections for Step 1 of Experiment 17.

Take the wire which comes up through hole *b* in the chassis, and connect it to the +1½A terminal.

Take the lead which you previously soldered to meter terminal *15,* and connect it to the +22½ terminal of the battery block. Watch the meter when you make this connection; there should be no movement of the pointer whatsoever.

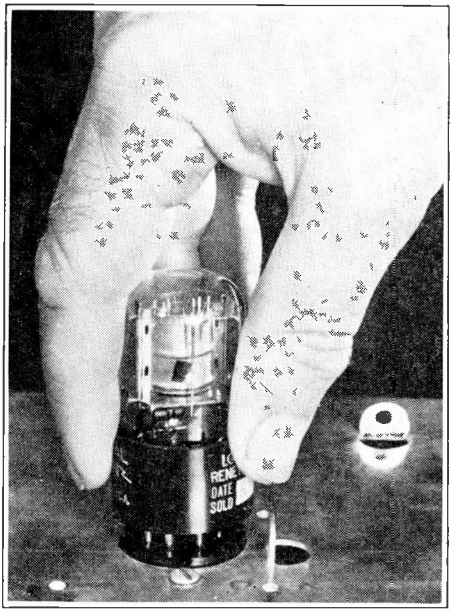


FIG. 21C. Hold a radio tube in the manner shown here when pushing it into or removing it from a socket. Make sure that the aligning key on the tube base is in the aligning slot on the tube socket before attempting to push a tube into its socket. Most of the downward pressure is applied by the thumb and forefinger gripping the base. It may be necessary to apply pressure also on the top of the glass envelope, and rock the tube gently from side to side while pushing downward, for the contacts in a new socket are sometimes a bit stiff. Use the same grip and rocking motion for pulling out the tube.

Check your work very carefully against the diagrams in Figs. *20B*, *21A* and *21B*, to make sure that every single wire is connected exactly as shown in these illustrations. This final checking of your work is extremely important, for a single error can damage circuit parts or discharge the battery. Do not probe carelessly around the wiring or terminals with a screwdriver or other metal part, for this tool may accidentally short-circuit certain terminals.

Insert the type 1C5GT tube (Part *2-10*) in its socket from the top of the chassis, by first setting the central black aligning pin of the tube base over the central hole in the socket, holding the tube upright while rotating it with the fingers until the aligning key and slot match and the tube drops down, then pushing the tube into its socket in the manner shown in Fig. *21C*.

If you have made all connections properly, the meter pointer should move up-scale when the tube is inserted. Read the meter on scale I_M, and record your reading in the first line of Table *17*.

Step 2. To determine the effect of opening the filament circuit in a diode vacuum tube circuit like that shown in Fig. 20A, disconnect temporarily the lead which goes to the +1½A battery terminal while watching the meter. Note the meter reading when this lead is disconnected, reconnect the lead, then record your observation in Table *17*. Be very careful that the disconnected lead does not touch either the +45 or the +22½ battery terminal, for this would burn out the tube filament instantly. Remove the tube from its socket by grasping with one hand and pulling firmly upward, as shown in Fig. *21C*. It is permissible to wiggle the tube sideways a bit by grasping the base, if removal is somewhat difficult at first.

Step 3. To determine the effect of reversing the plate supply voltage in a diode vacuum tube circuit like that shown in Fig. 20A, interchange the wires which are on the —B and +22½ terminals. In other words, the lead coming from meter terminal *15* should now go to —B, and the short lead from the —A terminal should now go to the +22½ terminal.

Replace the tube in its socket, note the meter reading on scale I_M, record your result in Table *17*, then remove the tube from its socket again and return the —B and + 22½ leads to their original positions as shown in Fig. *21B*.

Discussion: In your regular lessons, you learned that a vacuum tube must have at least two electrodes, a *cathode* and a *plate*. The cathode may be heated indirectly by a filament, as it is in tubes you will receive in later kits, or the filament itself may serve as the cathode, as is the case in the type 1C5GT tube you are now using. The electrons which are emitted by the heated cathode move through the vacuum in the tube to the plate when the plate is made positive with respect to the cathode by applying a suitable d.c. voltage. When a tube has only these two electrodes, it is known as a *diode*.

If a coil or spiral of wire is placed between the cathode and the plate in a tube, we have what is known as a *triode* tube, and the additional electrode is known as the *control grid*.

If another grid is placed between the control grid and the plate, we have a four-electrode tube called a *tetrode;* the added electrode is called the *screen grid*.

Finally, if we place still another wire electrode in the tube, between the screen grid and the plate, we have what is known as a *pentode* tube, and this third added electrode is known as a *suppressor grid*.

In the type 1C5GT tube which you now have, all three of these grids— the control grid, the screen grid and the suppressor grid — are present; your tube is therefore basically a pentode. In your tube, however, no terminal prong is provided for the suppressor grid; this grid is permanently connected to the cathode inside the tube. The suppressor grid in the type 1C5GT tube serves to repel slow-speed electrons which "bounce off" the plate due to secondary emission, thereby forcing them back to the plate.

In this experiment, we are interested only in the behavior of the tube as a diode. We can eliminate the effect of the control grid by connecting it to the cathode (connecting together tube socket terminals *5* and *7* does this), and we can eliminate the effect of the screen grid by connecting it to the plate (connecting together

STEP	NATURE OF MEASUREMENT	YOUR CURRENT READING ON SCALE I_M IN MA.	N.R.I. CURRENT READING ON SCALE I_M IN MA.
1	PLATE CURRENT IN DIODE CIRCUIT OF FIG. 20A WITH 22½ VOLTS ON PLATE	2.5	2.2
2	SAME AS STEP 1, BUT WITH FILAMENT CIRCUIT OPEN	0	0
3	SAME AS STEP 1, BUT WITH REVERSED PLATE VOLTAGE	0	0

TABLE 17. Record your results for Experiment 17 here.

tube socket terminals *3* and *4* does this). Although we cannot change the internal connection of the suppressor grid, we can ignore the effects of this grid for the present, since they are relatively unimportant in this experiment.

By connecting grids to either the cathode or the plate in this manner, any multi-element vacuum tube can be adapted for use as a simple diode.

The fact that you obtain a meter reading for the first step in this experiment shows that electrons will flow through a vacuum tube in the direction from the cathode to the plate when the cathode is heated and the plate is charged positively with respect to the cathode. We know the electrons take this direction because we previously found (Experiment 11) that the meter gives an up-scale deflection when electrons enter the minus terminal of the meter. If you trace around the plate circuit of Fig. *20A* in the direction which makes the electrons enter the minus terminal of the meter, you will find that electron flow is in the direction indicated by arrows, and is therefore from the cathode to the plate through the tube.

The exact value of plate current obtained in Step 1 is not particularly important, and your value will very likely differ considerably from the reading which we obtained. This is perfectly normal, and is due simply to the fact that different tubes, batteries and radio parts will vary considerably in their characteristics. In all measurements which you make in vacuum tube circuits, remember this fact, and do not expect to obtain values which agree closely with the N. R. I. readings.

The important thing for you to recognize is that your readings should increase when ours do, and your readings should decrease or drop to zero when our readings do this. In other words, your readings should verify basic radio principles by the *manner* in which they increase or decrease, rather than by agreeing with any specific values.

When you disconnect the filament circuit by removing the lead from the +1½A terminal, you interrupt the flow of current through the filament of the tube. As a result, the filament cools to normal room temperature, and ceases emitting electrons. Without electron emission, no electrons can flow to the plate, and consequently the plate current should drop to zero for Step 2.

When you reverse the B battery connections in Step 3, you make the plate negative with respect to the cathode. Under this condition, the plate repels rather than attracts electrons, forcing the emitted electrons to return to the cathode without getting anywhere.

The fact that the meter pointer is at zero with reversed plate voltage also tells that reversing the plate voltage source will *not* reverse the direction of electron flow. If it did, you would observe an off-scale movement of the pointer to the left of zero. Electrons cannot flow in a reverse direction through a vacuum tube because the plate is not heated and cannot emit electrons.

From a technical standpoint, we can consider the cathode-plate path in our vacuum tube to be a resistance. Furthermore, we can consider that the value of this resistance may be either high or low, depending upon the polarity with which the plate voltage supply is connected; with correct polarity as in Step 1, we obtained a definite current value, and with reverse polarity as in Step 3, we obtained no current (no current means that the tube has an infinitely high resistance).

Computing Circuit Current. In the diode vacuum tube circuit of Fig. *20A*, we have a 22.5-volt battery and a 2,000-ohm meter in series with the cathode-plate path through the tube. If this tube path were shorted or if it had zero resistance, the total circuit resistance would be 2,000 ohms and the plate circuit current would be 22.5 divided by 2,000, which is .01125 ampere, or 11.25 ma. Actually, we measure only about 2 ma. of plate current in Step 1 of this experiment; the only way to explain this is by assuming that the tube has resistance.

For computation purposes, let us assume that we obtain a plate current reading of 2 ma. With the aid of Ohm's Law, now, we can determine what the resistance of the tube actually is. By dividing 22.5 by .002, we get 11,250 ohms as the total resistance of the plate circuit. Since 2,000 ohms of this is already in the meter, the remainder or 9,300 ohms must be the plate-cathode resistance in this direct current circuit. This resistance is comparatively low, and consequently we can say that the type 1C5GT tube has good conducting ability when its plate is positive with respect to the cathode. In some specially designed diode rectifier tubes employed in radio receivers, the d.c. resistance value may be as low as 100 ohms.

When the plate was made negative with respect to the cathode, you found that no current flowed. This condition could exist only if the tube had an infinitely large resistance, and behaved like an open circuit.

Practical Extra Information. You already know that an a.c. voltage is equivalent to a repeated and regular reversal in the polarity of a d.c. voltage. Therefore, if an a.c. voltage is employed in the plate circuit of Fig. *20A* in place of the 22.5-volt B battery, the plate will be alternately positive and negative with respect to the cathode.

This experiment shows, however, that current will flow in the plate circuit only when the plate is positive with respect to the cathode. This means that when we apply an a.c. voltage to the plate, we will have a pulsating direct current in the plate circuit, with electrons flowing only in one direction. This is the basic principle of the power packs used in radio receivers to convert alternating current to direct current. In later experiments, you will actually demonstrate this important principle of rectification.

Multi-element vacuum tubes like that which you now have are actually being used as diode tubes in some types of radio equipment. For instance, some manufacturers often use a triode tube as a diode by connecting the control grid to the plate. Also, in emission-type tube testers, all grids of the tube under test are connected automatically to the plate, and the resulting plate current for a diode connection is measured at a suitable plate voltage value. If the tube is in good condition, the measured value of plate current will be normal, and the tube tester will indicate "GOOD."

Instructions for Report Statement No. 17. After you have completed this experiment and studied the discussion, measure the plate current through your diode-connected vacuum tube when there is an 18,000-ohm resistor in the plate circuit. To do this, remove the wire from the +22½ terminal, solder one lead of the 18,000-ohm resistor to this wire by means of a temporary lap or hook joint, then place the other resistor lead on the +22½ terminal after first bending a hook in its end. Insert the tube in its socket, read the meter on scale I_M, and record your result in Report Statement No. 17 as the plate current in ma. when an 18,000-ohm plate load is used.

EXPERIMENT 18

***Purpose:* To demonstrate that the grid voltage in a vacuum tube has more control over plate current than does the plate voltage.**

Step 1. To determine what happens to the plate current when the plate voltage is increased from 22.5 volts to 45 volts in a simple diode vacuum tube circuit, first take a 900-ohm resistor (Part *2-14*) and connect it between meter terminals *16* and *15* to serve as a shunt which will increase the current range of the meter three times, as shown in Fig. *22.* This connection can be made by bending a hook in one resistor lead, tinning the hook liberally, then holding the hook over the soldering lug of meter terminal *16* with one hand while applying the heated soldering iron to the joint with your other hand. Now simply make a soldered lap joint between the other resistor lead and meter terminal lug *15.* You can do this without removing the A-B-C battery block from the chassis.

With all other connections exactly

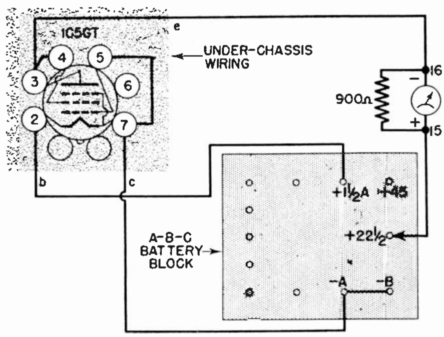


FIG. 22. Semi-pictorial wiring diagram for Step 1 of Experiment 18, in which you change the plate voltage on a diode tube from 22½ volts to 45 volts and note the effect upon plate current. The lead going to +22½ on the battery block is marked with an arrow to indicate that it is moved during the experiment.

as they were for Step 1 of Experiment 17 (with the long lead from terminal *15* going to +22½ as shown in Figs. *21A* and *21B*), insert the tube in its socket, read the meter on scale I_M, and record your reading on the first line of Table *18.* Multiply this reading by 3 to get the plate current value in ma., and record this answer also on the first line of Table *18.*

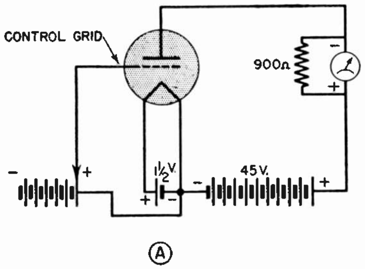
Now increase the plate voltage to 45 volts by removing the lead from the +22½ terminal and placing it on the +45 terminal. There is no need to remove the tube while doing this. Read the meter on scale I_M, record your results (first the meter reading, then the actual current value in ma.) on the second line of Table *18*, then remove the tube from its socket.

Step 2. To determine how much more effective the control grid is than the plate in controlling plate current, connect your type 1C5GT tube as a triode in the circuit shown in Figs. *23A* and *23B*, proceeding as follows:

Turn the chassis over carefully while holding the battery in position of your battery block, as shown in Fig. *24B*.

With a 5-inch length of red hook-up wire, connect the +C terminal to the —A terminal on the battery block as in Fig. *24B*.

You have now duplicated the circuit presented in Fig. *23*. Check your work carefully against the semi-pictorial circuit diagram in Fig. *23B* before proceeding further. You should have three leads hooked onto the —A terminal, and two leads on the +C terminal.



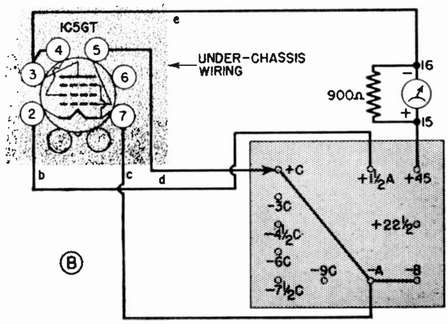


FIG. 23. Schematic *(A)* and semi-pictorial *(B)* diagrams for the triode vacuum tube circuit which you set up for Step 2 of Experiment 18.

so it does not fall out, and unsolder completely the short lead which connects together tube socket terminals *5* and *7*. Save this lead for future use.

Take an 11-inch length of red hook-up wire, push it almost completely through chassis hole *d*, and connect the exposed end of this lead to tube socket terminal *5* by means of a soldered temporary hook joint, as shown in Fig. *24A*. Do not disturb any other connections under the chassis.

Carefully set the chassis upright again while holding the battery in position, locate the other end of the long lead coming up through hole *d*, and connect it to the +C terminal

Insert the tube in its socket, read the meter on scale I_M for this condition whereby the plate voltage is 45 volts and the control grid voltage is 0 volts with respect to the cathode, and record your results (first the meter reading, then the actual current in ma.) on the third line in Table *18*.

Now remove the long lead (the lead coming through hole *d*) from the +C terminal and place it in turn on —3C, —4½C, —6C and —7½C until you find the terminal which gives a meter reading *nearest* the first meter reading you obtained in Step 1 (nearest the reading obtained for a plate voltage of 22.5 volts). If one terminal gives too much plate current but the next negative terminal gives too little

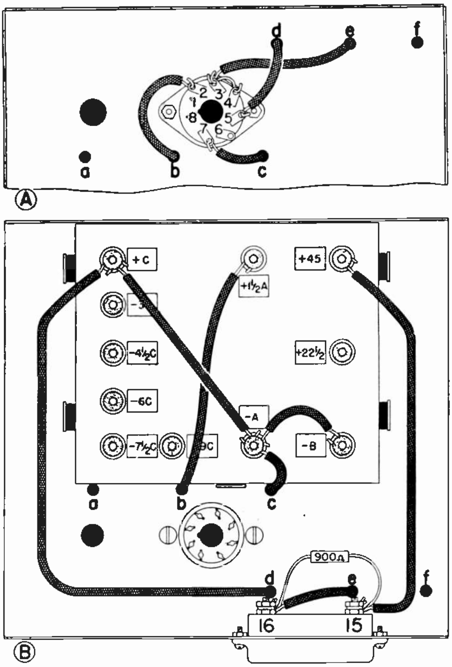


FIG. 24. Connections under the chassis for Step 2 in Experiment 18 should be as shown at *A*. The changes involved are as follows: Remove the lead which connects terminals 5 and 7, then bring a lead through hole *d* and connect it to terminal 5. Connections above the chassis should be changed to those shown at *B*. You now use the C terminals on the battery block for the first time.

current, select the terminal which gives nearest the desired plate current. Record on the last line of Table *18* the grid voltage value as marked on this terminal, the resulting meter reading on scale I_M, and the actual current value in ma. (three times meter reading).

Remove the tube from its socket, but leave all wiring as it is for the present.

Discussion: Since in this experiment we expect to deal with currents higher than 3 ma., the first thing we do in Step 1 is place across the meter a 900-ohm shunt resistor which increases the meter range approximately three times.* We then read the meter on scale I_M and multiply each reading by 3 to get the true current value in ma.

In Step 1, you measured the plate current of the diode tube with your meter first for a plate voltage of 22.5 volts, then for a plate voltage of 45 volts. One important fact to remember in these two measurements is that increasing the plate voltage makes the plate current *increase*.

In Step 2, you kept the plate voltage at 45 volts and determined how much voltage was required on the control grid in order to make the plate current drop to the first current value measured in Step 1 (cor-

* Actually, a 900-ohm shunt increases the range of a 2,000-ohm meter 3.2 times, but because of normal deviations in meter characteristics and resistor values during manufacture, we can, for all practical purposes, consider this scale multiplication factor to be 3.

STEP	PLATE VOLTAGE IN VOLTS	C BIAS VOLTAGE IN VOLTS	YOUR METER READING ON SCALE I_M	YOUR PLATE CURRENT VALUE IN MA. (METER READING X 3)	N.R.I. METER READING ON SCALE I_M	N.R.I. PLATE CURRENT VALUE IN MA. (METER READING X 3)
1	22.5	0	1.	3.	.8	2.4
	45	0	2.6	7.8	2.5	7.5
2	45	0	2.6	7.8	2.5	7.5
	45		.8 C BIAS = 4.5V	2.4	.6 (C BIAS=-4.5V)	1.8

TABLE 18. Record your results for Experiment 18 here.

responding to 22.5 volts on the plate).

As Table *18* indicates, we found in the N. R. I. laboratory that it took only about 4.5 volts of change in the control grid voltage (from the zero grid voltage value of the first reading in Step 2 to the —4.5 volt grid voltage value of the second reading in Step 2) to reduce the plate current the same amount as did a 22.5-volt change in the plate voltage (from +45 to +22.5). In other words, we found that 4.5 volts of variation in the control grid voltage had just as much effect upon plate current as did 22.5 volts of variation in the plate voltage.

Considering basic vacuum tube action now, we naturally expect that as we make the grid increasingly more negative with respect to the cathode, it repels electrons more and more. This is exactly what we demonstrated in this experiment—that increasing the negative grid voltage cut down the plate current.

The N. R. I. values indicate that a 4.5-volt change in grid voltage (from zero to —4.5) had as much effect upon plate current as a 22.5-volt change in plate voltage. We secure the number 5 when we divide 22.5 by 4.5; this indicates that the grid in the tube is five times more effective than the plate in controlling plate current. In technical language, we say that the amplification factor of the tube is 5 for the conditions in the N. R. I. laboratory.

Practical Extra Information. The closer the grid is to the cathode in a vacuum tube and the closer the turns of wire in the coiled grid are to each other, the greater is the control which the grid has over plate current.

With an elaboration of the measuring technique employed in this experiment, we can determine quite accurately the amplification factor of any vacuum tube. We would do this by varying the plate voltage enough to cause a convenient change in plate current, then vary the grid voltage exactly enough to cause this same variation in plate current. In each case, we would make accurate measurements of the voltages involved, then divide the plate voltage variation by the grid voltage variation to secure the amplification factor of the tube.

The fact that the grid is a certain number of times more effective than the plate in a vacuum tube means that we can employ the tube to build up the strength of signals. In other words, we can supply a small a.c. voltage to the grid and secure a much larger pulsating plate current which is equivalent to a larger a.c. voltage in series with the d.c. plate voltage. With a coupling condenser or coupling transformer, we can transfer this a.c. voltage alone to another circuit for further amplification or for feeding to a loudspeaker or other device.

It is this superior ability of the grid to control plate current which makes vacuum tubes suitable for use in amplifiers and oscillators. You will learn more about these special vacuum tube circuits later.

Instructions for Report Statement No. 18. Make one additional measurement with the triode vacuum tube circuit of Figs. *23* and *24*. Use a plate voltage of 45 volts and a C bias of —3 volts, with the grid return lead first connected normally to —A, then connected to +1½A, and note what the plate current is in each case. (Here are more detailed instructions: Start with your circuit connected *exactly* as shown in Fig. *24*. Take the lead which comes out

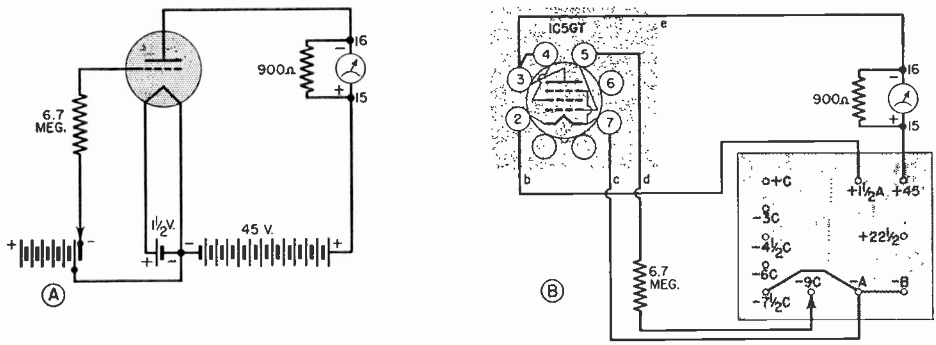


FIG. 25. Schematic *(A)* and semi-pictorial *(B)* diagrams for the triode vacuum tube circuit which you set up for Experiment 19.

of hole *d* and move it from +C to —3C to get a C bias of —3 volts. The grid return lead (going across the battery from +C) is already on —A, so read the meter to get the plate current value. Now remove from —A the lead which goes to +C, connect this lead to +1½A so that +C and +1½A are connected, and again read the meter to get the plate current value.)

Turning next to Report Statement No. 18 on the last page, place a check mark after the answer which describes the change you observed in the plate current value when the grid return lead was on +1½A.

From this extra test, you can make your own conclusions as to the importance of placing the grid return lead on a particular filament terminal when working with filament-type tubes such as the 1C5GT. The principles involved are covered in vacuum tube lessons in your fundamental course.

Put the grid return lead back on —A and remove the tube from its socket, but leave all other wiring as it is until you are ready to start the next experiment.

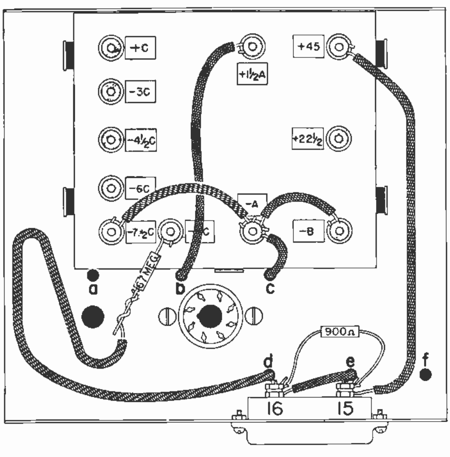


FIG. 26. Connections above the chassis should be modified to appear exactly as shown in this view, before starting to make measurements for Experiment 19.

EXPERIMENT 19

Purpose: **To demonstrate that a grid in a vacuum tube draws current when it is positive with respect to the cathode, but does not draw current when negative with respect to the cathode.**

Step 1. To secure plate current readings for different positive and negative values of C bias voltage when your vacuum tube is connected as a triode in the circuit of Fig. *25A*, use the semi-pictorial wiring diagram in Fig. *25B* and the top-of-chassis pictorial diagram in Fig. *26* as your guides for rewiring the vacuum tube circuit for this experiment. Connections under the chassis are left the same as for the previous experiment, and are therefore still as shown in Fig. *24A*.

The changes required above the chassis for this experiment are as follows: Remove the lead which connected +C to —A, and use a shorter lead, about 4 inches long, to connect —A to —7½C.

Now take the lead coming up

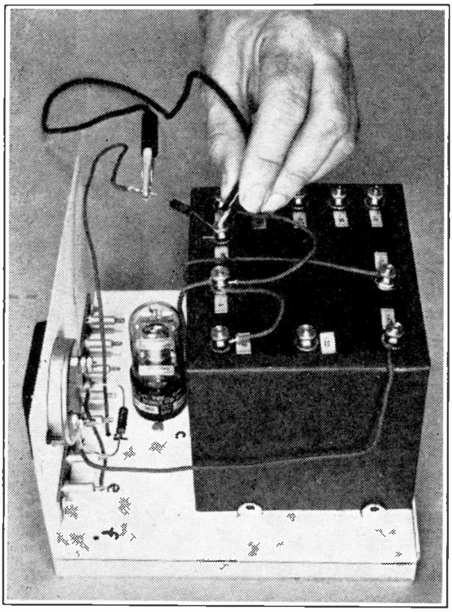


FIG. 27. Method of using a test lead to short out temporarily the grid resistor employed in Experiment 19.

through hole *d*, wind it about twice around one straight lead of the 6.7-megohm resistor (Part *2-11*) as shown in Fig. *26,* and solder this temporary joint. Connect the other lead of this resistor to battery terminal —9C.

Insert the tube in its socket, read your meter on scale I_M, and record your results on the first line of Table *19* as the plate current reading for a —1.5 volt C bias and 6.7 megohm grid circuit resistance. *Note:* Since the 900-ohm shunt is still across the meter, you must multiply each meter reading on scale I_M by 3 to get the plate current value in ma. Record the meter reading first in the space provided for this purpose in Table *19,* then multiply the reading by 3 and jot down your answer in the other space provided on the same line in the table.

Now take one of your test leads, attach its alligator clip to one lead of the 6.7-megohm resistor, and touch its test probe to the other resistor lead in the manner shown in Fig. *27,* so as to short out the resistor. Read the meter on scale I_M, and record your results (the meter reading and the current in ma.) on the second line of Table *19* as the plate current for the condition of —1.5 volts C bias and *zero* grid circuit resistance. Remove the test probe and allow it to rest on the table now without touching the chassis or any other part of the circuit, but leave the alligator clip on the other resistor lead.

Remove the lead of the 6.7-megohm resistor from the —9C terminal and connect this lead now to the —7½C terminal without changing any other connections. Read the meter on scale I_M and record your results on the third line of Table *19* as the plate current for zero C bias voltage and a grid circuit resistance of 6.7 megohms.

Now short out the 6.7-megohm resistor temporarily with the test lead, read the meter on scale I_M, and record your results in Table *19* as the plate current for zero C bias and zero grid circuit resistance. Now remove the short across the resistor.

Remove the lead of the 6.7-megohm resistor from the —7½C terminal and place this resistor lead on the —6C terminal. Read the meter on scale

C BIAS VOLTAGE IN VOLTS	GRID CIRCUIT RESISTANCE IN MEGOHMS	YOUR METER READING ON SCALE I_M	YOUR PLATE CURRENT VALUE IN MA. (METER READING X 3)	N.R.I. METER READING ON SCALE I_M	N.R.I. PLATE CURRENT VALUE IN MA. (METER READING X 3)
−1.5	6.7	1.8	5.4	1.8	5.4
−1.5	0	1.8	4.5	1.8	5.4
0	6.7	2.8	8.4	2.5	7.5
0	0	2.7	8.1	2.5+	7.5+
+1.5	6.7	2.9	8.7	2.7	8.1
+1.5	0	3+	9+	3+	9+
+3	6.7	3	9	2.7	8.1
+4.5	6.7	3	9	2.7	8.1

TABLE 19. Record your results for Experiment 19 here. A "+" sign *following* a value indicates that it was slightly *more* than the value given.

I_M, record your results in Table *19* as the plate current for +1.5 volts C bias and a grid circuit resistance of 6.7 megohms.

Now short the resistor with the test lead, read the meter on scale I_M, and record your results in Table *19* as the plate current for +1.5 volts C bias and zero grid circuit resistance. Now remove the test lead entirely from your circuit, since it will no longer be used in this experiment.

Remove the lead of the 6.7-megohm resistor from the —6C terminal, and place this lead on the —4½C terminal. Read the meter on scale I_M, and record your result in Table *19* as the plate current for +3 volts C bias and 6.7 megohms grid circuit resistance. The resistor should not be shorted when this C bias voltage is used because this would make the meter read off-scale.

Remove the lead of the 6.7-megohm resistor from the —4½C terminal and place this lead on the —3C terminal. Read the meter on scale I_M, and record your result in Table *19* as the plate current for 4.5 volts C bias and 6.7 megohms grid circuit resistance. Now remove the vacuum tube from its socket.

Discussion: For your first measurement, in this experiment, you make the grid 1.5 volts negative with respect to the cathode by connecting the cathode (filament) to the —7½C terminal of the C battery and by connecting the grid to the —9C terminal, which is 1.5 volts negative with respect to the —7½C terminal. (Instead of saying that the grid is 1.5 volts negative with respect to the cathode, technicians commonly say that they are using a *—1.5 volt C bias*, or a grid voltage of —1.5 volts.)

When the grid is made negative in this manner, it repels rather than attracts electrons, and consequently there is no electron flow in the grid circuit. You proved this by shorting the grid circuit resistance; if grid current did exist, it would flow through the grid resistor and produce across this resistor a voltage drop. Shorting of the resistor would remove this voltage drop from the grid circuit and change the resultant voltage on the grid, making the plate current change.

You found, however, that shorting of the grid resistor did not noticeably affect the plate current as indicated by the meter; this means that no grid current was flowing in your circuit. Actually, the grid-cathode path in a tube acts as an infinitely high resistance when a negative C bias is used, just as does the plate-cathode path when the plate is made negative with respect to the cathode (you proved this latter statement in Step 3 of Experiment 17).

Careful inspection of your circuit when you connect the resistor lead to the —7½C terminal will show you that now both the grid and the cathode of your tube are connected to the same terminal. This means that you are employing zero C bias, and the grid is therefore at cathode potential. Under this condition, the grid neither attracts nor repels electrons, and again we would expect that there would be no appreciable amount of grid circuit current. We obtain a higher plate current reading for zero bias than for —1.5 volts bias, simply because more electrons can get through the grid wires to the plate when the grid is no longer repelling them.

When using zero C bias, you again find that shorting the grid resistor has no great effect upon the meter reading. This proves definitely that there is no appreciable amount of grid circuit current flowing.*

When you make the grid 1.5 volts positive with respect to the cathode by connecting the resistor lead to the —6C terminal (this terminal is 1.5 volts positive with respect to the —7½C terminal to which the cathode is connected), the grid attracts some of the electrons which are emitted from the cathode. Those electrons which reach the grid travel through the 6.7-megohm grid circuit resistor in their way to the C bias battery, developing across this resistor a voltage drop which acts in series with that provided by the C bias battery but is of opposite polarity.

In other words, the voltage drop across the resistor neutralizes the voltage provided by the C bias battery, reducing the positive C bias value which is actually acting on the grid. As a result, the grid-cathode path through the tube does not get the full voltage provided by the C battery when the resistor is in the circuit. Cutting out the grid resistor proves this fact, for with the resistor removed, the meter reading increases noticeably.

Increasing the positive C bias to 3 volts, with the 6.7-megohm resistor in the grid circuit, does not give any more plate current than did a +1.5

* You may note a slight increase in the meter reading when shorting the resistor while using zero bias. This is due chiefly to a contact potential which exists between dissimilar metals in the grid circuit and in the grid lead inside the tube; this contact potential makes the grid slightly positive with respect to the cathode when the grid resistor is shorted out. Another reason for the increase is the fact that some electrons will be headed straight for grid wires and will hit these wires. When the grid resistor is present, these electrons travel through it and develop across it a small negative C bias. Shorting the resistor shorts out this bias, thus making the grid swing a small amount more positive.

volt C bias. The reason for this is simply that making the grid more positive in this manner causes it to attract more electrons, and the resulting increase in electron flow through the grid resistor increases the voltage drop across this resistor and completely neutralizes the increase in C bias voltage. We secure the same effect with a +4.5 volt C bias; in other words, all positive C bias voltages give essentially the same plate current reading when the 6.7-megohm resistor is in the circuit.

Of course, removing the resistor would allow the full voltage of the C battery to be applied to the grid; we cannot do this for the +3 and +4.5 volt bias values, however, because the resulting plate current would be way higher than the range of our meter, and would possibly damage the meter and the tube.

Practical Extra Information. In some radio circuits, both positive and negative C bias voltages are applied to the grid. There is no objection to this practice as long as the vacuum tube is designed to handle high plate current values and the grid circuit is so designed that it will not distort the radio signal. Whenever the grid circuit draws current, the source of grid voltage must supply a certain amount of power.

As a general rule, the control grids of the vacuum tubes employed in radio receivers are seldom driven positive, and therefore grid current is seldom present. An exception to this occurs in the case of certain power output tubes, which are intentionally driven positive to obtain increased audio output power.

Another exception occurs in the case of oscillator circuits; here the grid often is purposely allowed to become positive, but the circuit itself is so designed that it introduces automatically a negative bias which keeps the plate current down to a safe and useful value. This is done simply by employing the proper value of grid resistor, for as you learned in this experiment, a grid resistor can develop a voltage which will counteract an applied positive voltage on the grid.

We will use this same grid resistor scheme in the N. R. I. Tester as a precaution against damage to the tube and meter in the event that the grid of the tube is accidentally driven positive.

Instructions for Report Statement No. 19. After completing this experiment and studying the discussion, take one additional reading. With your apparatus set up as it was for the last measurement in this experiment (with the 6.7-megohm grid resistance in the circuit, a plate voltage of 45 volts, and a C bias of +4.5 volts obtained by having the grid resistor lead on —3C while —A is connected to —7½C), reduce the plate voltage from 45 volts to 22.5 volts by moving the plate lead (the lead which goes to meter terminal *15*) from +45 to +22½. Read the meter on scale I_M and record the value in Report Statement No. 19, then multiply your value by 3 to get the actual plate current in ma. for 22.5 volts on the plate, and record this also in the report statement. Finally, pull out the tube.

EXPERIMENT 20

***Purpose:* To secure data and prepare graphs which will show the grid voltage-plate current characteristics of your type 1C5GT vacuum tube when connected as a triode and when connected as a pentode under three different sets of operating conditions.**

Step 1. To secure the E_g-I_p characteristic curve for your tube when operated as a triode with a plate voltage of 45 volts, reconnect the tube and battery into the circuit shown in Fig. *23*. The connections are shown in pictorial form in Fig. *24*, but by now you should be able to follow semi-pictorial diagrams like that in Fig. *23B* and depend upon the photographs and pictorial diagrams only for checking purposes. For the first reading, set the C bias at —9 volts by placing on terminal —9C the lead which comes ing a C bias voltage of —4.5 volts.

To secure readings at additional C bias voltage values, first remove the tube from its socket; remove the lead which connects +C to —A, and use a shorter lead to connect —7½C to —A instead. Now place on terminal —9C the lead which comes from hole *d*, reinsert the vacuum tube in its socket, read the meter on scale I_M, and record your result in Table *20A* as the plate current for a C bias voltage of —1.5 volts.

Next, place the lead from hole *d*

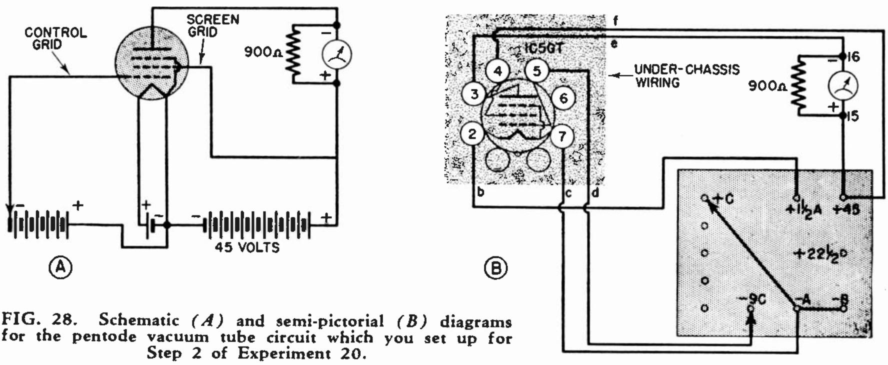


FIG. 28. **Schematic *(A)* and semi-pictorial *(B)* diagrams for the pentode vacuum tube circuit which you set up for Step 2 of Experiment 20.**

from chassis hole *d* (this lead is shown on +C in Fig. *23B*). Read the meter on scale I_M, and record your results (both the meter reading and the actual current in ma., which is three times the meter reading) on the first line of Table *20A* as the plate current for a C bias voltage of —9 volts.

Move the control grid lead (the one coming from hole *d*) in turn to —7½C, —6C, —4½C and —3C, read the meter on scale I_M in each case, and record the meter readings and the actual current values on the correct lines in Table *20A*. Since the cathode of the tube is connected to +C, the battery block markings are also the C bias voltages. In other words, when the lead from *d* is connected to —4½C, you are us-

on terminal —7½C to secure a reading for a C bias of zero volts, then place this lead on terminal —6C to secure a reading for a C bias of +1.5 volts; read the meter on scale I_M in each case, and record your results in Table *20A*.

You now have meter readings for C bias voltages ranging from —9 volts to +1.5 volts in 1.5-volt steps. Plot these values on Graph *20A* to secure the E_g-I_p characteristic curve for your tube when used as a triode. Do this in the following manner for each measured value:

Locate on the vertical scale at the left the measured plate current value in milliamperes. Draw a light horizontal pencil line across the entire graph, passing through this current value on the scale. Now locate on the horizontal scale at the bottom of the graph the C-bias voltage which gave you that current value, and draw a vertical pencil line upward from this C bias value. Where the two lines intersect, make a dot with your pencil. This dot now represents the current reading obtained for the C bias voltage in question.

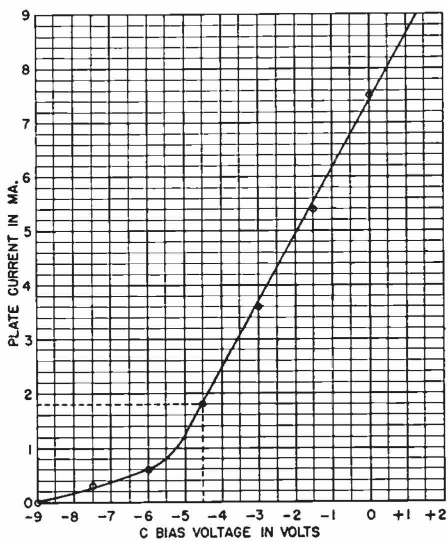
In the same manner, plot on this graph each other reading which you obtained in Step 1. After you have plotted a few values, you will find that you can trace along the horizontal and vertical lines with your pencil and place the dots in their correct positions without actually drawing in the horizontal and vertical pencil lines. Finally, draw a smooth free-hand curve which passes through or near the dots which you placed on the graph.

To illustrate this process of plotting values on a graph, we have plotted with small circles connected by a thin solid line the results obtained in the N. R. I. laboratory for this experiment. The horizontal and vertical lines for one point, corresponding to a C bias voltage of 4.5 volts and our plate current reading of 1.8 ma., are indicated as dash-dash lines to show you how they are used to locate a point on the graph. *You are not expected to get the same values or the same curve.*

Step 2. To secure the E_g-I_p *characteristic curve for your pentode tube when operated in the circuit shown in 28A, so that 45 volts is applied directly to the screen grid and the same 45 volts is applied to the plate through the 2,000-ohm meter shunted by the 900-ohm resistor,* remove the tube from its socket and change the wiring of your circuit in accordance with the semi-pictorial diagram in

C BIAS VOLTAGE IN VOLTS	YOUR METER READING ON SCALE I_M	YOUR PLATE CURRENT IN MA.	N.R.I. METER READING ON SCALE I_M	N.R.I. PLATE CURRENT IN MA.
−9	0	0	0	0
−7.5	.1	.3	.1	.3
−6	.3	.9	.2	.6
−4.5	.6	1.8	.6	1.8
−3	1.4	4.2	1.2	3.6
−1.5	1.8	5.4	1.8	5.4
0	2.5	7.5	2.5	7.5
+1.5	3	9	3+	9+

TABLE 20A. Record your results for Step 1 of Experiment 20 here. Corresponding values which were obtained in the N.R.I. laboratory, along with the curve representing these values on the graph at the right, are presented here merely for comparison purposes. Your own values may be different.



GRAPH 20A. Plot on this graph the results you obtain in Step 1 of Experiment 20, and connect the points together to give a smooth curve. This will then be the characteristic curve of your type 1C5GT tube when operated as a triode with a plate voltage of 45 volts and no plate load.

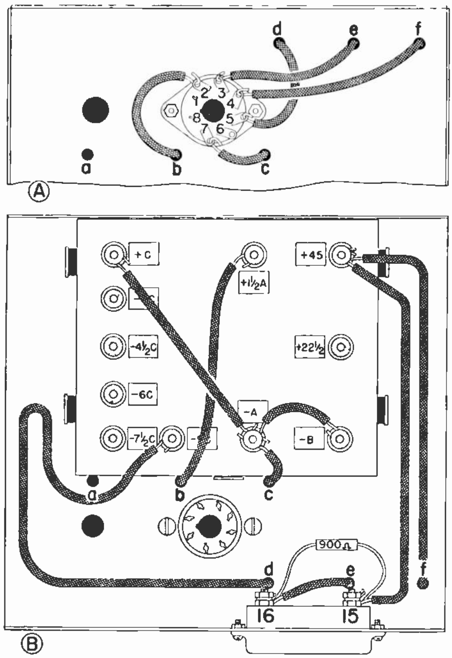


FIG. 29. Connections under the chassis for Step 2 of Experiment 20 should be as shown at *A*. Since the parts under the chassis are now wired according to Fig. *24*, simply remove the wire which connected terminals *3* and *4*, and run a wire through chassis hole *f* to terminal *4*. Battery connections are shown at *B*. Note that both the plate supply lead (from meter terminal *15*) and the screen grid supply lead (from hole *f*) go to +45.

Fig. *28B*. This will make the wiring appear as shown in Figs. *29A* and *29B*. Only two changes are necessary under the chassis; the bare wire which connected tube socket terminals *3* and *4* is removed, and a 12-inch long wire is brought through hole *f* and connected to tube socket terminal *4* by means of a soldered temporary hook joint. Above the chassis, the changes involved are connecting to the +45 battery terminal the wire which comes up through hole *f*, and returning the —A lead to +C.

For the first reading, place the control grid lead (coming up from hole *d*) on terminal —9C. Insert the tube in its socket, read the meter on scale I_M, and record your results in Table *20B* as the plate current for a C bias voltage of —9 volts. (Remember that the meter readings on scale I_M must be multiplied by 3 to get the current in ma. when the 900-ohm shunt resistor is being used across the meter.)

Move the control grid lead (coming through hole *d*) in turn to —7½C, —6C, —4½C and —3C; read the meter in each case and record your results in Table *20B*. The value marked on the battery terminal will be the C bias voltage in these cases, since the cathode is connected to +C.

To secure readings for other grid bias values, remove the lead which joins +C to —A, and use a shorter lead to connect —7½C to —A. Now place the control grid lead on —9C so as to secure a —1.5 volt C bias, read the meter on scale I_M, and record your results in Table *20B* as the plate current for a —1.5 volt C bias.

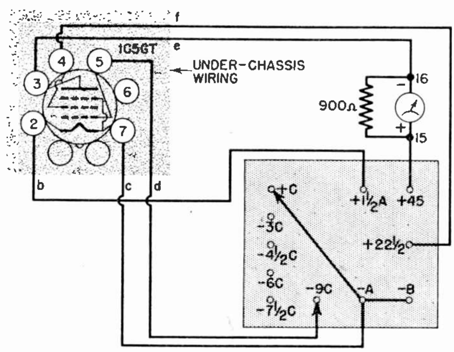


FIG. 30. Semi-pictorial wiring diagram showing all connections for Step 3 of Experiment 20. The only changes required to make your set-up coincide with this are moving of the screen grid lead (coming through hole *f*) from +45 to +22½, and returning the —A lead to +C.

Now place the control grid lead in turn on —7½C and on —6C, to secure C bias voltages of zero and +1.5 volts respectively. Read the meter on scale I_M in each case, and record your results in Table *20B*.

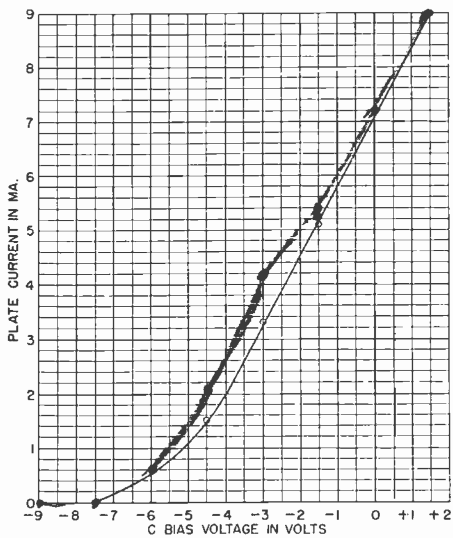
Plot your results for Step 2 on Graph *20B*, then draw a smooth curve passing through or near your points.

Step 3. To determine the effect of a lower screen grid voltage value upon the E_g-I_p characteristic curve of a pentode tube being operated with a plate voltage of 45 volts, move the screen grid lead (coming up through hole *f*) from the +45 terminal to the +22½ terminal of the battery, as in Fig. *30*, then reconnect —A to +C as shown in Fig. *30*, and repeat each measurement indicated in Step 2 and record your results in Table *20C*. Make two additional measurements; first use a C bias of +3 volts by placing the control grid lead on —4½C while leaving the cathode lead (from —A) on —7½C. Next, use a C bias of +4.5 volts by placing the control grid lead on —3C while leaving the cathode lead on —7½C.

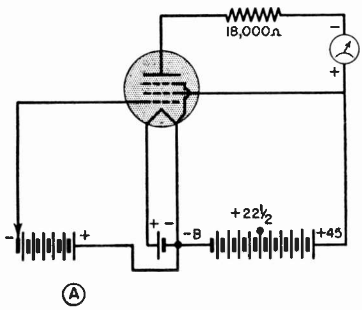
Step 4. To determine the effect of a plate load resistance upon the E_g-I_p characteristic curve of a pentode tube when operated with plate and screen grid voltages of 45 volts as indicated in the circuit of Fig. 31A, connect an 18,000-ohm resistor in series with the meter as indicated in Fig. *31B*. This is done by using terminal *6* on the tube socket as an insulated support for one resistor lead. The actual connections under the socket are shown in Fig. *32*; observe that the wire coming through hole *e* has been moved from terminal *3* to terminal *6*, and the 18,000-ohm resistor has been connected between terminals *3* and *6* by means of temporary hook joints. Now disconnect the 900-ohm shunt resistor from meter terminals *15* and *16* so that the meter will read current values in ma. directly on scale I_M. Vary the C bias voltage value from —9 volts to +4.5 volts in 1.5-volt steps by following

C BIAS VOLTAGE IN VOLTS	YOUR METER READING ON SCALE I_M	YOUR PLATE CURRENT IN MA.	N.R.I. METER READING ON SCALE I_M	N.R.I. PLATE CURRENT IN MA.
-9	0	0	0	0
-7.5	0	0	0	0
-6	2	.6	.2	.6
-4.5	7	2.1	.5	1.5
-3	1.4	4.2	1.1	3.3
-1.5	1.7	5.1	1.7	5.1
0	2.4	7.2	2.4	7.2
+1.5	3.0	9.0	3.0	9.0

TABLE 20B. Record your results for Step 2 of Experiment 20 here. Remember that your own values are not expected to be the same as the N.R.I. values given here for comparison purposes.



GRAPH 20B. Plot on this graph the results you obtain in Step 2 of Experiment 20, and connect the points together to give a smooth curve. This will then be the characteristic curve of your type 1C5GT tube when operated as a pentode with plate and screen grid voltages of 45 volts; no plate load.



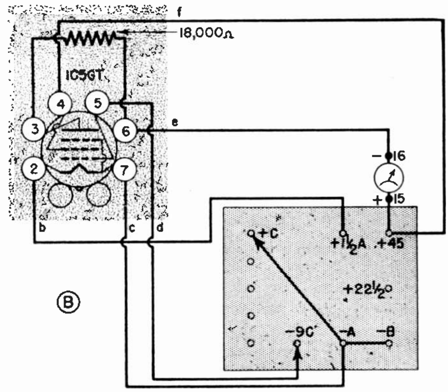


FIG. 31. Schematic *(A)* and semi-pictorial *(B)* diagrams for the circuit employed in Step 4 of Experiment 20.

exactly the same procedure employed in Steps 2 and 3, and read the meter on scale I_M in each case. Record your results in Table *20D*, and plot the results on Graph *20D*.

Step 5. Prepare the parts for assembly of the N. R. I. Tester by removing the vacuum tube from its socket, disconnecting all battery leads, unsoldering the leads on the meter terminals, unsoldering all connections to the tube socket, then pulling the leads out through the holes in the chassis. Straighten out the hooks at the ends of wires only when necessary to pull the wire through a hole, for you will usually have to form the hooks again when using the wire later. Separate the panel from the chassis by removing the three screws at the bottom of the panel, but leave the meter and jack strip mounted on the panel, and leave the tube socket on the chassis. Remove surplus solder from the meter terminal lugs, but do not remove these lugs. Remove surplus solder from the tube socket lugs; if difficulty is encountered in doing this, remove the socket temporarily from the chassis so you can shake or tap off the surplus molten solder from each lug in turn without getting it into the prong holes.

Discussion: First of all, you should realize that the variations which occur normally in vacuum tubes and radio parts during manufacture make it practically impossible for you to secure exactly the same values and the same curves which we secured in the N. R. I. laboratory. Our values and our curves are shown merely for comparison purposes and to illustrate the procedure for plotting this type of data on graphs. You can be sure

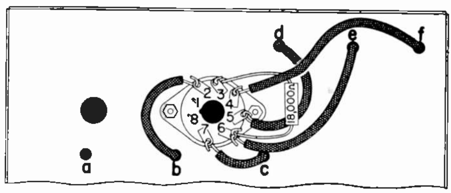


FIG. 32. Connections under the chassis for Step 4 of Experiment 20 should be as shown here. To make your circuit conform with this, move the plate lead (coming through hole *e*) from terminal *3* to terminal *6*, and connect an 18,000-ohm resistor between terminals *3* and *6*.

your work is entirely satisfactory if you secure merely the same general shape or slant of curves, but remember that even this shape or slant can vary considerably from that shown on a particular graph.

One thing which you should realize after performing this experiment is that the plate current does *not* always increase *uniformly* with changes in grid voltage. In other words, as the negative bias on the grid is reduced, the plate current will increase faster than it did when working with highly negative grid bias values, and the curve will tend to bend upward. Study your curves carefully, giving particular attention to the grid bias values at which the curves bend upward.

In Step 1 you take readings of plate current for various positive and negative C bias values while your type 1C5GT tube is connected as a triode without a plate load resistance. When you plot your values on Graph *20A* and connect the points together, you secure a curve which contains all of the information present in Table *20A*.

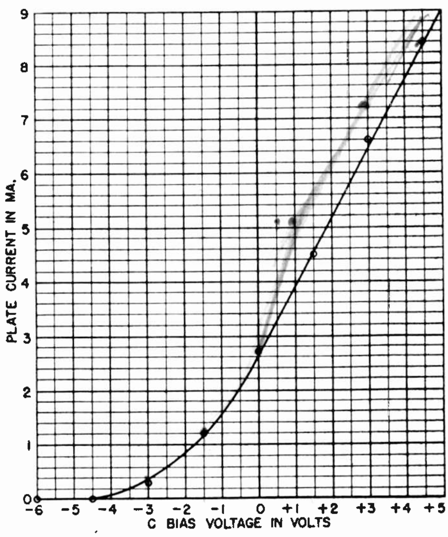
In addition, however, the curve which you draw can give you hundreds of other plate current values for C bias voltages in between the values at which you made measurements. Thus, if you wanted to find out what the plate current would be for a C bias voltage of —4 volts, you would simply trace upward from —4 on the horizontal scale until you came to the curve, then trace hoizontally to the left from that point on the curve and read the value of plate current where you intersect the vertical scale of current.

It is this characteristic of a graph, wherein you can estimate in-between values with accuracy, which makes graphs so valuable in radio work.

When you connect your tube as a pentode in Step 2, with 45 volts on both the plate and screen grid, you would naturally expect to secure a slightly different characteristic curve

C BIAS VOLTAGE IN VOLTS	YOUR METER READING ON SCALE I_M	YOUR PLATE CURRENT IN MA.	N.R.I. METER READING ON SCALE I_M	N.R.I. PLATE CURRENT IN MA.
-9	0	0	0	0
-7.5	0	0	0	0
-6	0	0	0	0
-4.5	0	0	0	0
-3	.1	3	.1	.3
-1.5	.4	1.2	.4	1.2
0	.9	2.7	.9	2.7
+1.5	1.7	5.1	1.5	4.5
+3	2.4	7.2	2.2	6.6
+4.5	2.8	8.4	2.8	8.4

TABLE 20C. Record your results for Step 3 of Experiment 20 here. Remember that your own values are not expected to be the same as the N.R.I. values given here for comparison purposes.



GRAPH 20C. Plot on this graph the results you obtain in Step 3 of Experiment 20, and connect the points together to give a smooth curve. This will be the characteristic curve of your type 1C5GT tube when operated as a pentode with a plate voltage of 45, a screen grid voltage of 22.5, and no plate load.

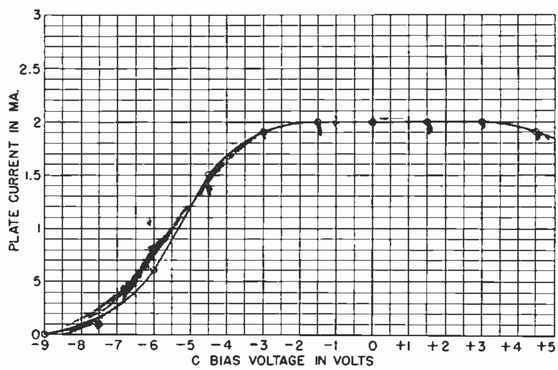
than for triode operation. The curves in Graphs *20A* and *20B* resemble each other quite closely under the conditions of this experiment, with only minor differences in corresponding values, but these triode and pentode characteristics of the 1C5GT tube may differ considerably under other operating conditions.

Reducing the screen grid voltage on your pentode tube to 22.5 volts lessens the effectiveness of the screen grid, with the result that the E_g-I_p characteristics are altered considerably. The N. R. I. curve in Graph *20C* differs quite appreciably from the previous two curves, as you can readily see by comparing them. The curve which you obtained for Step 3 should likewise differ from the previous curves in that it is shifted to the right on your graph with respect to values on the horizontal scale. The shape of the curve is still essentially the same as for Steps 1 and 2.

In Step 4, the 18,000-ohm resistor is placed in the plate circuit to limit plate current and duplicate more closely the actual operating conditions under which this tube would be used. The 900-ohm meter shunt is removed to improve the accuracy of readings, since the plate load resistor will limit the meter current to values considerably below the full-scale value of 3 ma. Now you secure a radically different characteristic curve, with a somewhat flat top. This curve is actually more useful to a radio man than the preceding three curves, for it more nearly represents actual conditions under which vacuum tubes are operated in radio circuits.

Instructions for Report Statement No. 20. To show the importance of graphs for giving operating values *in between* those actually measured for a vacuum tube, refer to your own characteristic curve for the type 1C5GT tube operating as a pentode

C BIAS VOLTAGE IN VOLTS	YOUR PLATE CURRENT IN MA. (READ DIRECTLY ON SCALE I_M)	N.R.I. PLATE CURRENT IN MA. (READ DIRECTLY ON SCALE I_M)
-9	0	0
-7.5	.1	.1
-6	.8	.6
-4.5	1.7	1.5
-3	1.9	1.9
-1.5	.2	2
0	.2	2
+1.5	2	2
+3	2	2
+4.5	1.9	1.9



GRAPH 20D (above). Plot on this graph the results you obtain in Step 4 of Experiment 20, and connect the points together to give a smooth curve. This will be the characteristic curve of your type 1C5GT tube when operated as a pentode with a plate voltage of 45 volts, a screen grid voltage of 45 volts, and an 18,000-ohm plate load.

TABLE 20D (left). Record your results for Step 4 of Experiment 20 here. Remember that your own values are not expected to be the same as the N.R.I. values given here for comparison purposes.

with no plate load (this is Graph *20C* on page 47), and determine the plate current for a C bias of —1 volt. Do this by locating the —1 point on the horizontal scale, tracing vertically upward from this until you intersect your own curve, then tracing horizontally to the left from the intersection so you can read the plate current value in ma. on the vertical scale. Record the value in Report Statement No. 20 on the last page, and send in the page for grading.

IMPORTANT: Send in your report statement for grading as soon as you finish Experiment 20. Start on the assembly of the N. R. I. Tester as soon as possible *after* you get this report statement back with a passing grade (A, B or C). You should have this tester completely assembled and calibrated by the time you receive the next radio kit (3RK).

How To Assemble the N. R. I. Tester

Introduction

THE N. R. I. Tester which you are now ready to build is a complete and modern test meter designed to meet the requirements of professional radio servicemen for many years to come. This instrument, when assembled and calibrated according to the instructions given in this manual, will allow you to make many different measurements in radio circuits.

Actually, the N. R. I. Tester is a combination vacuum tube voltmeter and multimeter which provides at least eighteen separate and distinct ranges. You will be able to measure a.c. voltages up to 550 volts in four ranges, d.c. voltages up to 450 volts in four ranges, direct current values up to 45 milliamperes in two ranges, resistance values up to 100 megohms in four ranges, and output measurements of radio receivers in four ranges.

Later, you will be provided with a headphone which can be plugged into the N. R. I. Tester; with this combination you can listen to the quality and strength of audio signals anywhere in a radio receiver, thereby speeding up the location of defects which are causing distortion.

The sensitivity of the voltmeter ranges in the N. R. I. Tester is quite high in comparison to that of other testers being used for service work. A sensitivity of 1,000 ohms-per-volt is considered satisfactory for most radio service work, but each d.c. voltage range in your N. R. I. Tester has a sensitivity better than 20,000 ohms-per-volt. (Actually, on one range of your instrument, the sensitivity is well over 2,000,000 ohms-per-volt.) As a result, you can connect the N. R. I. Tester to high-resistance circuits and make accurate voltage measurements without disturbing circuit conditions appreciably. Many of the measurements which are possible with the N. R. I. Tester could not be made with ordinary meters.

The N. R. I. Tester has been included in your practical demonstration course for several reasons. It gives you an opportunity to assemble a professional-quality test instrument yourself. It allows you to check circuit action and verify the various radio and electrical laws which are studied in your regular course. Finally, it gives you experience in using test instruments.

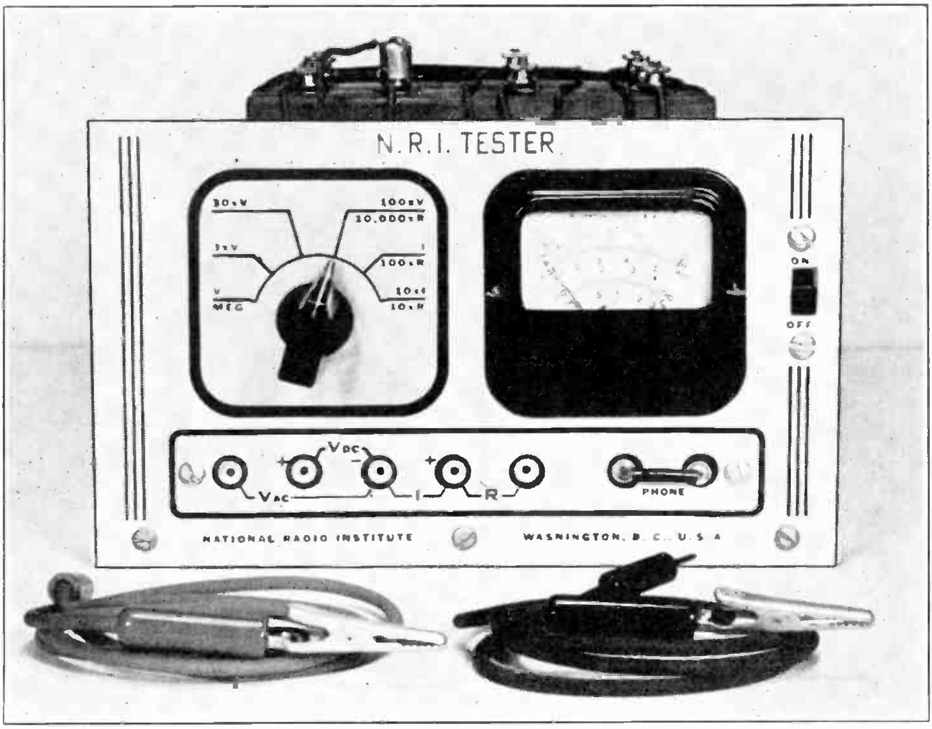


FIG. 33. Your N. R. I. Tester should look like this after you have assembled it according to the simple step-by-step instructions in this manual. The battery wiring will be modified, as explained later, if you use individual batteries in place of the special A-B-C battery block shown here.

A completely assembled N. R. I. Tester is shown in Fig. *33*. As you can readily see the panel layout is remarkably simple considering the number of uses which the instrument has. At the extreme right on the panel is the switch which turns the instrument on and off. Next to the switch is the special four-scale meter on which all values are read. On the upper left half of the panel is the selector switch, which automatically connects the meter into the test circuit you desire for a particular measurement.

Below the meter and selector switch is the jack strip into which you plug the test leads for various measurements. The two jacks at the extreme right are for the phone which you will receive later; the shorting strip shown in this view is plugged into these two jacks whenever the phone is not used.

Step-by-step instructions for assembling the N. R. I. Tester will now be given. Follow through these instructions slowly and carefully, doing the very best work of which you are capable, for you will want your instrument to show professional workmanship in each and every soldered joint. To make sure you do not miss any steps, place a check mark alongside each completed step as you go along.

Plan to devote a number of evenings to the assembly of this instrument, for the success of the remainder of your practical demonstration course depends entirely upon your assembling this instrument properly.

Remember that we are ready to help you with advice whenever you encounter difficulties or have trouble in understanding the instructions.

The complete circuit diagram of the N. R. I. Tester is given in Fig. *34* for reference purposes, and need not be studied at this time.

Instructions for using the N. R. I. Tester will be given progressively in later manuals, as the need arises for the various types of measurements which it makes.

Mounting the Parts on the Front Panel

Step 1. To prepare for the preliminary mounting of parts on the panel, place before you the following parts:

Front panel (Part *2-2*) on which you have already mounted (in Experiment 11) the 0-3-ma. milliammeter with two soldering lugs (Parts *1-8A* and *1-8B*) and the 7-jack strip (Part *2-3*), with each terminal on these two parts identified by a number marked on the back of the panel in the manner shown in Fig. *6* in connection with Experiment 11 in this manual.

One ON-OFF power switch (Part 2-5).

One 6-position rotary selector switch (Part *2-6*).

One bar knob for the selector switch (Part *2-8*).

Two ¼-inch long binder-head machine screws (Part *2-18A*) and two hexagonal nuts (Part *2-18B*).

At this same time, arrange before you the following tools and materials, which will be needed during the assembly of the N. R. I. Tester.

Long-nose pliers.
Side-cutting pliers.
Ordinary pliers.
Medium-size screwdriver.
Small screwdriver.
Twelve-inch ruler.
Soldering iron and holder (Parts *1-1*, *1-2*).
Rosin-core solder (Part *1-3*).
Red push-back hook-up wire (Part *2-17*).

One short length of yellow rubber and cotton-covered wire (Part *1-7F*).

(Small roll of ¾-inch wide ordinary friction tape if you are using individual batteries and desire to fasten them together according to the suggestions given in this manual; not needed if you use the A-B-C battery block.)

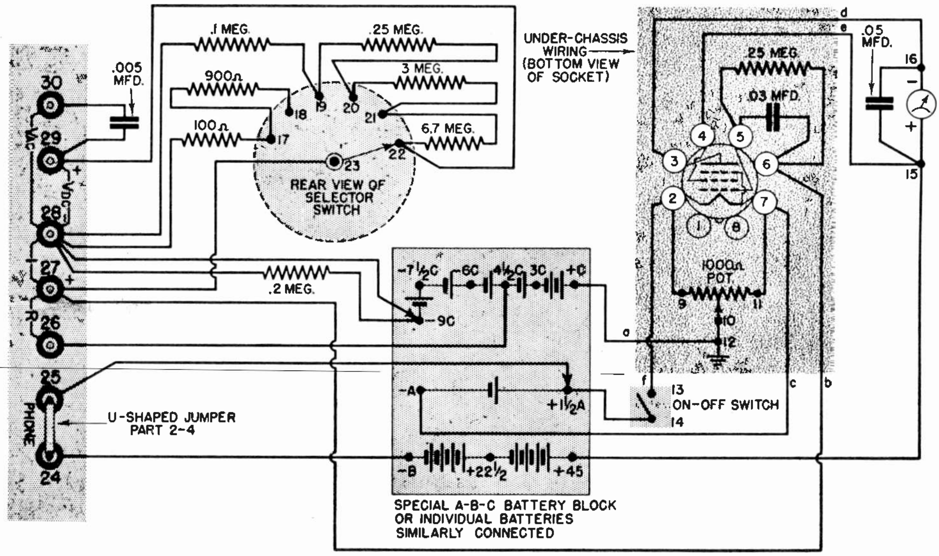


FIG. 34. Circuit diagram of the N. R. I. Tester. This is presented here for reference and checking purposes; you will follow pictorial diagrams and photographs when assembling the unit, to minimize chances for errors.

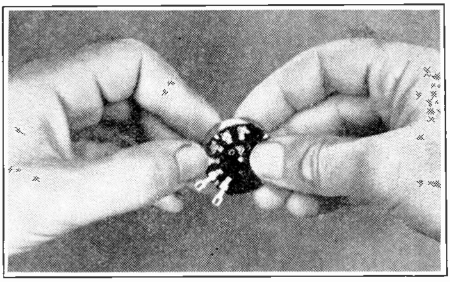


FIG. 35. Method of bending out the soldering lugs on the rotary selector switch (Part 2-6). Press them outward with your thumb, one at a time, until all the outer lugs point outward like the spokes of a wheel. Do not bend the single center lug.

Step 2. Mount the rotary selector switch (Part *2-6*) *on the panel* in the following manner:

While holding the switch in one hand in the manner shown in Fig. *35,* proceed to bend outward with the thumb of your other hand each of the six soldering lugs located along the outer edge of the switch, until the lugs are flat with relation to the insulating material at the back of the switch. Do not bend the single inside lug. *Do not use pliers for this bending;* the lugs can easily be pushed over with your thumb, if you start from one end of the row of lugs.

Remove the ⅜-inch nut from the shaft of the switch, and push the shaft through panel hole *t* (Fig. *36*) from the rear so that it has the position shown in Fig. *37*. Replace the nut on the shaft which now projects through the front of the panel, and tighten the nut first with your fingers and then with ordinary pliers as shown in Fig. *38,* while using one hand to hold the selector switch in the position shown in Fig. *37* (so that end terminals *17* and *22* on this switch are both the same distance from the top of the panel). Be careful not to let the pliers slip and scratch the panel.

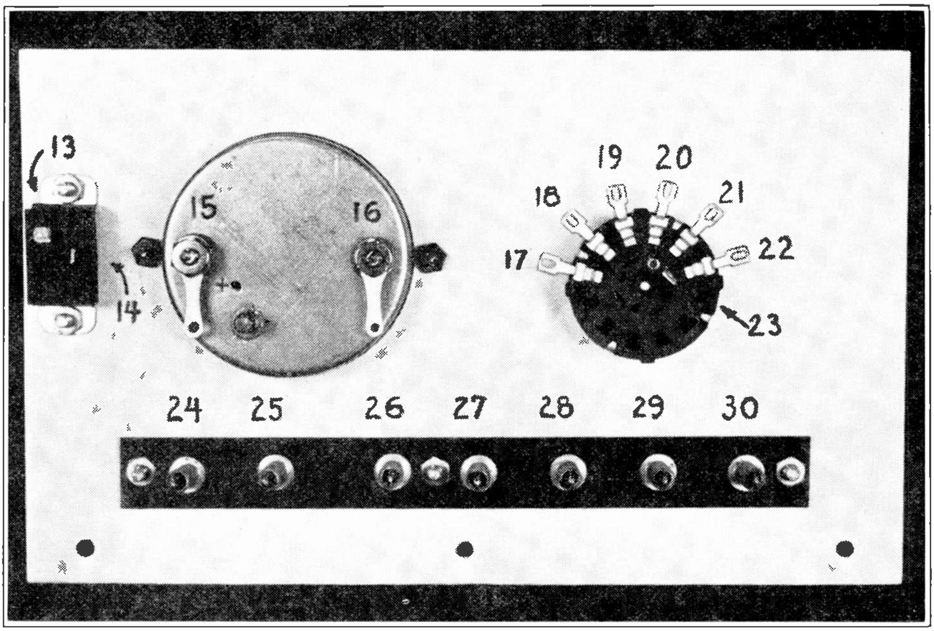


FIG. 37. The back of your tester panel should appear like this after you have mounted the selector switch and ON-OFF switch, as instructed in Steps 2 and 3. (The meter and jack strip were mounted as part of Experiment 11.) Number the various terminals on your own panel by marking them with crayon or pencil as shown in this view. Crayon markings can be wiped off with a cloth if errors in numbering are made.

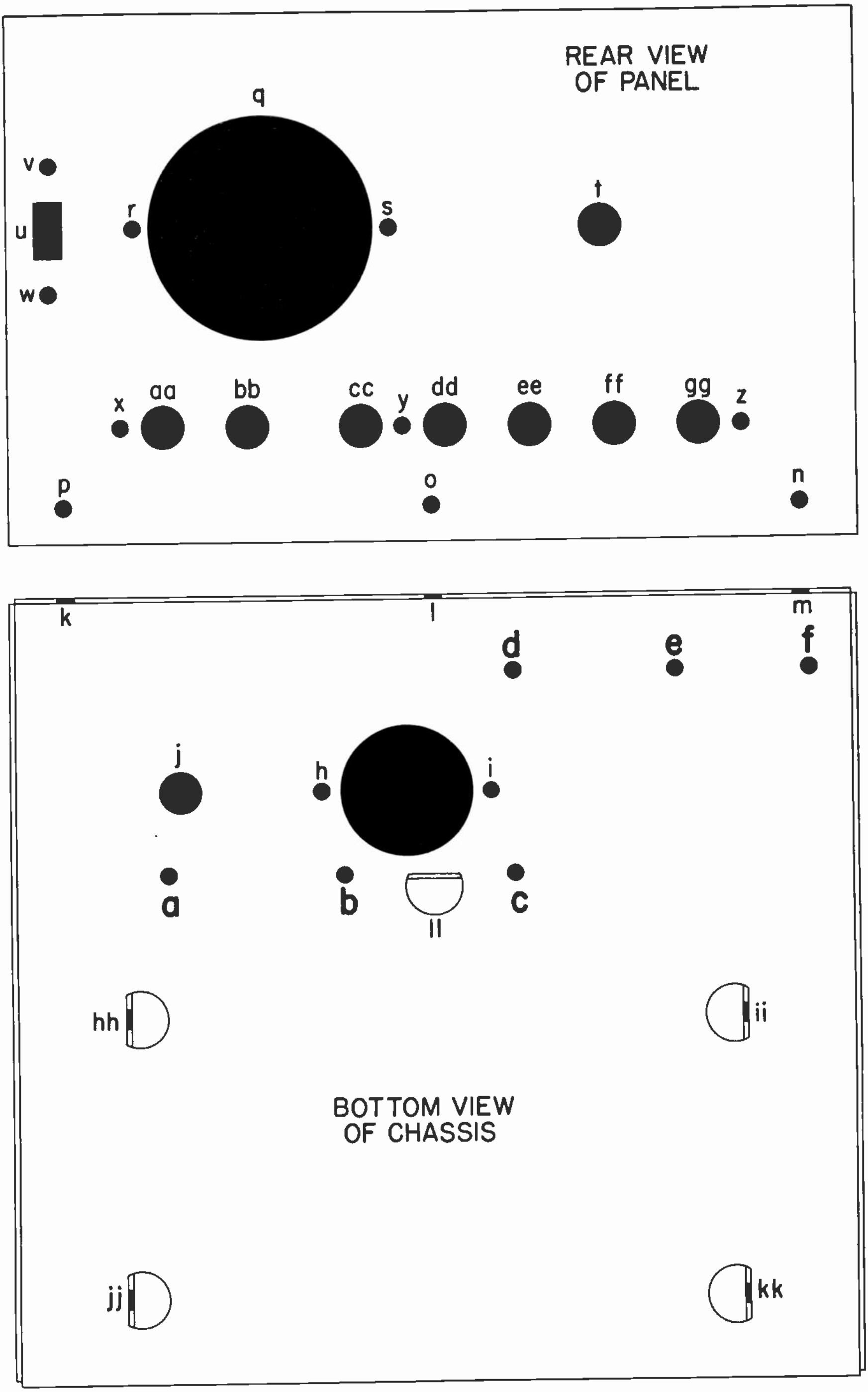


FIG. 36. Rear view of tester panel (above) and bottom view of chassis (below), with all holes identified by letters for convenience in referring to them. The only letters which are to be marked on your parts, however, are those identifying chassis holes *a*, *b*, *c*, *d*, *e* and *f*. Use these diagrams as your guides for locating the other holes when mounting the parts.

With a small screwdriver, loosen the set screw which is located in the thick end of the bar knob (Part *2-8*), place this knob over the shaft of the selector switch with the set screw next to the flat portion of the shaft, then tighten this set screw with your small screwdriver while pressing the knob toward the panel.

Rotate the selector switch knob as far as it will go in a counter-clockwise direction, so that the white line on the pointer of the knob is on the

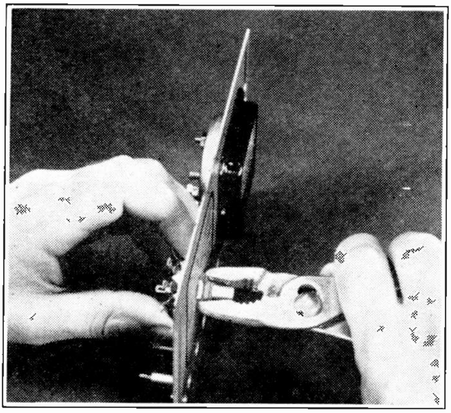


FIG. 38. Method of using ordinary pliers to tighten the nut on the rotary selector switch. Use the same technique for tightening the nut on the 1,000-ohm potentiometer.

panel line marked *V MEG*. If the pointer is not exactly on this line when looking directly at it with your eyes on a level with the knob, grasp the back of the selector switch with your hand and rotate it firmly but slowly until the pointer is exactly on the line.

Step 3. Insert the ON-OFF power switch (Part *2-5*) *in rectangular panel hole u* (Fig. *36*) *from the back of the panel* in the position which places the colored dot next to the panel notation *OFF*. (Flip the switch back and forth to find the dot, for it is visible in only one position of the sliding black button.)

Attach the switch to the panel with two binder-head machine screws (Part *2-18A*) and two hexagonal nuts (Part *2-18B*), with the heads of the screws at the front of the panel. Tighten each screw with a screwdriver while holding its nut with ordinary pliers.

Step 4. Complete the numbering of the terminals at the back of the panel in the manner shown in Fig. *37*. Since the terminals for the meter and the jack strip were numbered in a previous experiment, this leaves only power switch terminals *13* and *14* and the selector switch terminals *17* to *23* to be numbered. Place these numbers carefully and neatly on the panel, as close as possible to each terminal, with your crayon pencil. Finally, place *on the top* of each jack the identifying number which you have previously placed on the back of the panel above the jack. This will simplify identification of the jacks while working with the panel facing you. Sharpen the crayon with your pocket knife when necessary.

Making Resistor and Condenser Connections on the Panel

Step 5. Locate and place before you on the table the following parts from Radio Kits 1RK and 2RK:

One .05-mfd. tubular paper condenser (Part *1-13*).

One .25-megohm (250,000 ohms) fixed resistor (Part *1-14*).

One .1-megohm (100,000 ohms) fixed resistor (Part *1-15*).

One 6.7-megohm fixed resistor (Part *2-11*).

One 3-megohm fixed resistor (Part *2-12*).

One 900-ohm fixed resistor (Part *2-14*).

One 100-ohm fixed resistor (Part *2-15*).

One .005-mfd. tubular paper condenser (Part *2-16*).

One .2-megohm (200,000 ohms) fixed resistor (Part *2-22*).

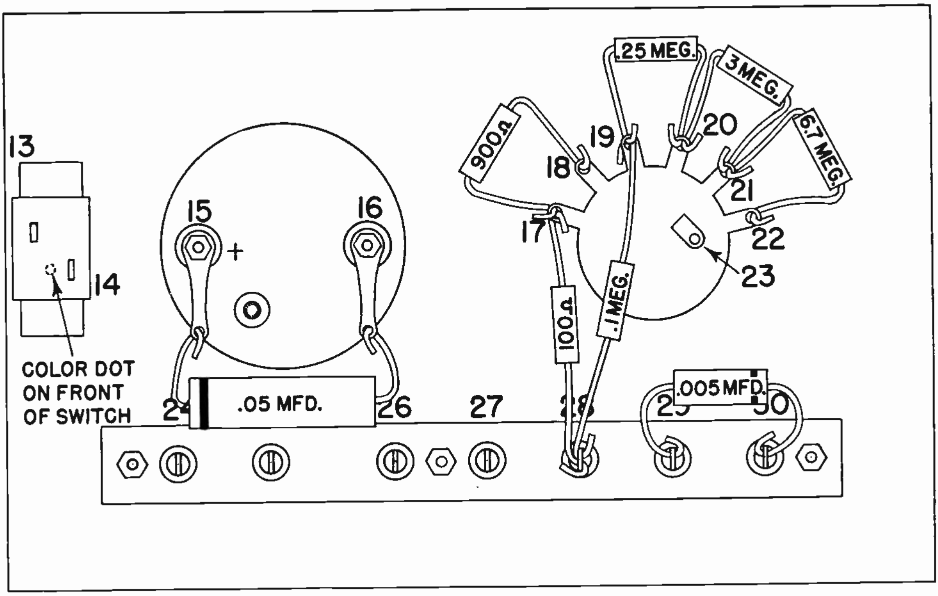


FIG. 39. Rear view of front panel, showing positions of all condensers and resistors. No soldered joints have been made yet. All hook joints should be closed when instructions for this are given in the text.

Step 6. Connect the .05-mfd. condenser (Part *1-13*) *between meter terminals 15 and 16* by first shortening the leads with side-cutting pliers so that each lead is now 1 inch long. (Make marks on the leads with crayon after measuring with a ruler, and check each mark carefully before cutting so as not to get a lead too short.) Bend the leads with your fingers to the shapes shown in Fig. *39*, so that the condenser will fit under the meter and its wires will reach to the meter terminal lugs, with the *OUTSIDE FOIL* lead going to the + terminal (*15*). Now bend an open hook in the end of each lead with long-nose pliers, and hook these leads through the holes in lugs *15* and *16* from behind. Close the hooks with long-nose pliers, but do not solder the joints until instructed to do so. In many cases, two or more wires must be placed on a lug prior to soldering.

Step 7. Connect the .005-mfd. condenser (Part *2-16*) *between jack terminals 29 and 30,* by first shortening each condenser lead until it is 1 inch long. Bend the leads with your fingers in the manner shown in Fig. *39*. Insert the end of the *OUTSIDE FOIL* lead into the hole in lug *30*, insert the end of the other condenser lead into the hole in lug *29* from the opposite direction, then bend the leads to form closed hooks, as shown in Fig. *39*.

Step 8. Connect the 900-ohm resistor (Part *2-14*) *between selector switch terminals 17 and 18,* by first shortening each lead so that it is 7/8 inch long. Bend the leads with your fingers to the approximate shapes shown in Fig. *39*. Bend an open hook in each lead with long-nose pliers. Insert the leads in terminal lugs *17* and *18* from behind, then close the hooks and squeeze them just enough so the resistor will support itself above the selector switch, in the position shown in Fig. *39*.

Step 9. Connect a 100-ohm resistor

(Part *2-15*) *between selector switch terminal 17 and jack terminal 28,* by first shortening each resistor lead so it is 7/8 inch long. Bend an open hook in one lead with long-nose pliers, hook this lead into the hole in terminal *17* from behind, and close the hook. Now bend a partial hook (a simple right-angle bend) in the other lead so that you can push this lead into the hole in jack terminal *28,* as indicated in Fig. *39,* but do not close the hook yet.

Step 10. Connect the .1-megohm resistor (Part *1-15*) *between selector switch terminal 19 and jack terminal 28,* by first shortening each resistor lead until it is 1¼ inches long. Bend the leads to the shapes shown in *Fig. 39* so that the resistor will be held away from the switch housing, bend an open hook in one lead, hook this through the hole in lug *28* alongside the resistor lead now in that lug, but do not close this hook yet. Now make a right-angle bend in the other lead on a level with the hole in lug *19,* push the lead through this hole from the front, and bend the lead with long-nose pliers to form a closed hook on this lug.

Step 11. Connect the .25-megohm resistor (Part *1-14*) *between selector switch terminals 19 and 20,* by first shortening each lead of this resistor until it is ⅞ inch long. Bend the leads with your fingers to the shapes shown in Fig. *39*. Bend an open hook in the end of each resistor lead. Hook these leads through the holes in lugs *19* and *20* respectively from behind, and squeeze the hooks just enough with long-nose pliers so the resistor will support itself as shown in Fig. *39*.

Step 12. Connect the 3-megohm resistor (Part *2-12*) *between selector switch terminals 20 and 21,* by first shortening each resistor lead until it is 7/8 inch long. Bend the leads as in Fig. *39*. Bend an open hook in the end of each lead. Insert the leads through the holes in lugs *20* and *21* from behind, then squeeze each hook with long-nose pliers. You will now have two leads in lug *20*.

Step 13. Connect the 6.7-megohm resistor (Part *2-11*) *between selector switch terminals 21 and 22,* by first shortening each resistor lead until it is 7/8 inch long. Bend the leads as in Fig. *39*. Bend a hook in the end of each lead. Hook the leads through the holes in lugs *21* and *22* from behind, then squeeze each hook with long-nose pliers. The back of the panel of your N. R. I. Tester should now appear exactly as shown in Fig. *39*.

Completing the Panel Connections

Step 14. Heat your soldering iron now, for you will be using it soon. Cut a 4½-inch length of hook-up wire from the roll furnished you as Part *2-17,* push the insulation back from one end, bend a hook in this end, and insert this hook in the hole in meter lug *15* from behind, alongside the condenser lead already in this hole. Close the hook with pliers while holding the wire straight down along the panel, as shown in Fig. *40*.

Now cut a 12-inch length of hook-up wire, push the insulation back from one end, bend a hook in that end, and insert this hook also in the hole in meter terminal lug *15*. Hold this wire straight down along the panel parallel to the other wire, then squeeze all three hooks which are in this lug. Solder this joint, using rosin-core solder. After the solder has hardened, push the insulation back toward the lug on each wire. Get the habit of pushing the insulation

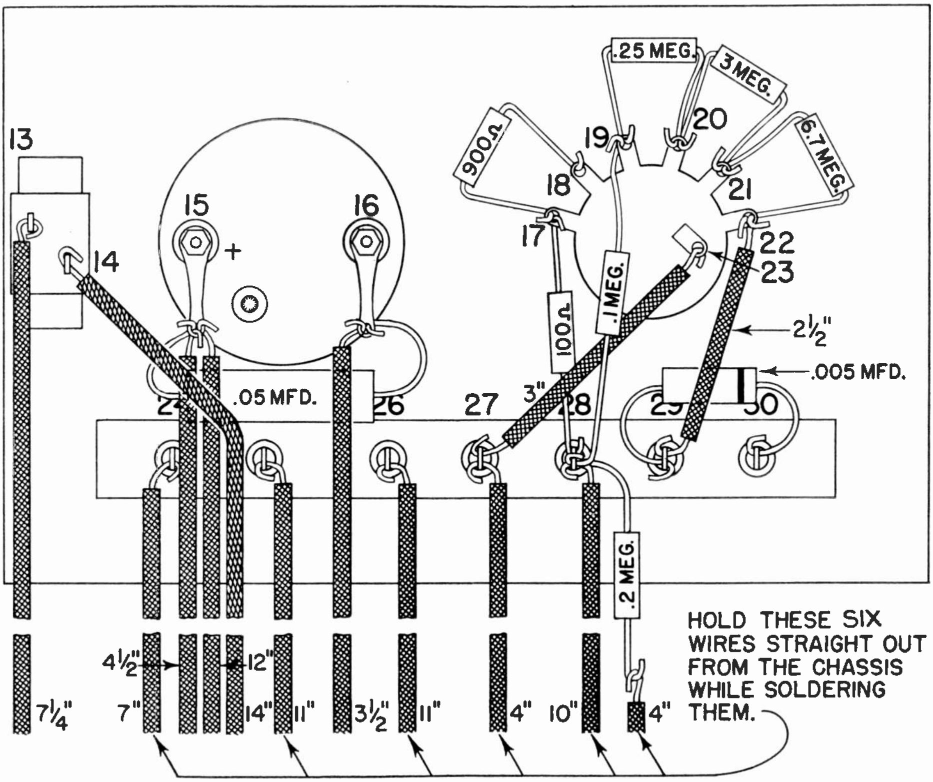


FIG. 40. Rear view of front panel after all leads and parts have been connected with permanent soldered hook joints. The length in inches to which you should cut each piece of hook-up wire is indicated alongside the wire. To save space in this manual and to simplify this diagram, the long leads are shown in shortened form below the panel. Each of the six long jack leads should be held at right angles to the panel while being soldered; these wires can then be bent to the right along the bottom of the panel so they will not interfere with your work. At this stage of the assembly, all joints should have *closed hooks* and be soldered exactly according to the instructions in the text.

over exposed wire like this whenever using push-back wire.

Be sure to bend the lug away from the meter case so that there is at least a ¼-inch clearance between the joint and the case.

Step 15. Cut a 3½-inch length of hook-up wire, connect one end of it to meter lug *16* by means of a hook joint, squeeze the hook tight while holding the wire straight down along the panel as shown in Fig. *40,* then solder this joint. Finally, push the insulation on the wire up toward the joint if any wire is exposed below the joint, and bend the lug out ¼ inch.

Step 16. To connect together selector switch terminal 23 and jack terminal 27, cut a 3-inch length of hook-up wire, make a permanent hook joint with one end of this wire at terminal *23,* and solder this joint. Form a hook joint with the other end of the wire on terminal *27,* but do not solder this yet.

Step 17. Cut a 4-inch length of yellow stranded tinned rubber and cotton insulated wire (Part *1-7F,* left over from the first ten experiments), remove the insulation from both ends for a distance of about ¼ inch, then connect one end of it to jack terminal

27 with a permanent hook joint. Hold the wire perpendicular to the panel, and squeeze the hooks on both wires at this lug so the 4-inch wire will stand upright by itself when the panel is lying on the table, and solder the joint. (It is necessary to use the yellow wire here because its rubber insulation prevents leakage.)

Step 18. Cut a 10-inch length of red hook-up wire, form a hook in one end, and insert this hook in the hole in terminal *28* alongside the two hooks already there. Next, take the .2-megohm resistor (Part *2-22,* color-coded red, black and yellow on a brown body color), and connect a 4-inch length of red hook-up wire to the end of one resistor lead by means of a permanent soldered hook joint so as to lengthen this lead. Shorten the other resistor lead to a length of 1 inch, bend a hook in the end of this lead, and insert this hook also in the hole in terminal *28.* There should now be four leads in the hole in this terminal. Hold the 10-inch wire and the resistor straight out from the panel, squeeze each of the four hooks together with pliers, then solder this joint. Push the insulation on the wire toward the joint, then bend the 10-inch wire and the resistor lead to the right along the panel. (Take a glance at Fig. *42* now to see how the wires are bent to the right so they will be out of the way until needed again. Do not make sharp bends; keep each bend at least an inch away from its joint. Figure *40* merely shows the points to which the wires should be connected on the panel; it does *not* show the correct positions of those wires which extend below the panel and are left unconnected now.)

Step 19. Connect together terminals 22 and 29 by taking a 2½-inch length of hook-up wire, connecting one end to terminal *29* and connecting the other end to terminal *22* with permanent hook joints. Solder the joints at terminals *22* and *29.*

Step 20. Solder the joints at terminals 17, 18, 19, 20, 21 and 30 in turn, without placing any additional wires on these joints.

Step 21. Cut a 7¼-inch length of hook-up wire and solder one end of it to power switch terminal 13 by means of a permanent hook joint, while holding the wire parallel to the panel as shown in Fig. *40.*

Step 22. Cut a 14-inch length of hook-up wire and solder one end of it to power switch terminal 14 by means of a permanent hook joint while holding the wire parallel to the panel and bending it as shown in Fig. *40.*

Step 23. Cut an 11-inch length of hook-up wire, attach it to jack terminal *25* by means of a permanent hook joint, hold the wire straight out from the panel, squeeze the hook together so the wire will stay there, then solder this joint on lug *25.* Push the insulation back, then bend the wire to the right.

Step 24. Cut a 7-inch length of hook-up wire, attach it to jack terminal *24* by means of a permanent hook joint, hold the wire straight out from the panel, squeeze the hook together so the wire will stay there, then solder the joint. Push the insulation back over the wire, then bend the wire to the right.

Step 25. Cut an 11- inch length of hook-up wire, attach one end of it to terminal *26* by means of a permanent hook joint, hold the wire straight out from the panel, squeeze the hook together so the wire will stay up, then solder the joint. Push the insulation back over the wire, then bend the wire to the right.

You have now completed all wiring

which is to go on the panel of the N. R. I. Tester.

Making Chassis Connections

Step 26. Set the completed front panel aside for the time being, and place before you the following parts from Radio Kits 1RK and 2RK.

Metal Chassis (Part *1-11*) on which you mounted (in Experiment 9) the octal-type tube socket (Part *1-10*).

1,000-ohm potentiometer (Part *2-7*).

One 13/16-inch long soldering lug (Part *1-8C*).

.25-megohm fixed resistor (Part *2-13*).

.03-mfd. tubular paper condenser (Part *1-12*).

45-inch length of black lace (Part *2-20*).

One grid cap clip (Part *2-21*).

Step 27. To mount the 1,000-ohm potentiometer (Part *2-7*) *on the chassis*, first remove the 3/8-inch hexagonal nut from the potentiometer shaft, insert the shaft through chassis hole *j* (Fig. *41*) from the bottom, and replace the nut on the shaft which now projects from the top of the chassis. Hold the potentiometer with one hand in the position shown in Fig. *41*, so that the middle soldering lug of the potentiometer is in line with the mounting bolts of the tube socket, and tighten the nut with ordinary pliers exactly as you tightened the nut on the selector switch shaft.

Step 28. Remove the nut from that tube socket mounting screw which is closest to the potentiometer (in hole *h*) without removing the screw, place on this screw a 13/16-inch long soldering lug (Part *1-8C*), and replace the nut. Tighten the nut partially with the fingers, bend the soldering lug up from the chassis at right angles, then line up the soldering lug with the middle lug of the potentiometer and tighten the nut finally with pliers and screwdriver.

Now take long-nose pliers and bend the outermost end of this lug back toward the chassis again so that it lies right over the center lug of the potentiometer, with the hole in lug *1-8C* coinciding with the slot in lug *10* of the potentiometer.

Mark the number *12* on the chassis alongside the lug which you have just

FRONT OF CHASSIS

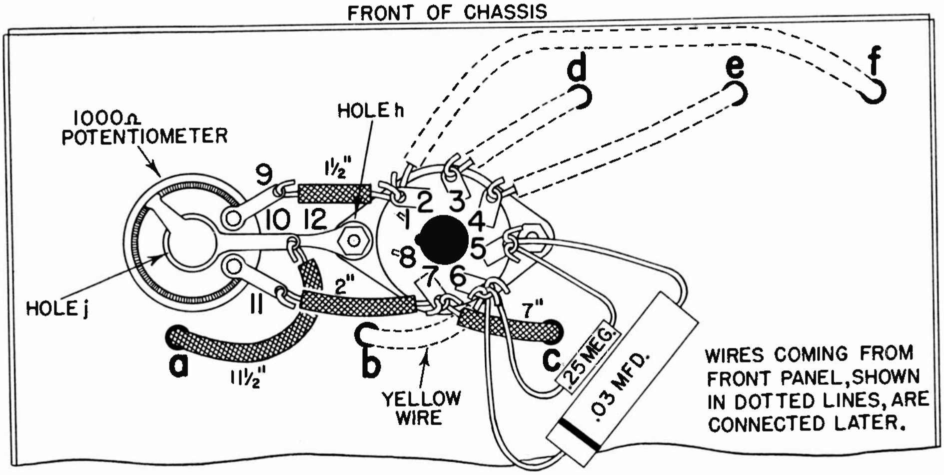


FIG. 41. Bottom view of chassis, showing preliminary assembly of leads and wires. After the chassis is bolted to the panel, four wires from the panel will be run through holes *b, d, e* and *f* and connected to terminals *6, 3, 4* and *2* respectively, as indicated by the dotted lines.

bolted to the chassis, as shown in Fig. *41*. Identify the potentiometer terminal lugs by numbers *9*, *10* and *11* marked on the chassis near the lugs, as shown in Fig. *41*.

Step 29. Cut an 11½-inch length of hook-up wire, push one end through chassis hole *a* from the top of the chassis, form an open hook in the end, insert this hook through the slot of lug *10* and the soldering hole in lug *12* (which now coincide), close the hook with long-nose pliers, then solder this joint so that lugs *10, 12* and the 11½-inch length of wire all form a single secure joint.

Step 30. Connect potentiometer terminal 11 to tube socket terminal 7 with a 2-inch length of hook-up wire, by forming permanent hook joints. Solder the joint at terminal *11*, but do not solder the joint at *7* yet.

Step 31. Cut a 7-inch length of hook-up wire, push one end through hole *c* from the top of the chassis, and connect this end to tube socket terminal *7* by means of a permanent hook joint. Now solder the joint at terminal *7*.

Step 32. Connect potentiometer terminal 9 to tube socket terminal 2 with a 1½-inch length of hook-up wire, using permanent hook joints. Solder terminal *9*, but do not solder terminal *2* yet.

Step 33. Connect the .25-megohm resistor (Part *2-13*) *between tube socket terminals 5 and 6,* by first shortening the resistor leads so that each is ¾-inch long. Bend the leads with your fingers to the shapes shown in Fig. *41*. Bend a hook in the end of each lead with long-nose pliers. Hook the leads through the holes in terminal lugs *5* and *6* from underneath, then close the hooks with long-nose pliers. Do not solder these joints yet.

Step 34. Connect the .03-mfd. condenser (Part *1-12*) *between tube socket terminals 5 and 6,* with the *outer foil* lead going to *6*, by first shortening the leads so that each is 1¼-inch long. Bend the leads as shown in Fig. *41* and form an open hook in the end of each with long-nose pliers. Hook the leads through the holes in terminals *5* and *6*, and close the hooks with long-nose pliers. Now solder the joints at terminal *5*, but do not solder terminal *6* yet. Adjust the leads now with your fingers and pliers so that the resistor and condenser are both self-supporting about ⅛-inch away from the metal chassis.

You have now completed the wiring underneath the chassis as much as you can before final assembly. The bottom of the chassis should now appear as shown in Fig. *41*. Two wires will be projecting up through the top of the chassis, through holes *a* and *c* respectively.

Step 35. Fasten the panel to the chassis now with the three remaining binder-head machine screws (Part *1-9A*) *and three hexagonal nuts* (Part *1-9B* just as you did in Step 2 of Experiment 11, after first bending the projecting wires temporarily out of the way. Insert the screws one after another, placing a nut on each and tightening loosely with the fingers while the chassis is in the position shown in Fig. *5*. Now align the panel neatly with respect to the chassis, and tighten the screws permanently with screwdriver and ordinary pliers. At this stage in the assembly process, your N. R. I. Tester should appear as shown in Fig. *42*.

Step 36. Locate the panel wire which you connected to terminal 13 of the power switch, and push this wire through chassis hole f (directly under terminal *13*). Connect to socket

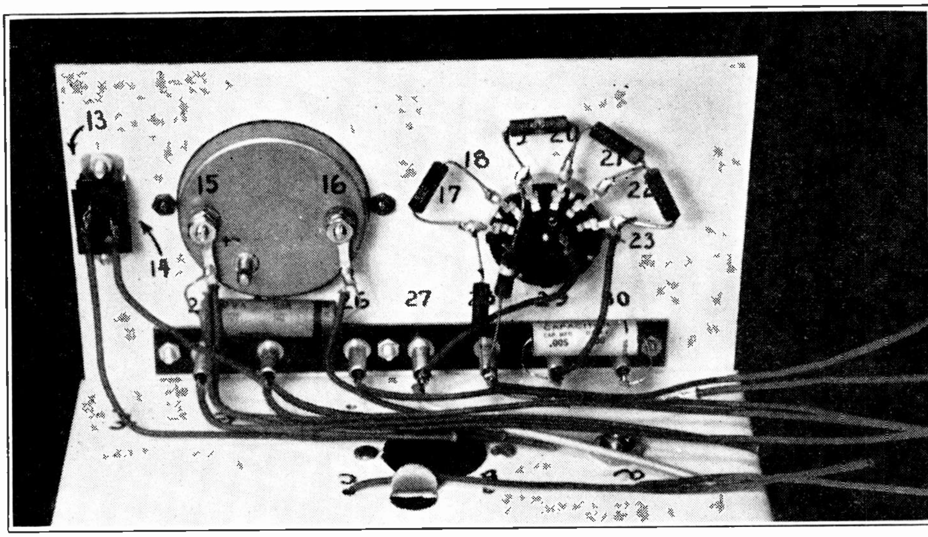


FIG. 42. Rear view of N. R. I. Tester after the panel is fastened to the chassis. Note that the leads have been temporarily bent off the chassis to the right to permit placing the battery block on the chassis between the five tabs. The position of the *OUTSIDE FOIL* lead of the condenser connected between meter terminals *15* and *16* does not matter, since neither meter terminal is grounded.

terminal *2* with a permanent hook joint the wire which projects underneath the chassis through hole *f*. Solder terminal *2* now (there should be two wires on this terminal).

Step 37. Locate the 4½-inch wire which is soldered to meter terminal 15, and push the free end of this wire through chassis hole e, which is almost directly under this meter terminal. Underneath the chassis, connect to tube socket terminal *4* by means of a permanent hook joint the wire which is now projecting through hole *e*, and solder this connection to terminal *4*.

Step 38. Locate the 3½-inch wire which is connected to meter terminal 16, push it through chassis hole d (directly under this meter terminal), then turn the chassis over and connect to tube socket terminal *3* by means of a permanent hook joint the wire which is now projecting under the chassis through hole *d*. Solder this joint on terminal *3* now.

Step 39. Locate the 4-inch yellow wire which is connected to jack terminal 27, and push it through hole b. When you have pulled the wire through, shape the wire neatly with your fingers above the chassis so that it goes around the tube socket. Now turn the chassis over and connect to tube socket terminal *6*, by means of a permanent hook joint, the yellow wire which projects underneath the chassis through hole *b*. Close the hook with long-nose pliers, then solder terminal *6*.

Step 40. Locate the U-shaped shorting piece made from heavy wire (Part *2-4*), *and push this piece all the way into the two jacks marked PHONE at the front of the panel.* This piece can be seen in the view of the completed N. R. I. Tester (Fig. *33*). Do not remove this piece until you receive instructions for doing so in connection with the use of a headphone unit.

Mounting the A-B-C Battery Block

NOTE: If you are using individual batteries in place of the special A-B-C battery block made for this tester, skip Steps 41 through 49, and follow the instructions given in Steps 50 through 63 for individual batteries.

Step 41. Place the A-B-C battery block on top of the chassis in the position shown in Fig. 43, so that it fits between the back of the chassis and the five upward-projecting tabs (*hh, ii, jj, kk* and *ll*). The battery terminals closest to the back edge of the chassis will then be +C, +1½A and +45.

Step 42. Locate the wire which projects through hole c and push the insulation back from its end about half an inch. Bend the end in a clockwise direction to form an open hook. Loosen the nut on battery terminal —A, place this hook under the nut and *under* the lock washer which is on the screw, close the hook, then tighten the nut with your fingers. Straighten out this lead now so that it goes neatly down from the —A terminal to hole *c*, as shown in Fig. *43*.

NOTE: Whenever you connect a wire to a screw terminal, always bend the hook in the wire in a clockwise direction. Since a nut is tightened by turning it in a clockwise direction also, tightening of the nut will tend to close the hook in the wire rather than open it. Hooks which are bent in the opposite direction (counter-clockwise) will sometimes spread apart and fall off when the nut is tightened, hence this is to be avoided.

Step 43. Locate the wire which comes up through chassis hole a, bring it straight up along the side of the battery, bend it sharply around the top corner of the battery, then run it along the —C terminals of the battery block. Push the insulation back, connect the wire to the +C terminal, then make a neat right-angle bend near the +C terminal as shown in Fig. *43*.

Step 44A. Locate the wire which is attached to one lead of the .2-megohm resistor (the other lead of this resistor is on jack terminal *28*), bend the longer of the resistor leads upward at right angles so the wire on this lead comes up along the side of the battery block, then attach the wire to battery terminal —9C with a closed hook placed under the lock washer, and tighten the knurled nut on this terminal.

Step 44B. Locate the wire which comes from jack terminal 28, and solder the grid clip (Part *2-21*) to the end of this lead by means of a permanent soldered hook joint as shown at the upper right in Fig. *43*. Now press this lead down along the chassis past the tube socket, bring it up along the side of the battery block, and bend it over the top on the —7½C side of terminal —9C, as shown in Fig. *43*. Push the clip over the knurled nut on terminal —9C. If the clip fits loosely, squeeze the clip together a bit with your fingers or with pliers so as to secure a snug fit. Arrange the surplus wire in the form of a neat loop beyond terminal —9C as shown in Fig. *43*. The extra wire here is required because this particular connection will sometimes be moved to terminals —7½C, —6C and —4½C.

Step 45. Locate the wire which comes from jack terminal 26, press it down along the chassis up to the battery block, bring it straight up the side of the battery block, and bend it over the top of the block between terminals —9C and —A. On a line with terminal —4½C, make a right-angle bend toward this terminal and connect the wire to this terminal. Tighten the knurled nuts on terminals —6C and —7½C at this time.

Step 46A. Locate the wire which comes from terminal 25, bring this

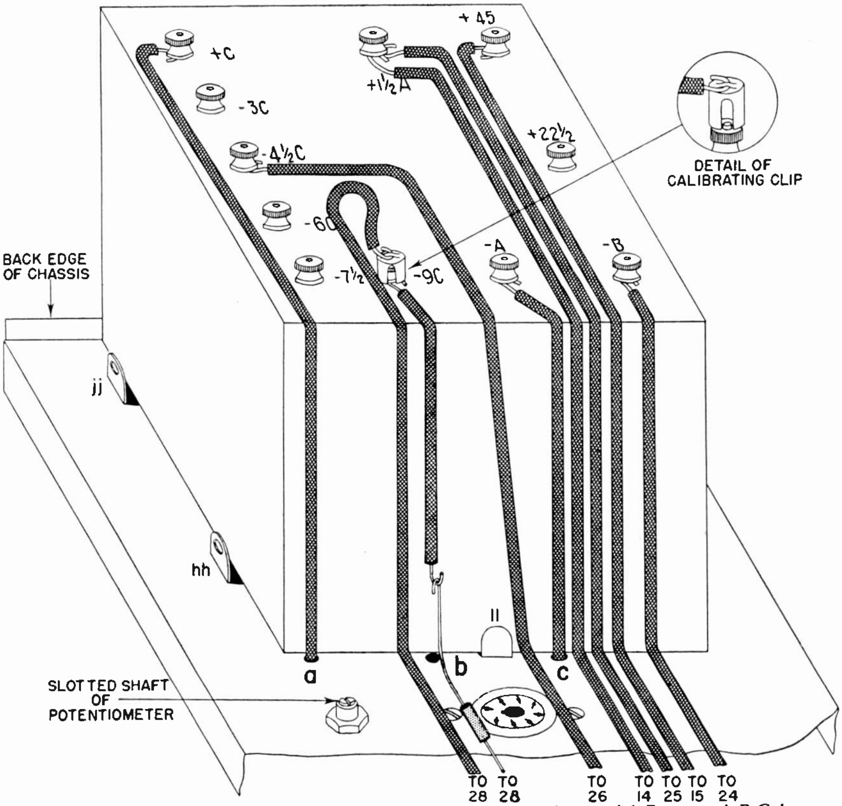


FIG. 43. Battery connections for the N. R. I. Tester when using the special Burgess A-B-C battery block. WARNING: DO NOT LET METER TERMINAL *15* OR THE +45 TERMINAL OF THE BATTERY COME IN CONTACT WITH THE CHASSIS OR WITH ANY OTHER BATTERY TERMINAL, BECAUSE AN ACCIDENTAL CONNECTION OF THIS NATURE MAY BURN OUT THE TUBE OR THE POTENTIOMETER, OR BOTH

wire straight back along the chassis, then straight up along the side of the battery block, over the front corner of the block and back along the top of the block between terminals —A and —B. Push back the insulation and connect this wire to the +1½A terminal, then adjust its position as shown in Fig. *43*.

Step 46B. Locate the wire which comes from power switch terminal 14 and bend it down between jacks *24* and *25*, down along the chassis and up along the side of the battery block, over the front corner of the block parallel to the wire mentioned in Step 46A, and connect this wire to the +1½A terminal.

Step 47. Locate the 12-inch wire which comes from meter terminal 15, bring it straight down from this meter terminal to the chassis, make a right-angle bend there and bring it straight back along the chassis to the battery block, then make another right-angle bend and bring it up along the side of the battery block. Bend the wire at right angles over the front top edge of the battery block, run it straight back along the top of the battery block between terminals —A and —B and between +1½A and +45, push back the insulation, connect the wire to the +45 terminal, then adjust its position as shown in Fig. *43*.

Step 48. Locate the wire which comes from jack terminal 24, bring it back along the chassis to the battery block, then make a right-angle bend and bring it up along the side of the battery block. At the top, bend the wire over and connect it to the —B terminal as shown in Fig. *43*.

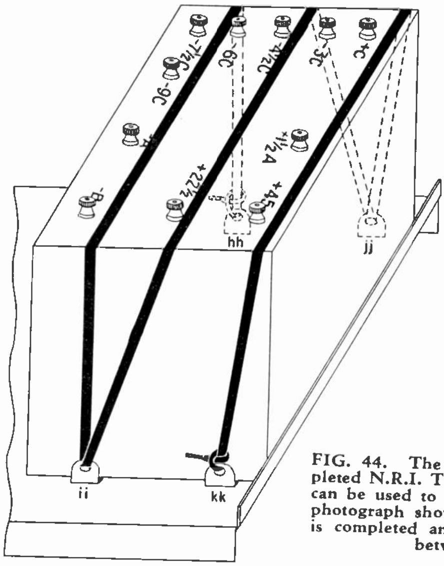
You have now completed the battery connections for the N.R.I. Tester. Go over all connections and push the insulation toward the joints whenever possible, to cover as much exposed wire as you can and thus minimize chances for accidental short circuits.

Step 49. Take the 45-inch length of black lace (Part *2-20*), *and insert one end in battery tab hole hh* after first lifting the battery and moving it temporarily away from this tab to give you more room. Now tie a simple knot in this end of the lace, as shown in Fig. *44*. When pulled tight, this simple knot will hold adequately for your purpose.

Bring the lace up the side of the battery, across the top of the battery parallel to the front panel, just behind terminal row —7½C, —9C, —A and —B, and down the other side of the battery. The lace goes over all wiring except the lead which has the clip; the lace will hold the wiring in position when tightened. Thread the lace through battery tab hole *ii* after first shifting the battery temporarily in the opposite direction to give you room near this tab.

From hole *ii*, bring the lace up diagonally across the side of the battery as shown in Fig. *44*, then across the top between the +22½ and +45 terminals, over the wiring and between the —3C and —4½C terminals. Now go down to battery tab hole *jj*, thread through this hole after first tilting battery block forward, bring the lace *behind* the battery block (not over the top yet), and thread it through battery tab hole *kk* while the block is still tilted forward.

Set the battery back in its normal position, and place over the top of the battery (just behind the back row of terminals) the loop of lace which is between *jj* and *kk*. Pull on the end of the lace while going over the entire length of lace, starting from *hh*, to



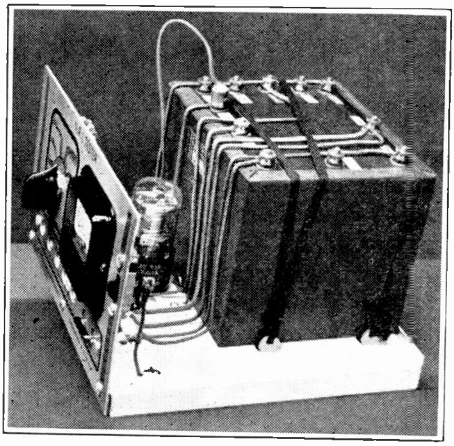


FIG. 44. The diagram at the left is a partial rear view of the completed N.R.I. Tester, showing how the length of black lace (Part *2-20*) can be used to tie down the special Burgess A-B-C battery block. The photograph shows how the battery block actually appears after wiring is completed and the lace put on; an optional position for the lace between tabs *ii* and *jj* is shown in this photo.

take up slack and make the lace lie flat. When you have pulled the lace through hole *kk* as tight as you can with your fingers (do not use pliers for this), place the blade or shank of a medium-size screwdriver between tab *kk* and the battery block, in the manner shown in Fig. *45*, to prevent the lace from slipping while you are tying the knot. Tie a simple knot here and pull it tight, as shown in Fig. *44*, then tuck surplus lace neatly behind battery tab *kk*. Finally, arrange all lace and wiring so that the lettering for each battery terminal will be visible.

If you have been following Steps 41 through 49 dealing with the special A-B-C battery block, skip Steps 50 through 63 and continue with Step 64 now.

Connecting Individual Batteries

Step 50. If you are using individual Burgess batteries for the N.R.I. Tester in place of the special A-B-C battery block, disregard Steps 41 through 49, and proceed as follows:

Place before you the following batteries which are equivalent to those used to make up the special A-B-C battery block:

One Burgess type 4FH 1.5-volt dry cell.
Two Burgess 2370 4.5-volt C batteries.
One Burgess type Z3ON 45-volt B battery.

Although the individual cells can be held in place with the length of black lace (Part *2-20*), we suggest you supplement the lace with a few strips of ordinary ¾-inch wide friction tape, to prevent the cells from sliding and to give a compact assembly which more nearly duplicates the convenience of the single A-B-C battery block. You will need only about five feet of tape.

Note: If for any reason you are using batteries which are different from those specified here, you can change the arrangement of the batteries on the chassis if necessary, provided you still make the same electrical connections specified in this manual.

Step 51. Place one of the C batteries in front of you in exactly the position shown in Fig. 46A, so that the terminals have exactly the position shown in the diagram. Cut two strips of friction tape, each 2½ inches long, and place these on the uppermost side of the battery in the manner shown in Fig. *46A*. Now place the other C battery on top of this in such a way that its + terminal is next to the —4½ terminal of the first

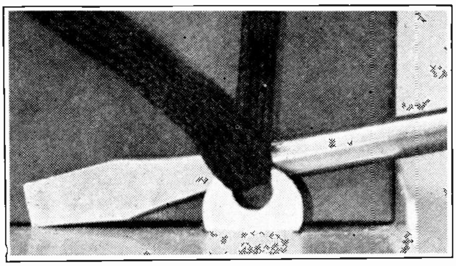


FIG. 45. Method of holding the lace with a screwdriver while tying the final knot at battery tab *kk*.

C battery. Set the two batteries upright now, in the position shown in Fig. *46B*.

Step 52. Cut a 19-inch long strip of friction tape; place it across the top of the two C batteries in the manner shown in Fig. *46B,* so that one end of the tape projects downward 2 inches on one side of the right-hand battery. Now, while holding the batteries together with one hand, bring the tape completely around the two batteries and overlap it on the 2-inch portion on the side of the right-hand battery. This will hold the two C batteries together, and strips *U* and *V* will prevent the batteries from slipping or twisting.

Step 53. Cut two 16¾-inch lengths of friction tape, place them parallel to each other on the table, 1⅝ inches apart, then place the B battery across these strips in the manner shown in Fig. *46C,* so that one edge of the battery projects ahead of the front strip, and ⅜ inch of the battery projects behind the rear strip. Allow about 1¾ inch of each strip to project on the right-hand side of the B battery, so that you can bring these strips up along the side of the battery as shown in Fig. *46C.*

Cut a 3½-inch length of friction tape, and place it approximately in the center of the left-hand side of the B battery as indicated in Fig. *46C.* Now place the 1.5-volt A battery alongside the B battery in such a way that the bottoms of the two batteries line up. Bring each strip of friction tape in turn around the A battery and then downward around the B battery. Let these ends of the strips overlap the other ends on the side of the B battery.

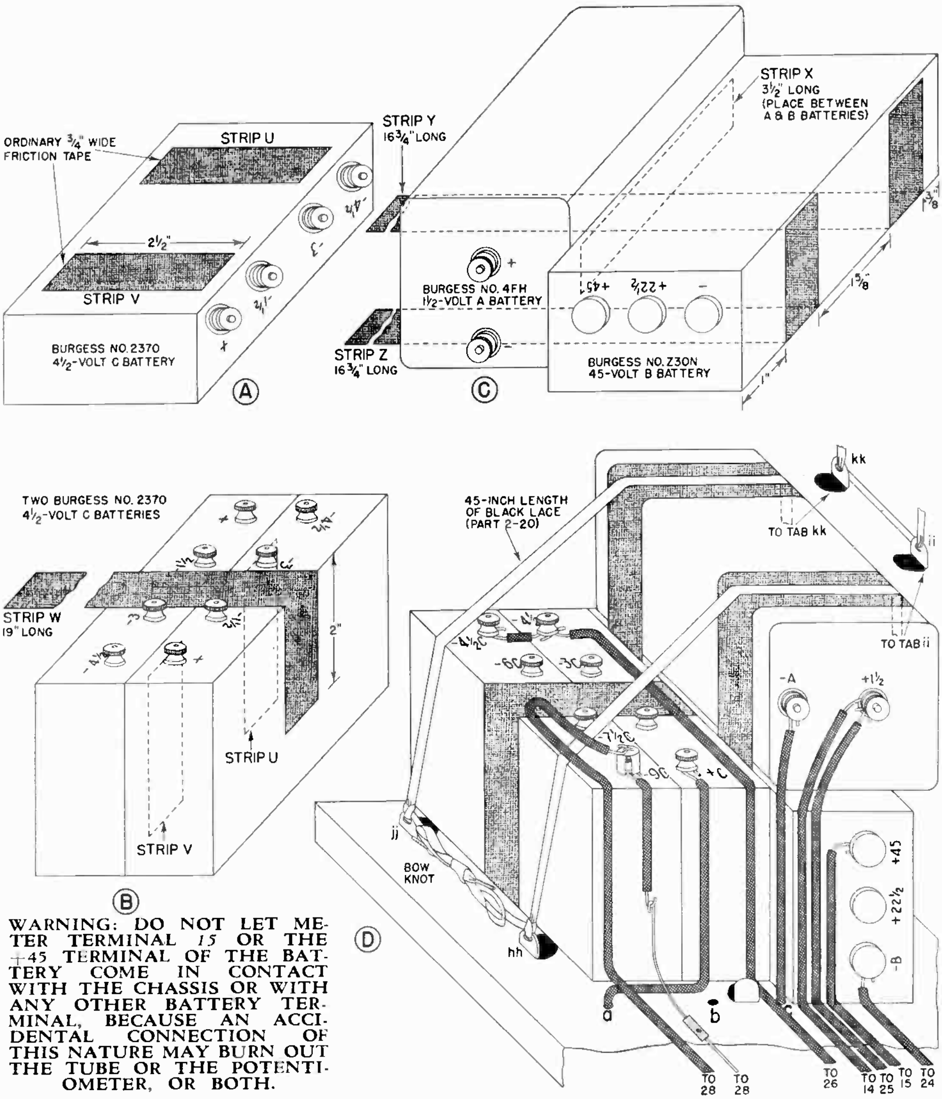
Step 54. Place the two taped groups of batteries between the tabs on the chassis, in the manner shown in Fig. *46D,* so that both groups are against the upward-projecting back of the chassis. Now reletter the terminals of each battery in the manner indicated in Fig. *46D,* so that the terminal markings will correspond to those used on the special Burgess A-B-C battery block. (These new terminal markings will be referred to from now on.) You can use a colored metal-marking crayon for these new markings if you keep its point sharp by frequent resharpening to permit making small letters clearly. The C batteries will be most difficult to letter, but this can be made easier by removing temporarily the knurled terminal nuts.

If you prefer, you can cut out a piece of stiff paper or cardboard having the approximate size of the top area of the combined C batteries, push this paper or cardboard over the terminal screws after first removing the nuts, then replace the screws and place your lettering on the paper with pencil or ink.

Step 55. Take the 45-inch length of black lace (Part *2-20*) *and tie one end into battery tab hole hh* with a simple knot in the manner shown in Fig. *46D,* leaving about 5 inches of lace projecting beyond the knot so you can tie a bow-knot with it later. Place it over the center of the front piece of friction tape on the A battery, and thread it through battery tab hole *ii* from the inside after shifting the battery group enough to give room for this. Now bring the lace back to tab *kk,* thread it through the hole in this tab from the outside, and bring the lace back across the batteries, running it in the center of the rear piece of friction tape on the A battery. Thread the lace through battery tab hole *jj,* adjust the battery groups until they are about midway between side tabs *hh* and *ii,* then go over the entire length of lace and pull it tight. Now tie a simple knot at tab *jj,* and tie a bow-knot with the loose ends, as indicated in Fig. *46D.*

Step 56. Locate the wire coming up through chassis hole a, and run this wire along the chassis to a point just below the +C terminal. From here, bring the lead straight up the side of the middle C battery, bend it over the top, and connect it to the +C terminal as shown in Fig. *46D,* after first cutting off any surplus length.

Step 57. Locate the wire coming from jack 28, run the wire diagonally back along the chassis, and bring it straight up along the side of the left-



WARNING: DO NOT LET METER TERMINAL *15* OR THE +45 TERMINAL OF THE BATTERY COME IN CONTACT WITH THE CHASSIS OR WITH ANY OTHER BATTERY TERMINAL, BECAUSE AN ACCIDENTAL CONNECTION OF THIS NATURE MAY BURN OUT THE TUBE OR THE POTENTIOMETER, OR BOTH.

FIG. 46. These diagrams show how to use individual Burgess batteries in place of the special Burgess A-B-C battery block. Individual batteries are more difficult to mount on the chassis than a single compact battery block, and battery terminals must be re-marked as shown at *D* above so they will correspond to the markings on the A-B-C block. Ordinary friction tape can be used to supplement the length of black lace in holding the batteries in position. Note: On Fig. *46D*, place the letter A after +1½ on the diagram.

hand C battery. Cut the wire so that it is long enough to reach one of the —4½C terminals at the far end of this battery, then solder the grid cap clip (Part *2-21*) to the end of this wire by means of a permanent soldered hook joint, as shown in Fig. *46D*. (This clip will be called the *calibrating clip,* since it will be moved only when calibrating the N. R. I. Tester.) Now loop the wire back as shown in Fig. *46D*, but do not press the clip over the —9C terminal until you have completed the next step. (This lead will at times be connected to —7½C, —6C or —4½C instead of to —9C, hence you must leave it long enough to reach —4½C.)

Step 58. Locate the wire which is attached to one lead of the .2-megohm resistor (the other lead of this resistor is on jack terminal *28*), bend the longer of the resistor leads upward at right angles so the wire on this lead comes up along the sides of the left-hand C battery, shorten the wire so it reaches terminal —9C, then attach the wire to terminal —9C with a closed hook placed around the screw and tighten the knurled nut on this terminal. Now squeeze the calibrating clip together with your fingers so that it is slightly smaller than the knurled nuts on the C batteries, and push the clip over the knurled nut on terminal —9C.

Step 59. Locate the wire which comes from jack 26, run it straight back along the chassis, straight up the side of the middle C battery, and back along the top of this battery. Connect this wire to the —4½C terminal on the middle battery, after cutting off surplus length. Now connect the —4½C terminal of the middle battery to the newly-marked —4½C terminal (originally the + terminal, but relettered —4½C in Step 54) of the other C battery, as shown in Fig. *46D,* if you have not already made this series connection for the experiments. Tighten the knurled nuts on terminals —6C and —7½C at this time.

Step 60. Locate the wire which comes up through chassis hole c, and connect it directly to the —A terminal of the 1.5-volt dry cell. This wire is already the correct length.

Step 61A. Locate the wire which comes from jack 25, run it back along the chassis and straight up along the front of the B battery, then connect it to the +1½ terminal as shown in Fig. *46D.*

Step 61B. Locate the wire which comes from power switch terminal 14, bend it down between jacks *24* and *25,* along the chassis and up along the front of the batteries, and connect it to the +1½A battery terminal.

Step 62. Locate the 12-inch wire which comes from meter terminal 15, run it straight down from this terminal to the chassis, straight back along the chassis to the B battery, straight up the B battery to the level of the +45 terminal, then make a right-angle bend toward this terminal and connect the wire to the +45 terminal after cutting off surplus length.

Step 63. Locate the wire which comes from jack 24, bring it straight back along the chassis to the B battery, then connect it to the —B terminal after cutting off surplus length.

Checking the Connections

Step 64. Having completed the assembly and wiring of the N. R. I. Tester, you are now ready to check the accuracy and completeness of your connections by means of the complete circuit diagram given in Fig. *34.* This checking procedure is an important part of any radio assembly job, so go through it slowly and carefully. *Place a check mark* (√) *in the space provided for this purpose after each step in the following checking procedure,* when you are certain that the connections called for in that step are correct.

Tube socket terminal *2* should have two leads, one going to potentiometer terminal *9* and the other going through chassis hole *f* to *ON-OFF* switch terminal *13.* ☑

Tube socket terminal *3* should have one lead, going through chassis hole *d* to meter terminal *16.* ☑

Tube socket terminal *4* should have one lead, going through chassis hole *e* to meter terminal *15*. ☑

Tube socket terminal *5* should have two leads, one from a .03-mfd. condenser and the other from a .25-megohm resistor. ☑

Tube socket terminal *6* should have three leads, one from a .03-mfd. condenser, another from a .25-megohm resistor, and a yellow lead going through chassis hole *b* to jack terminal *27*. ☑

Tube socket terminal *7* should have two leads, one going to potentiometer terminal *11*, and the other going through chassis hole *c* to the —A terminal of the battery block. ☑

Terminal *10*, the middle lug of the potentiometer, should be grounded to soldering lug *12* which is bolted to the chassis, and should have a lead going through hole *a* to the +C terminal on the battery. ☑

Terminal *14* on the *ON-OFF* switch should have one lead, going to the +1½A battery terminal. ☑

Terminal *15* on the meter should have three leads, one from a .05-mfd. condenser, one going to +45, and one going through chassis hole *e* to tube socket terminal *4*. ☑

Terminal *16* on the meter should have two leads, one from a .05-mfd. condenser and the other going through chassis hole *d* to tube socket terminal *3*. ☑

Selector switch terminal *17* should have two leads, one from a 100-ohm resistor and the other from a 900-ohm resistor. ☑

Terminal *18* should have one lead, from a 900-ohm resistor. ☑

Terminal *19* should have two leads, one from a .1-megohm resistor and the other from a .25-megohm resistor. ☑

Terminal *20* should have two leads, one from a .25-megohm resistor and the other from a 3-megohm resistor. ☑

Terminal *21* should have two leads, one from a 3-megohm resistor and the other from a 6.7-megohm resistor. ☑

Terminal *22* should have two leads, one from a 6.7-megohm resistor and the other going to jack terminal *29*. ☑

Terminal *23*, the central terminal on the selector switch, should have one lead, going to jack *27*. ☑

Jack terminal *24* should have one lead, going to —B. ☑

Jack terminal *25* should have one lead, going to +1½A. ☐

Terminal *26* should have one lead, going to —4½C.

Terminal *27* should have two leads, one going to selector switch terminal *23* and the other a yellow lead) going through chassis hole *b* to tube socket terminal *6*. ☑

Terminal *28* should have four leads, one from a .1-megohm resistor, one from a .2-megohm resistor, one from a 100-ohm resistor, and one going to the calibrating clip which should now be on terminal —9C. ☑

Terminal *29* should have two leads, one from a .005-mfd. condenser and the other going to selector switch terminal *22*. ☑

Terminal *30* should have one lead, from a .005-mfd. condenser. ☑

The U-shaped shorting piece should be in the phone jacks (connecting together jack terminals *24* and *25*.) ☑

Calibrating the N.R.I. Tester

Step 65. Place the assembled N. R. I. Tester on the table in front of you, with the panel facing you. Set the selector switch to the *100 × V* line on the panel (the selector switch is at this position in Fig. *33*). Set the power switch to the *OFF* position by pushing the black slide *down*.

Insert the vacuum tube in its socket on the tester chassis; do this by placing the aligning key of the tube gently in the corresponding hole in the socket, then rotating the tube until you can feel that the projecting pin on one side of this key is in the corresponding groove in the center hole of the socket. Now push the tube firmly into the socket until the tube base is resting on top of the socket. There should be no movement of the meter pointer yet.

Step 66. Turn on the tester switch by pushing the button on this switch upward toward the position marked *ON*. The colored dot under the button of this switch will now be visible. You will probably note a small movement of the meter pointer to the right when this is done.

CAUTION: If you are interrupted while calibrating the N. R. I. Tester, be sure to push this switch *OFF* in order to conserve battery life. Energy is drawn from the batteries whenever this switch is *ON*.

Step 67. With the tester still turned on, adjust the zero-correcting knob at the back of the meter until the pointer is at *O* on the *DC* scale (the scale directly above scale I_M), while tapping the top of the meter lightly with a finger to overcome bearing friction. *DON'T USE PLIERS* to turn the zero-correcting knob, because the pliers may touch meter terminal *15* and burn out both the tube and potentiometer.

Step 68. Remove the calibrating clip from battery terminal —9C, and place it on battery terminal —7½C (this calibrating clip is on the lead which goes to jack terminal *28*). Now adjust the 1,000-ohm potentiometer on the chassis (Part *2-7*) with a screwdriver while tapping the top of the meter lightly with a finger, until the meter pointer is at 1.5 on the *DC* scale.

Important: ALWAYS USE THE *DC* SCALE DURING CALIBRATION. The I_M scale is needed only when the meter is used by itself as it was in previous experiments; this I_M scale is no longer needed now that the meter is in the N. R. I. Tester circuit.

Step 69. Remove the clip from terminal —7½C and place it back on —9C. Readjust the zero-correcting knob at the back of the meter until the pointer is at *O* on the *DC* scale.

Step 70. Place the clip on terminal —7½C, and readjust the potentiometer until the meter pointer is at *1.5* on the *DC* scale.

Step 71. Continue this sequence of adjustments until you attain the desired condition whereby the meter pointer is at *O* when the clip is on terminal *—9C,* and the meter pointer is at *1.5* on the *DC* scale when the clip is on terminal *—7½C.* (Three repetitions of this procedure should give an accurate calibration.) This completes the calibration procedure, so your N. R. I. Tester is now ready for use.

Step 72. Place the clip permanently on the —9C terminal of the battery, turn off your completed and calibrated N. R. I. Tester by pushing the switch button downward to the position marked *OFF,* then place the tester aside until you receive further instructions for its use in Manual 3RK.

The meter pointer may drop *below zero* when you turn the tester off, but this action is unimportant and can be neglected. The pointer will move up to zero again when you turn on the tester and tap the panel.

SUPPLEMENTARY CALIBRATING INSTRUCTIONS

IMPORTANT: Read the following instructions carefully if you find it impossible to secure a satisfactory calibration of your tester (if you are unable to secure the desired condition described in Step 71). This supplementary procedure will allow you to compensate for a vacuum tube having a different emission than normal, and will permit recalibration when the batteries are partially exhausted.

Discussion: Although the manufacture of vacuum tubes is a highly developed art, it is nevertheless extremely difficult to make exactly identical tubes by mass production methods. The tubes which are made for the N. R. I. Tester are carefully processed and selected, but can still vary considerably in their characteristics. As a result, you may find that the tube which is sent you for use in your N. R. I. Tester will not permit the normal adjustments specified in Step 71. To be more specific, the tube which you receive may have higher cathode emission than normal, with the result that you will be unable to bring the meter reading *down to 1.5* on the *DC* scale by adjusting the potentiometer while the calibrating clip is on the *—7½C terminal.* This condition will occur only with a new battery, and is remedied by lowering the plate voltage on the tube temporarily in the manner described in the next step.

Step 73. To reduce the effective plate voltage by 1½ volts, connect the *B—* lead to *—A* instead of to *+1½A*. To do this, remove from the *+1½A* terminal the lead which goes to jack terminal *25*, and connect this lead to the *—A* terminal, so that there are now two leads on *—A* and only one lead on *+1½A*. After changing the wiring as instructed in this step, repeat the calibrating procedure set forth in Steps 68 to 72.

Remember that when the B battery in your A-B-C battery block ages sufficiently, it will drop in voltage and make it necessary for you to restore the original connection.

Discussion: As the B battery in your A-B-C battery block ages and its voltage drops, you will eventually reach the condition in which the plate voltage on the tube is too low to permit a calibration according to Step 71. In other words, you will find it impossible to bring the meter reading *up to 1.5* on the *DC* scale by adjusting the potentiometer. As a rule, this condition will not occur for several months if you follow the instructions given in later manuals for the use of the N. R. I. Tester and turn on the tester only while you are actually making measurements. The greatest hazard to battery life lies in leaving the tester turned on overnight or for several hours at a time when not using it.

Instead of buying a new A-B-C battery block when this condition occurs, you can lengthen the life of your present batteries by following the instructions in the next step.

Step 74. To increase the plate voltage in your N. R. I. Tester when it is impossible to bring the meter pointer up to 1.5 during calibration, it is suggested that you purchase a 7½-volt C battery (either a Burgess No. 5540 7½-volt C battery, or an Eveready No. 773 7½-volt C battery) and connect it in series with your existing B battery in the manner shown in Fig. *47*. This battery is thin enough so it can be slipped under the lace which holds the regular A-B-C battery block in position. It may be necessary to stretch the lace slightly to make this possible.

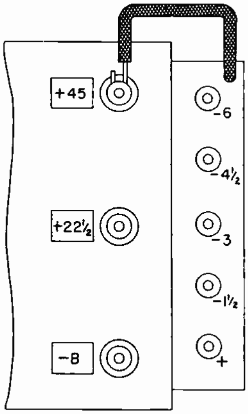


FIG. 47. Method of connecting an extra 7½-volt C battery to the B battery terminal of the special A-B-C battery block (or to the B battery itself if individual batteries are used) in order to compensate for a low B battery voltage.

Remove the wire which is now on the *+45* terminal of your battery, and connect this wire to the *—6* terminal of the extra C battery. Connect the flexible lead from the C battery (the —7½ lead) to the *+45* terminal on your B battery. This adds 1½ volts to the B supply voltage; if it is still impossible to bring the meter pointer up to 1.5 by adjusting the potentiometer, move the +B lead to the $-4\frac{1}{2}$ terminal so as to add 3 volts to the B supply voltage, and try the adjustment again.

As the B battery ages, it will be necessary to move this B+ lead closer and closer to the plus terminal on your C battery in order to make calibration possible. When it is no longer possible to bring the pointer up to 1.5 when the lead is on the +*C* terminal of the added battery, replacement of the entire A-B-C battery block is recommended. The added C battery can be saved for future use, for it will probably still be good when this condition occurs.

If you changed the position of the B— return lead in accordance with Step 73 when the A-B-C battery block was new, be sure to restore this lead to its original position before using the added C battery.

Remember that the calibration procedure outlined in Steps 68 through 72 must be followed each time the B supply voltage is changed.

Looking Forward

Now that you have built your N.R.I. Tester, you are undoubtedly anxious to begin making practical radio measurements. This desire will be realized very soon, for you will use various ranges of the N.R.I. Tester in each one of the next ten experiments. With this fine instrument and with the completely new assortment of radio parts furnished to you in Radio Kit 3RK, you will demonstrate to yourself the basic radio laws governing current and voltage values in both alternating current and direct current circuits.

NOTICE

If you write to N. R. I. regarding this tester, please refer to it as the *N. R. I. Tester for Experiments.*

WARNING

The N. R. I. Tester is a highly sensitive instrument, and can therefore be damaged by improper use. The tube and battery are particularly vulnerable to careless handling, so set your tester aside after completing its calibration, and wait until you receive detailed operating instructions in the next manual. Be sure to turn off the switch. Do not insert the test probes in the jacks.

IMPORTANT: Do not discard any of the parts supplied to you in N. R. I. radio kits until you have completed your course. The parts, wires, lugs, etc., which are left over after assembly of the N. R. I. Tester will be used again in later experiments.

Detach by Cutting Along This Line. Do Not Tear Off.

INSTRUCTIONS FOR PERFORMING RADIO EXPERIMENTS 21 TO 30

3 RK-1

NATIONAL RADIO INSTITUTE
ESTABLISHED 1914
WASHINGTON, D. C.

PIONEER HOME STUDY RADIO SCHOOL

A COURSE IN PRACTICAL DEMONSTRATIONS OF RADIO FUNDAMENTALS

THE UNKNOWN FUTURE OF RADIO

In the short period of approximately twenty years, radio has brought innumerable benefits to mankind. Continents have been drawn together, new cultural avenues have been opened up to rich and poor alike, entertainment has been brought to shut-ins, advertising methods have been revolutionized, and education of large audiences has been made possible.

But these are only a few of radio's achievements. Twenty-four hours a day in city or country, during hurricanes, floods and disasters on land or sea, radio brings help to those in distress. In the air, radio beam highways guide airplanes safely along their routes through storm, fog and darkness.

With 110,000,000 listeners and with hundreds of millions of dollars being spent yearly to provide programs, radio ranks first in American life. From breakfast to bedtime, broadcast band and short-wave stations alike pour forth entertainment, news, education and advertising, for all who own radio receivers and want to listen.

And yet today is only the beginning. Short-wave radio uses are expanding rapidly. Television, frequency modulation and electronic musical instruments are all taking on commercial status. Soon these and many more new services will be bringing even more startling marvels of sound and sight into American homes.

Yes, we have seen only the beginning of radio. Its unknown future for the years ahead is by far radio's greatest asset. And radio's future is *your future*.

J. E. SMITH.

Detach by Cutting Along ... Do Not Tear Off.

NATIONAL RADIO INSTITUTE

WASHINGTON, D.C.

1941 Edition

THIS EXPERIMENTAL MANUAL IS A PART OF THE N. R. I. COURSE WHICH TRAINS YOU TO BECOME A

RADIOTRICIAN & TELETRICIAN

(REGISTERED U. S. PATENT OFFICE) (REGISTERED U. S. PATENT OFFICE)

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Instructions for Performing Radio Experiments 21 to 30

Introduction

A PRACTICAL radio circuit consists of one or more sources of e.m.f. and one or more radio parts like resistors, coils and condensers. In every radio circuit, no matter how simple or how complex it may be, the distribution of voltages and currents is quite definite and is governed by three simple electrical laws. In the early lessons of your fundamental course, you learned that these three basic laws are: *1. Ohm's Law; 2. Kirchhoff's Current Law; 3. Kirchhoff's Voltage Law.*

To appreciate the actions which take place in a radio receiver, radio transmitter or other radio device, it is essential that you have a clear understanding of these three laws. In this manual, therefore, you will make a number of practical demonstrations which will illustrate each of these laws and convince you of their reliability.

The three basic electrical laws can be applied to any radio circuit whatsoever. With a.c. circuits, however, capacitive reactance and inductive reactance must be taken into account along with resistance. For this reason, it is convenient to use two forms of each law, one for d.c. circuits and the other for a.c. circuits. The laws are given below for reference purposes.

Ohm's Law for D.C. Circuits. **The current (I) flowing through a d.c. circuit is directly proportional to the voltage (E) acting in the circuit, and is inversely proportional * to the *resistance* (R) of the circuit. Formula: $I = E \div R$.**

Ohm's Law for A.C. Circuits. **The current (I) flowing through an a.c. circuit is directly proportional to the voltage (E) acting in the circuit, and is inversely proportional to the *impedance* (Z) of the circuit. Formula: $I = E \div Z$.**

Kirchhoff's Current Law for D.C. Circuits. **In any d.c. circuit, the *arithmetical* sum of the currents flowing to a point in the circuit is equal to the *arithmetical* sum of the currents flowing away from that point.**

Kirchhoff's Current Law for A.C. Circuits. **In any a.c. circuit, the *vector* sum of the currents flowing to a point in the circuit is equal to the *vector* sum of the currents flowing away from that point.**

Kirchhoff's Voltage Law for D.C. Circuits. **In any d.c. circuit, the *arithmetical* sum of the voltage sources acting in any one complete electron path is equal to the *arithmetical* sum of the voltage drops in that electron path.**

Kirchhoff's Voltage Law for A.C. Circuits. **In any a.c. circuit, the *vector* sum of the voltage sources acting in any one complete electron path is equal to the *vector* sum of the voltage drops in that electron path.**

Observe that the only difference between the d.c. and a.c. forms of Kirchhoff's two laws is the fact that we consider *arithmetical* sums in d.c. circuits (we add the voltage and current values together directly while taking their signs into account), while in a.c. circuits we must consider *vector* sums of the currents or voltages under consideration (we must consider phase relationships when combining the voltages or currents).

In d.c. circuits, resistance is the only thing which offers opposition to electron flow; voltage drops across resistors and currents through resistors are always in phase with each other, and hence voltage values or current values can be added or subtracted directly in d.c. circuits.

In a.c. circuits, we have inductive reactance and capacitive reactance

* Inversely proportional means that an *increase* in one quantity causes a corresponding proportional *decrease* in another quantity.

offering opposition to electron flow along with resistance, and consequently the currents in various parts of the circuit will have a definite *phase* relationship with each other. Likewise, the a.c. voltages under consideration will have a definite *phase* relationship with each other, making it necessary that we consider phase relationships by combining the values vectorially.

Purpose of Experiments in This Manual. Ohm's Law and Kirchhoff's Laws together constitute the foundation of all electrical and radio circuits. Without these three laws, engineers would be unable to design circuits or locate faults in circuits. Therefore, as a prospective Radiotrician you must have a clear understanding of how voltages and currents distribute themselves in circuits according to these laws. You must know, for example, what current changes are to be expected when a voltage, a resistance or a reactance is increased or decreased in value.

Complete failures of coils, condensers, resistors and circuit connections, as well as partial changes in the electrical values of these parts, are common everyday radio defects. Once you are familiar with the fundamental laws applying to radio circuits, you will be able to predict the effects which these failures will have upon circuits, and will therefore be able to locate defective parts very rapidly.

Briefly, then, the purpose of the next ten experiments (21 through 30) in your practical demonstration course is *to show you how Ohm's Law and Kirchhoff's Laws govern circuit behavior in radio equipment.* In these experiments, you will learn to use the N.R.I. Tester which you constructed after completing Experiment 20, and you will secure additional experience in reading schematic circuit diagrams.

Contents of Radio Kit 3RK-1

The parts included in your Radio Kit 3RK-1 are illustrated in Fig. *1*, and listed in the caption underneath. Check off on this list the parts which you receive, to be sure you have all of them. Do not destroy any of these parts until you have completed your entire N.R.I. course, for many of the parts will be used over and over again in later experiments.

IMPORTANT: If any part in your Radio Kit 3RK-1 is obviously defective or has been damaged during shipment, please return it to the Institute *immediately* for replacement.

INSTRUCTIONS FOR EACH EXPERIMENT

1. **Read the entire experiment, giving particular attention to the discussion.**
2. **Perform each step of the experiment and record your results.**
3. **Study the discussion and analyze your results.**
4. **Answer the report statement for the experiment. It will always be on the last page of the manual.**

EXPERIMENT 21

***Purpose:* 1. To show that d.c. voltage sources add when connected in series aiding; 2. To show that d.c. voltage sources subtract when connected in series bucking; 3. To show that d.c. voltage sources which are equal in value remain unchanged when connected in parallel.**

Step 1. To learn how to read the DC scale, study carefully the exact-size reproductions of this scale in Fig. *2,* where examples of readings for four different pointer positions are given. Observe that the scale reads from 0 to 4.5, with numerical values on the scale being read in much the same way as the values on scale I_M were read in previous experiments. When the pointer is directly on a numbered

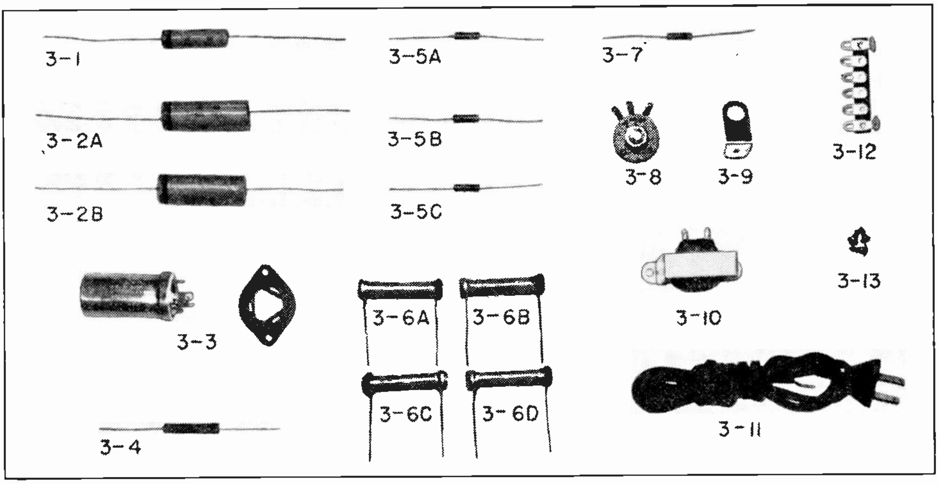


Fig. 1. The parts included in Radio Kit 3RK-1 are pictured above, and are identified in the list below. Some resistors may have a better tolerance (a lower percentage tolerance) than that indicated here.

Part No.	*Description*
3-1	One .05-mfd., 400-volt paper condenser.
3-2A	One .25-mfd., 400-volt paper condenser.
3-2B	One .25-mfd., 400-volt paper condenser. Same as Part *3-2A*.
3-3	One dual 10-10-mfd., 450 working volt electrolytic condenser with bakelite mounting piece.
3-4	One 200-ohm, 1-watt resistor with 10% tolerance (color-coded red, black, brown and silver).
3-5A	One 1,000-ohm, ½-watt resistor with 10% tolerance (color-coded brown, black, red and silver).
3-5B	One 1,000-ohm, ½-watt resistor with 10% tolerance (color-coded brown, black, red and silver).
3-5C	One 1,000-ohm, ½-watt resistor with 10% tolerance (color-coded brown, black, red and silver). Parts *3-5A*, *3-5B* and *3-5C* are identical.
3-6A	One 40,000-ohm, 3-watt resistor with 20% tolerance (color-coded yellow, black and orange).
3-6B	One 40,000-ohm, 3-watt resistor with 20% tolerance (color-coded yellow, black and orange).
3-6C	One 40,000-ohm, 3-watt resistor with 20% tolerance (color-coded yellow, black and orange).
3-6D	One 40,000-ohm, 3-watt resistor with 20% tolerance (color-coded yellow, black and orange). Parts *3-6A*, *3-6B*, *3-6C* and *3-6D* are identical.
3-7	One 1-megohm, ½-watt resistor with 10% tolerance (color-coded brown, black, green and silver).
3-8	One 1,000-ohm wire-wound potentiometer. (This is the same as Part 2-7.)
3-9	Mounting bracket for potentiometer.
3-10	One 10-henry choke coil with 25-ma. current rating.
3-11	One 5-foot power line cord with attached outlet plug. (Students who do not have power line facilities will use this cord for storage battery connections.)
3-12	One 6-lug terminal strip with four of the lugs insulated.
3-13	Three ⅜-inch No. 6 round-head wood screws.

You should have the following parts left over from Radio Kits 1RK and 2RK after you have performed the first twenty experiments and assembled the N.R.I. Tester.

Part No.	*Description*
1-1	One 55-watt electric soldering iron (or Part *1-1A*, a plain soldering iron).
1-2	One soldering iron holder.
1-3	Remainder of roll of rosin-core solder.
1-16	One 18,000-ohm, ½-watt resistor (color-coded brown, gray, orange and silver).
2-17	Remainder of roll of red push-back hook-up wire.
2-19A & 2-19B	Eight tinned copper strips, now mounted on the four 1.5-volt flashlight cells which you obtained yourself.
	Miscellaneous pieces of various types of hook-up wire, soldering lugs, and small amounts of plain solder, acid-core solder and paste flux.
	Assembled N.R.I. Tester with test leads.
	All tools which were specified in the previous experiments and which were to be obtained by you.

STEP	NATURE OF MEASUREMENT	YOUR VALUE IN VOLTS	N.R.I. VALUE IN VOLTS
3	VOLTAGE OF CELL A	1.5	1.5
	VOLTAGE OF CELL B	1.5	1.5
	VOLTAGE OF CELL C	1.5	1.5
	VOLTAGE OF CELL D	1.5	1.5
4	VOLTAGE OF CELL A	1.5	1.5
	VOLTAGE OF CELLS A+B	3.0	3.0
	VOLTAGE OF CELLS A+B+C	4.5	4.5
	VOLTAGE OF CELLS A+B+C+D	6.0	6.0
5	VOLTAGE OF CELLS A+B+C−D	3.0	3.0
	VOLTAGE OF CELLS B+C−D	1.5	1.5
	VOLTAGE OF CELLS C−D	0	0
6	VOLTAGE OF CELLS A+B−C−D	0 √	0 √
	VOLTAGE OF CELLS A+B−C	1.5 √	1.5 √
	VOLTAGE OF CELLS B−C	0 √	0 √
	VOLTAGE OF CELLS B−C−D	1.5 √	1.5 √
8	CELLS A,B,C AND D IN PARALLEL	1.5	1.5
9	CELLS A,B,C AND D IN SERIES-PARALLEL	3.0	3.0
10	CELLS A,B,C AND D IN SERIES-PARALLEL	3.0	3.0

TABLE 21. Record your results here for Experiment 21. The check mark (√) indicates that each of the readings obtained for Step 7 in the N.R.I. laboratory was the same as the corresponding reading for Step 6.

line, read the number above that line. When the pointer is on a short line between two numbered lines, read a value halfway between the values of the two adjacent numbered lines.

Step 2. Check the calibration of your N.R.I. Tester as instructed in the last section of Manual 2RK, and recalibrate if necessary. Be sure to remove both test leads from the jacks on the N.R.I. Tester panel during a check-up of calibration and during the recalibration procedure, and set the selector switch to *100×V* during calibration. Do not touch any terminals or leads behind the panel with your fingers during calibration, for body capacity, the resistance of the body (around 100,000 ohms), and hum voltage pick-up by the body can cause errors in calibration.

In the future, check the calibration of the N.R.I. Tester the first time you use the instrument each day. Additional checks can be made quickly at any time if you suspect an error in calibration.*

IMPORTANT: Overloading of the meter will appear to destroy the zero calibration of the N.R.I. Tester, but this is merely a temporary effect which will be corrected automatically if the next measurement you make will give nearly a full-scale reading. However, you can correct the calibration shift yourself by removing the calibrating clip from the −9C battery terminal, touching it momentarily to a terminal 4½ volts less negative

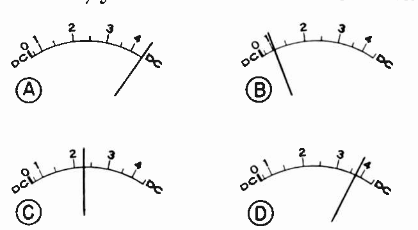


FIG. 2. Actual-size reproductions of the *DC* scale on the meter of the N.R.I. Tester, with examples showing how to read this scale at four different pointer positions. The readings are as follows: *A*—4.5; *B*—1.1; *C*—2.3; *D*—3.75.

* If you write to N.R.I. regarding this tester, please refer to it as the *N.R.I Tester for Experiments.*

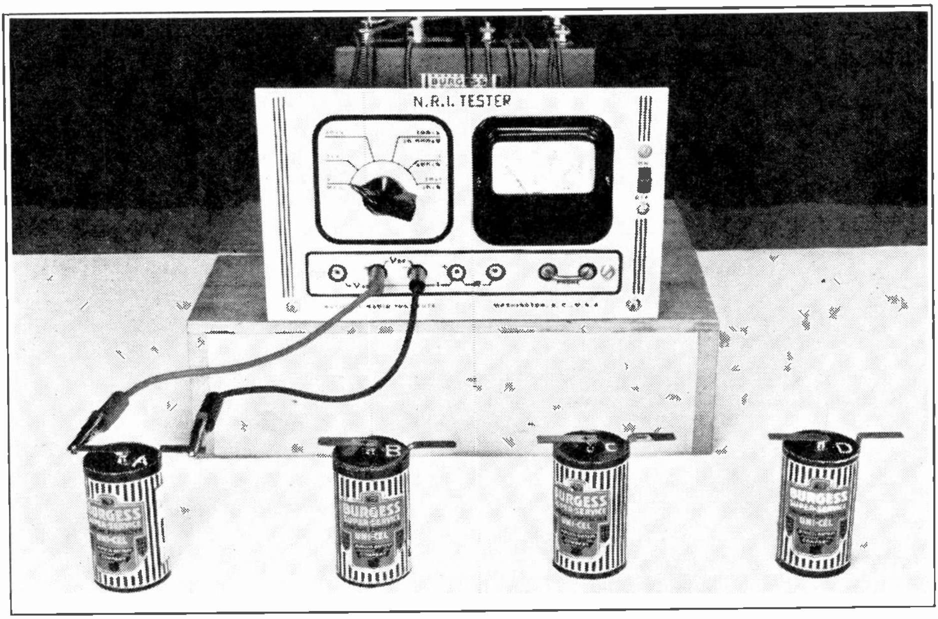


FIG. 3. Method of using the N.R.I. Tester to measure the voltages of individual dry cells. This set-up is used in Step 3 of Experiment 21. The test leads were shortened for this photograph in order to make them show more clearly, but *do not shorten your own test leads.* Placing the N.R.I. Tester on a box makes it easier to read the meter accurately.

(—4½C), then replacing the clip on its original terminal. This restores the iron vane in the meter to its normal non-magnetized state.

Step 3. Place before you the four flashlight cells on which you have previously placed terminal strips. Place before you also the N.R.I. Tester, with its panel and meter facing you. Plug the red probe into the $+V_{DC}$ jack, plug the black probe into the $-V_{DC}$ jack, and set the selector switch to V as shown in Fig. *3*, so that your N.R.I. Tester will serve as a 0 to 4.5-volt d.c. voltmeter and will read values in volts directly on the *DC* scale.

With your metal-marking crayon, mark your four cells *A*, *B*, *C* and *D* respectively, as shown in Fig. *3*.

Place the red clip on the + (center) terminal of cell *A*, place the black clip on the — terminal of this cell, turn on the N. R. I. Tester, read the meter on the *DC* scale, and record your result in Table *21* as the voltage of cell *A* in volts. In the same manner, measure the voltage of each of the other cells, and record their values in Table *21*.

> **WARNING**
>
> **Do not allow the alligator test clips to remain in contact with the panel or chassis of the N.R.I. Tester for any period of time, for this may short-circuit the C battery and drain it in a few minutes, even if the switch on the tester panel is *OFF*.**
>
> **Get the habit of pulling out the test probes whenever you put the N.R.I. Tester away or leave it for any reason, to prevent the clips from touching the chassis accidentally.**

Step 4. To measure the voltages of cells when connected in series-aiding, connect your four cells together in series-aiding exactly as shown in Fig. *4*, so that the — terminal of cell *A* goes to the + terminal of cell *B*, the — terminal of *B* goes to the + of *C*, and the — of C goes to the + of D. Since the cell terminals were previously tinned, simply overlap the terminals which are to be connected together, then apply the heated soldering iron to the uppermost terminal. Rotate

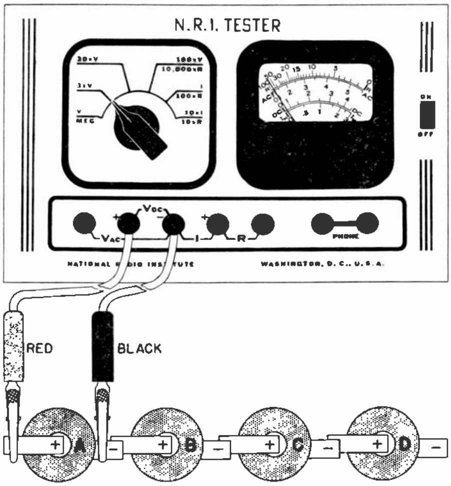


FIG. 4. This diagram illustrates how voltage measurements are made on a group of four flash-light cells connected in series-aiding for Step 4 of Experiment 21.

the selector switch one notch to the right, to setting $3 \times V$, without moving the probes. Your N. R. I. Tester is now serving as a 0 to 13.5-volt d.c. voltmeter, and you will have to multiply each reading on the *DC* scale by 3 to get the actual value of the voltage being measured.

Place the red clip on the + terminal of cell *A*, place the black clip on the — terminal of cell *A*, read the meter on the *DC* scale, multiply the reading by 3, and record the result in Table *21* as the voltage of cell *A*. (For reasons explained in the discussion, do not expect this reading to check exactly with the first reading taken in Step 3.)

Move the black clip to the — terminal of cell *B*, leave the red clip on the + terminal of cell *A*, read the meter on the *DC* scale, multiply the reading by *3*, and record your result as the voltage of cells $A + B$.

Place the black clip on the — terminal of cell *C*, read the meter on the *DC* scale, multiply the reading by 3, and record your result in Table *21* as the voltage of cells $A + B + C$.

Move the black clip to the — terminal of cell *D*, read the meter on the *DC* scale, multiply the reading by 3, and record your result in Table *21* as the voltage of cells $A + B + C + D$.

Step 5. To measure voltages when four cells are connected together in series with three aiding and one bucking, as shown in Fig. *5*, first disconnect cell *D* from the group. Now turn cell *D* around so that its — terminal is in contact with the — terminal of cell *C*, and solder these two terminals together. Place the red clip on the + terminal of cell *A*, place the black clip on the + terminal of cell *D*,

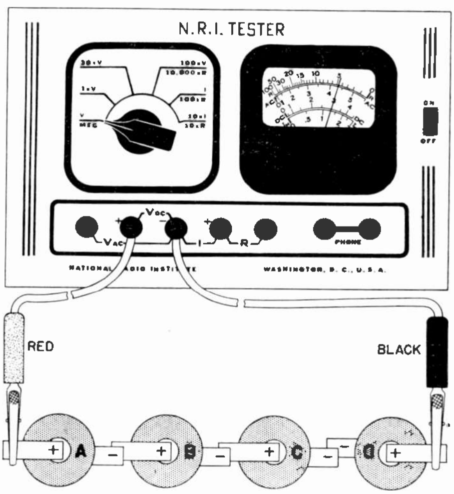


FIG. 5. Method of connecting four flashlight cells in series with three aiding and one bucking, with the *V* range of the N.R.I. Tester being used to check voltages. This measurement is made in Step 5 of Experiment 21.

change the selector switch to setting *V*, read the meter on the *DC* scale, and record this reading in Table *21* as the voltage of cells $A + B + C - D$.

Move the red clip to the — terminal of cell *A*, read the meter on the *DC* scale, and record your reading as the voltage of cells $B + C - D$.

Move the red clip to the $-$ terminal of cell B, read the meter on the DC scale, and record your reading as the voltage of cells $C - D$.

Step 6. To make voltage measurements on four cells connected in series, with two cells aiding and two cells

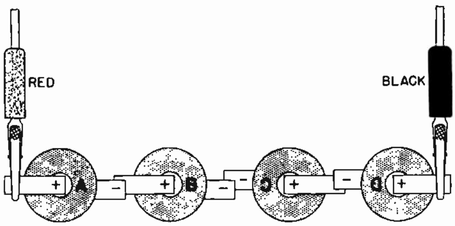


FIG. 6. Cell connections and test clip positions for Step 6 of Experiment 21.

bucking, unsolder the terminals of cell C from the others in this group, turn this cell around so that its $-$ terminal is on the $-$ terminal of cell B, then solder the cell terminals into position again as shown in Fig. *6*. Place the red clip on the $+$ terminal of A, place the black clip on the $+$ terminal of D, read the meter on the DC scale, and record your reading as the voltage of cells $A + B - C - D$.

Move the black clip to the $+$ terminal of cell C, read the meter, and record your result in Table *21* as the voltage of cells $A + B - C$.

Now move the red clip to the $+$ terminal of cell B, read the meter, and record your result as the voltage of cells $B - C$.

Move the black clip back to the $+$ terminal of cell D. The meter now reads backward, indicating improper polarity of connections, so reverse the positions of the red and black clips; in other words, place the black clip on the $-$ terminal of cell A, and place the red clip on the $+$ terminal of cell D. Read the meter and record your result in Table *21* as the voltage of cells $B - C - D$.

Step 7. Take a short length of red hook-up wire and connect the + terminal of cell B to the + terminal of cell C by means of temporary soldered lap joints. Take another length of hook-up wire and connect the $+$ terminal of cell A to the $+$ terminal of cell D by means of temporary soldered lap joints, as shown in Fig. *7*. If you notice a spark when making either of these connections, check the polarity of battery connections against the diagram in Fig. *7*. There should be no sparks if connections are made properly.

Now repeat each of the *measurements* called for in Step 6, to see if these two wire connections affect any of the voltage values. Make a small check mark after each of the readings for Step 6 in Table *21* which are still the same. Finally, remove the two wires and disconnect the four cells.

Step 8. To measure the voltage provided by four cells connected in parallel, first place the four flashlight

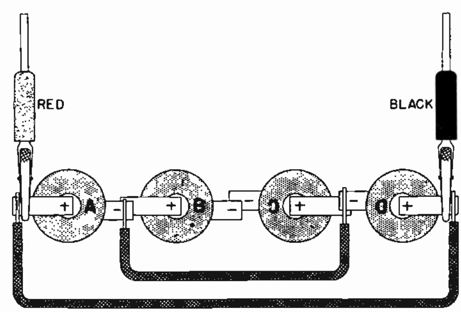


FIG. 7. Cell connections and test clip positions for Step 7 of Experiment 21.

cells side by side in the manner shown in Fig *8*. Cut a 6-inch length of hook-up wire and remove all insulation from it, then place this bare tinned copper wire over the $+$ terminals of the four cells as shown in Fig. *8*, and solder the wire to each terminal. In the same manner, take another 6-inch length of bare tinned copper wire and connect together the — terminals of the four cells. Place the red clip on any + terminal, place the black clip on any — terminal, and measure the voltage of these four cells in parallel with the *V* range of your N.R.I. Tester. Read the meter on the *DC* scale, and record your result in Table *21* as the voltage of four cells in parallel.

TOLERANCES OF RADIO PARTS

It is important to realize that any practical radio measurement will be affected by variations in the apparatus used in the circuit. When we calculate a value in mathematics, it is possible to obtain an answer that is so accurate it can be considered perfect. Measurements, on the other hand, depend upon the tolerances of parts, the characteristics of the measuring device and the ability to read scales closely.

Radio parts vary as much as 20% from the rated value in many cases, yet are considered satisfactory. (The standard tolerance is actually 20% in the case of resistors; thus, a resistor rated at 100 ohms may have any value from 80 ohms to 120 ohms.)

Therefore, do not expect to obtain exactly the calculated or N.R.I. values. You are using your own tester and parts, and the values of these parts can be quite different from the values of the parts used at N.R.I. without exceeding normal tolerances.

Obviously, there is little use in trying to make your readings extremely accurate, when radio parts are not exact in the first place. This is a practical fact, and you will find that the same condition exists in radio receivers and transmitters.

Step 9. To measure the voltage of parallel pairs of cells connected in series, cut each of the bare wires in Fig. *8* at its mid-point, then move down the cell groups including *C* and *D*, and connect the + terminal of *C* to the — terminal of *B* by means of a lap joint, as shown in Fig. *9*. Place the black clip on the — terminal of cell *D*, place the red clip on the + terminal of cell *A*, read the meter on the *DC* scale, and record your result as the voltage of four cells connected in series-parallel according to Fig. *9*. Now disconnect these four cells.

Step 10. To measure the voltage of four cells connected together in series-parallel, first connect cells *A* and *B* in series aiding, as shown in Fig. *10*. Next, connect cells *C* and *D* in series aiding also. Now connect these two series groups of cells in parallel in the manner shown in Fig. *10*, by using two 1½-inch lengths of bare tinned copper wire. (You can cut these lengths from the bare wire prepared for Steps 8 and 9.) Place the red clip on the + terminal of cell *A*, place the black clip on the — terminal of cell *B*, and read the meter on the *DC* scale. Record your result in Table *21* as the voltage of four cells connected in series-parallel.

Discussion: A dry cell delivers essentially 1.5 volts by itself when new. When the test leads of the N. R. I. Tester are plugged into the V_{DC} jacks, and the selector switch is set at position *V*, you can read the voltage of a dry cell directly in volts on the *DC* scale of the meter.

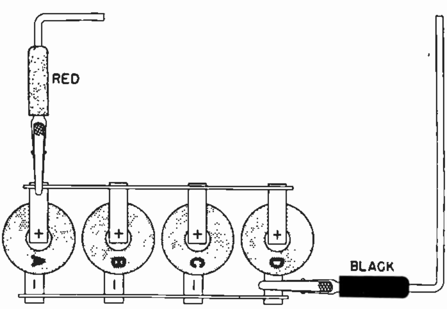


FIG. 8. Cell connections and test clip positions for Step 8 of Experiment 21.

There are four d.c. voltage ranges in all: *V*; *3×V*; *30×V*; *100×V*. In each case, you first read the meter on the *DC* scale, then multiply this reading by the factor indicated at the setting of the selector switch. Thus, when you place the selector switch at the *3×V* setting for one step in this experiment, you must read the meter on the *DC* scale, and multiply the value by 3 to get the actual voltage in volts.

This system for securing a number of different voltage ranges with only

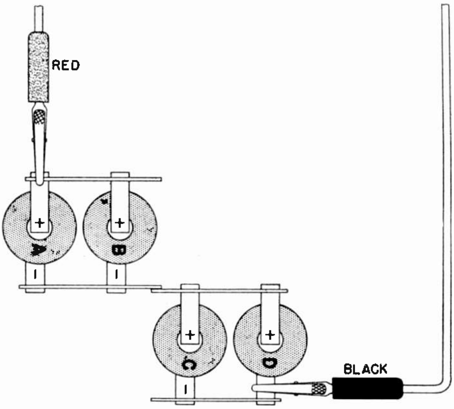


FIG. 9. Cell connections and test clip positions for Step 9 of Experiment 21, in which two parallel-connected pairs of dry cells are connected in series.

one meter is identical with that employed in the professional multimeters used by radio servicemen and radio engineers. After using an instrument a few times, these men find themselves able to multiply meter readings by the correct factors mentally and secure voltage values for the higher ranges almost as readily as when using a direct-reading range.

In the case of ranges which have multiplying factors of 10, 100, 1,000 or 10,000, it is a simple matter to add the indicated number of zeros to the meter reading. When the multiplying factor is 3 or 30, actual multiplication is required.

A good habit to form is that of turning the N. R. I. Tester on only while you are actually reading the meter. If you keep the power switch *OFF* during the preliminary set-ups and in between experiments, you will greatly increase the useful life of the batteries in the N. R. I. Tester.

In Step 3, you measure the voltage of each of the four flashlight cells with the N. R. I. Tester connected as a 0-4.5-volt d.c. voltmeter. Under this condition, your instrument has a sensitivity of 2,233,000 ohms-per-volt, which is exceptionally good for a d.c. voltmeter. If the four flashlight cells are new and all have the same dates stamped on them, they should all have essentially the same terminal voltages.

In Step 4, you use the *3×V* range for the first time, with your N. R. I. Tester serving as a 0-13.5-volt d.c. voltmeter under this condition. This means that you must multiply the reading on the *DC* scale by 3 to get the actual voltage each time. Naturally, you cannot read the voltage of a single cell as accurately with this range as you could with the *V* range, so do not expect your first reading to check too closely with the readings in Step 3.

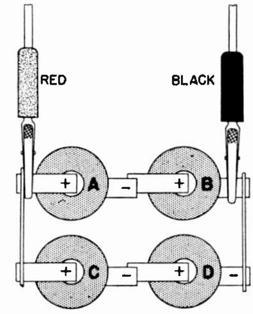


FIG. 10. Cell connections and test clip positions for Step 10 of Experiment 21, in which two series-connected pairs of dry cells are connected in parallel.

In Step 4, you connect the four cells in series-aiding, which means that unlike terminals of adjacent cells are connected together (— to +). Careful study of the voltage values which you obtained should indicate that the voltages of the individual cells add together when the cells are connected in series-aiding.

When connections to one of the cells are reversed as in Step 5, this cell is actually bucking the voltage of one of the other cells. Cells *C* and *D* in Fig. *5* can thus be considered to buck each other, so that there is essentially zero voltage between the positive terminals of these cells. As a result, voltage measurement across all four cells as shown in Fig. *5* should indicate the same voltage you obtained previously for cells *A* and *B* connected in series aiding. Likewise, when you connect the red clip to the + terminal of cell *B*, you should measure only the voltage of cell *B*. When the red clip is on the + terminal of cell *C*, the reading should be zero because these two cells buck each other.

When four cells are connected in series according to Step 6, so that cells *C* and *D* are connected with opposite polarity to that of cells *A* and *B*, we have the condition where one group of two series-connected cells is bucking the other group of two series-connected cells. As a result, the voltage across the group of four cells should be essentially zero for the measurement shown in Fig. *6*.

The additional measurements which you make in Step 6 should show you clearly how the voltages of cells in series add or subtract according to the polarity of their connections.

When an unequal number of cells are connected in a series-bucking arrangement, the polarity of the combination will be determined by the polarity of the greater voltage value. In other words, with three cells connected so that one bucks the other two, the polarity of the combination will be the polarity of the two cells which are identically connected. This holds true if the two identically connected cells are separated by the bucking third cell.

Step 7 illustrates clearly the fundamental fact that terminals which are at the same potential (zero voltage between them) can be connected together without affecting circuit conditions. You found in Step 6 that the + terminals of cells *A* and *D* were at zero potential with respect to each other, so in Step 7 you connect these two terminals together with a wire. You found also that the + terminals of cells *B* and *C* were alike in potential, so you connected these two together with another wire. It should be pointed out, however, that the + terminals of *B* and *C* are *not* at the same potential as the + terminals of *A* and *D*. In other words, a measurement between these two pairs of terminals would indicate a voltage, and this would be the voltage of cell *A*.

In your fundamental course, you learned that when identical voltage sources are connected together in parallel, the resultant voltage of the combination is the same as the voltage of an individual cell. In Step 8, you connect four identical cells in parallel and prove this fact for yourself. The voltage which you obtain for this step should be the same as the voltage for an individual cell.

Cells are connected in parallel when more current is required than can be supplied by a single cell. Four cells are capable of delivering four times as much current as one cell. This means that four cells in parallel will last essentially four times as long as one cell when used in a given circuit. Actually, the 1.5-volt A battery in your N.R.I. Tester contains four small cells connected in parallel.

When you divide the parallel group of four cells into two equal groups in Step 9, each group has a voltage of essentially 1.5 volts. When these groups are connected in series-aiding, you should obtain a voltage equal to that of two cells. With this series-parallel combination, you have a 3-volt battery which is capable of delivering twice the amount of current obtainable from two cells in series.

In Step 10, you set up another type of series-parallel circuit, and find that this gives exactly the same voltage as the circuit of Fig. *9*. Actually, these two series-parallel circuits have exactly the same characteristics, and would be identically the same electrically if the — terminals of cells *A* and *C* are connected together. These terminals are at the same potential, and hence the connection will not affect circuit conditions. Series-parallel circuits are used when both higher current and higher voltage are required than can be supplied by a single cell.

Practical Extra Information. Although the various steps in this experiment are relatively simple and easy to perform, they are of great practical importance. Dry cells connected in series, in parallel, and in various series-parallel combinations are used extensively in radio work.

The dry batteries used for portable radio receivers are a typical example; all of the voltages required for these sets are obtained from combinations of standard 1.5-volt dry cells. The plate circuits of these receivers require high voltages but low currents, and these are provided by large numbers of small 1.5-volt cells connected in series. The grid circuits have even lower current and voltage demands, and consequently the C batteries are also made up of small cells in series. The filament battery, on the other hand, must supply a low voltage but fairly high current, and usually you will find four dry cells connected in parallel for this purpose. A standard 45-volt B battery is made up of thirty 1.5-volt dry cells connected in series.

Dry cells are seldom connected in series-bucking in commercial radio equipment, but this connection is often utilized for experimental work. For example, if you required a voltage of 39 volts but had only a 45-volt B battery and four flashlight cells available, you could connect the four flashlight cells in series to give 6 volts, then connect this 6-volt battery in series-bucking with the 45-volt battery, so that the resulting voltage would be 45 — 6, or 39 volts.

Although we used dry cells as d.c. voltage sources in this experiment, the various rules and laws which were demonstrated will apply also to other d.c. voltage sources, such as d.c. generators.

Instructions for Report Statement No. 21. In the discussion of Step 9, it was pointed out that the series-parallel circuit shown in Fig. *10* had exactly the same characteristics as the series-parallel circuit of Fig. *9*; furthermore, you learned that these two circuits could be made the same *electrically* by connecting the minus terminals of Cells *A* and *C* together. (Any two points in a circuit can be connected together without affecting circuit conditions if the potential difference between those two points is zero.)

For this report statement, you are asked to prove that the — terminals of cells *A* and *C* in Fig. *10* are at the same potential. Do this by connecting the cells as shown in Fig. *10*, then place the red clip on the — terminal of cell *A*, and place the black clip on the — terminal of cell *C*. Measure the voltage between these points with the *V* range of the N. R. I. Tester, turn to the last page and make a check mark in Report Statement No. 21 after the voltage value which you obtained.

EXPERIMENT 22

***Purpose:* To demonstrate that Kirchhoff's Voltage Law holds true in a simple d.c. circuit.**

Step 1. Set up a simple series circuit consisting of four 1.5-volt dry cells and three 1,000-ohm resistors, as shown in Fig. *11A.*

The actual arrangement of these parts can be as shown in Fig. *11B,* in which the four flashlight cells are connected in series aiding. Connect resistor R_1 to the — terminal of cell D by means of a soldered lap joint. Connect resistors R_1, R_2 and R_3 together by means of temporary soldered hook joints.

Connect the right-hand terminal of R_3 to the + terminal of cell A with a suitable length of red hook-up wire, using a lap joint on the cell terminal and a soldered hook joint on the resistor lead. Set the N. R. I. Tester to measure d.c. voltages on the V range (set the selector switch to V, plug the red probe into the $+V_{DC}$ jack, and plug the black probe into the $-V_{DC}$ jack).

To prove Kirchhoff's Voltage Law, you will now measure the voltage across each part in this simple d.c. circuit, by starting with cell A and moving from part to part in the direction of electron flow. (Since electrons flow out of the — terminal of a voltage source, they will flow from the — terminal of A to the + terminal of B and continue in this direction through the circuit, as indicated by the arrows in the schematic diagram of Fig. *11A.*)

To prove Kirchhoff's Voltage Law, we must arbitrarily assume that a voltage having a given polarity (direction) in the circuit under consideration is a + value, and that a voltage having the opposite polarity is a — value. For the circuit of Fig. *11A,* we will assume that voltages having the same polarity as the dry cells are + values.

Place the red clip on the + terminal of cell A, and place the black clip on the — terminal of cell A, as shown in Fig. *11B.* Read the meter on the *DC* scale and record the value in Table *22* as the voltage of cell A. Place a + sign ahead of this value.

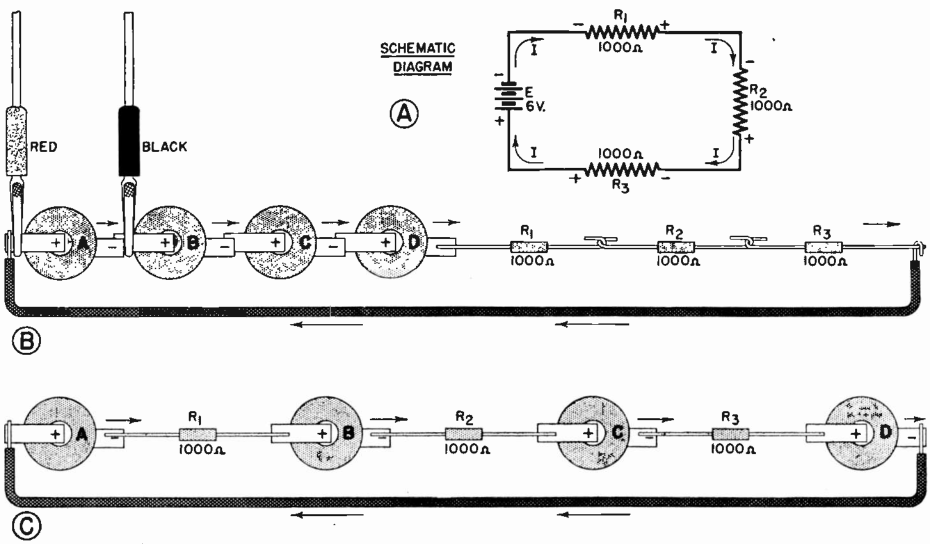


FIG. 11. Semi-pictorial and schematic circuit diagrams for Experiment 22. Arrows indicate the direction of electron flow in each case.

Now remove both clips at once, and move the clips to the terminals of the next part (cell *B*) without changing their relative positions. If an up-scale reading is secured, record it as a + value; if the meter reads backward, reverse the positions of the clips and record the reading as a — value. Remember that all other readings obtained with this reversed position of the clips must be recorded as negative values.

Here is another guide for determining the sign of a measured value in this circuit. Use a + sign when the black clip is ahead as you move in the direction of electron flow, and use a — sign when the red clip is ahead.

Move the red and black clips together around the circuit in the direction of electron flow until you have measured the voltage across each part and recorded it in Table *22*. Now, add together the + values first, then add together all the — values. The total of + values should be essentially equal to the total of — values if Kirchhoff's Voltage Law holds true for this d.c. circuit (they will seldom be exactly equal because all readings taken with meters are subject to normal variations).

Step 2. To show that Kirchhoff's Voltage Law holds true regardless of the positions of the resistors and cells in a simple d.c. circuit, rearrange your resistors and cells in the manner shown in Fig. *11C*. Following the same procedure outlined in Step 1, measure the voltage across each part in the circuit and record its value in the spaces provided for this purpose in Table *22*. When you have done this, break the circuit by unsoldering the red wire from the — terminal of cell *D*.

Add your measured values as described in Step 1 to check the accuracy of Kirchhoff's Voltage Law. Remember that natural inaccuracies in measuring and reading make an exact check almost impossible.

Dry cells are supplying energy whenever connected into a complete circuit. Therefore, if you stop making measurements for study purposes or any other reason while working with batteries, always break the circuit by unsoldering a lead from one cell terminal. You can easily reconnect this lead when you are ready to begin measurements again.

Discussion: In this experiment, you learned for yourself the exact nature of a voltage drop across a resistor. You know that the same current is flowing through all parts of your simple series circuit when it is completed. This flow of electrons through a resistor develops across the resistor a voltage, with the value of the voltage being determined by Ohm's Law (voltage = current × resistance).

Because your N. R. I. Tester is a

STEP 1			STEP 2		
PART BEING MEASURED	YOUR VOLTAGE IN VOLTS	N.R.I. VOLTAGE IN VOLTS	PART BEING MEASURED	YOUR VOLTAGE IN VOLTS	N.R.I. VOLTAGE IN VOLTS
A	+1.5	+1.5	A	+1.5	+1.5
B	+1.5	+1.5	R_1	-2.0	-2.0
C	+1.5	+1.5	B	+1.5	+1.5
D	+1.5	+1.5	R_2	-2.0	-2.0
R_1	-2.0	-2.0	C	+1.5	+1.5
R_2	-2.0	-2.0	R_3	-2.0	-2.1
R_3	-2.0	-2.1	D	+1.5	+1.5

TABLE 22. Record your results here for Experiment 22.

polarity-indicating device when connected as a d.c. voltmeter, you are able to determine the polarity of each voltage measured in this series circuit. In other words, whenever you secure an up-scale reading on the voltmeter, you know that the red clip of your meter is connected to the + terminal of the part whose voltage you are measuring.

One thing you should realize from this experiment is that a voltage drop produced across a part by the flow of current through it always has opposite polarity to that of the voltage source which is forcing that current through the circuit.

In Step 1, you find that each dry cell provides essentially 1.5 volts, with all four dry cells having the same polarity. This means that you have a voltage source of 6 volts in your circuit. Measurement of the individual voltages across the resistors shows a voltage of essentially 2 volts across each resistor. The resistors all have the same polarity, and this is opposite to the polarity of the dry cells. The three resistors thus have a combined voltage drop of essentially 6 volts, which is equal to the combined voltage of your source. If your results agree fairly closely with these values, you have proved the accuracy of Kirchhoff's Voltage Law for a d.c. circuit.

This experiment also allows you to determine for yourself the direction in which electrons flow through a resistor. You know the direction in which electrons flow in this complete circuit, for you learned in your fundamental course that electrons always come out the — terminal of a voltage source, and flow through the circuit toward the + terminal of the source. Since you know the direction of electron flow in your circuit and since you know the polarity of each voltage drop through your measurements (this polarity is as indicated in the schematic diagram in Fig. *11A*), you arrive at the basic radio fact that *the resistor terminal at which electrons enter is negative,* and *the resistor terminal which electrons leave is positive.*

Thus, if you know the polarity of the voltage drop across a resistor, you can immediately specify the direction in which electrons are flowing through that resistor. Conversely, if you know the direction in which electrons are flowing through a resistor, you can specify the polarity of the voltage drop developed across that resistor.

Resistor values of 1,000 ohms were chosen for this experiment because this particular value allows you to determine the current flowing through the resistor without going to the trouble of making a current measurement. It so happens that the current value in milliamperes flowing through a 1,000-ohm resistor is exactly equal to the voltage in volts across that resistor. This means that if you measure a voltage drop of 2 volts across 1,000-ohm resistor R_1, you have a current of 2 ma. flowing through that resistor. This relationship beteen current and voltage holds true only for a 1,000-ohm resistor, as you can readily verify by means of Ohm's Law.*

Step 2 verifies Kirchhoff's Voltage Law in much the same manner as does Step 1, and also demonstrates in a convincing manner the basic fact that in a series circuit, the current through the circuit and the voltage across individual parts in the circuit remain

---

* $E = I \times R$; when R is in ohms and E is in volts, I is in amperes in this equation. Dividing current in milliamperes by 1,000 gives current in amperes, so we can say that $E = \frac{I_{ma}}{1{,}000} \times R$; since R is 1,000, the formula becomes $E = \frac{I_{ma}}{1{,}000} \times 1{,}000$. Cancelling now gives $E = I_{ma}$.

exactly the same regardless of the positions of the parts in the circuit.

Once you understand clearly the simple basic facts presented in this experiment, and realize that Kirchhoff's Voltage Law must hold true for any simple d.c. series circuit, you will have taken a tremendous step toward complete mastery of fundamental radio principles.

Instructions for Report Statement No. 22. You learned in this experiment and in your regular course that the sum of the voltage sources acting in any given circuit must equal the sum of the voltage drops in that cir-

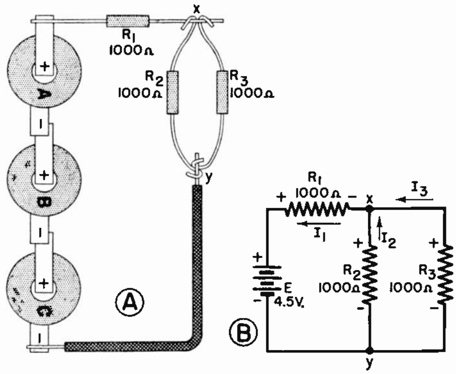


FIG. 12. Semi-pictorial and schematic circuit diagrams for Experiment 23.

cuit, according to Kirchhoff's Voltage Law. Under this condition, the voltage which you would measure between any two points in a circuit would be the difference between the voltage source values and the voltage drop values existing between these two points. For this report statement, you will make a measurement which proves the preceding statement.

Reconnect the red lead to the — terminal of Cell *D* in Fig. *11C*, then use your N. R. I. Tester to measure the voltage between the + terminal of cell *A* and the — terminal of cell *B*. To make this measurement, place the red clip of the N. R. I. Tester on the + terminal of cell *A*, and place the black clip on the — terminal of cell *B*. After measuring the voltage between these two points, turn to the last page and place a check mark after the voltage value which is closest to that which you measured.

Finally, turn off the N. R. I. Tester, then disconnect your circuit (Fig. *11C*) completely by unsoldering the resistors and the length of red hook-up wire.

EXPERIMENT 23

***Purpose:* To demonstrate that Kirchhoff's Voltage and Current Laws hold true for a complex d.c. circuit having a single voltage source.**

Step 1. After checking the calibration of your N. R. I. Tester (this is necessary only if this is the first experiment you are doing today), *set up the complex d.c. circuit shown in Figs. 12A and 12B,* by first connecting flashlight cells *A*, *B* and *C* in series aiding.

Connect one lead of resistor R_1 to the + terminal of cell *A* by means of a soldered lap joint. Connect a length of red hook-up wire to the — terminal of cell *C* with a soldered lap joint. Bend a hook in each end of the other two 1,000-ohm resistors (R_2 and R_3), then connect these two resistors in parallel between the free end of the hook-up wire and the free lead of R_1 with temporary soldered hook joints, as shown in Fig *12A*.

To prove that Kirchhoff's Voltage Law holds true for the closed circuit consisting of voltage source *E*, resistor R_1 and resistor R_2 in Fig. *12B*, use the N. R. I. Tester as a 0-4.5-volt d.c. voltmeter (the *V* range) to measure the voltage across each part of this closed circuit. Do this by measuring the source voltage first; place the red clip on the + terminal of *A*, place the black clip on the — terminal of *C*, read the meter, and record your result in Table *23*.

Now move your two test clips together around this circuit in the direction of electron flow. This means that you will next measure the voltage across R_2, by placing the black clip on its upper lead (at point x), and placing the red clip on its lower lead. Naturally, this makes the meter read down-scale since the voltage across R_2 is a voltage drop; therefore, reverse the positions of the test clips, read the meter, and record your result with a — sign ahead of it in the proper space in Table *23*.

Measure the voltage drop across R_1 and record its value in Table *23*.

Finally, measure the voltage drop across resistor R_3 and record its value in Table *23*, then unsolder joint y (Fig. *12A*) so as to prepare for the next experiment and at the same time open the circuit.

Since the voltage value measured across a 1,000-ohm resistor corresponds to the current value in ma. through the resistor, you will not have to record current values separately.

Discussion: The measurements which you make in this experiment will verify both of Kirchhoff's Laws for d.c. circuits. Let us first consider the voltage law.

The 4.5-volt voltage source, resistor R_1 and resistor R_2 form one complete circuit. If the measured value of the source voltage is essentially equal to the sum of the voltage drops across R_1 and R_2, you have confirmed Kirchhoff's Voltage Law for this circuit.

The other complete circuit around which Kirchhoff's Law should hold true is that consisting of E, R_3 and R_1. Add together arithmetically the values which you obtained for these resistors; if they add up to the source voltage, you have performed the experiment correctly.

Kirchhoff's Current Law says that the currents flowing to a given point in a circuit must be equal to the currents flowing away from that point. In other words, currents I_2 and I_3 in Fig. *12B* should add up to the value of current I_1. (The arrows on this diagram indicate the direction of electron flow; current flow is considered to be in the opposite direction. Either electron flow or current flow can be employed, provided you use the same one all through a series of calculations.)

NATURE OF MEASUREMENT	YOUR VOLTAGE IN VOLTS	N.R.I. VOLTAGE IN VOLTS
VOLTAGE ACROSS SOURCE	+ 4.5	+4.5
VOLTAGE ACROSS R_2 (SAME AS I_2 IN MA.)	−1.5	-1.5
VOLTAGE ACROSS R_1 (SAME AS I_1 IN MA.)	−3.0	-3.0
VOLTAGE ACROSS R_3 (SAME AS I_3 IN MA.)	−1.5	-1.5

TABLE 23. Record your results here for Experiment 23.

If the value which you obtained by adding currents I_2 and I_3 is essentially equal to current I_1, you have verified Kirchhoff's Current Law. Thus, adding N. R. I. values of 1.5 and 1.5 for I_2 and I_3 gives 3.0 ma., which is the same as the recorded N. R. I. value of 3.0 for I_1.

Note that the same voltage drops were measured across R_2 and R_3; this proves conclusively that parts connected in parallel all have the same voltage across them.

Instructions for Report Statement No. 23. Radio men sometimes find it necessary to measure the voltage of a source having terminals which cannot be reached conveniently without disconnecting a lot of apparatus. Sometimes it is a physical impossibility to measure the source voltage at its source; measurement of the induced voltage in a transformer is one example. In a situation like this, the practical radio man will break the circuit at some point and measure the voltage between the terminals thus provided. The voltage measured in this manner will be essentially equal to the source voltage if the voltmeter resistance is many times higher than any resistance in the circuit under consideration, and this condition is almost always true when using a vacuum tube voltmeter such as the N. R. I. Tester.

For this experiment, you will duplicate a practical voltage measurement like this by placing the black clip of the N. R. I. Tester on the red lead which you unsoldered from joint y in Fig. *12*, placing the red clip on either one or both of the resistor leads which formerly went to joint y, and measuring the voltage with the V range of the N. R. I. Tester. After doing this, turn to the last page and make a check mark after the voltage value which is closest to that which you measured.

EXPERIMENT 24

***Purpose:* To demonstrate that Kirchhoff's Voltage and Current Laws hold true in a circuit which has more than one source of e.m.f.**

Step 1. Starting with the circuit of Fig. 12A, insert 1.5-volt dry cell D in series with resistor R_3 in such a manner that your set-up now appears as shown in Fig. *13A*. The schematic circuit will now have the form shown in Fig. *13B*, with the + terminal of E_1 (dry cell D) going to one lead of R_3, and with the — terminal of this cell going to the — terminal of cell C.

Considering first the closed circuit consisting of E, R_1 and R_2, move completely around this circuit with your 0-4.5-volt d.c. voltmeter and measure the voltage across each part. Remember that when recording the voltage values in Table *24*, you are to place a + sign ahead of any value having the same polarity as battery E, and a — sign whenever a voltage has the opposite polarity. The set-up for measuring the voltage across R_1 is shown in Fig. *13C*.

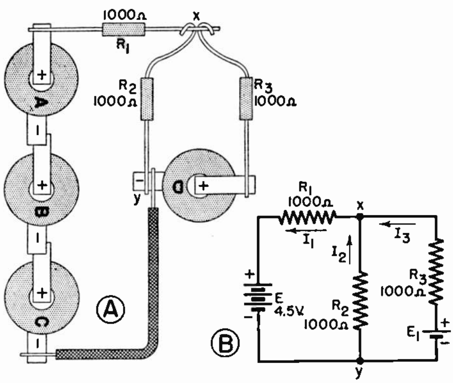


FIG. 13. Semi-pictorial and schematic circuit diagrams for Experiment 24.

Considering next the closed circuit consisting of E, E_1, R_3 and R_1, measure the voltage across each part in the same manner, and record in Table *24* the voltages measured for E_1 and R_3. You will find that the voltage across E_1 is opposite in polarity to that of E, and you will therefore have to place a — sign ahead of the measured value for E_1. You do not have to record the voltages for E and R_1 again, since you have already measured these.

Step 2. To check Kirchhoff's Voltage Law for the closed circuit consisting of E_1, R_3 and R_2, measure the voltage across each part while moving in the same direction around the circuit, giving a + sign to voltages having the polarity of E_1. Record your measured values on the last three lines in Table *24*.

Now unsolder the two leads from the — terminal of cell *D* (Fig. *13A*) and separate these leads, so as to prevent the dry cells from discharging.

Discussion: In each of the three complete circuits in which you made measurements for Steps 1 and 2, the source voltage (the sum of the source voltages in circuit E - E_1 - R_3 - R_1) should be approximately equal to the voltage drops when + and — signs are taken into account, for Kirchhoff's Voltage Laws hold true.

Thus, in circuit E - R_1 - R_2, the N. R. I. source value of +4.5 is equal to the sum of —2.5 and —2.0.

In circuit E-R_1-R_3-E_1, the source voltages of +4.5 and —1.5 buck each other, leaving a source voltage of 3 volts in this circuit, which is equal to the sum of the —2.5 and —.5 volt voltage drops.

In circuit E_1-R_3-R_2, the source voltage of +1.5 volts is equal to the algebraic sum (the numerical difference) of +.5 and —2.0, which is —1.5 volts. These values indicate that resistor R_2 is actually transferring into circuit E_1-R_3-R_2 a portion of the larger voltage source E, and cell E_1 is bucking out part of this voltage available across R_2. The difference, or .5 volts, appears across and sends current through R_3.

Before you can apply Kirchhoff's Current Law, you must determine the direction of electron flow through each resistor. You can do this very easily if you mark the polarity of each resistor on the schematic circuit diagram in Fig. *13B*. Do this as you make each voltage measurement. The direction of electron flow will then be from — to + through each resistor. You should find that the directions are as indicated by the arrows in Fig. *13B*. This means that currents I_2 *and* I_3 are flowing toward point x, and current I_1 is flowing away from this point. If the sum of I_2 and I_3 is essentially equal to I_1, you know that currents flowing to this point are equal to currents flowing away from the point, and you have proved Kirchhoff's Current Law.

Since 1000-ohm resistors are used, the current in ma. through a resistor will be the same as the voltage in volts across that resistor. Adding the N. R. I. values of 2.0 and .5 for I_2 and I_3 gives 2.5 ma., which is equal to the N. R. I. value of 2.5 ma. for I_1, thus verifying Kirchhoff's Current Law.

STEP	NATURE OF MEASUREMENT	YOUR VOLTAGE IN VOLTS	N.R.I. VOLTAGE IN VOLTS
1	VOLTAGE ACROSS E	+ 4.5	+4.5
	VOLTAGE ACROSS R_1 (SAME AS I_1 IN MA.)	-2.5	-2.5
	VOLTAGE ACROSS R_2 (SAME AS I_2 IN MA.)	- 2.0	-2.0
	VOLTAGE ACROSS R_3 (SAME AS I_3 IN MA.)	- .5	-.5
	VOLTAGE ACROSS E_1	- 1.5	-1.5
2	VOLTAGE ACROSS E_1	+ 1.5	+1.5
	VOLTAGE ACROSS R_3	+ .5	+.5
	VOLTAGE ACROSS R_2	-2.0	-2.0

TABLE 24. Record your results here for Experiment 24.

Practical Extra Information. The voltage drop produced by the flow of current through a resistor is widely used in radio. Perhaps the most common example is that of the cathode resistor in a vacuum tube circuit; the flow of plate-cathode current through this resistor develops across the resistor a voltage drop which is usually made to serve as the C bias voltage for the tube. Voltage drops across resistors are also used for automatic volume control purposes, for frequency-correcting purposes, for preventing undesirable oscillation, for protection against overloads, and for many similar purposes which will be studied in detail in the experiments which follow and in your regular course.

A voltage drop across a resistor is sometimes considered as a secondary source of

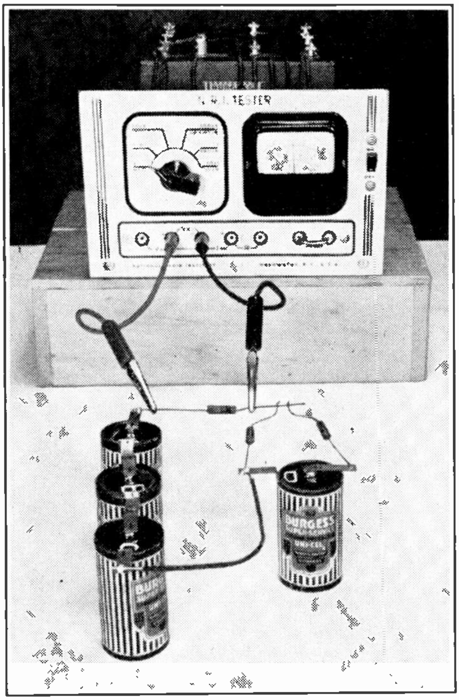


FIG. 13C. This photographic illustration shows the parts connected for Step 1 of Experiment 24, with the N.R.I. Tester connected to measure the voltage across R_1.

voltage when used in many of the applications just mentioned. Actually, the resistor in question is not a true voltage source, but is merely transferring a true source voltage (produced by a dry cell or power pack) from one circuit to another.

A knowledge of how voltages are distributed among resistors in a circuit will help considerably when you begin searching for troubles in radio circuits.

Instructions for Report Statement No. 24. If you reverse the polarity of either of the voltage sources employed in the circuit of Fig. *13*, circuit conditions will change.

For Report Statement No. 24, you will prove this by reversing the connections of cell D in Fig. *13* in the following manner: Unsolder the lead of R_3 from the + terminal of cell D. Turn the cell around, and solder the free lead of R_3 to the — terminal of this cell. Solder the red wire and the free lead of R_2 to the + terminal of cell D. You should now have the circuit of Fig. *13A* with the terminals of cell D reversed. After doing this, measure the voltage across R_3 with the N. R. I. Tester, and compare your measured value with that obtained across R_3 in Step 1. (When comparing these voltages, consider only the voltage values, without regard for + and — signs.) Now turn to the last page and check the answer which describes your result.

EXPERIMENT 25

***Purpose:* To demonstrate that a definite period of time is required to charge or discharge a condenser through a resistance.**

Step 1. To charge a .5-mfd. capacity through a 10-megohm resistance, first connect the two .25-mfd. tubular paper condensers (Parts *3-2A* and *3-2B*) in parallel to secure a combined capacity of .5 mfd., using temporary soldered connections in the manner shown in Fig. *14*. Now bend the condenser leads so that they can readily be inserted in the two R jacks on the N. R. I. Tester panel. Set the selector switch at V, turn on the N. R. I. Tester, and insert the .5-mfd. capacity into the R jacks while watching the meter. The schematic circuit for this set-up appears in Fig. *16A*. The pointer should rise rapidly to 4.5 volts, then return gradually to nearly 0; estimate the length of time it takes for the pointer to return from 4.5 to 1.5 on the *DC* scale, and record the value in Table *25*, but leave the condensers in the jacks for about two minutes, until the pointer comes to rest near zero.

You can estimate the time in seconds simply by counting at a normal speaking rate as follows: One hundred and one, one hundred and two, one hundred and three, etc. Each phrase will then be approximately equal to one second. If you practice counting first while watching the second hand of your watch or clock, you can do this very accurately.

STEP	NATURE OF MEASUREMENT	YOUR TIME IN SECONDS	N.R.I. TIME IN SECONDS	COMPUTED TIME CONSTANT IN SEC.
1	CHARGING .5 MFD. WITH 4.5 V. THRU 10 MEG.	6	6	5.
2	DISCHARGING .5 MFD. THRU 10 MEG.	6	6	5
3	DISCHARGING .5 MFD. THRU .9 MEG.	less than 1 SEC.	less than 1 SEC.	.45

TABLE 25. Record your results here for Experiment 25.

Do not touch the condenser leads while making this measurement; grasp the paper sleeves of the condensers with your fingers to hold them into the jacks, for otherwise the resistance of your body will give confusing readings.

Step 2. To observe how the voltage varies across a .5-mfd. capacity while it is being charged directly by a 4.5-volt d.c. source, touch the leads of the two parallel-connected .25-mfd. condensers together to discharge the condensers, then insert the leads in the V_{DC} jacks on the N. R. I. Tester panel. Attach the alligator clip of the red test lead to the condenser lead which is in the $+V_{DC}$ jack, and attach the black alligator clip to the condenser lead which is in the $-V_{DC}$ jack. Turn on the N. R. I. Tester, leaving the selector switch at *V*.

Using three of the flashlight cells connected in series aiding as the 4.5-volt d.c. source, hold the red probe on the + terminal of the cell group with one hand, and hold the black probe on the — terminal of the cell group, as shown in Fig. *15*, so as to secure the circuit shown in Fig. *16B*. When the meter pointer has come to rest at about 4.5 on the *DC* scale, remove the probes from the battery terminals, estimate the time required for the meter pointer to drop down to 1.5 on the *DC* scale, record your value in Table *25*, and turn off the Tester.

If you wish to repeat this experiment for any reason, discharge the condensers by shorting their leads with a screwdriver before starting the experiment again.

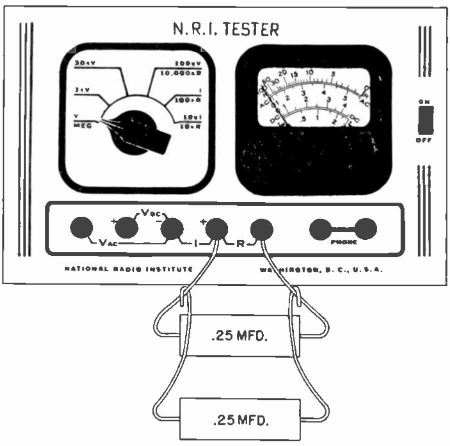


FIG. 14. Method of charging a .5-mfd. capacity for Step 1 of Experiment 25. (Two .25-mfd. condensers in parallel have a combined capacity of .5 mfd.)

Step 3. Connect the 1-megohm resistor (Part *3-7*) *in parallel with the .5-mfd. capacity as indicated in Fig. 16C, by using temporary soldered hook or lap joints,* and repeat the entire procedure set forth in Step 2. Again try to estimate the time re-

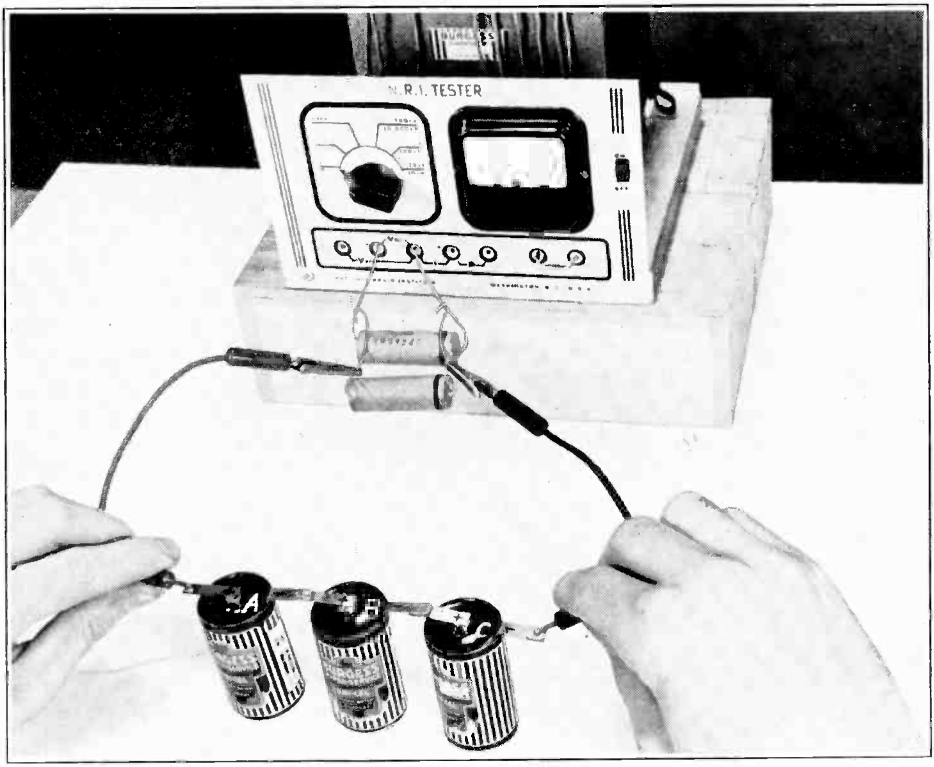


FIG. 15. Photographic illustration showing how apparatus is set up for Step 2 of Experiment 25.

quired for the pointer to drop from 4.5 to 1.5; if the pointer drops too fast for you to estimate the time, simply record in Table *25* the fact that the time was less than one second.

Now remove the test leads, remove the condenser-resistor combination from the V_{DC} jacks, and separate the condensers and resistor by unsoldering.

Discussion: When the .5-mfd. capacity is connected to the *R* jacks, the schematic circuit diagram for the set-up is as shown in Fig. *16A,* in which a 4.5-volt d.c. source (a portion of the battery system of the N. R. I. Tester) is charging the condenser through a 10-megohm resistor in the N. R. I. Tester. The meter and the vacuum tube in the N. R. I. Tester together measure the voltage developed across the 10-megohm resistor by the condenser charging current. When voltage is first applied to the condenser, the meter immediately swings to 4.5 on the *DC* scale, and therefore indicates the full voltage of the 4.5-volt d.c. source.

After reaching 4.5, the meter pointer immediately begins moving

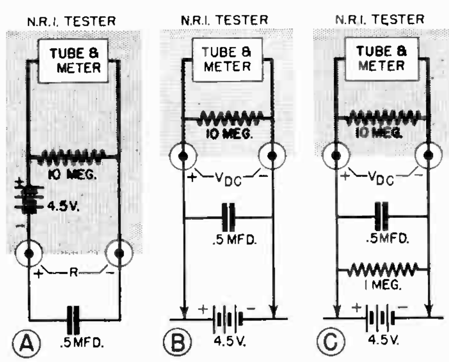


FIG. 16. Schematic circuit diagrams for Experiment 26.

down scale, rather rapidly at first and then more slowly. The pointer drops in this manner because the condenser acquires a back e.m.f. (a voltage drop) as it charges. As the voltage drop increases across the condenser, the voltage drop across the resistor reduces correspondingly because the source voltage of 4.5 volts must divide itself between these two parts according to Kirchhoff's Voltage Law.

It is a fundamental radio fact that the rate at which a condenser charges depends only upon the value of the condenser and upon the value of the resistor through which the charging current flows. Furthermore, multiplying the resistance value in megohms by the capacity value in microfarads gives a time value in seconds which is known as the *time constant* of the condenser-resistance combination. During charging of a condenser, this time constant will be the time in seconds required for the condenser to charge up to 63% of its final voltage.

In our case, 63% of 4.5 volts is 2.85 volts. Subtracting this value of 2.85 volts from the total available voltage of 4.5 volts leaves 1.65 volts as the voltage across the 10-megohm resistor at the end of the time constant period. Estimating the time it takes for the voltage across the 10-megohm resistor to drop to 1.5 volts is close enough.

According to theory, the time constant for a .5-mfd. condenser and a 10-megohm resistor is 10 x .5, or 5 seconds. The time which you estimate and record in Table *25* should therefore be about five seconds.

After the pointer passes below 1.5, it will still take several minutes before it comes to rest. The pointer will not drop entirely to zero, for the condenser has a leakage resistance value (somewhere around 100 megohms) which may allow some current to flow through the circuit even when the condenser is fully charged. Tap the meter housing lightly to overcome bearing friction when the pointer is near zero.

In Step 2, you use an external d.c. voltage source of 4.5 volts and connect it directly to the condenser, with the N. R. I. Tester connected across the condenser leads to measure the condenser voltage, as shown in the schematic diagram in Fig. *16C*. When you hold the probes across the 4.5-volt d.c. source, this voltage is applied to the condenser in parallel with the 10-megohm resistance of the N. R. I. Tester. The meter therefore indicates the full d.c. source voltage of 4.5 volts for as long as you hold the probes on the batteries. After the condenser was fully charged, you removed the probes from the battery terminals. This allowed the condenser to discharge through the 10-megohm input resistance of the N. R. I. Tester.

In the case of discharge, the time constant is the time in seconds required for the condenser to discharge until its voltage is 37% of its original charged voltage. In other words, when the condenser voltage drops to .37 x 4.5, or to 1.65 volts, the end of the time constant period is reached.

In Step 2, you are actually measuring the voltage across the condenser, because the meter, the 10-megohm resistor and the condenser are all in parallel. Theoretically, therefore, it will take the time constant value of about five seconds for the condenser to discharge from 4.5 volts to 1.5 volts in Step 2. If your estimate is within a few seconds of this value, you can consider that you have performed this experiment satisfactorily.

Shunting the 1-megohm resistor across the .5-mfd. condenser lowers the 10-megohm N. R. I. Tester input resistance to about .9 megohm, since these two resistors are now in parallel.

This means that the condenser will discharge through .9 megohm when the external voltage source is removed. The time constant for .9 megohm and .5 mfd. is about .45 second; this means that the condenser voltage will drop to 1.5 volts in about half a second after the voltage source is removed. As you observed, this short time is very hard to estimate accurately; it is sufficient simply to say the time was less than one second.

Practical Extra Information. The basic radio fact which you have just observed, wherein a condenser employed in series with a resistor in a d.c. circuit requires a certain amount of time to charge and to discharge, has many practical applications in modern radio receiver circuits. Perhaps the best known of these applications is the automatic volume control circuit, which you take up in your regular lessons; here, the time delay characteristics of the resistor and condenser control the speed with which the a.v.c. system responds to changes in signal strength. Fast a.v.c. action is desirable in order to keep the volume essentially constant during periods when stations are fading in and out rapidly and during tuning from one station to another, but a.v.c. action must not be so fast that it responds to audio variations. The time constant employed must be a compromise between these two conditions.

Instructions for Report Statement No. 25. In this experiment, you showed that decreasing the resistance value in the discharging circuit of a condenser will reduce the time constant of the circuit. It can also be shown that decreasing the capacity of the condenser without changing the resistance reduces the time constant.

For Report Statement No. 25, you will prove the preceding statement by reducing the capacity to .125 mfd. and discharging this through the 10-megohm input resistance of the N. R. I. Tester.

To carry out this experiment, connect the two .25-mfd. condensers in series by soldering a lead of one condenser temporarily to a lead of the other condenser; this gives you a combined capacity of .125 mfd. between the two free leads of this condenser group. Push one free condenser lead into the $+V_{DC}$ jack of the N. R. I. Tester, and push the other free condenser lead into the $-V_{DC}$ jack. With the selector switch still at *V*, turn on the tester, then charge the .125-mfd. capacity with a 4.5-volt d.c. source (use your two test leads and the three dry cells in series for this purpose; connect the + terminal of the cell group to the condenser lead in the $+V_{DC}$ jack with the red test lead, and connect the — terminal of the cell group to the condenser lead which is in the $-V_{DC}$ jack). Remove the charging source. Estimate the number of seconds it takes for the meter pointer to drop from 4.5 volts down to 1.5 volts on the *DC* scale while discharging through the 10-megohm resistance of the N. R. I. Tester, turn to the last page, and place a check mark after the result you obtain.

EXPERIMENT 26

Purpose: **To demonstrate that direct current will flow through a coil, and to prove that the d.c. voltage drop produced across a coil by current flow depends solely upon the value of the direct current flowing and the d.c. resistance of the coils.**

To demonstrate that direct current will not flow through a paper condenser.

To demonstrate that direct current will flow through an electrolytic condenser, and to show that the value of the current will change when the polarity of the condenser connection is reversed.

Step 1. To study the characteristics of a coil in a direct current circuit, set up a series circuit like that shown in Figs. *17A* and *17B*, consist-

STEP	NATURE OF MEASUREMENT	YOUR VALUE IN VOLTS	N.R.I. VALUE IN VOLTS
1	ACROSS COIL	.8	.9
	ACROSS 1000Ω	3.4	3.7
2	ACROSS 200Ω	.7	.7
	ACROSS 1000Ω	3.4	3.9
3	ACROSS 1000Ω	0	0
	ACROSS .25 MFD.	4.0	4.5
4	RESISTANCE OF .25 MFD. COND.	R= 100 MEG.	R= 100 MEG.
5	ACROSS 40,000Ω	.1	.1
6	ACROSS 40,000Ω	1.	1.7

TABLE 26. Record your results here for Experiment 26.

ing of flashlight cells *A*, *B* and *C*, the 10-henry choke coil (Part *3-10*), and one 1,000-ohm resistor (Part *3-5A*). With your N. R. I. Tester set for use as a 0-4.5-volt d.c. voltmeter (range *V*, with the test leads in the V_{DC} jacks), measure the voltage across the choke coil and across the resistor, and record each value in Table *26*. As soon as you have finished, open the circuit by disconnecting one coil lead, and turn off the N. R. I. Tester.

Step 2. To demonstrate that a coil in a d.c. circuit acts exactly like a resistor having the same ohmic value as the coil, replace the 10-henry choke coil with a 200-ohm resistor (Part *3-4*) and complete the series circuit connection so that your set-up corresponds to the circuit diagram in Fig.

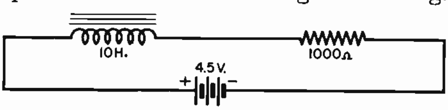


FIG. 17A. Schematic circuit diagram for Step 1 of Experiment 26.

18. Now repeat the measurements of Step 1, measuring the voltage across each part in turn to see if the resistor gives circuit values the same as were obtained for the coil. Record your results in Table *26*. Open the circuit and turn off the N. R. I. Tester as soon as you have finished measurements.

A 200-ohm resistor is used in place of the coil, because the coil has a d.c. resistance of about 200 ohms.

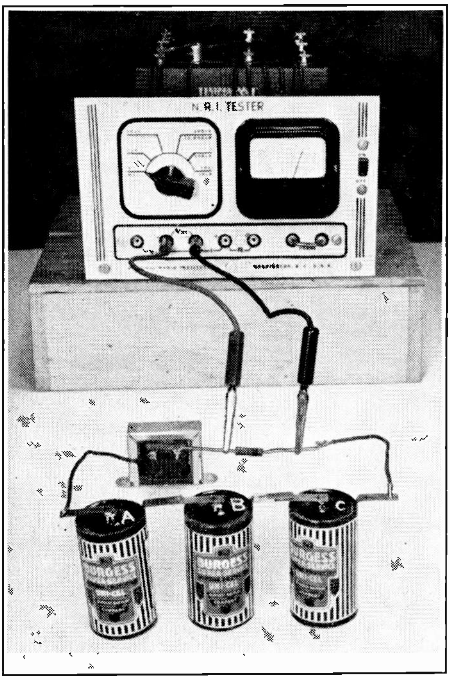


FIG. 17B. Method of measuring the voltage across the 1,000-ohm resistor in the coil-resistor circuit which you set up for Step 1 of Experiment 26.

Step 3. To study the behavior of a paper condenser in a d.c. circuit, connect the three cells in series with the 1,000-ohm resistor (Part *3-5A*) and the .25-mfd. paper condenser (Part *3-2A*), as shown in Fig. *19*. Measure the voltage across the resistor and the condenser, and record your results in Table *26*. Open the circuit and turn off the N.R.I. Tester.

Step 4. To confirm the results obtained in Step 3, measure the resistance of your .25-mfd. condenser by using the highest resistance range of the N.R.I. Tester.

Before making a resistance measurement with the N.R.I. Tester, it is

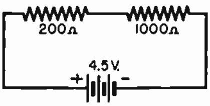


FIG. 18. Schematic circuit diagram for Step 2 of Experiment 26.

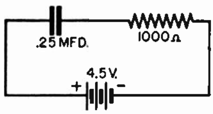


FIG. 19. Schematic circuit diagram for Step 3 of Experiment 26.

necessary to adjust the ohmmeter to zero. Set the selector switch to *MEG.*, short the *R* jacks so as to give zero external resistance (by plugging the test probes into these jacks and placing one test clip on the other clip), then adjust the potentiometer with a screwdriver until the pointer is at zero at the right-hand end of the *R* (top) scale.

After making the ohmmeter zero adjustment, leaving the selector switch set at *MEG.*, remove the test leads, then insert the condenser leads in the *R* jacks as shown in Fig. *20*, while watching the meter pointer. Do

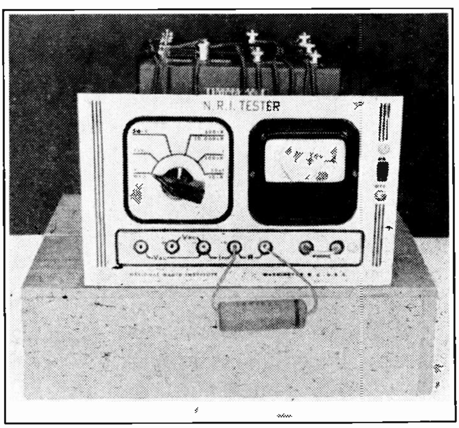


FIG. 20. Method of measuring the resistance of a .25-mfd. condenser with the N.R.I. Tester. Resistances up to 100 megohms can be measured with the N.R.I. Tester in this manner when the selector switch is set at *MEG.*

not touch the condenser leads with your fingers while doing this. Hold the condenser in this position until the meter pointer has come to rest definitely. Tap the top of the meter lightly with your finger to make sure the pointer has reached its final position, then read the meter on the *R* scale and record your reading in Table *26* as the resistance of the .25-mfd. condenser in megohms.

When the selector switch of the N.R.I. Tester is set at *MEG.*, and the *R* jacks are being used, your instrument is serving as a 0-100-megohm

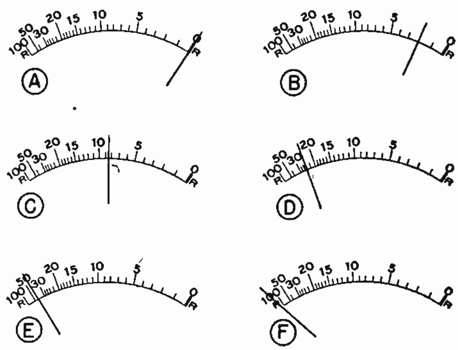


FIG. 21. Examples illustrating how to read the *R* scale on the meter of your N.R.I. Tester. The readings are as follows: *A*—0; *B*—2.0; *C*—8.5; *D*—24; *E*—40; *F*—INFINITY.

ohmmeter, and its indications are read directly in megohms on the *R* scale at the top of the meter.

You should have no difficulty in reading the *R* scale after your experience with the *DC* scale and scale I_M. The only thing you should watch for is the fact that this scale reads from right to left. Between 0 and 20 on this scale, each small division represents 1. Between 20 and 30, each small division represents 2.

Readings for six different positions of the pointer on the *R* scale are indicated in Fig. *21*. Study each one of these carefully until you are certain you know how to read this scale, for you will use the ohmmeter scale extensively in your practical demonstration course and in actual radio work.

After completing resistance measurements, be sure to restore the original calibration. This can be done in a moment, simply by moving the calibrating clip to its calibrating position on —7½C and readjusting the potentiometer to give a meter reading of 1.5 on the *DC* scale, then returning the clip to —9C.

Step 5. To determine how an electrolytic condenser behaves in a d.c. circuit, connect one section of the dual 10-mfd. electrolytic condenser (Part *3-3*) in series with a 40,000-ohm resistor (Part 3-6A) and a series-connected group of three flashlight cells, as shown in Figs. *22A* and *22B*.

Correct connections for the electrolytic condenser are shown in Fig. *22B*. Observe that the three outside lugs, two with holes and one without, are all a part of the metal housing of the condenser; internally, this housing is connected to the — terminals of both 10-mfd. electrolytic condenser sections. The two terminal lugs in the center, one having a triangular cut-out alongside it in the fiber base, and the other having a square cut-out in the base, are the + terminals of the condenser sections.

Since both sections are of the same value in this particular dual unit, it does not matter which central lug you use for the + terminal of your electrolytic condenser. Of course, you can use either of the outer lugs for the negative terminal, since they are connected together anyway through the housing.

Observe that the negative terminal of the electrolytic condenser is connected to the negative terminal of the cell group in the circuit of Fig. *22B*. This is the correct method of connecting an electrolytic condenser to a circuit in which a d.c. voltage is present.

With the N. R. I. Tester being used as a 0-4.5-volt d.c. voltmeter, measure the voltage across the 40,000-ohm resistor and record your value in Table *26*.

Step 6. Reverse the connections to the electrolytic condenser in the circuit of Fig. 22A, so that the + terminal of the condenser now goes to the — terminal of the cell group. Again measure the voltage across the 40-000-ohm resistor, and record your result in Table *26*.

Discussion: The resistance of the coil which you used in Step 1 is about 200 ohms (230 ohms to be exact, but we can consider this to be 200 ohms for all practical purposes). Adding 200 ohms to 1,000 ohms (the resistor value) gives a total circuit resistance of 1,200 ohms. We know that three dry cells connected in series aiding give a voltage of 4.5 volts, so we can easily determine the circuit current by means of Ohm's Law. The formula to be used is: $I = E \div R$; dividing 4.5 by 1,200 gives .00375 ampere, and this is equal to 3.75 ma.

Your measurement for Step 1 should confirm the 3.75-ma. value for the circuit current. You will recall that the voltage measured across a 1,000-ohm resistor corresponds to the current through that resistor in ma.; therefore, if you measured approximately 3.75 volts across the 1,000-ohm resistor, you know that you performed the experiment correctly.

A current of 3.75 ma. flowing through the 200-ohm coil will develop across this coil resistance a voltage of $200 \times .00375$, or .75 volt. If the voltage which you measured across the coil was approximately ¾ of a volt, you have confirmed the basic fact that a coil acts exactly like a resistance in a d.c. circuit. In other words, the only thing which limits the flow of current through a coil is the resistance of the wire used in winding the coil.

A coil is intended primarily for use in a.c. circuits, for there it has a reactance which opposes the flow of alternating current.

Step 2 shows even more convincingly the resistive nature of a coil in a d.c. circuit. This time, the resistor which replaced the coil in your circuit has about the same ohmic value as the coil. Therefore, your measured voltage values across the 200 and 1,000-ohm resistors should be essentially the same as in Step 1.

When the voltage across the condenser is measured in Step 3, you find that it is equal to the source voltage of 4.5 volts. Actually, the voltage is zero at the start, and builds up gradually to this final value as the condenser becomes charged.

When you measure the resistance of the .25-mfd. condenser in Step 4, you encounter the same charging phenomenon at first. The meter swings upscale, then gradually swings back to the left. You must wait until the pointer has stopped moving before taking a reading. If your condenser is in good condition, it will have a resistance above 50 megohms.

The one type of condenser which has a fairly low resistance is the electrolytic condenser. Between the plates of an electrolytic condenser is a paste or liquid which has considerably lower resistance than the mica, paper or air used between the plates in other condensers. Furthermore, an electrolytic condenser will allow more direct current to flow in one direction than in the other. This is why you must always consider polarity when connecting an electrolytic condenser.

The correct polarity for an electrolytic condenser is always such that the — terminal of the condenser goes to the — terminal of the voltage source; this is the connection we use in Step 5. The voltage measured across the 40,000-ohm resistor is an indication of the amount of current flowing through the condenser. We are not concerned with the exact current value at present, even though we could compute it by means of Ohm's Law. The important thing is to compare the measured voltage in Step 5 with the measured voltage in Step 6. You should obtain a higher voltage in Step 6, indicating that a higher value of direct current flows through

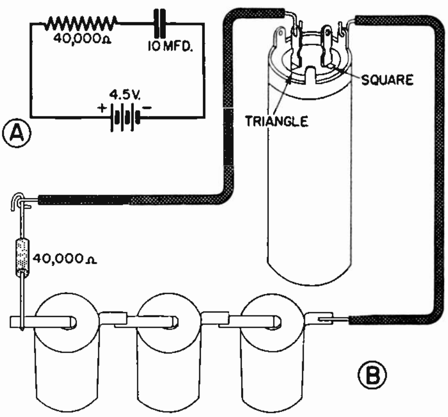


FIG. 22. Schematic (*A*) and semi-pictorial (*B*) circuit diagrams for Step 5 of Experiment 26.

an electrolytic condenser when it is improperly connected.

Practical Extra Information. Your results in Steps 5 and 6 indicate that an electrolytic condenser has a definite resistance, and that this resistance is lower for an improper connection than for the correct polarity of connections. Since an electrolytic condenser is primarily intended for use as a capacitance, it is desirable to keep direct current through it at a minimum. With improper polarity of connections, excessive current through the condenser causes it to overheat and destroy itself.

Instructions for Report Statement No. 26. Radio servicemen frequently find it necessary to make continuity tests in order to determine whether a complete d.c. circuit exists between any two points in a piece of radio apparatus. Resistances of various parts in a circuit must also be checked to determine whether any part is shorted or open. In many circuits, the part which is to be tested may be shunted by a paper condenser. You have proved that a paper condenser will not conduct direct current once it is charged; this means that you can ignore the presence of a paper condenser across a part if you know that the condenser is in good condition. In

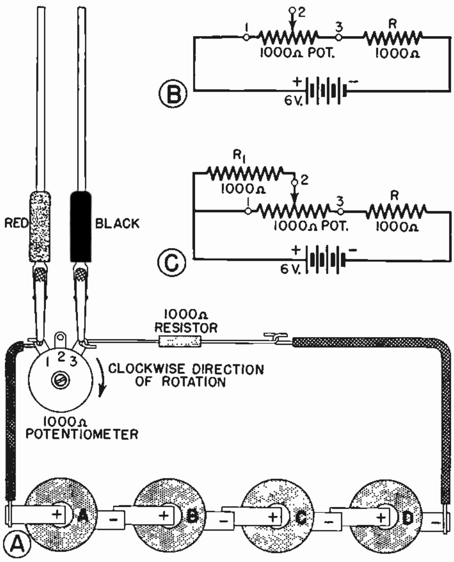


FIG. 23. Semi-pictorial (*A*) and schematic (*B* and *C*) circuit diagrams for Experiment 27.

practical radio work, you can seldom be sure that a condenser is in good condition, so it is best to disconnect shunt condensers when making continuity tests.

For this report statement, make an additional test of this statement by setting up the circuit of Fig. *18*, connecting a .25-mfd. condenser across the 200-ohm resistor, and measuring again the d.c. voltage across the 1,000-ohm resistor. Compare the measured voltage value with that obtained originally for this circuit set-up, then turn to the last page and place a check mark after the answer you obtain.

EXPERIMENT 27

***Purpose:* To show that during no-load conditions the voltages across various parts of a voltage divider will divide exactly according to resistance; to show that application of a load across a part of the voltage divider affects the division of voltages.**

Step 1. To set up a simple voltage divider circuit, connect together in series the four flashlight cells, the 1,000-ohm potentiometer (Part *3-8*) and the 1,000-ohm resistor *R* (Part *3-5A*) according to the semi-pictorial wiring diagram in Fig *23A*, so that you will have the circuit represented by the schematic diagram in Fig. *23B*. Use temporary soldered joints throughout. The potentiometer and the 1,000-ohm resistor can be placed on the table, and connected to the group of four cells with lengths of hook-up wire as shown. Number the potentiometer lugs *1*, *2* and *3* as indicated in Fig. *23A*, by writing on the fiber base of the potentiometer alongside each lug.

Measure the voltage drop across the potentiometer by placing the red clip on terminal *1*, and placing the black clip on terminal *3*, as shown in Fig. *23A*. Set the selector switch at *V*, plug the test probes into the V_{DC} jacks (remember that the red probe goes into the + jack), turn on the N. R. I. Tester, read the meter on the *DC* scale, and record the value in Table *27* as the voltage in volts across the 1,000-ohm potentiometer.

Now measure the voltage across the 1,000-ohm resistor *R* and record its value in Table *27*.

Step 2. To demonstrate how the potentiometer can provide a variable voltage, measure the voltage between movable terminal *2* and fixed terminal *1* on the potentiometer while rotating the potentiometer shaft from one ex-

STEP	NATURE OF MEASUREMENT	YOUR VOLTAGE IN VOLTS	N.R.I. VOLTAGE IN VOLTS
1	VOLTAGE ACROSS 1000Ω POT.	3.	2.9
	VOLTAGE ACROSS 1000Ω RES. R	2.9	3.1
2	VOLTAGE AT O ROTATION	0	0
	VOLTAGE AT ¼ ROTATION	1.6	.6
	VOLTAGE AT ½ ROTATION	1.5	1.4
	VOLTAGE AT ¾ ROTATION	2.1	2.1
	VOLTAGE AT FULL ROTATION	3.1	2.9
4	VOLTAGE ACROSS 1000Ω POT.	2.	2.1
	VOLTAGE ACROSS 1000Ω RES. R	3.8	3.9
	VOLTAGE AT O ROTATION	0	0
	VOLTAGE AT ¼ ROTATION	.5	.5
	VOLTAGE AT ½ ROTATION	1.1	1.1
	VOLTAGE AT ¾ ROTATION	1.4	1.4
	VOLTAGE AT FULL ROTATION	2.1	2.1

TABLE 27. Record your results here for Experiment 27.

treme to the other. Do this by placing the red clip on terminal *1* and the black clip on terminal *2* (terminal *2* goes to the movable contact, as you can readily see by studying the construction of the potentiometer). The potentiometer has a slotted shaft, which can readily be rotated by inserting a screwdriver in the slot. After rotating the potentiometer back and forth a few times to see how the meter pointer behaves, rotate the potentiometer to the extreme clockwise position, read the voltage on the *DC* scale of the meter, and record it in Table *27* as the voltage for zero rotation. Now rotate the potentiometer through approximately ¼ of its complete movement, read the voltage again, and record it in Table *27* as the voltage for ¼ rotation. Repeat for ½, ¾ and full rotation of the potentiometer, recording the voltage in Table *27* each time.

Step 3. To prove that rotation of the movable contact of the potentiometer has no effect upon the voltage across the potentiometer when there is no load, connect the 0-4.5-volt d.c. voltage range of the N. R. I. Tester across the potentiometer (to terminals *1* and *3*) and watch the meter while you rotate the potentiometer shaft back and forth.

Step 4. To study the action of your voltage divider circuit under loaded conditions, connect a 1,000-ohm resistor R_1 (Part *3-5B*) between terminals *1* and *2* of the potentiometer by means of temporary soldered hook joints, as indicated in the schematic circuit diagram in Fig. *23C,* so that this resistor will serve as a load across one section of the potentiometer. Rotate the potentiometer shaft to its extreme counter-clockwise position, so that R_1 is in parallel with the entire resistance of the potentiometer, then repeat each of the measurements and tests called for in Steps 1 and 2 and record your results in Table *27.* Now disconnect one battery lead to open up the circuit and conserve battery life.

Discussion: Theoretically, the voltages which you measure across the 1,000-ohm resistor and 1,000-ohm potentiometer in Step 1 should be equal; actually, they may not be equal for the reason that manufacturing tolerances may make the values of these two parts higher or lower than 1,000 ohms. Therefore, with the 6-volt d.c. source, you should obtain somewhere around 3 volts across each of these parts. In other words, resistances of equal value connected in series will divide a voltage in half.

With essentially 3 volts across the entire potentiometer, you would expect to secure half of this value, or 1.5 volts, when the movable arm is at the halfway position in Step 2. Likewise, at the ¼ and ¾ positions, you would expect approximately .75 volt and 2.25 volts respectively. If you secure approximately these values in Step 2, you can consider your work as satisfactory.

Step 2 thus shows that the varying voltage obtainable from a potentiometer is proportional to the resistance across which the voltage is obtained when there is no load connected across this resistance. This method for obtaining a variable voltage is widely used in radio receivers for providing a control over volume.

Varying the position of the movable arm of the potentiometer in Step 3 has no effect upon the voltage across the potentiometer, simply because nothing is connected to the movable arm.

When you connect a 1,000-ohm load between the movable terminal and one end terminal of the potentiometer in Step 4, and rotate the potentiometer to its extreme counter-clockwise position, this 1,000-ohm load is in parallel with the full 1,000 ohms of the potentiometer. Two equal resistors in parallel always give a combined value equal to half that of one resistor, and consequently the resistance between terminals *1* and *3* in your circuit is now 500 ohms. The voltage drop across this 500 ohms should be only half the voltage drop across the 1,000-ohm fixed resistor; if you measured about twice as much voltage across resistor R as across the potentiometer, you verified this fact.

When the potentiometer arm is in its mid-position, you have the 1,000-ohm load shunted across half of the potentiometer resistance, which is 500 ohms. A 1,000-ohm resistor in parallel with a 500-ohm resistor gives a resultant or combined resistance of 333 ohms,* and this 333-ohm resistance acts in series with the remaining 500-ohm section of the potentiometer and the 1,000-ohm fixed resistor to give a total circuit resistance of 1,833 ohms. By means of Ohm's Law now, it is possible to compute what the voltage drop should be across each section of this circuit.

Computation. To find the circuit current, divide 6 by 1,833. This gives approximately .0033 ampere. To obtain the voltage drop across any section, we simply multiply this current value by the resistance of that section. Thus, the voltage drop across 1,000-ohm resistor R will be approximately 1,000 $\times$ .0033, or 3.3 volts. Across the unloaded 500-ohm section of the potentiometer, the drop should be 500 $\times$ .0033, or about 1.6 volts. Across the loaded section of the potentiometer (across R_1), the drop should be 333 x .0033, or about 1.1 volts, when the arm is at the mid-position. If you measured approximately this last value of 1.1 volts for the ½-rotation position in Step 4, you can consider your work satisfactory. Observe that you get less voltage across the loaded section of the potentiometer than across the unloaded section; this shows that the presence of the load disturbs the normal distribution of voltages in a voltage divider circuit.

Practical Extra Information. The important fact to remember in connection with Step 4 is that for a given setting of the potentiometer arm, the voltage will be less with a load than without a load. Furthermore, the lower the ohmic value of the load, the lower will be the voltage obtained. However, adjusting the potentiom-

* The method of calculating this combined resistance of two resistors in parallel is given here for students who are interested:

$$R = \frac{R_1 \times R_2}{R_1 + R_2} \qquad R = \frac{1{,}000 \times 500}{1{,}000 + 500}$$

$$R = \frac{500{,}000}{1{,}500} \qquad R = 333 \text{ ohms}$$

eter will compensate for increased load and give the required voltage in most circuits.

In the voltage divider circuits of radio receivers, fixed resistors are generally used in place of potentiometers. This is possible because the value of the load across each resistor section is known, and its effect upon the voltage can be calculated by the set designer and compensated for.

Instructions for Report Statement No. 27. In the variable voltage divider circuit shown in Fig. *23B*, the fixed 1,000-ohm resistor serves the purpose of reducing the maximum voltage obtainable across the potentiometer. You will encounter this series resistor quite often in radio circuits, for oftentimes the source has a far higher voltage than can safely be applied directly to the terminals of the potentiometer.

For this report statement, make an additional measurement to determine whether a change in the value of the fixed 1,000-ohm resistor will have any effect upon the voltage provided by the potentiometer. To do this, connect the N. R. I. Tester to measure the voltage between terminals *1* and *2* of the potentiometer, complete the battery circuit which was previously disconnected to conserve battery life, adjust the potentiometer until the N. R. I. Tester indicates the voltage of 2 volts, then take your other 1,000-ohm resistor and shunt it temporarily across the 1,000-ohm resistor already in the circuit so as to reduce this series resistance to 500 ohms. Note the change in the N. R. I. Tester reading, then turn to the last page and place a check mark after the answer in Report Statement No. 27 which describes your result.

EXPERIMENT 28

Purpose: **To show that coils and condensers offer a definite amount of opposition to the flow of current in an a.c. circuit.**

Step 1. To set up a power supply circuit which will give you a 5-volt

A. C. EXPERIMENTS

If you do not have 110 to 120-volt, 50 to 60-cycle a.c. power in your home or in the place where you plan to carry out future experiments in this practical demonstration course, you are temporarily excused from performing the a.c. experiments (28, 29 and 30). This applies also to students who have only 25 or 40-cycle power.

Read these experiments carefully, however, giving especial study to the discussions so that you understand the basic principles involved, but do not answer the last three questions in the report statements at the present time. In the margin alongside Report Statements 28, 29 and 30 on the last page, write in pencil the words *"NO A.C. POWER,"* and send in this last page for grading. Your grade for Manual 3RK will be based upon the seven experiments which you have performed. In the next assignment, you will be provided with special instructions for carrying out three similar a.c. experiments and future experiments requiring a.c. power.

If you *do have a.c. power* in your home, you are expected to perform the following three experiments and answer *all ten* of the report statements.

a.c. voltage when it is connected to the 115-volt a.c. line, first secure a scrap piece of wood which is at least ½ inch thick and at least 5 inches wide and 7 inches long. Take the six-lug terminal strip (Part *3-12*) and mount it on this board with two of the ⅜-inch No. 6 round-head wood screws (Part *3-13*) in approximately the position shown in Fig. *24*.

Take the mounting bracket for the potentiometer '(Part *3-9*) and mount it on your wood baseboard with the remaining ⅜-inch wood screw in approximately the position shown in Fig. *24*.

Mount the 1,000-ohm wire-wound potentiometer (Part *3-8*) on its mounting bracket by removing the hexagonal nut from the potentiometer shaft, inserting this threaded shaft through the large hole in the bracket from behind, replacing the nut on the shaft, and tightening the nut with ordinary pliers while holding the potentiometer so that its three terminal lugs are at the top (the correct position of the potentiometer is shown in Fig. *24*).

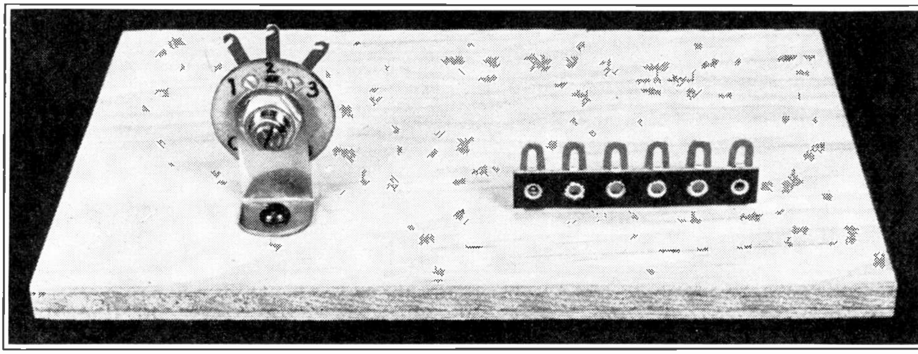


FIG. 24. For Step 1 of Experiment 28, mount the terminal strip and the potentiometer bracket in approximately the positions shown here, on a wooden base-board approximately 5" wide, 7" long and ½" thick.

Assemble your a.c. power supply circuit on the baseboard according to the schematic circuit diagram in Fig. *25A* by making the connections exactly as shown in Fig. *25B,* in the following order:

a. Number each of the lugs on the terminal strip in the manner shown in Fig. *25B* by placing the numbers on the baseboard directly under the respective lugs, and using either pencil, ink or crayon for marking purposes. The potentiometer terminals will already be numbered *1, 2* and *3* from the previous experiment.

b. Connect the 1,000-ohm resistor (Part *3-5A*) to terminals *4* and *5* by means of temporary hook joints, but solder the joint at terminal *4* only.

c. With a suitable length of hook-up wire, connect potentiometer terminal *1* to terminal *7,* but solder only the joint at terminal *1.*

d. With a suitable length of hook-up wire, connect potentiometer terminal *2* to terminal *6,* soldering both joints this time.

e. With a suitable length of hook-up wire, connect potentiometer terminal *3* to terminal *5,* but solder only terminal *3.*

f. Take the four 40,000-ohm resistors (Parts *3-6A, 3-6B, 3-6C* and *3-6D*) and connect them all together in parallel, with 3-inch lengths of hook-up wire serving as the leads for the group, in the manner shown in Fig. *25B*. This can be done by cutting away or pushing back the insulation for about 1 inch from the end of a 3-inch length of hook-up wire, winding this bare end of the hook-up wire several times around the group of four resistor leads, then applying solder to the joint liberally so that it flows between all of the resistor leads. Do the same for the other group of four resistor leads. Now connect one of the leads for this resistor group to terminal *7*, and connect the other lead to terminal *9*, but solder only terminal *7* at this time. Four 40,000-ohm resistors in parallel give a combined resistance of 10,000 ohms.

g. Take the 5-foot length of power line cord with attached plug (Part *3-11*), twist the bare ends if they have become untwisted, connect one lead of this cord to terminal *9* by means of a temporary hook joint, and connect the other lead of this cord to terminal *5* in the same way. Solder both joints.

h. Check all connections carefully against the semi-pictorial wiring diagram in Fig. *25B*, for a single mistake here may result in your blowing the house fuse when you plug this circuit into the power line. Be sure that there are no wires or lumps of solder shorting together adjacent lugs on the terminal strip.

Step 2. To become familiar with the reading of the AC scale on the meter of the N. R. I. Tester, study carefully the actual-size reproductions of this scale in Fig. *26*. An analysis of the four examples which are given should enable you to read this scale at any position of the pointer, for the *AC* scale is read in essentially the same way as the *DC* scale.

The *AC* scale on your meter is used for all four of the a.c. voltage ranges: *V*, *3*$\times$ *V*, *30*$\times$ *V* and *100*$\times$ *V*. When using the *V* range, read the voltage in volts directly on this scale. When using the *3*$\times$ *V* range, multiply the reading on the *AC* scale by 3. When using the *30*$\times$ *V* range, multiply the reading by 30. When using the *100*$\times$ *V* range, multiply the reading by 100.

Step 3. To measure the voltages which are present across various parts of an a.c. voltage divider circuit when there is no load, first set the N. R. I. Tester to measure the highest a.c. voltage which you will encounter. This will be the 115-volt a.c.line voltage, so set the selector switch to *30*$\times$ *V*. Plug the red probe into the left-hand V_{AC} jack, and plug the black probe into the $-V_{AC}$ jack.

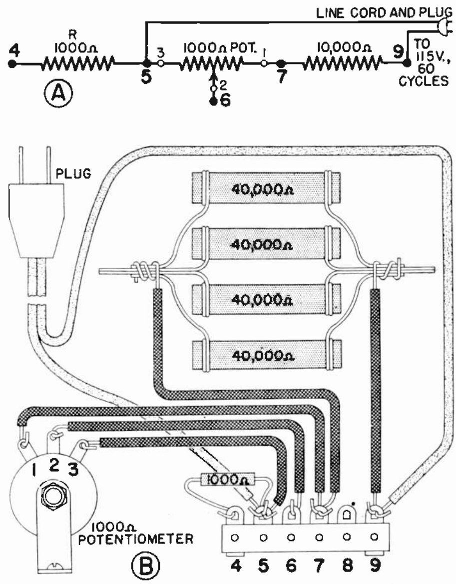


FIG. 25. Schematic (*A*) and semi-pictorial (*B*) circuit diagrams for the a.c. power supply source which you set up in Step 1 of Experiment 28.

CAUTION: It is extremely important that you perform all a.c. experiments on an insulated bench or table. An ordinary wooden table is ideal, as also is a wooden table covered with linoleum or oilcloth, but a porcelain-top table is unsatisfactory because the porcelain is applied to a metal base. A.C. experiments should be performed at a location where you are out of reach of any grounded objects such as a radiator, water pipe, gas pipe, sink, metal beams, grounded pipe or flexible conduit enclosing electric wiring, metal outlet boxes to which grounded conduit is attached, or damp concrete basement floors. If your experiments must be done in a basement, any inexpensive rug or piece of linoleum placed on the floor will eliminate the shock hazard from this source.

The most important precaution for you to observe, however, is never to touch a terminal at which a.c. line voltage may exist, if you can possibly avoid doing this. As an added precaution, use only one hand while working with electrical apparatus with the power on. If you should accidentally touch a high-voltage terminal with

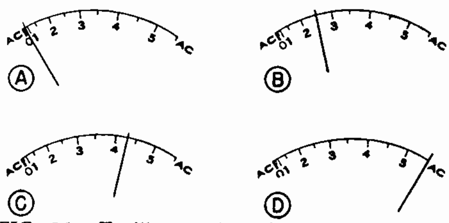


FIG. 26. To illustrate how the *AC* scale on the meter of the N.R.I. Tester is read, readings corresponding to four different positions of the pointer are given in these examples. The readings are as follows: *A*—.5V; *B*—2.5V; *C*—4.3V; *D*—5.5V.

one hand, and no part of your body is grounded, there will be no danger of shock.

Safety Rules for A.C. Circuits

Disconnect your equipment from the a.c. line at all times except when actually making a test or reading.

Do not allow any part of your body to come in contact with a grounded object while working with a.c. equipment.

Whenever it is necessary for you to handle equipment while power is on, use only one hand for this purpose. Many engineers keep the unused hand in their pocket to avoid using it unconsciously, such as for grabbing a part which may be falling over.

Always connect the black clip of the N. R. I. Tester to the a.c. terminal which is nearer to ground potential whenever making a voltage measurement. Observing this precaution may prevent you from getting a shock when you touch the panel or chassis of the N. R. I. Tester. When you do not know which of the a.c. terminals is grounded, measure between each of them and a ground wire; the one which gives a voltage reading to ground will be hot, so the other will be grounded.

To locate the terminal of your a.c. voltage divider which is nearer to ground potential, place the black clip on a ground wire going to any convenient ground such as a water pipe, and place the red clip on terminal *9*. Insert the power cord plug in the a.c. outlet, note the meter reading on the *AC* scale, then reverse the position of the plug in the outlet and again note the meter reading. In one position the reading should be essentially zero, and in the other position the reading should be almost 4 on the *AC* scale, indicating a voltage of about 4×30, or 120 volts. Record your value in Table *28* as the voltage measured between the hot a.c. line terminal (*9*) and ground.

Use that position of the plug which gives approximately the 120-volt reading between terminal *9* and ground, and make a clearly distinguishable mark both on the plug and on the outlet so that you will always replace the plug in this position during the next three experiments. Now pull out the plug. This position of the plug makes terminal *9* hot, so be especially careful not to touch this terminal (or the resistor leads connected to it) while power is on.

Since one side of the a.c. line is always grounded, terminal *5* will be *grounded* when terminal *9* is hot. Check this by measuring the voltage between terminal *5* and ground; set the N. R. I. Tester to the $30 \times V$ range, place the black clip on the ground wire, and place the red clip on terminal *5*. Read the meter on the *AC* scale, and record your result (it should be zero) in Table *28*, as the voltage between terminal *5* and ground.

Measure the line voltage existing between terminals *5* and *9*. Remember that terminal *5* will be at ground potential during the next three experiments. Place the black clip on terminal *5*, place the red clip on terminal *9*, set the N. R. I. Tester to $30 \times V$, turn on the tester, insert the plug in the outlet, read the meter on the *AC* scale, multiply the reading by 30 and record your result in Table *28* as the line voltage between terminals *5* and *9*. Pull out the plug and turn off the N. R. I. Tester.

Measure the a.c. voltage across the 10,000-ohm resistor (the four 40,000-ohm resistors in parallel are equivalent to one 10,000-ohm resistor, and will therefore be referred to as a 10,000-ohm resistor during these experiments), by placing the back clip on terminal *7* (this is closer to ground than terminal *9*) and placing the red clip on terminal *9*. Turn on the N.R.I. Tester, insert the plug in the outlet, read the meter on the *AC* scale, multiply the result by 30, and record it in Table *28* as the voltage existing between terminals *7* and *9*. Pull out the plug and turn off the N. R. I. Tester.

Measure the voltage across the 1,000-ohm potentiometer by placing the black clip on terminal *5*, placing the red clip on terminal *7*, turning on the N. R. I. Tester with the selector switch still at *30*$\times$*V*, and inserting the plug into the outlet. Read the meter on the *AC* scale and multiply the result by 30; if this result is below 16.5 volts (the maximum value on the next lower *AC* scale), rotate the selector switch in *3*$\times$*V*. Read the meter again on the *AC* scale, multiply the reading by 3 this time, and record it in Table *28* as the voltage in volts between terminals *5* and *7*. Pull out the plug and turn off the N. R. I. Tester.

Step 4. To adjust the voltage between terminals 5 and 6 to 5 volts, place the black clip on *5*, and place the red clip on *6*. Set the N. R. I. Tester to the *3*$\times$*V* range, turn on the switch, insert the power cord plug in an outlet, then rotate the potentiometer with a screwdriver until the meter pointer is approximately at 1.75 on the *AC* scale (corresponding to 5 volts on this scale). This value is safely within the next lower range of your meter, so change the selector switch to the *V* range and make a more accurate adjustment of the potentiometer to give meter reading of 5 on the *AC* scale. Pull out the plug and turn off the N. R. I. Tester, without changing the potentiometer setting.

Step 5. To measure voltage and current values for a 1,000-ohm resistor (R_1) *which is connected between terminals 4 and 6 of the a.c. voltage divider to give the circuit shown in Fig. 27A,* take one of your 1,000-ohm resistors (Part *3-5B*), shape the leads

STEP	NATURE OF MEASUREMENT	YOUR VALUE IN VOLTS	N.R.I. VALUE IN VOLTS
3	VOLTAGE BETWEEN 9 AND GROUND	120	120
	VOLTAGE BETWEEN 5 AND GROUND	0	0
	VOLTAGE BETWEEN TERMINALS 5 AND 9	120	120
	VOLTAGE BETWEEN TERMINALS 7 AND 9	107	108
	VOLTAGE BETWEEN TERMINALS 5 AND 7	10	12
5	VOLTAGE ACROSS 1000Ω R_1	2.	2.4
	VOLTAGE ACROSS R (SAME AS CURRENT IN MA.)	2.	2.5
6	VOLTAGE ACROSS .5 MFD. C		4.9
	VOLTAGE ACROSS R (SAME AS CURRENT THRU C IN MA.)		.9
7	VOLTAGE ACROSS 10 MFD. C		1.9
	VOLTAGE ACROSS R (SAME AS CURRENT THRU C IN MA.)		4.6
8	VOLTAGE ACROSS 10 HENRY L		4.7
	VOLTAGE ACROSS R (SAME AS CURRENT THRU L IN MA.)		.9

TABLE 28. Record your results here for Experiment 28.

so that one will touch terminal *6* when the other is on terminal *4* of the terminal strip mounted on your baseboard, tin the end of each lead liberally with rosin-core solder, apply surplus solder to the tip of your soldering iron, then hold the resistor against these terminals in the manner shown in Fig. *28*, and apply the soldering iron to each resistor lead in turn, long

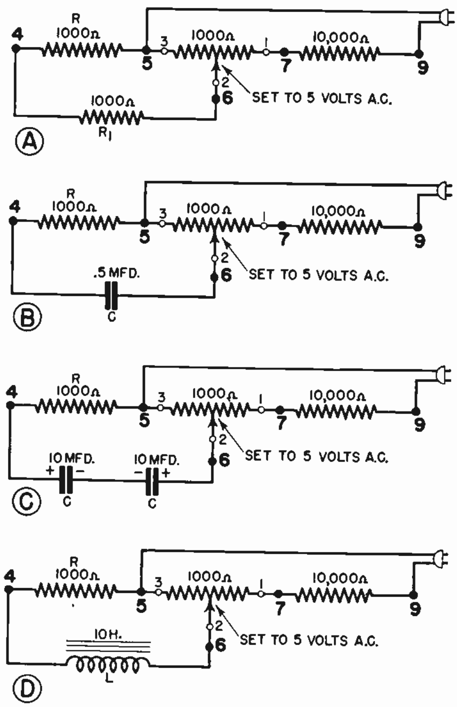


FIG. 27. Schematic circuit diagrams for the circuits which you set up in Steps 5, 6, 7 and 8 in Experiment 28 to determine how resistors, coils and condensers behave in 60-cycle a.c. circuits.

enough to fuse the solder and give a temporary soldered lap joint at each terminal.

This 1,000-ohm resistor R_1 is now in series with 1,000-ohm resistor R previously mounted on the terminal strip between lugs *4* and *5*; resistor R provides a convenient means for determining the circuit current when various radio parts are connected between terminals *4* and *6*, for the voltage drop across a 1,000-ohm resistance is equal to the current in milliamperes through that resistance.

Connecting a load between terminals *5* and *6* in this manner will make the voltage between these terminals drop below 5 volts, so readjust this voltage between terminals *5* and *6* to 5 volts in the manner described in Step 4, then pull out the plug.

To measure the voltage across R_1, place the black clip on terminal *4* (this is nearer to ground potential) and place the red clip on terminal *6*. Insert the plug in the outlet, read the meter on the *AC* scale, and record the result in Table *28* as the voltage in volts across 1,000-ohm resistor R_1. Pull out the plug.

To measure the current through R_1, move the red clip to terminal *4*, move the black clip to terminal *5*, reinsert the plug, read the meter on the *AC* scale, and record this value in Table *28* as the voltage in volts across R. This will also be the value in ma. of the current through R_1. Pull out the plug, and turn off the N. R. I. Tester.

Step 6. To measure voltage and current values for a .5-mfd. capacity which is connected into an a.c. circuit having a 5-volt a.c. source, first disconnect 1,000-ohm resistor R_1 from terminals *4* and *6*, and remove the N. R. I. Tester clips. Connect a .5-mfd. capacity (two .25-mfd. condensers, Parts *3-2A* and *3-2B*, connected in parallel) to terminals *4* and *6* as indicated in Fig. *27B*. Do this by tinning the condenser leaders, holding them against terminals *4* and *6*, and applying the heated soldering iron to fuse the solder and provide secure temporary soldered lap joints, just as you did for resistor R_1 in Step 5.

Adjust the voltage between terminals *5* and *6* to 5 volts again, by placing the black clip on *5* and the red clip on *6*, setting the N. R. I. Tester to the $3 \times V$ range, and adjusting the potentiometer roughly to a meter reading of 1.75 on the *AC* scale, then switching to the *V* range and adjusting the potentiometer until the meter reads exactly 5 on the *AC* scale. This is the same adjustment as described in Step 4. Pull out the plug now.

To measure the voltage across capacity *C*, place the black clip on terminal *4* and place the red clip on terminal *6*. Turn on the N. R. I. Tester, leaving it set at the *V* range. Read the meter on the *AC* scale, and record the value in Table *28* as the voltage in volts across .5-mfd. capacity *C*. Pull out the plug.

To measure the current through *C*, place the black clip on terminal *5*, and place the red clip on terminal *4*. Insert the plug in the outlet, read the meter on the AC scale, and record the value in Table *28* as the voltage across *R*. This will also be the value in ma. of current through .5-mfd. capacity *C*. Pull out the plug, turn off the N. R. I. Tester, remove the two test clips, disconnect the .5-mfd. capacity, then separate the two .25-mfd. condensers. Do not straighten out the hooks in the condenser leads yet.

Step 7. To measure voltage and current values for a 10-mfd. electrolytic condenser connected according to the schematic circuit diagram in Fig. 27C, take two 3-inch lengths of red hook-up wire, connect one to each of the center terminal lugs of the dual 10 - 10 - mfd. electrolytic condenser (Part *3-3*), then connect one of these leads to terminal *4* and the other to terminal *6* by means of temporary soldered lap joints. This places the two sections of the condenser in series bucking, with their — terminals connected together internally through the common metal housing of the unit, but gives a resultant capacity which is essentially the same as the capacity of only one active 10-mfd. individual unit; this is true only with electrolytic condensers.

Adjust the potentiometer in the manner described in Steps 4 and 6, so as to give exactly 5 volts a.c. between terminals *5* and *6*, then pull out the plug.

To measure the voltage across the 10-mfd. capacity, place the black clip on *4*, place the red clip on *6*, insert the plug, read the meter on the *AC* scale, and record your result in Table *28* as the voltage in volts across the 10-mfd. capacity *C*. Pull out the plug.

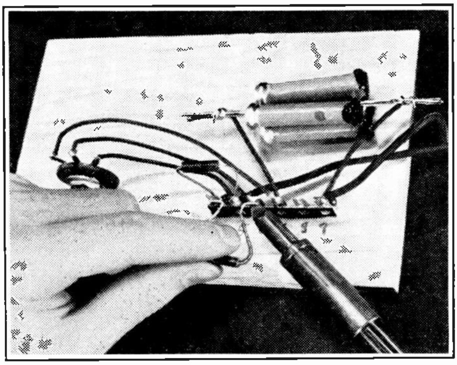


FIG. 28. This illustration shows you how to make a temporary soldered lap joint for the purpose of connecting a radio part temporarily between two terminals. This technique allows you to hold the part with one hand (instead of holding the solder in that hand), and gives a joint which can easily be disconnected.

To measure the current through the 10-mfd. capacity, place the red clip on terminal *4*, place the black clip on terminal *5*, insert the plug, read the meter on the *AC* scale, and record the value in Table *28* as the voltage across *R*. This will also be the current in ma. through the 10-mfd. capacity *C*. Pull out the plug, turn off the N. R. I. Tester, remove the clips, and disconnect the dual 10-10-mfd. condenser from terminals *4* and *6*.

Step 8. To study the action of a coil in an a.c. circuit, take the 10-henry choke coil (Part *3-10*), attach a 3-inch length of hook-up wire to each of its terminal lugs by means of a temporary soldered hook joint, connect one of these leads to terminal *4*, and connect the other lead to terminal *6*, so that you have the circuit arrangement shown in Fig. *27D*.

Adjust the potentiometer as previously described, to give exactly 5 volts a.c., then pull out the plug.

To measure the voltage across coil *L*, place the black clip on *4*, place the red clip on *6*, insert the plug, read the meter on the *AC* scale, and record the result in Table *28* as the voltage in volts across coil *L*. Pull out the plug.

To measure the current through coil *L*, place the black clip on *5*, place the red clip on *4*, insert the plug, read the meter on the *AC* scale, and record the result in Table *28* as the voltage across *R*. This will also be the current in ma. through the 10-henry coil *L*. Pull out the plug, turn off the N. R. I. Tester, remove the clips, then disconnect the coil but leave the two leads connected to the coil terminals. Leave the remainder of the circuit set up for the next experiment.

Discussion: If you have done any previous experimenting or if you have worked at all with a.c. house wiring, you undoubtedly know already that a 110-volt a.c. voltage can give you an unpleasant shock. Furthermore, under certain conditions this voltage can be dangerous. These dangerous conditions are quite easy to avoid, for they depend upon electricity going through your entire body, particularly through the region of the heart.

By keeping all parts of your body away from any grounded metal object and by touching radio apparatus with only one hand whenever there is a possibility that power might be on, you make it impossible for current to find a path through your body. Under these conditions, you can work with 110-volt a.c. voltages with perfect safety.

Every radio man must work extensively with 110-volt a.c. apparatus, so form the proper safety habits right from the start. Safety rules are even more important when working with ordinary a.c. radio receivers; here you encounter stepped-up a.c. voltages approaching 1,000 volts, which are considerably more dangerous than 110 volts, unless these same safety precautions are used.

Study of the schematic circuit diagram in Fig. *25A* will show that your voltage divider consists of a 10,000-ohm resistor and a 1,000-ohm potentiometer connected in series across the a.c. line. This gives a total of 11,000 ohms.

With no load connected across the voltage divider (Step 3), you should find that the voltages divide exactly in proportion to the resistances, just as in the case of the d.c. voltage divider used in the previous experiment. There should be ten times as much voltage across the 10,000-ohm resistor as there is across the 1,000-ohm resistor, and these two voltages should add up to the line voltage. Looking at it another way, the potentiometer resistance is only 1/11 of the total resistance, and consequently the potentiometer voltage should be only 1/11 of the total voltage.

If the line voltage in your case is slightly high, say about 120 volts, the voltage across the 1,000-ohm potentiometer will be about 11 volts. You are thus using this voltage divider to reduce the 120-volt line voltage to 11 volts a.c. for this experiment.

In Step 5, you use a 1,000-ohm resistor R_1 as a load across one section of the potentiometer, with a 1,000-ohm resistor *R* in series with this load for current-measuring purposes. The voltage drop across the 1,000-ohm resistor *R* is exactly equal in value to the current in milliamperes through the load.

When you turn on the power after connecting 1,000-ohm resistor R_1 to terminals *4* and *6*, you will find that the voltage between terminals *5* and *6* is about 1 volt lower than the original no-load value of 5 volts. This proves that the same action holds true for a.c. circuits as for d.c. circuits, wherein the placing of a load across a portion of a voltage divider reduces the voltage available at that portion of the divider.

Actually, in Step 5 you have two 1,000-ohm resistors connected in series across an a.c. voltage of 5 volts (between terminals *5* and *6*). According to Kirchhoff's Voltage Law, the voltages across the two resistors should add up to the 5-volt a.c. voltage available between terminals *5* and *6*. Furthermore, because the resistors are equal in value, the voltages across them should be equal (each should be 2.5 volts). Of course, practical conditions make it unlikely that the voltages will be exactly equal and practical limitations in your measuring instrument make it unlikely that the two measured voltages will add up to exactly 5 volts, but your results should be close enough to the expected values to verify the basic law involved.

If the 1,000-ohm resistor R_1 were shorted out, there would be only 1,000 ohms connected between terminals *5* and *6*, and you would measure the full source voltage across resistor R (between terminals *4* and *5*). This means that 5 ma. would be flowing through this resistor. If you obtain a load current reading of about 2.5 ma. with both the 1,000-ohm resistors serving as load in Step 5, you can say that a resistor has exactly the same current-limiting characteristics in an a.c. circuit as it has in d.c. circuits.

When using the N. R. I. Tester for voltage measurements, make it a practice to estimate first the maximum voltage which could exist between the points across which a measurement is to be made, then set the selector switch to a range which will include this maximum value. If your estimate is high and you find it difficult to read the meter accurately, simply lower the range one step at a time until you can secure a better scale reading.

You may observe that when using the N. R. I. Tester as an a.c. voltmeter on the *V* range, a meter reading can be obtained when only one test clip is connected to an a.c. circuit. This reading is obtained simply because the test leads are picking up stray a.c. energy due to the house wiring.

Even touching your finger to one of the *disconnected* test clips can cause an increase in the meter reading, for then your own body is picking up additional electrical energy, and the N. R. I. Tester is measuring your voltage with respect to the other leads. The distributed capacity between leads is sufficient to complete the circuit through the 10-megohm input resistance of the N. R. I. Tester, but does not affect meter readings at all when both clips are connected.

In Step 6, you have a 1,000-ohm resistor and a .5-mfd. capacity connected in series across the 5-volt a.c. source. When you add together the voltages which you measure across the condenser and the resistor, you will find that they come to considerably more than 5 volts. Kirchhoff's Voltage Law for a.c. circuits says, however, that you cannot add voltages arithmetically in a.c. circuits having condensers or coils. You must add the voltages vectorially, taking phase into account, for the condenser and resistor voltages are 90° out of phase.

When the N. R. I. voltage values

across the condenser and resistor are added together vectorially in the manner shown in Fig. *29A,* the result is about 5 volts. Your values should add vectorially to approximately 5 as well, but remember that exact agreement is seldom possible because of practical conditions.

Adding Voltages Vectorially. For convenience, let 1 inch represent 1 volt on your vector diagram, and use the resistor voltage as your reference vector. Choose a starting point for your diagram (point *S* in Fig. *29A*), then lay out horizontally to the right from this starting point a line (*IR* in Fig. *29A*) having a length which is proportional to the value of the voltage measured across 1,000-ohm resistor *R*. Place an arrow at the end of this line.

Next, from starting point *S* draw a vector for the voltage across the added part. Since it is a condenser, draw the vector straight down from the reference point, because the voltage across a condenser always lags the voltage across a resistor by 90°.

Having plotted your two vectors for Step 6, add them together by completing the rectangle as indicated with dotted lines in Fig. *29A,* then draw in the diagonal of the rectangle. This diagonal is the resultant vector, representing the sum of the two vectors acting 90° out of phase. Measure the length of this vector in inches; this value will be the resultant voltage in volts, and should be essentially 5 volts.

Electrolytic Condenser Characteristics. When two electrolytic condensers are connected in series but with their respective negative terminals tied together, as is done in Step 7, one condenser always retains its desired capacitive properties despite the continual reversal of the a.c. voltage which is applied to the condenser group. In other words, for any given point in the a.c. cycle, one condenser is acting as a true condenser but the other is merely acting as a conductive path. For this reason, the combined capacity of the two electrolytic condensers is only the capacity of one of the units.

As a matter of practical information, this series opposition method of connecting electrolytic condensers is employed in actual practice whenever electrolytics are to be used in a.c. circuits. Otherwise, a single electrolytic unit cannot be used as a condenser in an a.c. circuit.

When Step 7 was carried out in the N. R. I. laboratory, values of 4.6 volts across the resistor and 1.9 volts across the condenser were obtained, as indicated in Table *28.* When these were added together vectorially in the manner shown in Fig. *29B,* a resultant voltage of essentially 5 volts was obtained, giving additional confirmation of Kirchhoff's Voltage Law for a.c. circuits.

Let us compare the relative current-limiting actions of the .5-mfd. and 10-mfd. condensers in this a.c. circuit. We will use the N. R. I. values here for comparison, but you can do the same thing with those values you measured.

The .5-mfd. condenser gave a current of .9 ma., while the 10-mfd. condenser gave a current of 4.6 ma. This indicates that both condensers serve to limit the value of a.c. current flowing, with the smaller condenser offering more opposition to current flow than did the larger condenser. This is exactly what you would expect from basic electrical principles, for the higher the electrical capacity value of a condenser, the lower is its resistance at a given frequency, and the less it limits current flow.

When the 10-henry choke coil was placed in series with the 1,000-ohm resistor as a load for a 5-volt a.c. source during the performance of Step 8 in the N. R. I. laboratory, a voltage of .9 volt was measured across the 1,000-ohm resistor, and 4.7 volts was measured across the coil. Adding these together vectorially at right angles in the manner shown in Fig. *29C* gives only 4.77 volts, which is a bit off from the applied a.c. voltage of 5 volts. The reason for this discrepancy is simply that the coil has considerable resistance, which is completely overlooked in the vector diagram in Fig. *29C*.

Your 10-henry coil has a d.c. resistance of about 200 ohms. When this coil is used in an a.c. circuit, however, certain a.c. losses make the resistance of the coil go up considerably. You will determine this value in the next experiment, but for purposes of clarifying the vector diagram in Fig. *29C*, let us assume that this a.c. resistance is 1,500 ohms.

A voltage of .9 volt across the 1,000-ohm resistor indicates a current of .9 ma. through the circuit. This current flowing through the 1,500-ohm a.c. resistance of the coil gives a resistive voltage drop across the coil of .0009 x 1,500, which is 1.35 volts. Knowing that the total voltage across the coil is 4.7 volts and its resistive component is 1.35 volts, we can use the construction shown in Fig. *29D* to obtain the reactive component of voltage across

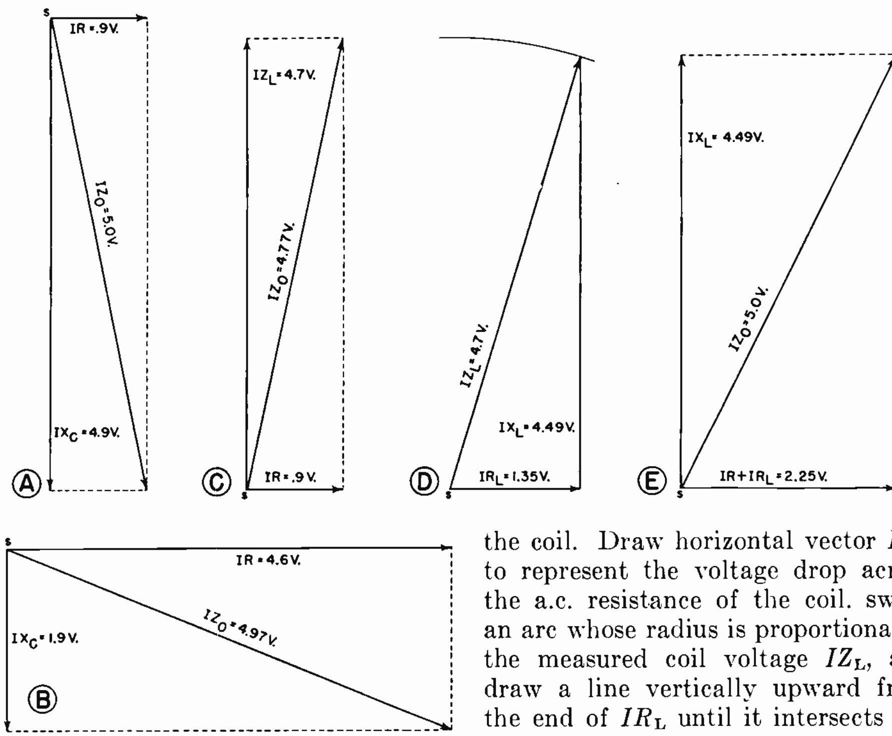


FIG. 29. These vector diagrams, based upon voltage values measured in the N.R.I. laboratory for the various steps of Experiment 28, prove definitely that Kirchhoff's Voltage Law holds true for a.c. circuits. One volt corresponds to ½-inch of vector length on these diagrams.

the coil. Draw horizontal vector IR_L to represent the voltage drop across the a.c. resistance of the coil. swing an arc whose radius is proportional to the measured coil voltage IZ_L, and draw a line vertically upward from the end of IR_L until it intersects the arc. The length of this vertical line will now correspond to IX_L, the reactive component of the coil voltage.

Adding the resistive component of the coil voltage to the voltage drop across the 1,000-ohm resistor gives 1.35+.9, or 2.25 volts. We plot this horizontally in Fig. *29E*, then draw in the reactive component of coil voltage as vector IX_L, at right angles to the first vector. Completing the rectangle now gives vector IZ_O, whose length will be proportional to the total voltage across the coil and resistor combined. For this vector we secure a value of 5 volts, which is correct.

This experiment has shown you quite clearly that we must take phase into account whenever adding voltages in a.c. circuits. You have thus demonstrated for yourself Kirchhoff's important voltage law for a.c. circuits.

Instructions for Report Statement No. 28. In an a.c. circuit, circuit conditions can be changed by shunting any part in the circuit with a resistor, a coil or a condenser, provided that the shunting part has a low enough resistance or impedance. For Report Statement No. 28, you will verify this.

Using the voltage divider circuit shown in Fig. *25,* connect between terminals *4* and *6* an 18,000-ohm resistor (Part *1-16*) and two .25-mfd. condensers, so that you have an 18,000-ohm resistor in parallel with a .5-mfd. capacity. Set the potentiometer to give maximum a.c. voltage (slightly over 10 volts) between terminals *5* and *6,* as measured with the N. R. I. Tester, then pull out the power cord plug. Place the black clip of the N. R. I. Tester on terminal *5,* place the red clip on terminal *4,* insert the plug, and read on the meter the voltage across 1000-ohm resistor *R* (use the *V* range). Now pull out the plug, disconnect the two .25-mfd. condensers, insert the plug again, and note the voltage now indicated across 1000-ohm resistor *R.* Turn to the last page and check the answer which describes your result.

EXPERIMENT 29

Purpose: **To show that when a coil and condenser are connected in series, a resonant effect exists, and one part will partially or totally cancel the current-limiting effect of the other part; to show that the a.c. resistance of a coil is higher than the d.c. resistance of the coil.**

Step 1. Using the same a.c. voltage-dividing circuit employed in Experiment 28, connect one .25-mfd. condenser (Part *3-2A*) to terminals *4* and *6* by means of temporary soldered lap joints; the circuit is given in Fig. *30A.*

Place the black clip on terminal *5,* place the red clip on terminal *6,* set the selector switch to $3 \times V$, turn on the N. R. I. Tester, insert the plug in the outlet, and adjust the potentiometer until the meter reads approximately 4 volts (1.3 on the *AC* scale when using the $3 \times V$ range). Now switch to the *V* scale and adjust accurately to 4 volts. (Note the change to 4 volts, as compared to the 5-volt value used in the previous experiment.) Pull out the plug.

To measure the voltage across the

STEP	NATURE OF MEASUREMENT	YOUR VALUE IN VOLTS	N.R.I. VALUE IN VOLTS
1	VOLTAGE ACROSS .25 MFD. C		4.0
	VOLTAGE ACROSS R (SAME AS CURRENT IN MA.)		.3
2	VOLTAGE ACROSS .25 MFD. C		5.4
	VOLTAGE ACROSS 10 HENRY L		2.25
	VOLTAGE ACROSS R (SAME AS CURRENT IN MA.)		.5
3	VOLTAGE ACROSS .5 MFD. C		10.8
	VOLTAGE ACROSS 10 HENRY L		11.0
	VOLTAGE ACROSS R (SAME AS CURRENT IN MA.)		1.4
	VOLTAGE ACROSS .55 MFD. C		9.6
4	VOLTAGE ACROSS .5 MFD. C		14.4
	VOLTAGE ACROSS 10 HENRY L		15.75

TABLE 29. **Record your results here for Experiment 29.**

.25-mfd. condenser, leave the red clip on *6* but move the black clip to terminal *4*. With the N. R. I. Tester still set at *V*, insert the plug, read the meter on the *AC* scale, and record the value in Table *29* as the voltage in volts across .25-mfd. condenser *C*. Pull out the plug.

To measure the current through the .25-mfd. condenser, place the black clip on *5*, place the red clip on *4*, and insert the plug. Read the meter on the *AC* scale and record the value in Table *29* as the voltage in volts across *R* and the current in ma. through *R* and *C*. Pull out the plug.

Step 2. To measure current and voltage values in a series circuit consisting of 1,000-ohm resistor R, 10-henry choke coil L and .25-mfd. condenser C, first disconnect the condenser lead from terminal *4*. Connect this condenser lead to one lead of the 10-henry choke coil (Part *3-10*), and connect the other choke coil lead to terminal *4*, as indicated in the schematic circuit diagram in Fig. *30B*.

Adjust the voltage between terminals *5* and *6* to *4* volts in the manner described in Step 1, then pull out the plug.

To measure the voltage across the .25-mfd. condenser *C*, place the red clip on terminal *6*, and place the black clip on the junction of the condenser and coil leads. With the N. R. I. Tester set to the *3*×*V* range, insert the plug, read the meter on the *AC* scale, multiply your result by 3, and record the result in Table *29* as the voltage in volts across .25-mfd. condenser *C*. Pull out the plug.

To measure the voltage across coil *L*, move the black clip to terminal *4*, and move the red clip to the junction of the coil and condenser leads. Leaving the N. R. I. Tester set at the *3*×*V* range, insert the plug, read the meter on the *AC* scale, multiply the value by 3, and record the result in Table *29* as the voltage in volts across 10-henry coil *L*. NOTE: If the voltage reading for the coil on the *3*×*V* range is less than 5.5 volts, change over to the *V* range in order to get a more accurate reading.

To measure the current in this series circuit, move the red clip to terminal *4* and move the black clip to terminal *5*. With the N. R. I. Tester set at *V*, read the meter on the *AC* scale and record the result in Table *29* as the voltage in volts across *R* and

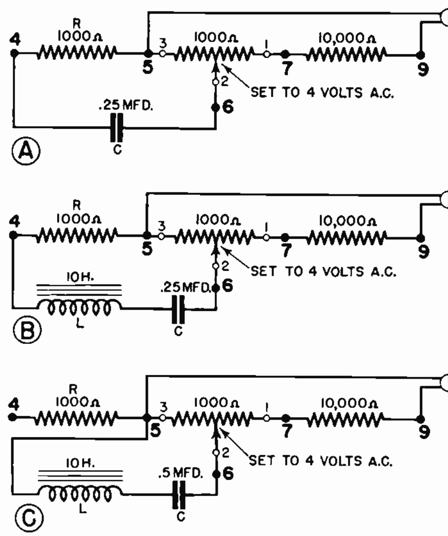


FIG. 30. Schematic circuit diagrams for Experiment 29.

the current in ma. through the *R-L-C* circuit. Pull out the plug and remove the clips, but do not disturb other parts of the circuit.

Step 3. In order to repeat Step 2 with the condenser value in the circuit of Fig. 30B increased to .5 mfd., connect the other .25-mfd. condenser (Part *3-2B*) in parallel with the .25-mfd. condenser already in the circuit, using temporary soldered hook joints.

Now insert the plug in the outlet, readjust the voltage between terminals *5* and *6* to 4 volts, and repeat each of the measurements called for in Step 2. Record the results in Table *29*. Be particularly careful to set the voltmeter range first to $3\times V$ for each measurement, lowering to the V range only when you are certain the voltage will not overload the meter. Pull out the plug.

As a final measurement in this step, take the .05-mfd. condenser (Part *3-1*) and connect it in parallel with the group of two .25-mfd. condensers, soldering one lead by means of a temporary soldered lap joint to the common junction of the coil and condenser, but leaving the other lead unsoldered. With the red clip on terminal *6* and the black clip on the common junction of the condensers and the coil, and with the N. R. I. Tester set at $3\times V$, insert the plug in the outlet. Grasp the .05-mfd. condenser by its paper housing and press the free lead against terminal *6*. Read the meter on the *AC* scale, multiply the value by 3, and record the value in Table *29* as the voltage in volts across the .55-mfd. capacity. Pull out the plug, turn off the N. R. I. Tester, remove the clips, and unsolder the .05-mfd. condenser completely from the circuit.

Step 4. To remove from your circuit the 1,000-ohm resistor which has been present in the previous steps for current-measuring purposes, disconnect the coil lead from terminal *4* and solder it instead to terminal *5*, as indicated in Fig. *30C*. Adjust the voltage between terminals *5* and *6* to exactly 4 volts in the manner previously described. Pull out the plug, set the selector switch to $30\times V$, leave the red clip on terminal *6*, but move the black clip to the common junction of the condensers and coil. Insert the plug in the outlet, read the meter on the *AC* scale as accurately as possible, multiply the reading by 30, and record the result in Table *29* as the voltage across the .5-mfd. condenser. Pull out the plug.

The meter reading will be very low, below 1 on the scale, indicating a voltage value somewhere between 15 and 30 volts. You cannot estimate the value very accurately at this end of the scale, but can make a much more accurate reading on the $3\times V$ range if the voltage happens to be below the maximum value of 16.5 volts for this range. Therefore, switch to $3\times V$. If the meter pointer swings to the upper end of the scale, read the meter on the *AC* scale; multiply the result by 3, and record it in Table *29* as the voltage for this measurement. If, however, the meter pointer merely vibrates around *0* when you switch to the $3\times V$ range, or reads slightly backward, do not attempt to get a more accurate reading. (It is a characteristic of the N. R. I. Tester to vibrate near *0* when overloaded on any of the *AC* voltage ranges. A similar action, usually in the form of a reversed reading, occurs during overloading on any of the *DC* voltage scales. Whenever an overload indication is secured, switch to the next higher range.) Remember that an overload will usually shift the *0* position of the pointer. As previously pointed out, this condition can be corrected simply by touching the calibrating clip momentarily to the —4½C terminal on the battery block.

To measure the voltage across coil *L*, place the black clip on terminal *5*, and place the red clip on the common junction of the coil and condenser leads. Set the N. R. I. Tester to $30\times V$, insert the plug, read the meter on the *AC* scale, and multiply the value by 30. If the value comes out to be close to 16.5 or below this value, see if you can secure a more accurate reading on the $3\times V$ scale. Record your final value in Table *29* as the voltage across coil L. Pull out the plug, turn off the N. R. I. Tester, remove the clips, and disconnect the coil and the condenser group, but leave the two .25-mfd. condensers connected together.

Discussion: In Step 1, you have a .25-mfd. condenser connected in series with the 1,000-ohm resistor across the a. c. voltage source of 4 volts. At the power line frequency of 60 cycles, the reactance of a .25-mfd. condenser is 10,600 ohms.*

This is about ten times the ohmic value of the 1,000-ohm resistor, so you should expect to measure about ten times as much voltage drop across the condenser as you do across the resistor.

In the N. R. I. laboratory, the voltage across C was just about 4 volts. The voltage across the resistor was very low and difficult to read, with the estimated reading being .3 volt. If these voltages are added together vectorially, taking into account the fact that they are at right angles (90° out of phase), the resultant voltage across R and C together will still be about 4 volts, the source voltage. In other words, the circuit is essentially capacitive. The circuit current was about .3 ma. in this case.

The insertion of a 10-henry coil in series with the condenser and resistor to give the circuit shown in Fig. *30B*, while keeping the a.c. source voltage at 4 volts, will make both the circuit current and the condenser voltage go up. The fact that circuit current goes up is proof that the total impedance of the circuit has been lowered.

Now we obtain more voltage across the condenser than we have available at the source. From your fundamental course you learned, however, that the voltages across a coil and a condenser in a series circuit are 180° out of phase; this means that the combined voltage across them is the *difference* between their numerical values. The reason the current goes up is simply because the inductive reactance of the coil cancels out part of the capacitive reactance of the condenser, thereby lowering the total impedance in the circuit.

When the capacity in the circuit of Fig. *30B* is increased to .5 mfd. in Step 3, you will find that the coil, condenser and resistor voltages go up considerably. Coil and condenser voltages will be almost equal, indicating a condition very nearly approaching resonance. The difference between the coil and condenser voltages, when added vectorially to the resistor voltage, should presumably equal the source voltage of 4 volts. In the case of the N. R. I. values, however, adding the difference value of .2 volt at right angles to the resistor voltage of 1.4 volts does not give a value anywhere near 4 volts. We can be reasonably sure that this discrepancy is due to the a.c. resistance of the coil; furthermore, the voltage drop due to the a.c. resistance must be quite large.

It is possible to make measurements from which both the a.c. resistance of the coil and the Q factor of the coil can be computed. You do this by connecting the coil to a known a.c. voltage source in series with a condenser whose value will bring about the approximate condition of series resonance. Under this condition, the condenser and the coil both have maximum voltage values. The ratio of the coil voltage to the supply voltage is then the Q factor of the coil at the frequency used for the test (60 cycles in our case) and for the current value

*The formula used for determining this reactance value is: $X_C = \frac{1,000,000}{6.28 \times f \times C}$, where X_C is the reactance in ohms, f is the frequency in cycles and C is the capacity in mfd.

flowing through the coil in the case of iron-core coils.

Knowing the Q factor, you can compute the a.c. coil resistance simply by dividing the reactance of the coil by the Q factor. This formula is correct for series resonant circuits, because at resonance the voltage of the source is dropped entirely in the coil resistance, and the a.c. resistance value therefore determines what the circuit current will be.

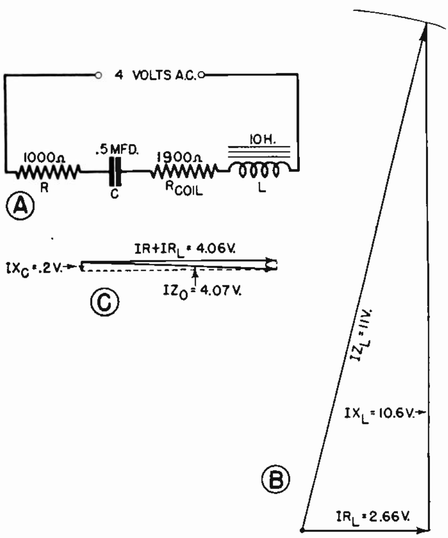


FIG. 31. Equivalent simplified circuit diagram corresponding to Fig. *30B*, and vector diagrams which prove that Kirchhoff's Voltage Law for a.c. circuits holds true in this particular circuit when tested out with the values obtained in the N.R.I. laboratory. One volt on these diagrams corresponds to ¼-inch of vector length.

As an example illustrating how the computations are made, we will use the values measured in the N. R. I. laboratory. We can assume that .5 mfd. tunes the coil essentially to resonance, particularly if the addition of the .05-mfd. condenser in Step 3 made the condenser voltage drop. We know that at resonance, the reactances of the coil and condenser are equal. We do not know the coil reactance because the inductance of this coil varies with the amount of current flowing through the coil (the rated value of 10 henrys applies only when rated current of 25 milliamperes is flowing). Therefore, we can compute the condenser reactance and assume that the choke will also have this reactance.

At 60 cycles, a .5-mfd. condenser has a reactance of about 5,300 ohms, so this will be used as our coil reactance value.

The measured N. R. I. voltage value across the choke coil in Step 3 was 11 volts. Dividing 11 by the a.c. source voltage of 4 gives a value of 2.75 for the Q factor of the coil.

Dividing the coil reactance of 5,300 ohms by the Q factor value of 2.75 gives approximately 1,900 ohms as the a.c. resistance of the coil at 60 cycles, for the connections used in Step 3. We assumed a value of 1,500 ohms in a previous experiment, which is not unreasonable due to the fact that at different values of current, the Q factor and reactance of the coil will be different.

Knowing the a.c. resistance value, we can use the values for Step 3 and see if we can make Kirchhoff's Voltage Law for a.c. circuits check in this case. The circuit diagram in Fig. *31A*, in which the a.c. resistance of the coil is separated from the coil inductance, will help you to understand this circuit.

To calculate the voltage drop across the a.c. resistance of the coil, multiply the a.c. resistance value by the circuit current value obtained in Step 3; 1,900 x .0014, which is approximately 2.66 volts.

Next, we must find the true voltage drop across the inductance of the coil. The drop across the a.c. resistance of the coil is 2.66 volts, and the total coil impedance drop obtained in Step 3 is 11 volts. We draw a horizontal vector for 2.66 volts, then swing an arc having a radius proportional to 11 volts, and draw a line vertically upward from the end of the 2.66-volt vector until it intersects the arc, as shown in Fig. *31B*. The length of this vertical line will now be proportional to the voltage drop across the inductive reactance of the coil. Using the values measured at N.R.I., this drop came out to be 10.6 volts.

The resultant drop across the reactances in this circuit will be the difference between 10.8 and 10.6, or .2 volts. If we add this reactance drop at right angles to the total drop of 4.06 volts (2.66 + 1.4) across the 1,000-ohm resistor and the a.c. resistance of the coil in the manner shown in Fig. *31C*, we secure a resultant voltage vector which is just about 4 volts. Again we have confirmed Kirchhoff's Voltage Law for a.c. circuits.

This experiment has established the fact that in a series circuit, the reactances of a coil and a condenser cancel each other partially or completely. Furthermore, this experiment has proved definitely that the a.c. resistance of a coil is greater than its d.c. resistance. Finally, the experiment has shown that when a coil and condenser are connected in series, the combined reactance will be less than the largest individual reactance.

Instructions for Report Statement No. 29. An important principle to remember in connection with resonant circuits is that a change in the applied voltage does not affect the conditions of resonance.

With your parts connected according to the circuit shown in Fig *30C*, adjust the potentiometer until the a.c. voltage as measured between terminals *5* and *6* is 4 volts, then measure the voltage across condenser *C* while observing the safety precautions emphasized in previous a.c. experiments. Make a note of the voltage value observed, then readjust the voltage between terminals *5* and *6* to 2 volts, which is half of 4 volts, and measure again the voltage across condenser *C*. Compare the two voltage values measured across *C*, then turn to the last page and place a check mark after the answer which applies to your observation.

If the voltage across any part of the resonant circuit (such as across the condenser) drops proportionately when you reduce the source voltage to half its value, you have proved the statement brought forth above.

EXPERIMENT 30

***Purpose:* To show that the combined reactance of a coil and condenser connected in parallel in an a.c. circuit is higher than that of the lowest reactance in the combination.**

Step 1. With the a.c. voltage divider used in Experiments 28 and 29, connect the 10-henry coil between terminals *4* and *6* to give the same circuit arrangement as is shown in Fig. *27D*. Set the N. R. I. Tester to *3×V*, place the black clip on terminal *5*, place the red clip on terminal *6*, insert the plug in the outlet, turn on the tester, and adjust the potentiometer until you have 10 volts between terminals *5* and *6*, as indicated by a reading of 3.3 on the *AC* scale. Pull out the plug.

Place the black clip on terminal *5*, place the red clip on terminal *4*, insert the plug, and note the meter reading with the N. R. I. Tester set at *3×V*. If the actual voltage indication is below 5.5 volts, change to the *V* range to secure a more accurate reading. Record your final value as the current in ma. through *R* and *L*, then pull out the plug.

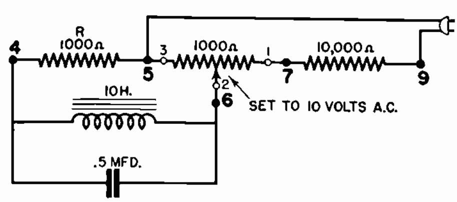


FIG. 32. Schematic circuit diagram for Step 2 of Experiment 30.

Step 2. Place a .5-mfd. condenser in parallel with the coil as shown in Fig. 32 (use the two .25-mfd. condensers, Parts *3-2A* and *3-2B*, which you previously connected in parallel to give .5 mfd.). Use temporary soldered lap joints to terminals *4* and *6* for this purpose. Readjust the voltage between terminals *5* and *6* to 10 volts in the manner specified in Step 1, then pull out the plug. Place the black clip on terminal *5*, place the red clip on terminal *4*, leave the N. R. I. Tester set at the *V* range, turn on the N. R. I. Tester, reinsert the plug, read the meter on the *AC* scale, and record the result in Table *30* as the current in ma. through *R*, *L* and *C*. Pull out the plug, and turn off the Tester.

STEP	NATURE OF MEASUREMENT	YOUR VALUE IN MA.	N.R.I. VALUE IN MA.
1	CURRENT THRU R AND L		1.7
2	CURRENT THRU R,L AND C		.5

TABLE 30. Record your results here for Experiment 30.

Discussion: In this experiment, you measure the current first through a 10-henry inductance having an impedance of approximately 5,300 ohms at 60 cycles, then through a parallel circuit consisting of the inductance and a .5-mfd. capacity which likewise has an impedance of 5,300 ohms. If you performed this experiment correctly, you should find that the mere shunting of the coil with this condenser serves to reduce the circuit current to 1/3 of the value for the coil alone. The parallel coil-condenser combination must therefore have a reactance of about 3 times the 5,300-ohm value for the coil alone, or 15,900 ohms.

The currents through the coil and the condenser are 180° out of phase, and therefore the total current drawn by these two parts must be equal to the difference between the currents through the individual parts.

The important fact for you to remember in connection with this experiment is that when a coil is shunted by a condenser, the combined impedance is greater than the lowest reactance.

Instructions for Report Statement No. 30. Suppose we repeated this experiment with a large condenser shunted across the choke coil, so that the condenser impedance is much lower than the coil impedance. Would the fundamental rule presented in this experiment still hold true? You can easily check this by making the following additional measurements.

Starting with your apparatus connected according to the circuit of Fig. *32*, disconnect both the 10-henry coil and the .5-mfd. condenser from terminals *4* and *6*, then connect to these same terminals a 10-mfd. capacity (your dual 10-10-mfd. condenser connected for a.c. operation, as was done in Step 7 of Experiment 28). Adjust the voltage between terminals *5* and *6* to 5 volts a.c., then measure the a.c. voltage across 1000-ohm resistor *R* (between terminals *4* and *5*). Remember that this voltage value is also the current in ma.; the higher this current, the lower is the impedance between terminals *4* and *6*.

Now connect to terminals *4* and *6* the 10-henry choke coil, so it is in parallel with the 10-mfd. capacity, and measure again the a.c. voltage across 1000-ohm resistor *R*. Check your answer in Report Statement No. 30. Pull out the plug, turn off the N. R. I. Tester, then disconnect the voltage divider.

IMPORTANT: Do not discard any of the parts supplied to you in N. R. I. radio kits before you have completed your course. The parts will be used again in later experiments.

INSTRUCTIONS FOR PERFORMING RADIO EXPERIMENTS 28 TO 40

4RK-DC

NATIONAL RADIO INSTITUTE

ESTABLISHED 1914

WASHINGTON, D. C.

A COURSE IN PRACTICAL DEMONSTRATIONS OF RADIO FUNDAMENTALS

A PLAN FOR TODAY

I WILL AWAKEN:	With a smile brightening my face; with reverence for this new day in my life and the opportunities it contains.
I WILL PLAN:	A program which will guide me successfully past the many temptations and distractions of a busy day and bring me one step closer to my goal of success.
I WILL WORK:	With my heart always young and my eyes open so that nothing worth while shall escape me; with a cheerfulness that overcomes petty irritations and unpleasant duties; with the purpose of my work always clearly in mind.
I WILL RELAX:	When tired, so as to accumulate fresh energy and live long enough to enjoy the success my work will bring.
I WILL PLAY:	With the thought that today is my day, never to be lived over again once it is ended; with relaxation and pure enjoyment as the only purposes of play; putting work and worldly worries out of mind for this short portion of my day.
I WILL RETIRE:	With a weariness that woos sleep; with the satisfaction that comes from a day well lived, from work well done.
I WILL SLEEP:	Weary, but content; with tomorrow a vision of hope.

J. E. SMITH.

NATIONAL RADIO INSTITUTE

WASHINGTON, D.C.

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

NCP1M1040

Printed in U. S. A.

Instructions for Performing Radio Experiments 28 to 40

Introduction

A RADIO receiver, transmitter, public address amplifier or other vacuum tube device must be supplied with power. The grid and plate electrodes of vacuum tubes require d.c. voltages having as little a.c. ripple as possible, while filaments require either a.c. or d.c. voltages.

When radio apparatus is to be used in a location where a.c. power is available, the usual practice is to step this a.c. line voltage (ordinarily 115 volts, 60 cycles) down to about 6 volts a.c. by means of a step-down transformer, for supplying voltage to the filaments of vacuum tubes. The ripple-free high d.c. voltage is obtained by first stepping up the a.c. voltage to a considerably higher value (approximately equal to the d.c. voltage required), then rectifying this a.c. voltage by means of a diode-type tube, and feeding the resulting pulsating d.c. voltage through a choke coil-condenser filter circuit which allows direct current to pass but suppresses or chokes any a.c. components which may be present.

A single transformer, commonly called the power transformer, is used both for stepping down the line voltage to the filament value and for stepping up the line voltage to the high d.c. value. Any required number of secondary windings can be wound on the iron core of a transformer along with the primary winding.

The rectifier tube oftentimes requires a different filament voltage than the other tubes. In this case, an additional low-voltage secondary winding is required on the power transformer. The power transformer, rectifier tube and filter network together constitute an a.c. power pack.

In localities where a.c. power is not available, there are a number of other possible solutions to this power supply problem besides using individual batteries. All of these are considered in your regular course, so only vibrator systems need be considered here.

An ordinary 6-volt storage battery which is charged by a wind charger or small gasoline engine-driven generator is used extensively as a main source of power in locations where a.c. is not available. The 6-volt d.c. output of the storage battery is applied directly to the filaments of the tubes, and the high d.c. voltage value for the other tube electrodes is obtained by using an electromechanical vibrator to change this d.c. voltage approximately to 12 volts a.c. The resulting a.c. voltage can then be stepped up to a higher a.c. value approximating the desired high d.c. value, then rectified and filtered in much the same manner as is done in a.c. power packs.

There are two widely used vibrator systems. One system employs a synchronous vibrator; this converts d.c. to a.c., and also changes the a.c. back to a pulsating d.c. voltage after the a.c. voltage has been stepped up. In the other system, the vibrator serves only to convert d.c. to a.c., and a separate tube rectifier is used to con-

STORAGE BATTERY DATA

A standard 6-volt storage battery is needed to operate the d.c. power pack which you will use for *every remaining experiment* in your practical demonstration course, so it is absolutely essential that you borrow or buy a battery as soon as possible if you do not already have one.

It is not necessary to secure an expensive battery; those sold by mail order firms and auto supply stores with a 12-month guarantee are adequate. These will have about a 75 ampere-hour rating, which should give a total of at least 25 hours operation of the d.c. power pack on full load. If you follow the instructions in this manual (turn on the power pack only while making measurements and turn it off right after completing a measurement), you may be able to complete your entire practical demonstration course without having the battery recharged.

If you plan to start radio servicing, your storage battery can be used for shop tests of auto radios after completing your course. Otherwise, it can be used for automotive service if you order the correct type for your car.

A second-hand battery should be used only if you are certain it is in good condition. An old battery which is just about ready to fail may be a nuisance in that it will require recharging frequently.

One way to tell when a storage battery needs recharging is with a hydrometer. It is inexpensive, so it is a good idea to buy one along with the battery. Recharging is necessary when the hydrometer reading drops to 1100. If the battery is allowed to become completely discharged before being recharged, its life may be shortened considerably.

The storage battery should be located within reach of the battery leads of your power pack. Do not attempt to extend these leads, for the resulting voltage drops in the leads would lower the voltage applied to the power pack terminals and make it difficult to get satisfactory experimental results.

In brief, your storage battery should receive the same attention and care which is given to an automobile storage battery.

vert the a.c. back into d.c. after it has been stepped up.

Since you have previously informed us that you do not have 115-volt, 60-cycle power available in your home, or in the location where you plan to carry out your experiments, you are receiving in Radio Kit 4RK-DC a d.c. power pack which will operate from a 6-volt storage battery. Although it would be less expensive to supply you with a synchronous vibrator, we are sending instead the more costly vibrator-rectifier tube power pack in order that you can perform vacuum tube rectifier experiments just as if you had an a.c. outlet in your home. The processes of rectification and filtering will then be essentially the same as in the a.c. power packs of a.c. radio receivers.

Information About Experiments 28, 29 and 30. Since you do not have a.c. power, you were unable to perform the last three experiments in Manual 3RK. The d.c. power pack which you are now going to build can supply 12 volts a.c., permitting you to perform these three experiments. Since slight modifications in the experimental procedure must be made because the frequency of the 12-volt a.c. output is about 120 cycles (twice as high as ordinary a.c. line voltage), the instructions for these experiments are repeated in this manual. Be sure

DON'T USE DRY CELLS

Although four dry cells in series would give the 6 volts d.c. required by the d.c. power pack, the dry cells are not capable of supplying for any period of time the relatively high current drawn by the power pack on full load, and would become discharged quickly. Furthermore, the voltage of a dry cell drops with age, making it impossible to compare experimental results obtained at different times. Therefore, do not use dry cells in place of a storage battery.

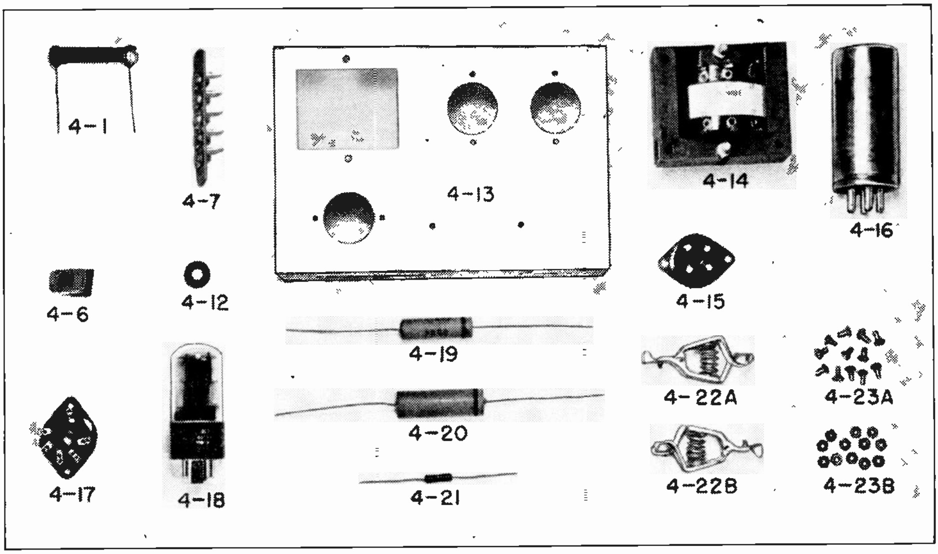


FIG. 1. The parts included in Radio Kit 4RK-DC are pictured above, and are identified in the list below. Numbers which are omitted from the part number sequence for 4RK-DC belong to parts which are included in the corresponding a.c. version of this kit and which have been replaced here by special d.c. power pack parts such as Parts *4-13* to *4-22*. Some resistors may have a better tolerance (a lower percentage tolerance) than that indicated here.

Part No.	*Description*
4-1	One 50,000-ohm, 3-watt resistor with 20% tolerance (color-coded green, black, orange).
4-6	One slide type power switch.
4-7	One 5-terminal, screw-type binding post strip.
4-12	One small rubber grommet for the power cord.
4-13	One cadmium-plated steel chassis bent to shape, with all holes already punched for the vibrator-type power pack.
4-14	One vibrator transformer for 120-cycle operation, with center-tapped primary winding and center-tapped secondary winding.
4-15	One type UX 4-prong tube socket for the vibrator.
4-16	One vibrator.
4-17	One octal-type tube socket with 6 terminal lugs.
4-18	One type 6X5GT full-wave rectifier tube.
4-19	One .01-mfd., 1,200-volt paper condenser.
4-20	One .5-mfd., 200-volt paper condenser.
4-21	One 10-megohm, ½-watt resistor with 10% tolerance (color-coded brown, black, blue, silver).
4-22A	One large storage battery clip, marked +.
4-22B	One large storage battery clip, marked —.
4-23A	Twelve ¼-inch long, 6-32 cadmium-plated binder-head machine screws.
4-23B	Twelve cadmium-plated hexagonal nuts for 6-32 screws.

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

Part No.	*Description*
1-8D	One ⅝-inch soldering lug.
1-16	One 18,000-ohm, ½-watt resistor with 10% tolerance (color-coded brown, gray, orange, silver).
3-2A	One .25-mfd., 400-volt paper condenser.
3-2B	One .25-mfd., 400-volt paper condenser.
3-3	One dual 10-10-mfd., 450 working volts electrolytic condenser with bakelite mounting piece.
3-5A & B	Two 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.
3-9	Mounting bracket for potentiometer.
3-10	One 10-henry choke coil with 25-ma. current rating.
3-11	One 5-foot power cord with attached outlet plug, to be used for battery leads.
3-12	One 6-lug insulated terminal strip.
3-13	Three ⅜-inch No. 6 round-head wood screws.

that you answer Report Statements Nos. 28DC, 29DC and 30DC on the last page of this book after completing these experiments.

Power Pack Experiments. After you have completed the three basic a.c. experiments left over from Manual 3RK, you will study the behavior of vacuum tube rectifiers and filter circuits by carrying out various experiments with your power pack. Thus, you will demonstrate that a vacuum tube rectifier system possesses the characteristic of voltage regulation, whereby its output voltage goes down as the load is increased. You will find out that the type of filter circuit and the power-handling ability of the power transformer affect the amount which the voltage drops with load.

You will demonstrate that a power pack having a condenser input filter possesses an entirely different characteristic from a power pack having a choke input filter. In other words, you will prove for yourself that both the d.c. output voltage value and the amount of hum in the output voltage depend upon the nature of the filter circuit employed.

To complete your practical experience with power packs, you will introduce circuit changes equivalent to defective filter condensers, and see how the filtering action is impaired by these defects. Another practical demonstration you make is the effect which tuning the choke coil has upon hum. Every single one of the experiments you perform brings out facts which are highly important to practical radio men.

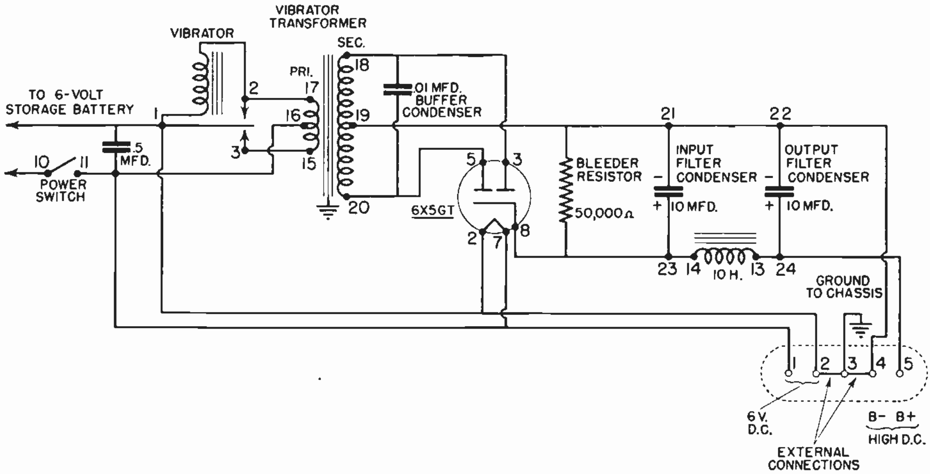


FIG. 2. Schematic circuit diagram for the d.c. power pack which you build before beginning the experiments in this manual. The terminals on this schematic diagram are numbered to correspond with the terminals shown on the semi-pictorial diagrams in Figs. *5* and *8*.

Contents of Radio Kit 4RK-DC

The parts included in your Radio Kit 4RK-DC 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. Do not destroy any of these parts until you have completed your entire N.R.I. course, for many of the parts will be used over and over again in later experiments.

IMPORTANT: If any part in your Radio Kit 4RK-DC is obviously de-

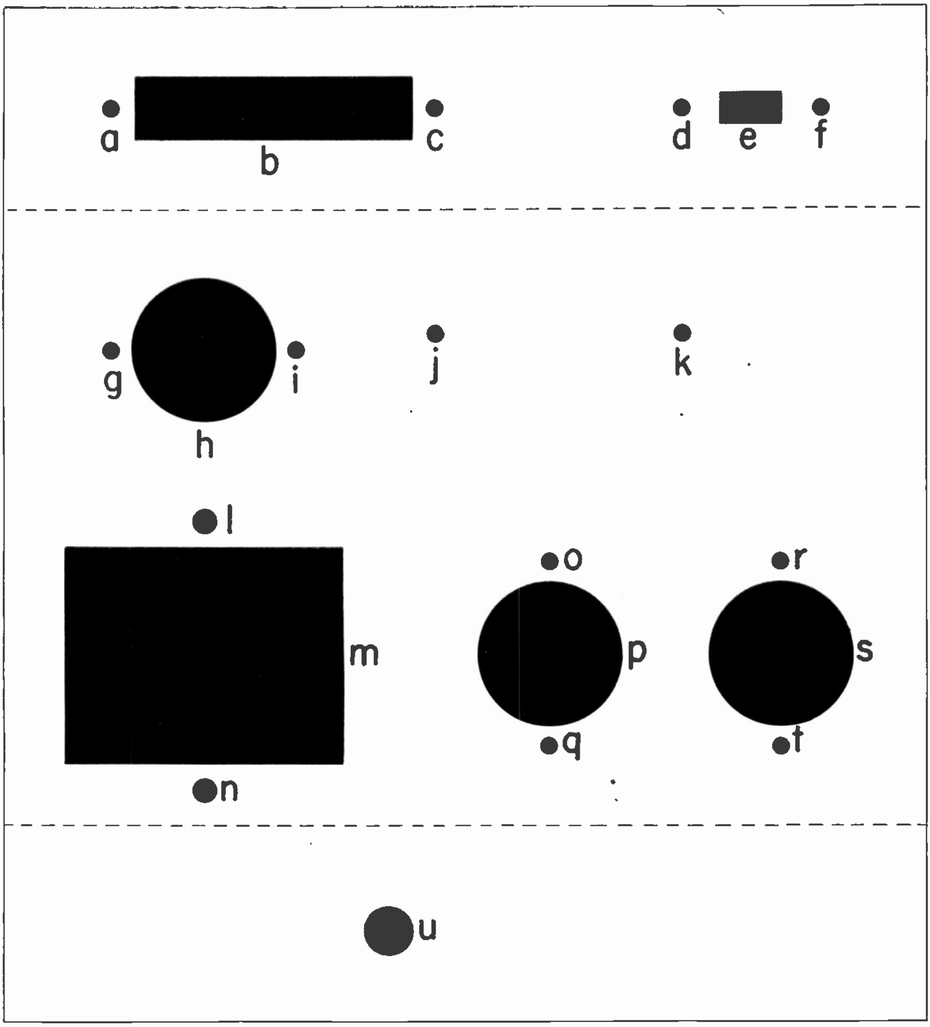


FIG. 3. Chassis layout diagram for the d.c. power pack, drawn to show what you would see if you looked at the bottom of the chassis while it was a flat sheet (before bending the sides). The dotted lines indicate the positions of the bends. The holes are lettered here merely for your convenience in locating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

fective or has been damaged during shipment, please return it to the Institute *immediately* for replacement.

Instructions for Assembling the D.C. Power Pack

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

The schematic circuit diagram for

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

Mounting the Parts on the Chassis

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

50,000-ohm resistor (Part *4-1*).
Slide-type power switch (Part *4-6*).
5-terminal screw-type binding post strip (Part *4-7*).
Rubber grommet for power cord (Part *4-12*).
Cadmium-plated steel chassis (Part *4-13*).
Vibrator transformer (Part *4-14*).
4-prong type UX tube socket (Part *4-15*).
Vibrator (Part *4-16*).
Octal-type tube socket (Part *4-17*).
Type 6X5GT tube (Part *4-18*).
.01-mfd. condenser (Part *4-19*).
.5-mfd. condenser (Part *4-20*).
Two large battery clips (Parts *4-22A* and *4-22B*).
Twelve ¼-inch binder-head machine screws (Part *4-23A*) with twelve hexagonal nuts (Part *4-23B*).
⅝-inch soldering lug (Part *1-8D*).
Dual 10-10-mfd. electrolytic condenser with bakelite mounting piece (Part *3-3*).
10-henry choke coil (Part *3-10*).
Power cord with plug (Part *3-11*).

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

Step 3. To mount on the chassis the 4-prong socket for the vibrator, take the type UX 4-prong tube socket (Part *4-15*) and hold it against the bottom of the chassis over holes *g, h* and *i* in such a way that terminals *1* and *2* are nearest to the far side of the chassis, exactly as shown in Fig. *5*. The terminal numbers will be found embossed on the bottom of the socket alongside the terminals. Fasten the

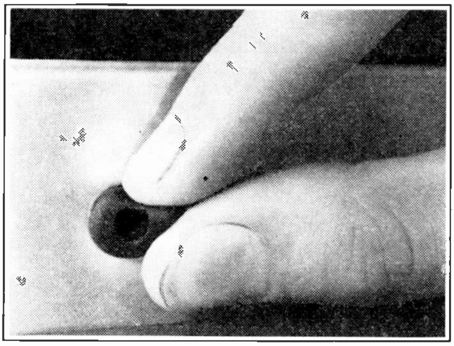


FIG. 4. Squeeze the grommet for the power line cord between your thumb and forefinger in the manner shown here while forcing it into hole *u* in the side of the chassis. This grommet can be placed in position with your fingers; it may take a little time at first, but you will soon get the "knack" of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

socket to the chassis with two machine screws and nuts (Parts *4-23A* and *4-23B*), keeping the screw heads above the chassis. (The vibrator has only three terminal prongs; the fourth prong, which fits into tube socket terminal *4*, is a dummy which is provided to anchor the vibrator more firmly in its socket.)

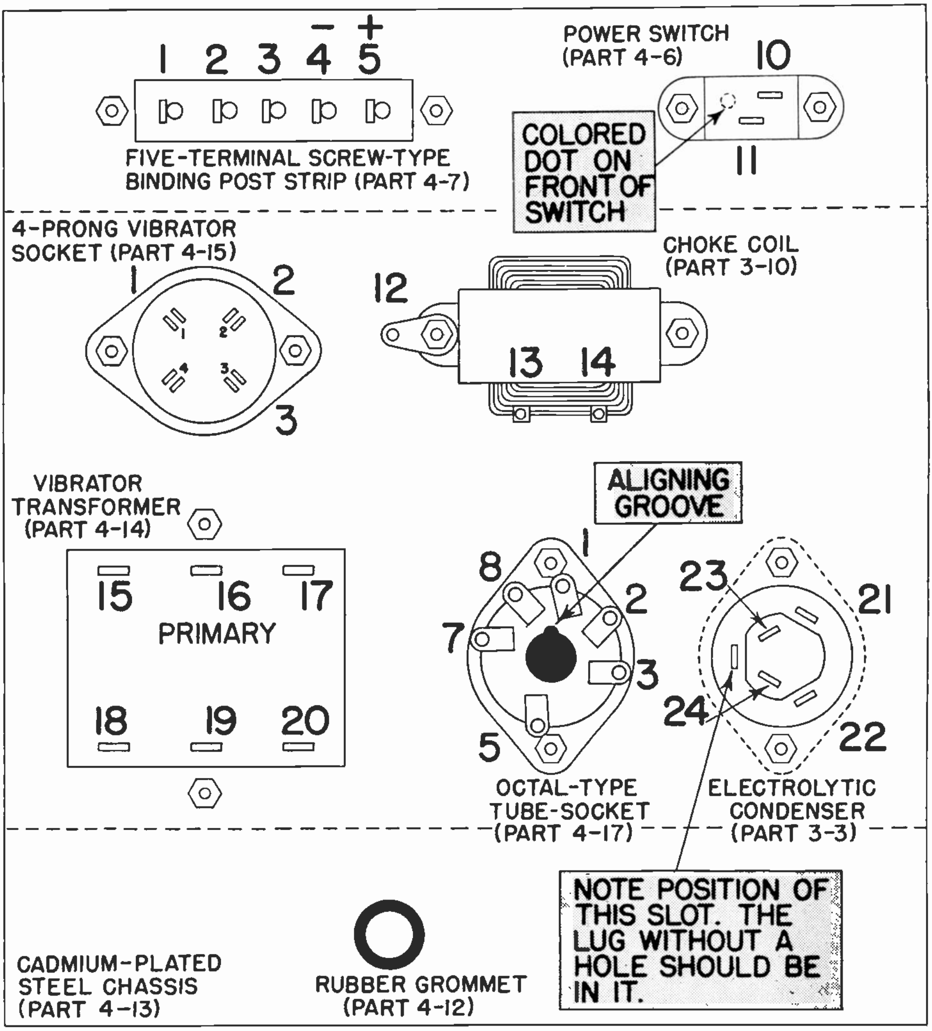


FIG. 5. Bottom view of chassis with sides spread out, showing exact positions of all parts which are mounted directly on the chassis, and showing positions of all numbers which you are to place on the chassis and on the parts with metal-marking crayon. The dotted lines indicate the positions of the bends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

Step 4. To mount on the chassis the socket for the rectifier tube, take the octal-type tube socket (Part *4-17*) and hold it against the bottom of the chassis over holes *o*, *p* and *q* in such a way that the aligning groove in the socket is in the position shown in Fig. *5*. Fasten the socket to the chassis in this position with two machine screws and nuts, keeping the screw heads above the chassis.

Step 5. To mount the electrolytic condenser on the chassis, take the bakelite mounting piece for this condenser and hold it against the top of the chassis over holes *r*, *s* and *t* in such a manner that the slots in this piece will have exactly the positions shown in Fig. *5* when looking at the bottom of the chassis. Bolt the bakelite piece to the chassis with two machine screws and nuts inserted in holes *r* and *t*, with the screwheads above the chassis.

Now take the electrolytic condenser (Part *3-3*) and insert its lugs in the slots of the bakelite mounting piece from the top of the chassis, in such a way that *the outer lug which has no hole* in it will be *next to the tube socket* in hole *p* on the chassis. If this condenser is inserted correctly, the two large inside lugs at the bottom of the condenser will be almost in line with the condenser mounting screws, as indicated in Fig. *5*.

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

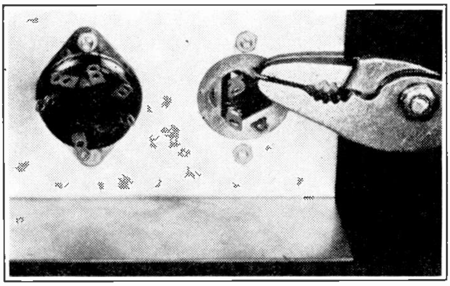


FIG. 6. This illustration shows the correct position of the bakelite mounting piece on the chassis, with the electrolytic condenser in position, and also shows how the outer lugs of the condenser are twisted a small amount with pliers to fasten the condenser unit to the bakelite mounting piece. Two of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

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

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

Step 8. To mount the choke coil on the chassis, take the 10-henry choke coil (Part *3-10*) and hold it against the bottom of the chassis in such a way that its mounting tabs are over holes *j* and *k* and its terminal lugs are on the side facing the octal-type rectifier tube socket, as shown in Fig. *5*. Fasten the choke coil to the chassis with two machine screws and nuts. Keep the screw heads above the chassis, and place a ⅝-inch soldering lug (Part *1-8D*) under the nut for hole *j*.

Step 9. To mount the vibrator transformer on the chassis, first take this vibrator transformer (Part *4-14*) and remove the nuts from the two long machine screws which go through the transformer core. Place the transformer on top of the chassis over holes *l, m* and *n* in such a way that the lettering *PRIMARY* on the bottom of the transformer is next to the four-prong vibrator socket, as shown in Fig. *5*. Now insert the long machine screws through the transformer mounting holes and through holes *l* and *n* respectively on the chassis. On each screw underneath the chassis, place a nut, and tighten the screw with a screwdriver while holding the nut with ordinary pliers.

This completes the mounting of the large parts on the chassis. The top

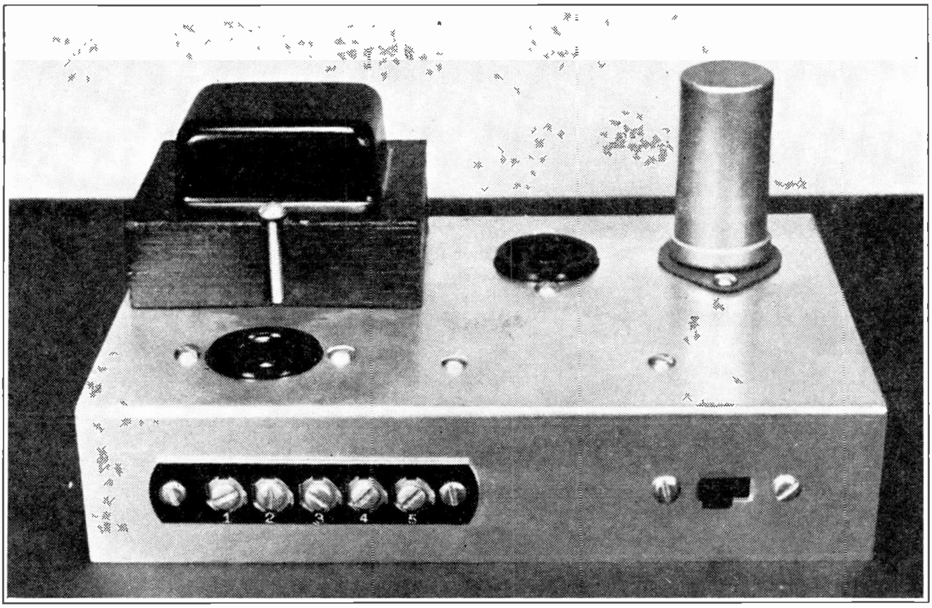


FIG. 7. Top view of the completed d.c. power pack chassis before the vibrator and rectifier tube have been inserted in their sockets.

of the chassis should now appear as shown in Fig. 7.

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

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

Step 11. To connect together the various terminals with hook-up wire, prop up the chassis upside down on your bench so it is level and the terminals are readily accessible, and follow carefully the detailed step-by-step instructions which will now be given. Be particularly careful to make *temporary* soldered joints where specified. Use rosin-core solder (supplied in a previous kit) for all joints. Do not solder a joint until told to do so, for premature soldering will make it difficult for you to get additional wires into the hole in a lug. Use the semi-pictorial diagram in Fig. *8* and the photographic illustration in Fig. *9* as your guides for positioning the wiring.

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

Use red push-back hook-up wire throughout; you should have enough of this left from previous kits to take care of all wiring requirements for the power pack and the experiments dealing with it.

a. Connect output terminal *4* to transformer terminal *19* with a 7¼-inch length of hook-up wire, making permanent hook joints but soldering only terminal *4*.

b. Connect transformer terminal *19* to electrolytic condenser terminal *22* with a 6¼-inch length of hook-up wire, making *temporary* hook joints in both cases but soldering only terminal *22*.

c. Connect output terminal *5* to choke coil terminal *13* with a 2¼-

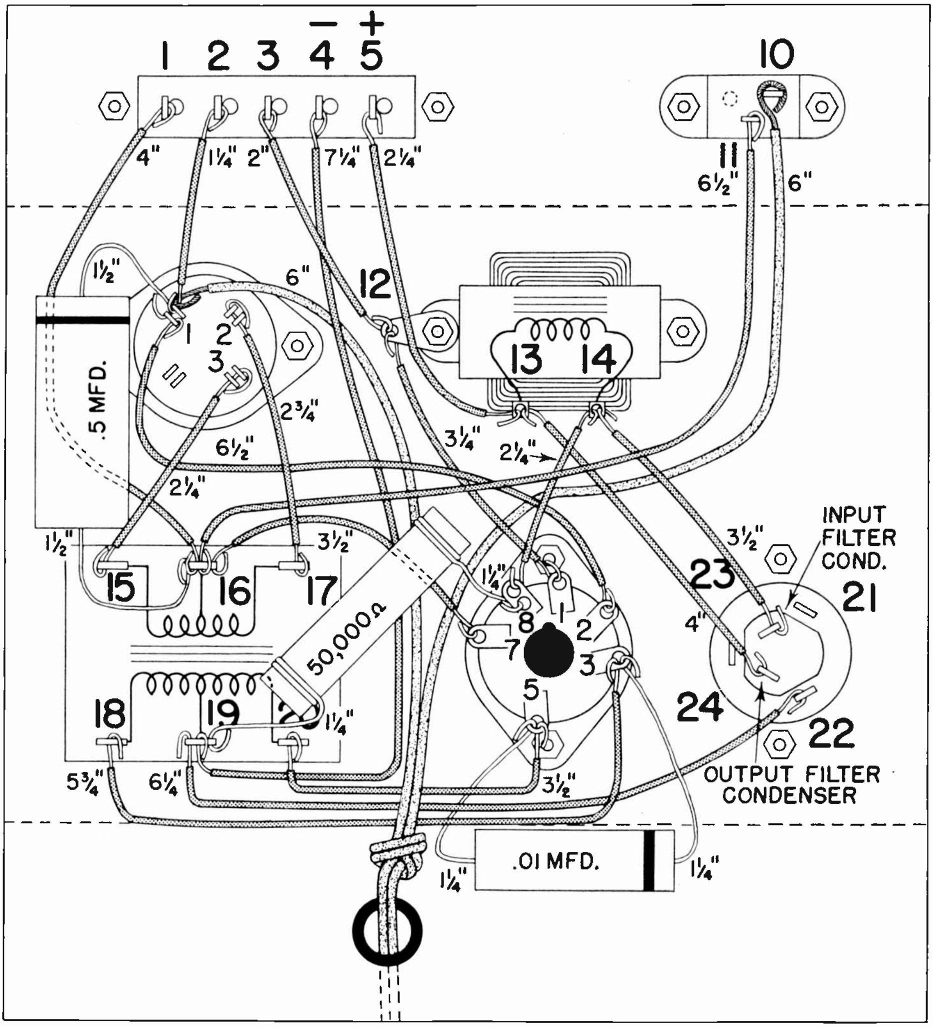


FIG. 8. Semi-pictorial wiring diagram showing how all connections are made under the chassis of the d.c. power pack. The sides of the chassis have been flattened out for clearness, but the wire lengths specified on this diagram are correct for the actual chassis.

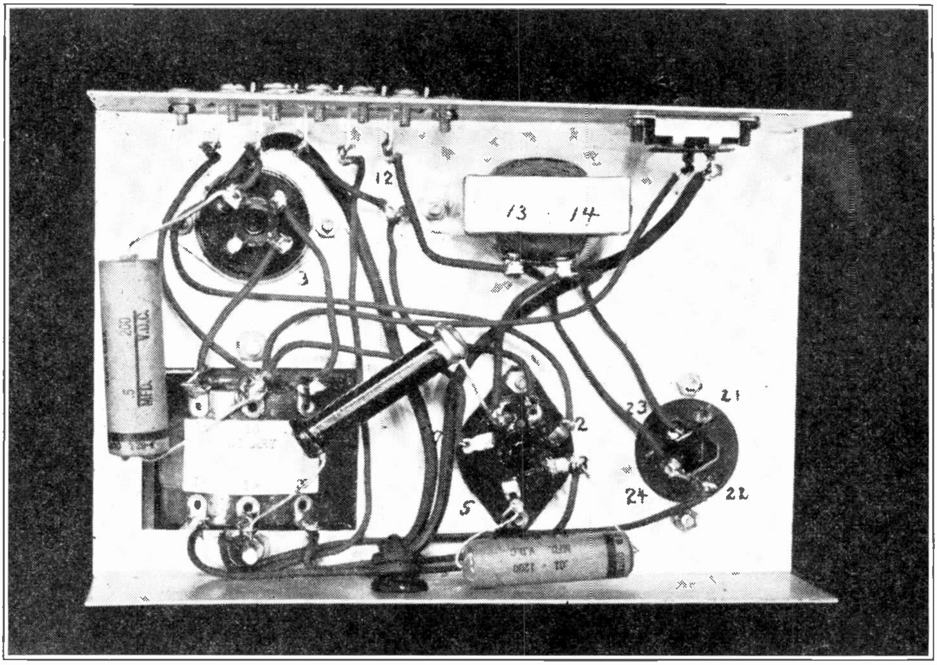


FIG. 9. Your vibrator power pack should appear like this under the chassis after all wiring has been completed.

inch length of hook-up wire, making *temporary* hook joints in both cases but soldering only terminal *5*.

d. Connect choke coil terminal *13* to electrolytic condenser terminal *24* with a 4-inch length of hook-up wire, making *temporary* hook joints in both cases and soldering both joints.

e. Connect output terminal *3* to grounding lug *12* with a 2-inch length of hook-up wire, making permanent hook joints but soldering only terminal *3*.

f. Connect grounding lug *12* to rectifier tube socket terminal *1* with a 3¼-inch length of hook-up wire, making permanent soldered hook joints in both cases.

g. Connect vibrator socket terminal *1* to rectifier tube socket terminal *2* with a 6½-inch length of hook-up wire, making permanent hook joints but soldering only terminal *2*.

h. Connect output terminal *2* to vibrator socket terminal *1* with a 1¼-inch length of hook-up wire, making permanent hook joints but soldering only output terminal *2*.

i. Connect choke coil terminal *14* to electrolytic condenser terminal *23* with a 3½-inch length of hook-up wire, making *temporary* hook joints in both cases, but soldering only terminal *23*.

j. Connect choke coil terminal *14* to rectifier tube socket terminal *8* with a 2¼-inch length of hook-up wire, making *temporary* hook joints but soldering only terminal *14*.

k. Connect rectifier tube socket terminal *7* to transformer terminal *16* with a 3½-inch length of hook-up wire, making permanent hook joints but soldering only terminal *7*.

l. Connect output terminal *1* to transformer terminal *16* with a 4-inch length of hook-up wire, making permanent hook joints but soldering only output terminal *1*.

m. Connect switch terminal *11* to

transformer terminal *16* with a $6\frac{1}{2}$-inch length of hook-up wire, making permanent hook joints but soldering only terminal *11*.

n. Connect vibrator socket terminal *3* to transformer terminal *15* with a $2\frac{1}{4}$-inch length of hook-up wire, making permanent hook joints and soldering both terminals.

o. Connect vibrator socket terminal *2* to transformer terminal *17* with a $2\frac{3}{4}$-inch length of hook-up wire, making permanent hook joints and soldering both terminals.

p. Connect transformer terminal *20* to rectifier socket terminal *5* with a $3\frac{1}{2}$-inch length of hook-up wire, making permanent hook joints but soldering only terminal *20*.

q. Connect transformer terminal *18* to rectifier socket terminal *3* with a $5\frac{3}{4}$-inch length of hook-up wire, making a permanent hook joint at terminal *3* and leaving it unsoldered, and making a *temporary* soldered hook joint at terminal *18*.

r. Connect the 50,000-ohm resistor (Part *4-1*) between rectifier tube socket terminal *8* and transformer terminal *19*, after first shortening the resistor leads so they are each about $1\frac{1}{2}$-inches long. Make permanent hook joints and solder both terminals.

s. Connect the .01-mfd. condenser (Part *4-19*) between rectifier tube socket terminals *5* and *3* with the grounded foil lead going to *3*, after first shortening the condenser leads so they are each about $1\frac{1}{4}$-inches long. Make permanent hook joints and solder both terminals.

t. Connect the .5-mfd. condenser (Part *4-20*) between vibrator socket terminal *1* and transformer terminal *16* with the *grounded foil* lead going to *1*, after first shortening the condenser leads so they are each about $1\frac{1}{2}$-inches long. Make permanent hook joints, but solder only terminal *16*.

u. Insert the free end of the two-wire power cord (Part *3-11*) through the rubber grommet which is in hole *u*, starting from the outside. Pull about a foot of the cord through the grommet, then tie a simple knot in the cord in the manner shown in Fig. *8*, so that 6 inches of wire is left beyond the knot. Split this 6-inch length down to the knot as shown in Fig. *8*, by pulling the two rubber-covered wires apart with your fingers. Take one 6-inch length, bring it between the rectifier tube socket and the choke coil by threading it under all leads as indicated in Fig. *8*, then connect this rubber-covered wire to power switch terminal *10* with a permanent soldered hook joint, after first untwisting the strands, scraping them lightly with a knife, then twisting the strands of wire together so you can hook them around the lug.

Untwist the strands of the other 6-inch length, clean the strands by scraping, then twist the strands together, bring the wire up to vibrator socket terminal *1* by threading it under all leads as indicated in Fig. *8*, then connect the wire to vibrator socket terminal *1* with a permanent hook joint formed around the entire lug or around one of the wires already on this lug, and solder this terminal.

Cut off and discard the plug which is at the other end of this two-wire rubber-covered battery lead, for this plug is not needed. Split the wires apart at this cut end for about 6 inches. Squeeze or cut the insulation from one wire for about half an inch, clean the strands by scraping, twist the strands together tightly, then tin the strands and shake off surplus solder. Bend this tinned end into a hook with pliers, hook it under the screw head on one of the battery clips (Part *4-22A*), tighten the screw, then squeeze together the lugs on the clip so they will grip the rubber-covered insulation on the wire. In the same manner, connect the remaining battery clip (Part *4-22B*) to the other wire. It does not matter which battery clip goes on a particular lead.

Inspect each soldered joint carefully now, to make sure you have a good electrical connection and to make sure that no parts of any joint are touching nearby terminals or the chassis.

Step 12. To check all connections in the d.c. power pack by means of continuity tests with the ohmmeter ranges of your N.R.I. Tester, first prepare the N.R.I. Tester for ohmmeter measurements by following the instructions given elsewhere in this manual for "OHMMETER MEASUREMENTS."

Whenever measurements with the N.R.I. Tester are called for in the ex-

OPERATING INSTRUCTIONS FOR N.R.I. TESTER

OHMMETER MEASUREMENTS

1. With test probes out, check the general calibration of the N.R.I. Tester (as instructed elsewhere in this manual and in previous manuals under the heading "CHECKING THE CALIBRATION"), and recalibrate if necessary.
2. Plug the red probe into the $+R$ jack, plug the black probe into the right-hand *R* jack, and set the selector switch to *MEG.*
3. To check the zero adjustment of the ohmmeter, short the test clips together by placing the black clip on the red clip. If necessary, adjust the potentiometer on the tester chassis with a screwdriver until the meter reads *0* on scale *R* (until the pointer is at the extreme right-hand mark on the uppermost scale). This adjustment will now be correct for all ohmmeter ranges. *Do not change the setting of the knob at the back of the meter.*

   IMPORTANT: Make this ohmmeter calibration as quickly as possible, and separate the test clips as soon as you have finished (all batteries are supplying current when the test clips are together and the switch is on).
4. Although you can start with any ohmmeter range without damaging the tester (provided the power supply of the device being tested is turned off), when making resistance measurements it is usually convenient to start with the $10{,}000 \times R$ range. Since resistance values can be read most accurately near the middle of the *R* scale, switch to the range which brings the pointer closest to the center of the scale. Use the *MEG.* range for leakage tests.
5. Place the test clips on the terminals between which resistance is to be measured. Disregard the colors of the clips unless otherwise instructed. (When checking the resistance of an electrolytic condenser, the *red* test clip must go to the *black* or minus condenser terminal, and the *black* test clip must go on the *red* or plus condenser terminal.)
6. On the *MEG.* range, read the *R* scale directly in megohms. On the $10{,}000 \times R$ range, multiply the *R* scale reading by 10,000 to get the resistance value in ohms. Multiply by 100 for the $100 \times R$ range, and multiply by 10 for the $10 \times R$ range to get the resistance value in ohms.
7. Check the ohmmeter zero adjustment occasionally while using ohmmeter ranges, by touching the test clips together momentarily; the pointer should go to *0* on scale *R* when this is done. If it does not go to zero, repeat Step 3 above.
8. Whenever using ohmmeter ranges, turn on the N.R.I. Tester and connect the test clips *only long enough to get the desired readings.* The ohmmeter ranges draw considerable current from the C batteries in the N.R.I. Tester whenever the clips are connected to a resistor, regardless of whether the switch is on or off, so this precaution is necessary to conserve battery life. *Remember: Turn off the tester switch and remove at least one test clip each time you finish an ohmmeter measurement.*
9. When finished with resistance measurements, pull out the test probes and restore the original calibration of the N.R.I. Tester according to instructions for "CHECKING THE CALIBRATION."

periments, you are expected to refer to and follow the instructions given in the "OPERATING INSTRUCTIONS FOR N.R.I. TESTER" boxes which appear in this manual the first time each type of measurement is called for.

In the following continuity tests, failure to obtain the specified result indicates either a mistake in wiring or a defective part. If no mistake in wiring can be found by checking against the semi-pictorial circuit diagram in Fig. *8*, check each individual part in the circuit under consideration. If you are certain that one of the parts is defective, return it to National Radio Institute *immediately* so that a new part can be sent to you without unnecessarily delaying your practical training.

Do not connect the battery clips of your power pack to a storage battery until you have completed the following continuity tests. Battery connections are not made until Step 13.

a. To prepare the power pack for continuity tests, first insert both the rectifier tube and the vibrator in their sockets. (Note that two prongs on the vibrator are thicker than the others; these go into the two larger holes in the vibrator socket.) Set the power switch to the *OFF* position (the red dot alongside the sliding button is visible when this switch is *ON*, but does not show when the switch is *OFF*).

b. To check continuity between the battery clips, place the red test clip on one battery clip, place the black test clip on the other battery clip, set the selector switch at *MEG.*, turn on the N.R.I. Tester, and read the resistance in megohms directly on scale *R*. The reading should be above 50 megohms.

Leaving the test clips on the battery clips, close the power switch on the power pack chassis so that the red dot shows. The meter should now read about *zero* on scale *R*. Leave the power pack switch in the *ON* position. Turn off the N.R.I. Tester and remove the test clips after completing each measurement. Turn on the tester and connect the test clips only when ready for a new measurement.

c. To check for grounds in the A battery circuit, remove the vibrator from its socket, place the black clip on the chassis, place the red clip on one battery clip, and measure the resistance with the *MEG.* range of the N.R.I. Tester. The reading should be above 50 megohms. Now move the red clip to the other battery clip and repeat the measurement. Again you should obtain a reading above 50 megohms if there are no grounds in this circuit. Leave the vibrator out for the present.

d. To check the insulation between the high-voltage secondary winding of the vibrator transformer and the chassis, leave the black clip on the chassis, place the red clip on output terminal screw *4*, and measure the resistance with the *MEG.* range of the N.R.I. Tester. The reading should be above 50 megohms.

e. To check the filter circuit and the bleeder resistor, place the red clip on output terminal *4*, place the black clip on output terminal *5*, and measure the resistance with the *10,000* $\times$ *R* range of the N.R.I. Tester. The reading should be somewhere between 40,000 and 60,000 ohms.

f. To check rectifier tube filament circuit wiring, remove the rectifier tube, clip together the + and — battery clips, place the black clip on rectifier socket terminal *7*, place the red clip on rectifier socket terminal *2*, and measure the resistance with the *10* $\times$ *R* range of the N.R.I. Tester. The reading should be essentially zero. Leave the rectifier tube out.

g. To check the continuity of the A battery circuit up to output terminals *1* and *2*, leave the battery clips connected together, place the black clip on output terminal *1*, place the red test clip on output terminal *2*, and measure the resistance with the *10* × *R* range of the N.R.I. Tester. The reading should be essentially zero.

h. To check the continuity of the high-voltage secondary winding of the power transformer, place the black clip on rectifier socket terminal *3*, place the red clip on rectifier socket terminal *5*, and measure the resistance with the *100* × *R* range of the N.R.I. Tester. The reading should be between 400 and 650 ohms.

i. To make sure that output terminal *3* is grounded to the chassis, place the black clip on the chassis, place the red clip on output terminal *3*, and measure the resistance with the *10* × *R* range of the N.R.I. Tester. The reading should be essentially zero.

Step 13. To check the operation of the d.c. power pack, place the chassis right side up with the terminal strip facing you, replace both the rectifier tube and the vibrator in their respective sockets, and push the power switch to its *OFF* position (red button does not show).

Next, connect output terminal screws *2*, *3* and *4* together externally with a 2½-inch length of bare hook-up wire. To do this, form a hook in one end of the wire, hook this over screw *4* in a clockwise direction after loosening this screw, loosen screw *3* and bring the wire underneath this screw, then bring the wire under loosened screw *2* and bend it around this screw to form a closed hook. Cut off surplus wire, then tighten all three screws. The method of making this connection is shown in Fig. *10*. Keep these three terminals connected together until you receive instructions for separating them.

Next, make an external ground connection to output terminals *2*, *3* and *4* by connecting to terminal *3* the ground wire which you have provided at your bench for experimental purposes. This ground wire should go to a cold water pipe or other good ground.

IMPORTANT: This ground connection to output terminals *2*, *3* and *4* should be made whenever the power pack is used, to avoid getting a shock under certain operating conditions. You are simply duplicating normal operating conditions by grounding these terminals, for they are invariably grounded in actual radio apparatus.

Place your 6-volt storage battery in a position well out of the way of your hands and feet. There is generally a small amount of acid on the outside of any storage battery, and this can burn your skin, damage your clothing, or destroy the insulation on radio parts with which it comes in contact. Probably the safest place for a storage battery would be on a shelf underneath your bench or table, well back out of the way of your feet.

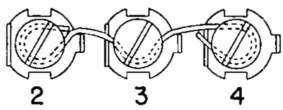


FIG. 10. Method of connecting together output terminals, *2*, *3* and *4* externally on the d.c. power pack with a 2½-inch length of bare hook-up wire. Always connect a ground wire to these terminals before you use the power pack, as a safety precaution.

Place the + battery clip on the + terminal of the 6-volt storage battery, place the — battery clip on the — terminal of the storage battery, then turn on the power pack switch. (Actually, the polarity of battery connections does not affect the operation of this power pack. If battery polarity is not marked, simply disregard polarity when attaching the battery clips.) The vibrator should start

CHECKING THE CALIBRATION

Check the calibration *the first time you use the N.R.I. Tester each day,* in the following manner:

1. **Pull out both test probes. Set the selector switch at *100 × V.* Turn on the tester switch. Tap the top of the meter gently with a finger. The pointer should be exactly at *0* on the *DC* scale; if necessary, adjust the zero-correcting knob at the back of the meter to give this zero reading. Do not tilt the N.R.I. Tester during calibration or use, for the meter should be in a vertical position. Look squarely at the face of the meter when making a meter reading.**
2. **Move the calibrating clip from its permanent position on terminal —9C to a terminal 1.5 volts less negative (—7½C). The meter should now read *1.5* on the *DC* scale when the meter case is tapped. If necessary, readjust the potentiometer on the N.R.I. Tester chassis to get a 1.5 reading.**
3. **Move the calibrating clip back to its permanent position on —9C. If the potentiometer adjustment has altered the zero position of the pointer, repeat the entire calibration procedure once more, so as to secure *DC* scale readings of *0* and *1.5* for the two positions of the calibrating clip. *Be sure to return the clip to its permanent position on —9C corresponding to a zero meter reading.* If you are unable to secure these two readings, refer to the special calibrating instructions given at the end of Manual 2RK.**

IMPORTANT: Pull out the test probes when through using the N.R.I. Tester. If the alligator clips touch the panel or chassis while the probes are in the jacks, the C battery may be drained, regardless of the position of the *ON-OFF* switch on the panel.

humming immediately, and the cathode of the rectifier tube should show a small bright red or white glow about half a minute later when looking straight down on top of the tube. Now turn off the power pack switch.

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

If the vibrator fails to operate or the rectifier tube does not show a glow while the switch is on, rotate each battery clip a small amount so the teeth will cut through the layer of dirt on the battery terminals. If you notice a burning odor or sparking anywhere, turn off the power pack switch immediately (or remove one of the battery clips) and check your wiring of the d.c. power pack again, looking particularly for accidental shorts. Check also for defective parts.

To measure the high-voltage d.c. output of your power pack, first check the calibration of the N.R.I. Tester and prepare it for d.c. voltage measurements, as instructed elsewhere in this manual.

Measure the d.c. voltage between output terminals *4* and *5* according to the instructions given in this manual for "D. C. VOLTAGE MEASUREMENTS." (Place the red test clip on output terminal *5*, place the black test clip on output terminal *4*, place the red probe in the $+V_{DC}$ jack, place the black probe in the $-V_{DC}$ jack, set the selector switch to *100 × V*, turn on the power pack, turn on the N.R.I. Tester, wait about half a minute for the rectifier tube to warm up, read the meter on the *DC* scale, and multiply your reading by 100 to get the d.c. output voltage of the power pack in volts.)

The d.c. output voltage should be approximately 430 volts if you have assembled the power pack correctly and all parts are in good condition. This value is for a normal storage battery voltage of slightly over 6 volts, and will vary slightly with the state of charge of the storage battery. Therefore, any voltage value between about 400 volts and 450 volts can be considered satisfactory.

The highest d.c. voltage which can be measured directly with the N.R.I. Tester is 450 volts. It is entirely possible for the power pack to deliver a d.c. voltage slightly higher than this value under certain conditions. Instructions for doubling any voltage range of the N.R.I. Tester to permit measurements like this are given in this manual under the heading "EXTENDING VOLTAGE RANGES."

Be sure the test clips do not touch each other during an output voltage measurement, for that would short-circuit the power pack output and possibly damage some part.

Now turn off the power pack while watching the meter. Note that it takes several seconds for the pointer to drop down to zero; this action occurs because the electrolytic filter condensers hold their charges for that period of time after power is removed.

Always turn off the power pack switch as soon as you have completed your measurement or test with it. This rule applies to all battery-operated devices, and is intended to conserve battery life.

Discussion: The normal hum of the vibrator employed in your d.c. power pack serves as an indication that the power pack is on and is delivering a useful yet dangerously high voltage. Whenever you hear this vibrator hum, do not touch any terminal of the power pack or any voltage supply terminal in the equipment connected to the power pack.

Make a practice of waiting a few seconds after turning off the power pack, to allow time for the filter condensers to discharge, before touching the terminals or test clips. Otherwise you may secure an unpleasant shock from the condensers even though the power is off.

How the Vibrator Works. Since you will use the a.c. output voltage of the vibrator in Experiments 28DC, 29DC and 30DC, a knowledge of how this vibrator converts the 6-volt d.c. voltage of the storage battery into an a.c. voltage will help you in

OPERATING INSTRUCTIONS FOR N.R.I. TESTER

D. C. VOLTAGE MEASUREMENTS

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

EXTENDING VOLTAGE RANGES

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

Simply connect one lead of this resistor temporarily to the + terminal of the d.c. voltage source being measured (the ungrounded terminal in the case of a.c. measurements) and place the red test clip on the other resistor lead. The true voltage reading will then be the meter reading multiplied by *twice* the multiplying factor indicated at the selector switch setting. Thus, when using this voltage multiplier on the *100* × *V* range, a meter reading of 2.4 would correspond to 480 volts.

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

analyzing the results of your experiments.

Although vibrator connections are shown in the complete schematic circuit diagram of the d.c. power pact in Fig. *2,* the vibrator circuit alone is repeated in enlarged form in Fig. *11A* to simplify a study of its operation.

The armature of the vibrator is mounted on a flat spring steel blade (commonly called a *reed*), which holds the armature contact midway between fixed contacts *X* and *Y* when the vibrator is not in operation, as indicated in Fig. *11A*. Whenever current flows through the vibrator coil, the armature is attracted toward the core of this coil until its contact touches contact *X*, shorting the vibrator coil so no current flows through the coil. Spring action then makes the armature fly back far enough so that its contact touches fixed contact *Y*. Now let us see how a continuous vibrating or back and forth movement of the armature is obtained, and how it serves to convert d.c. to a.c.

Closing the power switch places the vibrator coil and the upper half of the vibrator transformer primary winding P_1 in series across the 6-volt storage battery. Current flow through P_1 causes a voltage to be induced in the other half of the vibrator transformer primary winding (P_2) by what is commonly known as *auto-transformer action*. As a result, the voltage between terminals *17* and *15* is essentially twice the voltage between terminals *17* and *16*. In Fig. *11B,* which represents the wave form of the voltage existing between terminals *17* and *15,* we indicate this by labeling the first peak in the curve as having a 12-volt amplitude.

The initial flow of current through the vibrator coil when the power switch is closed causes the armature to be pulled upward. The armature contact then touches contact *X*, short-circuiting the vibrator coil. Now the storage battery is connected directly to P_1, and no current is flowing through the vibrator coil. The armature moves away from the coil due to the action of its spring, and the momentum of the armature carries it over to contact *Y*. Now P_2 is connected across the storage battery, with opposite polarity to the previous

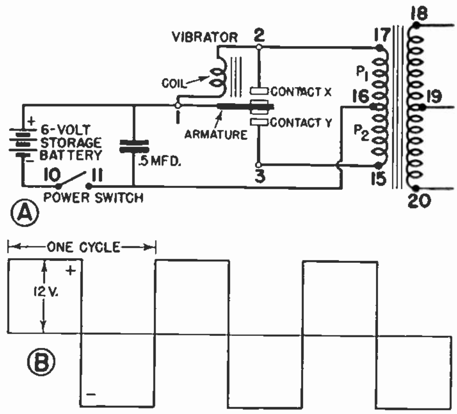


Fig. 11. Schematic circuit diagram (*A*) of the vibrator circuit in your d.c. power pack, and wave form (*B*) of the a.c. voltage which is applied to terminals *15* and *17* of the vibrator transformer primary winding by the vibrator.

connection. By auto-transformer action again, double voltage is developed across the entire primary winding to give the negative voltage pulse and complete one cycle in Fig. *11B*.

When the armature is on contact *Y*, the entire 12 volts across the vibrator transformer primary winding is applied to the vibrator coil, energizing this coil and causing the armature to be attracted away from contact *Y*. As soon as this contact is broken, the battery voltage alone energizes the vibrator coil and pulls the armature over to contact *X* again, thereby starting the next cycle and repeating the entire process.

The vibrator in your power pack is so designed that this action occurs at the rate of approximately 120 cycles per second. The vibrator is really a type of automatic switch *which connects one storage battery terminal alternately to opposite ends of the vibrator transformer primary winding.* The other battery terminal is *permanently connected* to the center tap of this winding. Each movement of the vibrator thus reverses the direction of current flow through the vibrator transformer primary, so that we have an a.c. voltage developed across terminals *15* and *17* as indicated in Fig. *11B*.

Facts About Square Wave Voltages. It must be emphasized that the a.c. voltage developed by a d.c. power pack has a square wave characteristic considerably different from the sine wave a.c. voltage ordinarily encountered.

Mathematical analysis tells us that a square wave has a fundamental frequency (corresponding to the 120-cycle frequency of the vibrator) and many *odd* harmonics of this fundamental frequency. In your case, these harmonics will have the following values: 3rd harmonic—360 cycles; 5th harmonic—600 cycles; 7th harmonic—840 cycles; etc. The 3rd harmonic will be 1/3 as strong as the fundamental; the 5th harmonic will be 1/5 as strong as the fundamental, etc. The peak voltage value at the fundamental frequency will be 1.27 times the peak voltage value of the square wave; since we have a 12-volt square wave peak, this means that the *peak voltage value* of the *120-cycle voltage* developed across the vibrator transformer primary will be 1.27×12, or about 15.3 volts.

These highly technical facts have been brought out simply to show that the a.c. voltage which you will use in your next three experiments is a highly complex voltage. A condenser offers *less* opposition to high-frequency currents (to harmonics of your a.c. voltage) than to low-frequency currents (such as the fundamental), and a coil offers *more* opposition to high-frequency currents than it does to low-frequency currents. You will still be able to show, however, that the simple circuits which you set up act in accordance with basic laws for a.c. circuits.

INSTRUCTIONS FOR PERFORMING EACH EXPERIMENT

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

EXPERIMENT 28DC

Purpose: **To show that coils and condensers offer a definite amount of opposition to the flow of current in an a.c. circuit.**

Step 1. To set up an a.c. voltage divider circuit, first secure a piece of wood which is ½-inch or more thick, about 5 inches wide and about 7 inches long. Take the 6-lug terminal strip (Part *3-12*) and mount it on this board with two of the ⅜-inch No. 6 round-head wood screws (Part *3-13*) in approximately the position shown in Fig. *12*.

Take the mounting bracket for the potentiometer (Part *3-9*) and mount it on your wood baseboard with the remaining ⅜-inch wood screw in approximately the position shown in Fig. *12*.

Mount the 1,000-ohm wire-wound potentiometer (Part *3-8*) on its bracket, keeping the three terminal lugs at the top, as shown in Fig. *12*.

Assemble your a.c. voltage divider circuit on the baseboard according to the schematic circuit diagram in Fig.

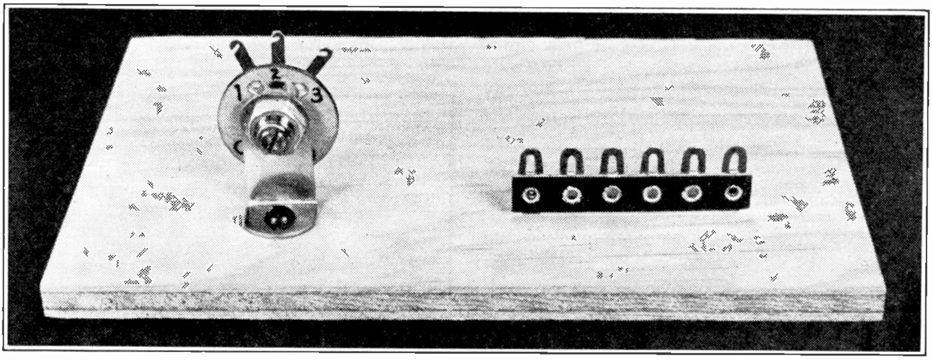


FIG. 12. For Step 1 of Experiment 28DC, mount the terminal strip and the potentiometer bracket in approximately the positions shown here, on a wood baseboard approximately ½-inch thick, 5 inches wide and 7 inches long.

13A by making the connections exactly as shown in Fig. *13B*, in the following order:

a. Number each of the lugs on the terminal strip in the manner shown in Fig. *13B*, placing the numbers on the baseboard directly under the respective lugs, and using either pencil, ink or crayon for marking purposes. Number the potentiometer terminals *1*, *2* and *3* as shown in Fig. *13B* if you have not already done so.

b. Connect the 1,000-ohm resistor (Part *3-5A*) to terminals *4* and *5* by means of temporary hook joints, but solder the joint at terminal *4* only.

c. With a suitable length of hook-up wire, connect potentiometer terminal *1* to terminal *7*, but solder only the joint at terminal *1*.

d. With a suitable length of hook-up wire, connect potentiometer terminal *2* to terminal *6*, soldering both joints this time.

e. With a suitable length of hook-up wire, connect potentiometer terminal *3* to terminal *5*, but solder only terminal *3*.

f. With a suitable length (about 1 foot) of hook-up wire, connect terminal *5* to terminal *15* on the vibrator transformer in your power pack, making temporary hook or lap joints and soldering both joints.

g. With a suitable length (about 1 foot) of hook-up wire, connect terminal *7* on the terminal strip to terminal *17* on the vibrator transformer in your power pack, making temporary hook or lap joints and soldering both joints. Arrange the two vibrator transformer leads so that they come out through the open end of the power pack chassis.

h. Check all connections carefully against the semi-pictorial diagram in Fig. *13B*, for a single mistake here may result in your damaging some part in the power pack when you connect it to the storage battery. Be sure there are no wires or lumps of solder shorting together adjacent lugs on the terminal strip.

i. Remove the rectifier tube from its socket on the power pack since you will not be using the high d.c. output of the power pack during the next three experiments.

Step 2. To become familiar with the AC scale on the meter of the N.R.I. Tester, study carefully the actual-size reproductions of this scale in Fig. *14*. An analysis of the four examples which are given should enable you to read this scale at any position of the pointer, for the *AC* scale is read in essentially the same way as the *DC* scale.

The *AC* scale on your meter is used for all four of the a.c. voltage ranges: *V*, *3* × *V*, *30* × *V* and *100* × *V*. When using the *V* range, read the voltage in volts directly on this scale. When using the *3* × *V* range, multiply the reading on the *AC* scale by 3. When using the *30* × *V* range, multiply the reading by 30. When using the *100* × *V* range, multiply the reading by 100.

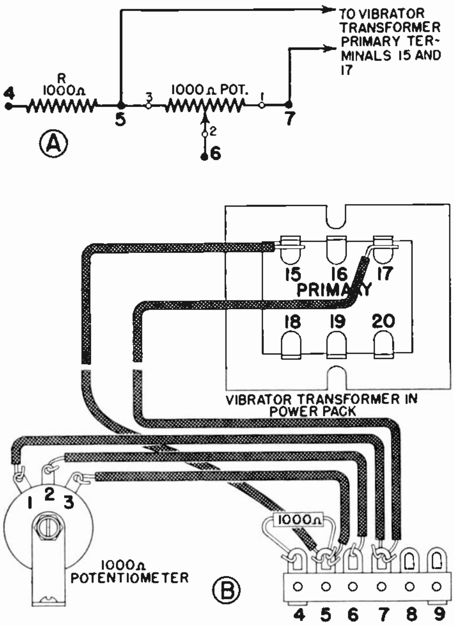


FIG. 13. Schematic *(A)* and semi-pictorial *(B)* circuit diagrams for the a.c. voltage divider which you set up according to the instructions given in Step 1 of Experiment 28DC.

Step 3. To measure the voltages which are present across various parts of an a.c. voltage divider circuit when there is no load, first prepare the N.R.I. Tester for a.c. voltage measurements by following the operating instructions given in this manual for "A.C. VOLTAGE MEASUREMENTS."

To measure the a.c. voltage between terminals *5* and *7* on the terminal strip mounted on your wood baseboard, place the test clips on these terminals. (Polarity of test clip connections does not matter in Experiments 28DC, 29DC and 30DC.) Connect the battery clips of the d.c. power pack to the terminals of your 6-volt storage battery, then turn on the power pack and proceed to measure the voltage by following the instructions given in this manual for "A.C. VOLTAGE MEASUREMENTS." Record your result in Table *28DC* as the a.c. voltage between terminals *5* and *7;* this corresponds to the voltage across the primary of the vibrator transformer.

Step 4. To adjust the voltage between terminals 5 and 6 to 5 volts a.c., move the test clips to these two terminals while leaving the N.R.I. Tester set to the *3* × *V* range. Turn on the power pack, turn on the N.R.I. Tester, then rotate the potentiometer with a screwdriver until the meter pointer is approximately at 1.75 on the *AC* scale (corresponding to 5 volts on this scale). This value is safely within the next lower range on your meter, so change the selector switch to the *V* range and make a more accurate adjustment of the potentiometer to give a meter reading of *5* on the *AC* scale. Leave the potentiometer at this setting, then turn off the N.R.I. Tester and turn off the power pack.

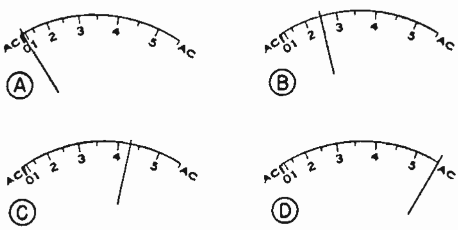


FIG. 14. To illustrate how the *AC* scale on the meter of the N.R.I. Tester is read, readings corresponding to four different positions of the pointer are given in these examples. The reading for *A* is .5 ma.; *B* is 2.5 ma.; *C* is 4.3 ma.; *D* is 5.5 ma.

During Experiments 28DC, 29DC and 30DC, the power pack can either be resting on its back side so that all connections under the chassis are exposed, or resting normally upright with the wires from the vibrator transformer primary coming out through an open side of the chassis.

Step 5. To measure voltage and current values for a 1000-ohm resistor (R_1) which is connected between terminals 4 and 6 of the a.c. voltage divider to give the circuit shown in Fig. 15A, take one of your 1,000-ohm resistors (Part *3-5B*), bend the leads so that one will touch terminal *6* when the other is on terminal *4* of your a.c. voltage divider, tin the end of each lead liberally with rosin-core

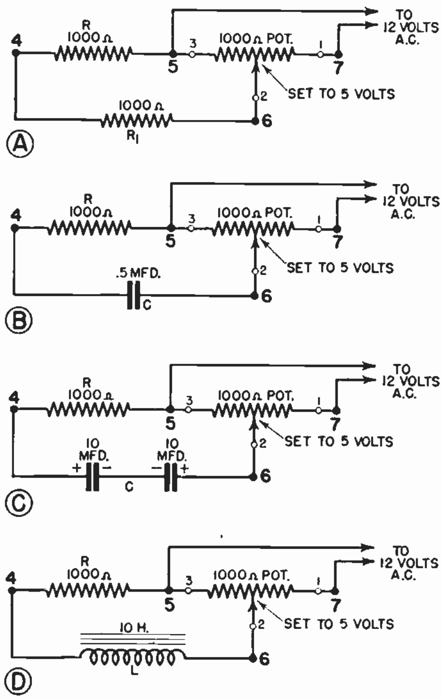


FIG. 15. Schematic circuit diagrams for Steps 5, 6, 7 and 8 in Experiment 28DC.

solder, apply surplus solder to the tip of your soldering iron, then hold the resistor against these terminals in the manner shown in Fig. *16,* and apply the soldering iron to each resistor lead in turn, long enough to fuse the solder and give a temporary soldered lap joint at each terminal.

This 1,000-ohm resistor R_1 is now in series with 1,000-ohm resistor R previously mounted on the terminal strip between lugs *4* and *5;* resistor

STEP	NATURE OF MEASUREMENT	YOUR VALUE IN VOLTS	N.R.I. VALUE IN VOLTS
3	A.C. VOLTAGE BETWEEN TERMINALS 5 AND 7		11.1
5	A.C. VOLTAGE ACROSS 1000 Ω R_1		2.5
	A.C. VOLTAGE ACROSS R (SAME AS CURRENT IN MA.)		2.5
6	A.C. VOLTAGE ACROSS .5 MFD. C		4.7
	A.C. VOLTAGE ACROSS R (SAME AS CURRENT THRU C IN MA.)		1.6
7	A.C. VOLTAGE ACROSS 10 MFD. C		1.0
	A.C. VOLTAGE ACROSS R (SAME AS CURRENT THRU C IN MA.)		4.9
8	A.C. VOLTAGE ACROSS 10 HENRY L		5.0
	A.C. VOLTAGE ACROSS R (SAME AS CURRENT THRU L IN MA.)		.5

TABLE 28DC. Record your results here for Experiment 28DC.

R provides a convenient means for determining the circuit current when various radio parts are connected between terminals *4* and *6,* for the voltage drop across a 1,000-ohm resistance is equal to the current in milliamperes through that resistance.

Connecting a load ($R + R_1$) between terminals *5* and *6* in this manner will make the voltage between these terminals drop below 5 volts a.c., so readjust this voltage now to 5 volts as instructed in Step 4.

Measure the a.c. voltage between terminals *4* and *6,* and record your result in Table *28DC* as the a.c. voltage in volts across 1,000-ohm resistor R_1.

Measure the a.c. voltage between terminals *4* and *5*, and record your result in Table *28DC* as the a.c. voltage in volts across R. This will also be the value in ma. of the alternating current flowing through R_1.

Step 6. To measure voltage and current values for a .5-mfd. capacity which is connected into an a.c. circuit having a 5-volt a.c. source, first remove the test clips and disconnect 1,000-ohm resistor R_1 from terminals *4* and *6*. Now connect a .5-mfd. capacity (two .25-mfd. condensers, Parts *3-2A* and *3-2B*, connected in parallel) to terminals *4* and *6* as indicated in Fig. *15B*. Use temporary soldered lap joints for this purpose, just as you did when connecting resistor R_1 to these terminals in Step 5.

Adjust the voltage between terminals *5* and *6* to 5 volts again, as instructed in Step 4.

Measure the a.c. voltage between terminals *4* and *6*, and record your result in Table *28DC* as the a.c. voltage in volts across .5-mfd. capacity C.

Measure the a.c. voltage between terminals *4* and *5*, and record your result in Table *28DC* as the a.c. voltage across R and the alternating current in ma. through .5-mfd. capacity C. Disconnect the .5-mfd. capacity, and separate the two .25-mfd. condensers without straightening out the condenser leads yet.

Step 7. To measure voltage and current values for a 10-mfd. electrolytic condenser connected according to the schematic circuit diagram in Fig. *15C,* first remove the dual 10-10-mfd. electrolytic condenser unit (Part *3-3*) from your d.c. power pack. Do this in the following manner: Remove from terminal *14* the lead which goes to terminal *23*, but do not disconnect it from *23*. Remove from terminal *13* the lead which goes to terminal *24*, but do not disconnect it from *24*. Remove entirely the lead which connects terminals *19* and *22*, and set this aside for replacement later. Remove the two screws and nuts which fasten the bakelite mounting piece of the electrolytic condenser unit to the chassis.

Connect one of the condenser leads to terminal *4* on the a.c. voltage di-

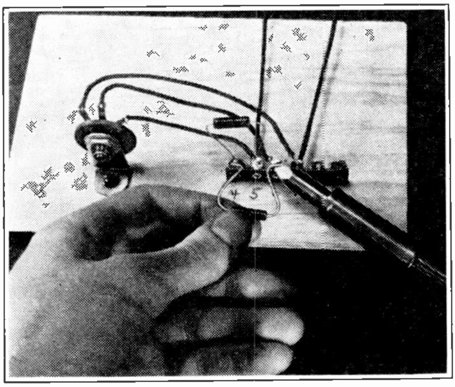


FIG. 16. This illustration shows you how to make a temporary soldered lap joint for the purpose of connecting a radio part such as a resistor temporarily between two terminals. If the parts being connected together are liberally tinned beforehand, this technique allows you to hold the part with one hand (instead of holding solder in that hand), and gives a joint which can easily be disconnected.

A.C. VOLTAGE MEASUREMENTS

1. **Plug the black probe into the $-V_{AC}$ jack on the panel, and plug the red probe into the left-hand V_{AC} jack.**
2. **Set the selector switch at $100 \times V$.**
3. **Place the test clips on the terminals between which the voltage is to be measured. The black clip should go to the terminal which is closer to ground. When both terminals have essentially the same potential with respect to ground, the polarity of the test clip connections can be disregarded.**
4. **Turn on your apparatus, then turn on the N.R.I. Tester. This protects the tester against high-voltage surges when the apparatus is turned on.**
5. **Lower the selector switch setting, one range at a time, until you reach the lowest range which does not make the meter pointer swing off-scale.**
   IMPORTANT: When working with apparatus using vacuum tubes, wait long enough for the tubes to warm up (about half a minute is sufficient) before lowering the selector switch setting. This applies whenever you use the entire a.c. power pack (with the rectifier tube in its socket).
6. **Read the meter on the *AC* scale, and multiply the reading by the correct factor for the range being used.**
7. **Turn off the N.R.I. Tester first, then turn off the power source. Pull out the test probes when through using the N.R.I. Tester, to prevent draining of the C battery in case the test clips accidentally touch the tester panel or chassis.**
   NOTE: When the N.R.I. Tester is being used as an a.c. voltmeter on the *V* range, a meter reading may be obtained *when only one test clip is connected.* This is due to pick-up of stray a.c. energy by the test leads, and is particularly noticeable in the case of a.c. house wiring. The effect may not be observed at all when using a storage battery and d.c. power pack. Disregard this condition, as it has no effect on the readings when both test leads are connected.

vider, and connect the other lead to terminal *6*, using temporary soldered lap joints. (Polarity does not matter since both leads are +.) This places the two sections of the electrolytic condenser in series *bucking* as indicated in Fig. *15C*, for the minus terminals of the condenser section are connected together internally through the common metal housing of the unit. The combined capacity is still 10 mfd., because one section is always conductive while the other is acting as a capacity. (This is true only with electrolytic condensers.)

Adjust the potentiometer as described in Step 4, so that you have exactly 5 volts a.c. between terminals *5* and *6*.

Measure the voltage between terminals *4* and *6*, and record your result in Table *28DC* as the a.c. voltage in volts across the 10-mfd. capacity *C*.

Measure the a.c. voltage between terminals *4* and *5*, and record your result in Table *28DC* as the a.c. voltage across *R*. This will also be the alternating current in ma. through the 10-mfd. capacity *C*. Disconnect the leads of the dual 10-10-mfd. condenser from terminals *4* and *6*, and set the condenser aside for the present.

Step 8. To study the action of a coil in an a.c. circuit, first remove the 10-henry choke coil (Part *3-10*) from your d.c. power pack in the following manner: Remove from socket terminal *8* the lead which goes to choke coil terminal *14*, but do not disconnect this lead from *14*. Remove from output terminal *5* the lead which goes to choke coil terminal *13*, but do not disconnect this lead from *13*. Remove the mounting screws and nuts for the choke coil, and remove the choke coil. Fasten soldering lug *12* temporarily to the chassis directly with one of the screws and nuts.

To connect the choke coil between terminals *4* and *6*, connect one of its leads to terminal *4* and the other to terminal *6* by means of temporary soldered lap joints, so that you now have the circuit arrangement shown in Fig. *15D*.

Readjust the potentiometer as previously described, so that you have exactly 5 volts a.c. at terminals *5* and *6*.

Measure the a.c. voltage between terminals *4* and *6*, and record your result in Table *28DC* as the a.c. voltage in volts across coil *L*.

Measure the a.c. voltage between terminals *4* and *5*, and record your result in Table *28DC* as the a.c. voltage across *R*. This will also be the alternating current in ma. through the 10-henry coil *L*. Disconnect the coil from terminals *4* and *6*.

Discussion: Although you are working in this experiment with a.c. voltages so low that they cannot give a shock under any conditions, it is well worth pointing out at this time the safety techniques required for working with higher a.c. voltages.

If you have worked at all with a.c. house wiring, you undoubtedly know already that a 110-volt a.c. voltage can give an unpleasant shock. Also, under certain conditions, this 110-volt a.c. voltage can be quite dangerous. Dangerous conditions are easy to avoid, however, for they depend upon electricity going through your entire body.

By keeping all parts of your body away from any grounded metal objects, by standing on a good insulating material such as wood or rubber (not on a concrete floor), and by touching radio apparatus with only one hand whenever there is a possibility that power might be on and dangerously high voltages might exist, you make it impossible for current to find a path through your body. Under these conditions, you can work with 110-volt a.c. line voltages with perfect safety. Many engineers keep the unused hand in their pocket to avoid using it unconsciously when working with high-voltage apparatus. This prevents them from grabbing a dangerous wire or part which may be falling over.

Radio men work extensively with 110-volt a.c. apparatus, so form the proper safety habits right from the start, even though you are not yet working with dangerous voltages. Safety rules are even more important when working on power packs of ra-

OPERATING INSTRUCTIONS FOR N.R.I. TESTER

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

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

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

dio apparatus; here you encounter stepped-up a.c. voltages approaching 1,000 volts, which are considerably more dangerous than 110 volts unless the same safety precautions are followed. Be particularly careful to avoid touching power pack output terminal *5* (this can give up to a 500-volt shock) and vibrator transformer terminals *18* and *20* (these can give up to an 800-volt shock).

In Step 3, you measure the a.c. voltage across the entire primary winding of the vibrator transformer, for terminals *5* and *7* on your voltage divider are directly connected to these terminals of the power pack. Although the N.R.I. value indicated in Table *28DC* is 11.1 volts, you can consider any voltage within about 2 volts of this value as entirely satisfactory. We measure this voltage merely to check the operation of the vibrator, for only 5 volts is required in the experiment. As the circuit diagram in Fig. *15A* indicates, this 5 volts is obtained by applying the entire vibrator primary voltage to the end terminals of a 1,000-ohm potentiometer, and obtaining our desired voltage value between the movable terminal and one of the end terminals of the potentiometer. Terminals *5* and *6* will thus be the a.c. voltage source terminals for this experiment.

In Step 5, you use a 1,000-ohm resistor R_1 as a load across the potentiometer section which is serving as your voltage source, with a 1,000-ohm resistor R in series with this load for current-measuring purposes.

When you turn on the power after connecting 1,000-ohm resistor R_1 and current-measuring resistor R in series across terminals *5* and *6* as indicated in Fig. *15A*, you will find that the voltage between terminals *5* and *6* is about 1 volt lower than the original no-load value of 5 volts. This proves that the same action holds true for a.c. circuits as for d.c. circuits, wherein the placing of a load across a portion of a voltage divider reduces the voltage available at that portion of the divider. In each step, you must readjust the position of the movable contact on the voltage divider to give exactly 5 volts a.c. between terminals *5* and *6*.

Actually, in Step 5 you have two 1,000-ohm resistors in series across an a.c. voltage of 5 volts. According to Kirchhoff's Voltage Law, the voltages across these two resistors should add up to the 5-volt a.c. voltage. Furthermore, because the resistors are equal in value, the voltages across them should be equal, or each should be 2.5 volts.

The N.R.I. voltage value of 2.5 volts across resistor R means that 2.5 ma. of alternating current is flowing through load resistor R_1. This is entirely in accordance with Ohm's Law, which says that when the voltage is 5 and the total circuit resistance is 2,000 (1,000 + 1,000), the circuit current should be 5 ÷ 2,000, or .0025 ampere, corresponding to 2.5 ma.

If there were only the 1,000-ohm resistor R connected between terminals *5* and *6* of the voltage divider, and the source voltage were still 5 volts, the current would be 5 ma. according to Ohm's Law. We thus see that the insertion of the 1,000-ohm resistor in this a.c. circuit gives exactly the same current-reducing effect as it would in a d.c. circuit.

In Step 6, you have a .5-mfd. load capacity in series with the 1,000-ohm current-measuring resistor R across the 5-volt a.c. source. If you add together the voltages measured across the condenser and resistor R, you will find that they total up to considerably more than 5 volts. Kirchhoff's Voltage Law for a.c. circuits says, however, that you cannot add voltages arithmetically in a.c. circuits having condensers or coils. You must add the voltages vectorially, taking phase into account, for the condenser and resistor voltages are 90° out of phase.

When the N.R.I. values across the condenser and resistor are added together vectorially, in the manner shown in Fig. *17A*, the resulting voltage vector *IZ* is about 5 volts. Your values should add vectorially approximately to 5 also, but remember that exact agreement is seldom possible because of practical conditions.

Adding Voltages Vectorially. If you desire to add a.c. voltage values yourself vectorially to prove that Kirchhoff's Voltage Law holds true for a.c. circuits, here are some suggestions. For convenience, let 1 inch represent 1 volt on your vector diagram, and use the resistor voltage as your reference vector. Use a starting point for your diagram (point *S* in Fig. *17A*), then lay out horizontally to the right from this starting point a line (*IR*) having a length which is proportional to the value of the voltage measured across 1,000-ohm resistor *R*. Place an arrow at the end of this line, and label the vector just as is done in Fig. *17A*.

Next, from starting point *S* draw a vector for the voltage across the added part. Since it is a condenser in Step 6, draw the vector straight down from the reference point, because the voltage across a condenser in a series circuit always lags the voltage across a resistor by 90°.

Having plotted your two vectors, add them together by completing the rectangle as indicated with dotted lines in Fig. *17A*, then draw in the diagonal of the rectangle. This diagonal is the resultant vector, representing the sum of two vectors acting 90° out of phase. Measure the length of this vector in inches, then convert this result to voltage in volts; the result should be essentially 5 volts, proving the validity of Kirchhoff's Voltage Law again.

Electrolytic Condenser Characteristics. When two electrolytic condensers are connected in series with their negative terminals tied together, as is done in Step 7, one condenser always retains its desired capacitive properties. In other words, at any instant during an a.c. cycle, one unit is acting as a true condenser and the other is merely a conductive path. For this reason, the combined capacity of the two electrolytic condensers is only the capacity of one of the units.

This series opposition method of connecting electrolytic condensers is employed in actual practice whenever electrolytics are to be used in a.c. circuits. If only a single electrolytic condenser were connected across an a.c. voltage source, it would be conductive on alternate half cycles; with no other capacity in the circuit to limit the current, the condenser would soon be destroyed.

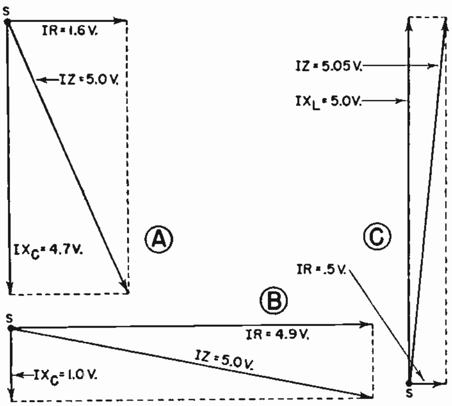


FIG. 17. These vector diagrams, based upon voltage values measured in the N.R.I. laboratory for the various steps in Experiment 28DC, prove definitely that Kirchhoff's Voltage Law holds true for a.c. circuits.

When Step 7 was carried out in the N.R.I. laboratory, values of 4.9 volts across the resistor and 1.0 volt across the condenser were obtained, as indicated in Table *28DC*. When these voltages were added together vectorially in the manner shown in Fig. *17B*, a resultant voltage of essentially 5 volts was obtained, giving additional confirmation of Kirchhoff's Voltage Law for a.c. circuits. Such close agreement as this is not always obtainable, however, for the harmonics which are present in the a.c. voltage output of the vibrator produce voltage drops across the resistor but little or no voltage drops across the condenser (the reactance of the condenser becomes very low at the higher harmonic frequencies). Your values may differ considerably from the N.R.I. values and still be entirely correct for your own apparatus.

Let us compare the relative current-limiting characteristics of the .5-mfd. and 10-mfd. condensers in this a.c. circuit. We will use the N.R.I. values here, but you can do the same thing with your own values.

The .5-mfd. condenser gave a current of 1.6 ma., while the 10-mfd. condenser gave a current of 4.9 ma. This indicates that the smaller condenser offers considerably more opposition to current flow than does the larger condenser, and indicates also that the larger condenser has very little reactance at the 120-cycle frequency (the current could increase only to 5 ma. with the condenser shorted out).

Coil Characteristics. When the 10-henry choke coil was placed in series with the 1,000-ohm resistor R to serve as a load for a 5-volt a.c. source during the performance of Step 8 in the N.R.I. laboratory, a voltage of .5 volt was measured across the resistor, and 5 volts was measured across the coil. Adding these together vectorially as in Fig. *17C* gives essentially 5 volts. Practically the entire a.c. voltage of 5 volts is thus dropped across the choke coil, indicating that this coil has a much higher reactance than the 1,000-ohm resistance of the resistor.

This experiment has shown quite clearly that phase must be taken into account whenever adding voltages in a.c. circuits. You have thus demonstrated for yourself Kirchhoff's highly important voltage law for a.c. circuits.

Instructions for Report Statement No. 28DC. In an a.c. circuit, conditions can be changed by shunting any part in the circuit with a resistor, a coil or a condenser, provided that the shunting part has a low enough resistance or impedance. For Report Statement No. 28DC, you will verify this fact.

Set up again the circuit shown in Fig. *15A*, in which a 1,000-ohm resistor R_1 is connected between terminals *4* and *6*, and shunt across R_1 a .5-mfd. capacity (two .25-mfd. condensers in parallel) by connecting this capacity to terminals *4* and *6* also. Adjust the potentiometer as previousy described, to give exactly 5 volts a.c. between terminals *5* and *6*, then measure the voltage across resistor R. Compare this voltage value with that which you measured across resistor R in Step 5 when R_1 alone

STEP	NATURE OF MEASUREMENT	YOUR VALUE IN VOLTS	N.R.I. VALUE IN VOLTS
1	A.C. VOLTAGE ACROSS .25 MFD. C		3.8
	A.C. VOLTAGE ACROSS R (SAME AS CURRENT IN MA.)		.8
2	A.C. VOLTAGE ACROSS .25 MFD. C		5.5
	A.C. VOLTAGE ACROSS 10 HENRY L		11.4
	A.C. VOLTAGE ACROSS R (SAME AS CURRENT IN MA.)		1.0
3	A.C. VOLTAGE ACROSS .125 MFD C		11.1
	A.C. VOLTAGE ACROSS 10 HENRY L		8.4
	A.C. VOLTAGE ACROSS R (SAME AS CURRENT IN MA.)		.9
4	A.C. VOLTAGE ACROSS .125 MFD. C		12.5
	A.C. VOLTAGE ACROSS 10 HENRY L		10.5

TABLE 29DC. Record your results here for Experiment 29DC, in which you check the characteristics of series resonant circuits.

was in the circuit, then turn to the last page and place a check mark after the answer in Report Statement No. 28DC which describes your conclusion regarding the effect of the added shunt condenser upon current flow.

EXPERIMENT 29DC

***Purpose:* To show that the total impedance of a series resonant circuit (a coil and condenser in series) is *lower* than the reactance of either part alone.**

Step 1. To measure a.c. voltage and current values for a .25-mfd. condenser alone, first connect one .25-mfd. condenser (Part *3-2A*) to terminals *4* and *6* of your a.c. voltage divider circuit by means of temporary soldered lap joints, according to the circuit shown in Fig. *18A*.

Place the test clips on terminals *5* and *6*, set the selector switch to *3* × *V*, turn on the power pack and the N.R.I. Tester, then adjust the potentiometer until the meter reads approximately 4 volts (1.3 on the *AC* scale when using the *3* × *V* range). Now switch to the *V* scale and adjust accurately to 4 volts. (Note the change to *4 volts,* as compared to the 5-volt value used in the previous experiment.) Turn off the N.R.I. Tester and the power pack.

Measure the a.c. voltage between terminals *4* and *6*, and record your result in Table *29DC* as the a.c. voltage in volts across .25-mfd. condenser *C*.

Measure the a.c. voltage between terminals *4* and *5*, and record your result in Table *29DC* as the a.c. voltage in volts across *R* and the current in ma. through *C*.

Step 2. To measure current and voltage values in a series circuit consisting of 10-henry choke coil L, .25-mfd. condenser C and 1,000-ohm resistor R, first disconnect the condenser lead from terminal *4*. Connect this condenser lead to one lead of the 10-henry choke coil (Part *3-10*), and connect the other choke coil lead to terminal *4*, as indicated in the schematic circuit diagram in Fig. *18B*.

Adjust the voltage between terminals *5* and *6* to 4 volts in the manner described in Step 1.

Measure the a.c. voltage between terminal *6* and the junction of the coil and condenser leads, and record the result in Table *29DC* as the a.c. voltage in volts across .25-mfd. condenser *C*.

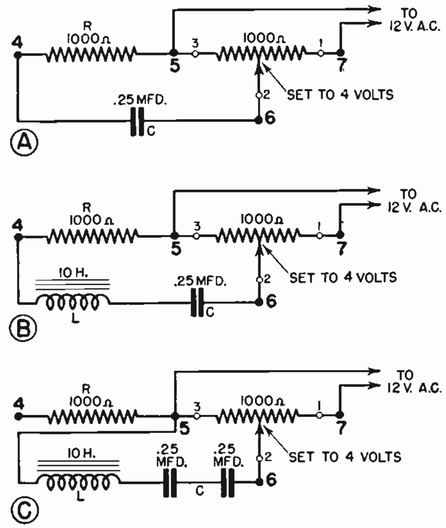


FIG. 18. Schematic circuit diagram for Experiment 29DC.

Measure the voltage between terminal *4* and the junction of the coil and condenser leads, and record your result in Table *29DC* as the a.c. voltage in volts across 10-henry coil *L*.

Measure the a.c. voltage between terminals *4* and *5*, and record your result in Table *29DC* as the a.c. voltage in volts across *R* and the current in ma. through the *R-L-C* circuit.

Step 3. In order to repeat Step 2 with a capacity value of .125 mfd. instead of .25 mfd., disconnect the condenser lead from terminal *6*, and connect your other .25-mfd. condenser (Part *3-2B*) between the disconnected condenser lead and terminal *6*. Use temporary soldered joints.

Readjust the voltage between terminals *5* and *6* to 4 volts, then repeat each of the measurements called for in Step 2 and record your results in Table *29DC*. Consider the two .25-mfd. condensers as a single .125-mfd. condenser, for the combined capacity of two equal condensers in series is always half the capacity of one condenser.

Step 4. To repeat the measurements of Step 3 with the 1,000-ohm resistor R removed, first disconnect the coil lead from terminal *4* and solder this lead instead to terminal *5* as indicated in Fig. *18C*.

Adjust the voltage between terminals *5* and *6* exactly to 4 volts in the manner previously described.

Measure the a.c. voltage between terminal *6* and the common junction of the coil and condenser leads, and record your result in Table *29DC* as the a.c. voltage in volts across the .125-mfd. capacity *C*.

Measure the a.c. voltage between terminal *5* and the common junction of the coil and condenser leads, and record your result in Table *29DC* as the a.c. voltage across the 10-henry coil *L*.

Discussion: In Step 1, you have a .25-mfd. condenser connected in series with the 1,000-ohm resistor across the a.c. voltage source of 4 volts. At the vibrator frequency of 120 cycles, the reactance of this .25-mfd. condenser is approximately 5,300 ohms.* This is about five times the ohmic value of the 1,000-ohm resistor, so you should expect to measure about five times as much voltage drop across the condenser as you do across the resistor.

The N.R.I. voltage value across *C* was about 3.8 volts, and the voltage across resistor *R* was about .8 volt. This voltage across *R* may be difficult to read, however, because the *AC* scale is extremely crowded at the *0* end. Therefore, do not expect to obtain close agreement when dealing with a.c. voltages below about 2 volts.

If we add together vectorially the N.R.I. voltages of 3.8 volts and .8 volt, taking into account the fact that they are 90° out of phase, the resultant voltage will be just about equal to the source voltage of 4 volts.

The insertion of a 10-henry coil in series with the condenser and resistor in Step 2, to give the series resonant circuit shown in Fig. *18B*, should make both the circuit current and the condenser voltage go up. The fact that circuit current goes up is proof that the total impedance of the circuit has been lowered.

Looking at the N.R.I. values given in Table *29DC* for Step 2, we see that now we have more voltage across the coil and across the condenser than we have at the source. From your fundamental course you learned, however, that voltages across a coil and condenser in a series circuit are 180° out of phase, and each of these voltages is 90° out of phase with the appreciably high voltage drop across the a.c. resistance of the coil. This means that the measured voltage values would have to be added vectorially to obtain a check.

In Step 3, reducing the value of capacity *C* to .125 mfd. reduces the N.R.I. voltage value across the coil from 11.4 to 8.4, but increases the condenser voltage from 5.5 to 11.1 volts. This apparently indicates that resonance (with equal voltages across the coil and condenser) is obtained with a capacity value somewhere between .125 and .25 mfd., but we can-

*The formula used for determining this reactance value is: $X_C = \frac{1{,}000{,}000}{6.28 \times f \times C}$, where X_C is the reactance in ohms, f is the frequency in cycles, and C is the capacity in mfd.

OVERLOADING OF N.R.I. TESTER

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

An overload will usually shift the *0* position of the pointer. This condition will be corrected automatically the next time you make an approximately full-scale voltage reading, or can be corrected immediately by lifting up the calibrating clip and touching it momentarily to the —4½C or —3C terminal on the battery block. Be sure to return the clip to —9C.

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

not say definitely that this is true because the distribution of voltages in our resonant circuit is quite complex due to the presence of harmonics. The coil and condenser voltages might be equal at the fundamental frequency, but at harmonic frequencies practically all of the voltage drop occurs across the coil, with no harmonic voltage drop across the condenser.

The removal of the 1,000-ohm resistor in Step 4 increases the voltage across both the coil and the condenser. With this 1,000-ohm resistor removed, the total resistance of the circuit at resonance is lower, greater current flows, and the voltage drops across the coil and the condenser are higher. Note that an N.R.I. value of 12.5 volts was obtained across the condenser in Step 4 of Table *29DC*. This indicates clearly that our series resonant circuit is capable of stepping up the 4-volt a.c. source voltage over three times, due to resonance.

Instructions for Report Statement No. 29DC. An important principle to remember in connection with resonant circuits is that a change in the value of the applied voltage does not affect the condition of resonance. At any frequency, such as at the 120-cycle frequency of your d.c. power pack, resonance is affected only by the values of inductance and capacity. For this report statement, you will make an additional test to prove this fact.

With the parts still connected according to the circuit shown in Fig. *18C,* adjust the potentiometer until the a.c. voltage as measured between terminals *5* and *6* is exactly 4 volts, then measure the voltage across condenser *C*. This value will, of course, be essentially the same as that which you recorded in Step 4 of Table *29DC*. Now readjust the potentiometer to give 2 volts a.c. between terminals *5* and *6,* and again measure the voltage across condenser *C*. Compare the two voltage values which you have just measured across *C*, then turn to the last page and place a check mark after the answer which applies to your observation.

If the voltage across any part of the resonant circuit (such as across the condenser) drops proportionately when you reduce the source voltage to half its value (drops to half its original voltage value), you have proved that the impedance of a resonant circuit is independent of the applied voltage.

EXPERIMENT 30DC

***Purpose:* To show that the total impedance of a parallel resonant circuit (a coil and condenser connected in parallel) is *higher* than the lowest individual reactance in the circuit.**

Step 1. To measure the current which a 4-volt a.c. source sends through a .25-mfd. condenser, first remove the 1,000-ohm resistor *R* from your a.c. voltage divider set-up, and connect in its place an 18,000-ohm resistor (Part *1-16*), so that this 18,000-ohm resistor is between terminals *4* and *5* as indicated in Fig. *19A*.

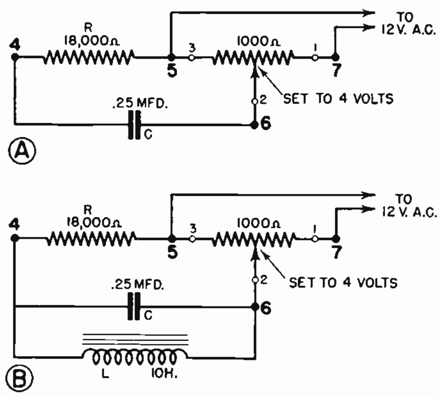


FIG. 19. Schematic circuit diagrams for Experiment 30DC.

Now connect a .25-mfd. condenser (Part *3-2A*) between terminals *4* and *6* of your revised voltage divider set-up.

Adjust the potentiometer to give 4 volts a.c. between terminals *5* and *6*.

Measure the voltage between terminals *4* and *5*, and record your result in Table *30DC* as the voltage across *R* when the load is a .25-mfd. condenser. This value will be proportional to the alternating current in ma. flowing through *C*, as set forth by Ohm's Law.

Step 2. To measure the current which a 4-volt a.c. source sends through a parallel resonant circuit consisting of .25-mfd. condenser C and 10-henry choke coil L, connect your choke coil (Part *3-10*) to terminals *4* and *6* of the voltage divider by means of temporary soldered lap joints.

Adjust the potentiometer to give 4 volts a.c. between terminals *5* and *6*.

Measure the voltage between terminals *4* and *5*, and record your result in Table *30DC* as the voltage across *R* when the load is a coil and condenser connected in parallel. This value will be proportional to the alternating current in ma. flowing through the parallel resonant circuit.

Discussion: In this experiment, you measure the current which a 4-volt a.c. source sends through a .25-mfd. condenser alone, then through a parallel circuit consisting of this condenser and a 10-henry choke coil. Of course, you cannot measure this current directly without upsetting circuit conditions; therefore, you let the current flow through an 18,000-ohm resistor and measure the voltage drop across the resistor. This voltage drop will be proportional to the current flowing. You could calculate the exact value of current by means of Ohm's Law (current equals voltage divided by resistance), but this is not necessary.

The N.R.I. values in Table *30DC* indicate that the voltage across the 18,000-ohm resistor drops to about half its value when the coil is placed in parallel with the condenser. This indicates that the circuit current was cut in half by the addition of the coil, and therefore the total impedance of the circuit was just about doubled by the addition of the coil.

Actually, we have a parallel resonant circuit, with the coil serving with the condenser to give approximate resonance. You learned in your fundamental course that at resonance, the impedance of a parallel resonant circuit is a maximum; you demonstrate this fact partially in this experiment, for you observe that the impedance of the parallel combination is *higher* than the reactance of the condenser alone. In other words, less current flows through the parallel resonant circuit than flows through the condenser used alone.

Instructions for Report Statement No. 30DC. As you become more familiar with parallel resonant circuits, you will discover that the value of the resistance which is in series with the coil has considerable influence upon the resonant impedance of the circuit. You will check this fact for Report Statement No. 30DC.

With the parts connected as shown in Fig. *19B*, disconnect the coil lead from terminal *6*. Take two of your 1,000-ohm resistors (Parts *3-5A* and *3-5B*) and connect them in series. Connect one lead of this resistor group to terminal *6*, and connect the other lead to the free coil lead, so that you have 2,000 ohms in series with the coil in your parallel resonant circuit.

Adjust the a.c. voltage between terminals *5* and *6* to 4 volts as previously instructed, then measure the a.c. voltage drop across 18,000-ohm resistor *R* by placing the test clips on terminals *4* and *5*. Compare this result with that which you recorded as your second reading in Table *30DC*, then place a check mark after the answer in Report Statement No. 30DC which describes your result.

Special Instructions. Turn off the N.R.I. Tester and the power pack, disconnect the voltage divider, and remove surplus solder from the lugs and leads. Unsolder also the two leads which you previously attached to terminals *15* and *17* of the vibrator transformer. Do not remove the leads from the choke coil terminals.

You have now completed the three a.c. experiments left over from the previous manual, and are ready to start the series of ten d.c. power pack experiments which constitute the next section of your practical demonstration course.

EXPERIMENT 31DC

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

Step 1. To replace the choke coil and filter condenser unit in your power pack and restore the original connections, first fasten the choke coil to the chassis with its mounting screws and nuts, being sure to place the soldering lug (terminal *12*) under the nut on one of the screws, as indicated in Fig. *8*. Tighten the screws with screwdriver and pliers, then mount the electrolytic filter condenser unit. Make sure that the outer lug which has no hole in it is next to the rectifier tube socket, as indicated in Fig. *5*.

NATURE OF MEASUREMENT	YOUR VALUE	N.R.I. VALUE
VOLTAGE ACROSS R WHEN LOAD IS .25 MFD. C		3.8
VOLTAGE ACROSS R WHEN LOAD IS L AND C IN PARALLEL		2.0

TABLE 30DC. Record your results here for Experiment 30DC, in which you check the characteristics of parallel resonant circuits.

Connect to output terminal *5* with a *permanent* soldered hook joint the 2¼-inch lead which is on choke coil terminal *13*.

Connect to choke coil terminal *13* with a *temporary* soldered hook joint the 4-inch lead which is on condenser terminal *24*.

Connect to terminal *8* with a *permanent* soldered hook joint the 2¼-inch lead which is on choke coil terminal *14*.

Connect to choke coil terminal *14* with a *temporary* soldered hook joint the 3½-inch lead which is on condenser terminal *23*.

Replace the lead which connects terminals *19* and *22*, making *permanent* soldered hook joints in both cases.

Replace the rectifier tube in its socket.

Step 2. To measure the high d.c. output voltage of your power pack, first place the power pack in an upright position, with the terminal strip facing you.

Measure the d.c. voltage between output terminals *4* and *5* by following the instructions previously given for "D.C. VOLTAGE MEASUREMENTS," and record your result in Table *31DC* as the d.c. output voltage in volts between output terminals *4* and *5*.

CAUTION: As was previously pointed out, high voltages exist at some terminals underneath the power pack chassis when the unit is in operation. Therefore, do not touch output terminals *4* and *5* or any terminals under the chassis with your fingers while the power pack switch is on.

Step 3. To measure the a.c. ripple voltage which is present at d.c. output terminals 4 and 5, leave the test clips on these terminals but move the red probe to the left-hand V_{AC} jack according to instructions previously given for "A.C. VOLTAGE MEASUREMENTS."

Measure the a.c. voltage between terminals *4* and *5*, and record your result in Table *31DC* as the a.c. ripple voltage in volts between output terminals *4* and *5*. If the pointer flickers back and forth continually, estimate its average position. If the pointer does not move at all from zero even when the meter case is tapped, record your result as zero volts.

Step 4. To measure the d.c. filament supply voltage provided by your d.c. power pack, first prepare the N.R.I. Tester for d.c. voltage measurements.

Since you do not yet know the polarity of the d.c. output terminals *1* and *2*, simply place one test clip on output terminal screw *2* and the other on output terminal screw *1*. Turn on the power pack and the N.R.I. Tester, then switch to the lowest voltage range which does not give an off-scale reading. If no meter reading is obtained, polarity is incorrect; in this case, simply reverse the positions of the test clips on terminals *1* and *2*. Record your result in Table *31DC* as the d.c. output voltage in volts between terminals *1* and *2*.

STEP	NATURE OF MEASUREMENT	YOUR VALUE IN VOLTS	N.R.I. VALUE IN VOLTS
2	D.C. OUTPUT VOLTAGE BETWEEN TERMINALS 4 AND 5		430
3	A.C. RIPPLE VOLTAGE BETWEEN TERMINALS 4 AND 5		.5
4	D.C. VOLTAGE BETWEEN TERMINALS 1 AND 2		6.3

TABLE 31DC. Record your results here for Experiment 31DC, in which you measure voltages in your d.c. power pack under no-load conditions while it is connected normally for full-wave rectification and condenser input.

Discussion: Although you previously measured the d.c. output voltage to secure a check upon your assembly of the d.c. power pack, you repeat this measurement in Step 2 so you can record the value in Table *31DC* along with the other output voltage values of your d.c. power pack. You will use the values which you record in this table for reference purposes in connection with later experiments.

The power pack which you assembled according to the instructions in this manual serves the dual purpose of teaching you the underlying principles of vacuum tube rectifier

REDUCING LEAKAGE RESISTANCE EFFECTS

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

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

circuits and providing the filament, grid and plate supply voltages required for future vacuum tube circuit experiments. Filament voltages are obtained from the storage battery, but convenient terminals (output terminals *1* and *2*) are provided on the power pack output terminal strip for this purpose.

When using the a.c. voltmeter range of the N.R.I. Tester, there is a condenser in series with the measuring circuit inside the tester to block the flow of direct current. Under this condition, the only voltage which can normally affect the meter reading when measuring between d.c. output turminals *4* and *5* is the a.c. ripple voltage. If this is below about 1 volt, your d.c. power pack can be considered entirely satisfactory.

When you measured the a.c. ripple voltage, you probably noticed a flickering of the pointer. No matter how carefully a vibrator is designed and constructed, it will occasionally make a poor connection at one set of contacts. This causes erratic fluctuations in the primary alternating current, and these fluctuations are increased many times in amplitude through voltage step-up by the vibrator transformer. Disregard the flickering, and estimate an average pointer position when making the a.c. ripple voltage reading. Line voltage fluctuations cause this same phenomenon in a.c. power packs, so you are observing common radio action.

When you measure in Step 4 the d.c. voltage provided at output terminals *1* and *2*, which are connected directly to the leads going to the storage battery clips, you will find that a standard storage battery actually has a voltage somewhat higher than 6 volts (usually around 6.3 volts). Elsewhere in the course, you learn that tubes designed for storage battery operation have filament voltage ratings of 6.3 volts, to correspond to the actual voltage of a storage battery.

If you always place the + battery clip on the + battery terminal, you will have a definite polarity at terminals *1* and *2*, and can mark the polarity of these terminals with a metal marking crayon. The red clip of the N.R.I. Tester will be on the + terminal when an up-scale meter reading is obtained.

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

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

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

Instructions for Report Statement No. 31DC. Measure the no-load d.c. output voltage at terminals *4* and *5* again, and record your result in Report Statement No. *31DC*.

Next, measure the d.c. voltage directly at the terminals of your storage battery while the power pack is on, and record this value also in Report Statement No. 31DC. It should be essentially the same as the value you recorded in Table *31DC* for terminals *1* and *2*.

These two values will tell whether you have mastered the proper techniques for making d.c. voltage measurements with the N.R.I. Tester, and will also tell whether your power pack is operating properly.

EXPERIMENT 32DC

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

Step 1. To connect four 40,000-ohm resistors in parallel to the high-voltage d.c. output terminals of the power pack so as to secure a 10,000-ohm load, first secure the four 40,000-ohm, 3-watt resistors (Parts *3-6A*, *3-6B*, *3-6C* and *3-6D*) which were supplied you in Radio Kit 3RK. Bend a hook in each lead of one resistor, loosen the screws on output terminals *4* and *5* of the power pack, hook these resistor leads over screws *4* and *5* in the manner shown in Fig. *20A*, then tighten the screws while holding the resistor with your fingers and exerting a gentle upward pull to keep the hooks under the screw heads. Now bend the resistor leads downward until the resistor is about on a level with the screws.

Take another 40,000-ohm resistor, tin the ends of its leads, and connect this resistor in parallel with the first one by means of temporary soldered joints after bending and arranging the leads as shown in Fig. *20B*.

Connect the remaining two 40,000-ohm resistors in parallel with the first two resistors by means of temporary soldered lap joints in the same manner, so that you now have a parallel combination of four resistors like that shown in Fig. *20C*. These give the desired equivalent resistance of 10,000 ohms.

Step. 2. To measure the d.c. output voltage of your power pack with various load values, first place the

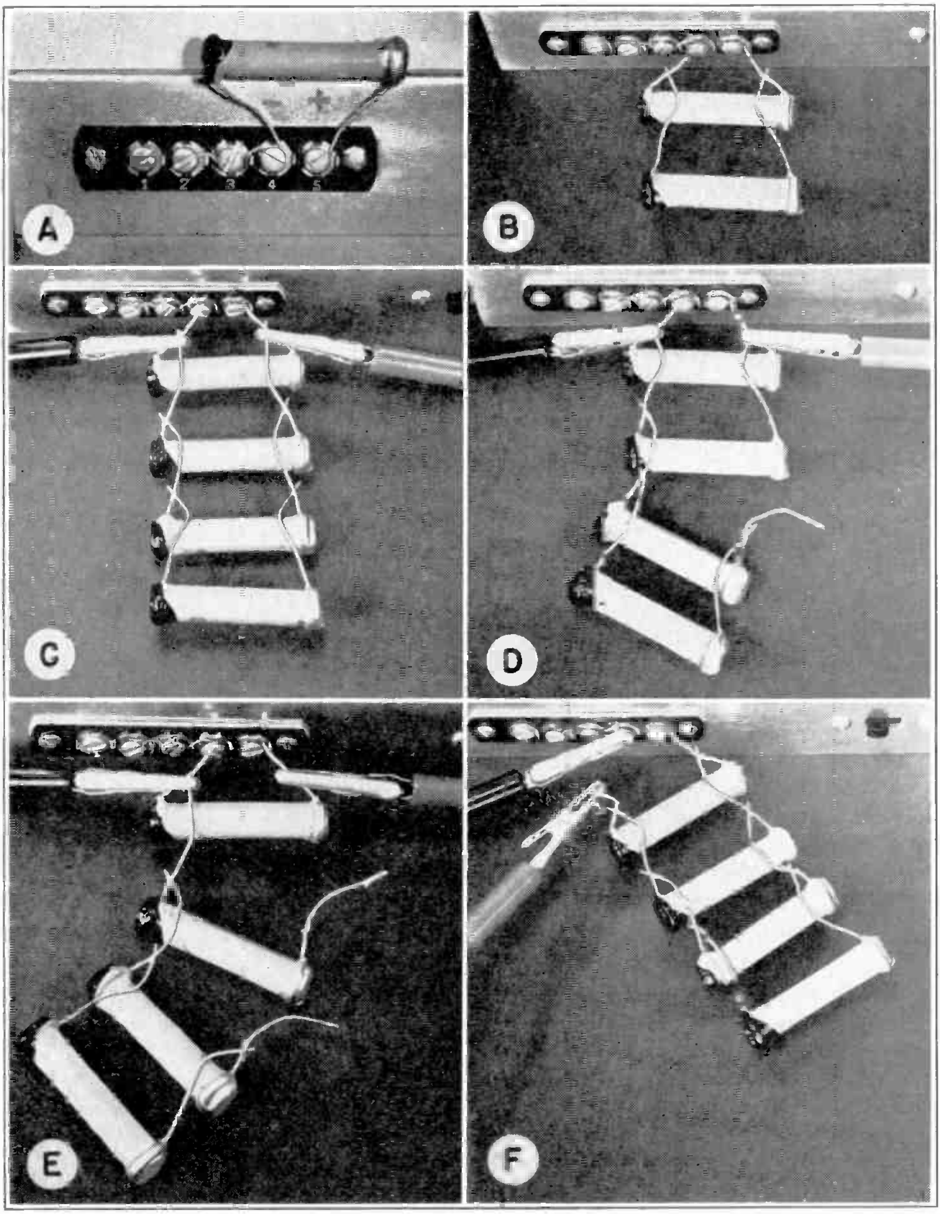


FIG. 20. Methods of connecting resistors to the d.c. output terminals of your power pack for d.c. output voltage and d.c. load current measurements are illustrated here. In all cases, there should be an external ground wire going to terminal group *2-3-4* as a safety precaution while the power pack is in use. Note that current is measured at the grounded point (terminal *4*) in the load circuit; this keeps the chassis of the N.R.I. Tester at ground potential.

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

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

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

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

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

F—Method of connecting the test clips for measurement of the d.c. load current flowing through a 10,000-ohm load resistance.

test clips on the load resistor leads going to output terminals *4* and *5* in the manner shown in Fig. *20C*, so as to minimize chances for the clips touching the chassis or touching each other and shorting the power pack.

Measure the d.c. voltage between output terminals *4* and *5*, and record your result in Table *32DC* as the d.c. output voltage at terminals *4* and *5* when using a 10,000-ohm load.

Measure the d.c. voltage between output terminals *4* and *5* for a 20,000-ohm load, after first removing two of the resistors from your parallel group by unsoldering one resistor lead in the manner shown in Fig. *20D*. The two 40,000-ohm resistors which are still connected to output terminals *4* and *5* give a load resistance of 20,000 ohms. Record your result in Table *32DC* as the d.c. output voltage in volts for a 20,000-ohm load.

Measure the d.c. voltage between output terminals *4* and *5* for a 40,000-ohm load, after first unsoldering one more resistor lead in the manner shown in Fig. *20E*, so that only one 40,000-ohm resistor is connected to terminals *4* and *5*. Record your result in Table *32DC* as the d.c. output voltage at terminals *4* and *5* for a 40,000-ohm load.

Measure the d.c. voltage between terminals *4* and *5* for no load, after first removing the entire 40,000-ohm resistor group and placing the test clips directly on terminals *4* and *5*. Record your result in Table *32DC* as the no-load d.c. output voltage in volts.

Step 3. To measure load currents for the three load resistance values used in Step 2, first connect the four 40,000-ohm resistors in parallel again by means of temporary soldered lap joints to secure a 10,000-ohm resistance. Connect one lead of this resistor group to output terminal screw *5*. Place the red test clip on the other lead of the resistor group, and place the black test clip on output terminal screw *4* in the manner shown in Fig. *20F*, so that the current measurement will be made at grounded terminal *4*.

Measure the current through the 10,000-ohm load by following the instructions given elsewhere for "DIRECT CURRENT MEASUREMENTS," and record your result in

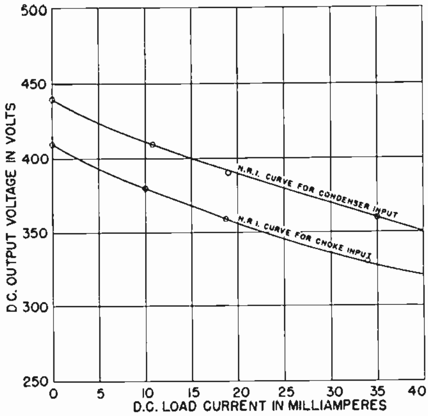
OPERATING INSTRUCTIONS FOR N.R.I. TESTER

DIRECT CURRENT MEASUREMENTS

1. **Place the black test probe in the *—I* jack, and place the red test probe in the *+I* jack.**
2. **Set the selector switch at *10 × I*.**
3. **Open the circuit at a point as close as possible to ground potential. If you disregard this rule, you may get a shock when touching both the tester chassis and a grounded object (such as the power pack chassis).**
4. **Place the black clip on the circuit lead going to the — terminal of the voltage source (this terminal is usually grounded), and place the red clip on the other circuit lead.**
5. **Turn on the voltage source and the N.R.I. Tester, wait about half a minute if there are any heater-type tubes in your set-up, then read the meter on the *DC* scale and multiply the reading by 10 to get the current in milliamperes.**
6. **If the current value is less than 4.5 ma., set the selector switch at the *I* range and read the direct current value in ma. directly on the *DC* scale.**
7. **Turn off the N.R.I. Tester, then turn off the power source. Pull out the test probes to prevent draining the C battery in case the test leads accidentally touch the tester panel or chassis.**

LOAD RESISTANCE IN OHMS	D.C. OUTPUT VOLTAGE IN VOLTS AT TERMINALS 4 AND 5		D.C. LOAD CURRENT IN MILLIAMPERES	
	YOUR VALUE	N.R.I. VALUE	YOUR VALUE	N.R.I. VALUE
10,000		360		35
20,000		390		19
40,000		410		11
NO LOAD		440		0

TABLE 32DC. Record your results here for Experiment 32DC, in which you measure d.c. output voltages and currents for various load values while your power pack is connected normally for condenser input and full-wave rectification.



GRAPH 32DC. Plot your results for Experiment 32DC on this graph and draw a smooth line through the dots to secure a d.c. load current-d.c. output voltage curve for *condenser input*. Later, you will use values obtained in Experiment 34DC to plot another curve on this graph for a *choke input* type of filter circuit.

Table *32DC* as the d.c. load current in milliamperes for a 10,000-ohm load.

Measure the current through a 20,000-ohm load, after first removing two resistors completely from your combination so as to give this load value. Record your result in Table *32DC* as the load current in ma. for a 20,000-ohm load.

Measure the current through a 40,000-ohm load, after first disconnecting one more resistor completely from the resistor group, so that you have only one 40,000-ohm resistor left to serve as load. Record your result in Table *32DC* as the load current in ma. for a 40,000-ohm load.

Since no current can flow when there is no load, record a zero in Table *32DC* as the current for the no-load condition.

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

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

Discussion: Step 1 gives additional experience in making the temporary soldered lap joints which are used so extensively by radio servicemen for test connections. Apply solder liberally to each lead and to the soldering iron tip beforehand, to eliminate the need for three hands. With proper pretinning, you can hold in one hand the part being soldered, and hold the soldering iron in the other hand.

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

Do not touch the 40,000-ohm resistors with your fingers until they have had ample time to cool after you have turned off the power pack.

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

Load Current Computations. You can easily check your measured values of load current by means of Ohm's Law. To compute what the load current in amperes will be, divide the measured value of d.c. output voltage by the ohmic value of the load resistance employed. Multiplying the result by 1,000 will give you the load current in milliamperes. Of course, you cannot expect perfect agreement because the actual ohmic values of the resistors may be as much as 20% off from rated values due to normal manufacturing tolerances.

By plotting the load current values on Graph *32DC* and drawing the curve for the points, you can see at a glance how the d.c. output voltage increases gradually to the no-load value as the load current is reduced by increasing the load resistance. Furthermore, with your curve you can determine what the d.c. output voltage will be for any intermediate value of load current.

Your d.c. power pack is designed to deliver at least 350 volts d.c. continuously at a d.c. load current value of 25 ma., when the power pack is connected to a standard 6-volt storage battery. The N.R.I. curve for this experiment (the *CONDENSER INPUT* curve in Graph *32DC*) shows that the d.c. output voltage is well above 350 volts at this rated full-load current value of 25 ma. Even greater currents can be obtained safely for short periods of time, as you demonstrated in this experiment.

Voltage Regulation. To express how the output voltage of a power pack will drop when full load is applied, engineers often use a rating called *per cent voltage regulation.* This is obtained by taking the difference between the no-load and full-load voltages, dividing this difference by the no-load voltage value, then multiplying the result by 100. We can use the N.R.I. laboratory values to illustrate how per cent voltage regulation is computed for your d.c. power pack.

Voltage Regulation Computations. The N.R.I. curve for condenser input (the type of filter circuit you are now using) in Graph *32DC* tells that the d.c. output voltage will be approximately 380 volts at a full-load current of 25 ma. This curve also tells that the no-load d.c. output voltage is 440 volts, hence the difference between these values is 60 volts. Dividing this difference value of 60 volts by the no-load value of 440 volts gives roughly .14, and multiplying by 100 gives 14% as the voltage regulation of the d.c. output section of the power pack.

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

To explain the theoretical operation of your power pack, the simplified circuit diagram of Fig. *21* will be easier to follow than the detailed schematic diagram in Fig. *2*. Rectifier tube *VT* in Fig. *21* allows each power transformer secondary voltage E_{AC} in turn to send electrons through load resistor R_L and choke coil L in one direction only, as indicated by arrows.

Input filter condenser C_1 (Fig. *21*) is charged by the pulsating d.c. voltage produced by the rectifier tube-vibrator transformer combination. When the pulsating d.c. source voltage drops below the input condenser voltage, this condenser discharges through R_L and L; the input condenser current then adds to the existing current flow over this path, thereby keeping the load current nearly constant despite the fact that the pulsating d.c. voltage is dropping to zero between each half-cycle.

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

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

First of all, an increased load makes C_1

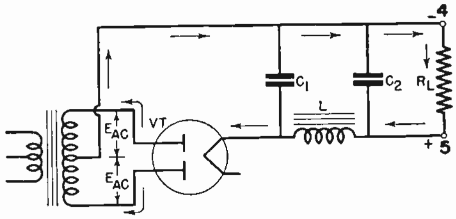


FIG. 21. Simplified schematic circuit diagram of the high-voltage section of your d.c. power pack, with arrows indicating the direction of electron flow. R_L represents an external load resistance connected to d.c. output terminals *4* and *5* of the power pack.

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

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

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

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

EXPERIMENT 33DC

***Purpose:* To demonstrate the voltage regulation characteristics of the high-voltage secondary winding of the vibrator transformer in your power pack.**

Step 1. To measure no-load and full-load a.c. voltages across half of the high-voltage secondary winding, first connect a 10,000-ohm load (four 40,000-ohm resistors in parallel) to d.c. output terminals *4* and *5.* Be sure the resistor leads do not touch the chassis.

With the power pack chassis resting on its back side so as to make the vibrator transformer terminals accessible, measure the a.c. voltage between transformer terminals *18* and *19,* and record your result in Table *33DC* as the a.c. voltage in volts between transformer terminals *18* and *19* for a 10,000-ohm load.

Remove the 10,000-ohm load from the power pack, measure the a.c. voltage again between transformer terminals *18* and *19*, and record your result in Table *33DC* as the no-load a.c. voltage in volts between terminals *18* and *19*.

Discussion: You should observe a definitely lower a.c. voltage value

NATURE OF MEASUREMENT	A.C. VOLTAGE IN VOLTS	
	YOUR VALUE	N.R.I. VALUE
VOLTAGE AT TRANSFORMER TERMINALS 18 AND 19 FOR 10,000 Ω LOAD		400
VOLTAGE AT TRANSFORMER TERMINALS 18 AND 19 FOR NO LOAD		460

TABLE 33DC. Record your results here for Experiment 33DC, in which you measure the a.c. voltage across the secondary of the vibrator transformer while your power pack is connected normally for full-wave rectification and condenser input, first with a 10,000-ohm load and then with no load on the power pack.

with the 10,000-ohm load than is obtained with no load. This will prove conclusively that the a.c. voltage at the high-voltage secondary winding drops when load is applied to the power pack. There is no need to measure the voltage across the entire secondary winding, for it is always twice the voltage across half the winding.

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

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

Consideration of the equivalent transformer circuit shown in Fig. *22* will help you to understand the actions occurring in a practical transformer. If a definite load voltage value V_L is required across transformer load R_L, the secondary winding of the ideal transformer must supply a higher voltage E_S which will be equal to the vectorial sum of the load voltage V_L, the a.c. voltage drop across the secondary a.c. resistance value R_S, and the a.c. voltage drop across the secondary inductive reactance X_S. The higher the load current, the higher are the voltage drops across R_S and X_S, and the higher must E_S be to overcome these drops.

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

When the input voltage is fixed (as it is in your case), all these voltage drops make the output voltage *lower* than for a perfect transformer. Increasing the load makes these voltage drops increase, thereby reducing the output voltage still more.

The 50,000-ohm bleeder resistor was loading the vibrator transformer when you measured the no-load output voltage for this experiment, and consequently you did not get a true no-load transformer secondary voltage measurement. You cannot remove

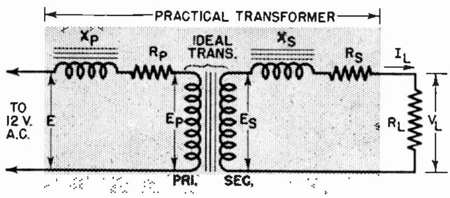


FIG. 22. Simplified equivalent circuit diagram for the primary winding and high-voltage secondary winding of a power transformer. The portion of the diagram designated as an ideal transformer has no losses. Parts X_P, R_P, R_S and X_S represent equivalent loss-producing resistances and reactances which are present in a practical iron-core transformer.

this resistor without risking damage to the input filter condenser, but instructions will now be given for making a true no-load measurement.

Instructions for Report Statement No. 33DC. Remove the rectifier tube, so as to break the circuit between the vibrator transformer secondary and the filter system. As the schematic circuit diagram in Fig. *2* indicates, there is essentially no load (only a condenser) across the secondary of the vibrator transformer when the rectifier tube is out.

Measure the true no-load voltage across half the transformer secondary (between terminals *18* and *19*), compare your measured value with that which you recorded in Table *33DC* as the no-load value (corresponding to an internal 50,000-ohm load), then answer Report Statement No. 33DC.

EXPERIMENT 34DC

Purpose: **To show how the d.c. load voltage of your power pack varies with the load when a choke input filter connection is employed.**

Step 1. To secure a choke input filter circuit connection in your d.c. power pack, disconnect the input filter condenser by unsoldering the lead which is on condenser terminal *23* and bending up this lead so it cannot touch other parts or terminals. Replace the rectifier tube in its socket on the power pack chassis.

Step 2. To measure the d.c. output voltage with choke input for different load values, first measure the no-load d.c. output voltage at terminals *4* and *5*, and record your result in Table *34DC* as the d.c. output voltage in volts for no load. Connect one 40,000-ohm resistor to d.c. output terminals *4* and *5*, measure the d.c. voltage at these terminals again, and record your result in Table *34DC* as the output voltage in volts for a 40,000-ohm load.

Connect another 40,000-ohm resistor in parallel with that already attached to output terminals *4* and *5*, using temporary soldered lap joints, then measure the d.c. voltage at these terminals and record your result in Table *34DC* as the d.c. output voltage in volts for a 20,000-ohm load.

Connect the two remaining 40,000-ohm resistors in parallel with those already on terminals *4* and *5*, measure the d.c. voltage at these terminals, and record your result in Table *34DC* as the d.c. output voltage in volts for a 10,000-ohm load.

Step 3. To measure the d.c. load current for various load values when using a choke input connection, start with the 10,000-ohm load since that is already connected to output terminals *4* and *5*, measure the current through this load just as you did in Experiment 32DC, and record your result in Table *34DC* as the d.c. load current in milliamperes for a 10,000-ohm load.

LOAD IN OHMS	D.C. OUTPUT VOLTAGE IN VOLTS		D.C. LOAD CURRENT IN MILLIAMPERES	
	YOUR VALUE	N.R.I. VALUE	YOUR VALUE	N.R.I. VALUE
NO LOAD		410		0
40,000		380		10
20,000		360		19
10,000		330		34

TABLE 34DC. Record your results here for Experiment 34DC, in which you measure the d.c. output voltage and current values for various loads while your d.c. power pack is connected for full-wave rectification and choke input.

Disconnect two of the 40,000-ohm resistors from the group, measure the load current, and record your result in Table *34DC* as the d.c. load current in milliamperes for a 20,000-ohm load.

Remove one more 40,000-ohm resistor, measure the load current, and record your result in Table *34DC* as the d.c. load current in milliamperes for a 40,000-ohm load.

Record a zero in Table *34DC* for the no-load current.

Step 4. To get a better picture of how load current varies with d.c. out-

put voltage when the input filter condenser is disconnected to give choke input, plot on Graph *32DC* the four sets of readings you just obtained for d.c. load current and d.c. output voltage, and connect the points with a curved line. Label this as your curve for *choke input,* to distinguish it from the curve you previously drew for condenser input.

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

By starting with no load, you can at least get some of your readings before it is necessary to stop measurements because of overheating of a part. Sometimes the readings will indicate a tendency toward failure sufficiently in advance for you to stop the experiment and change the part or circuit to correct the condition.

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

Familiarity with the performance of a filter system having an open input filter condenser will help you to recognize trouble of this type when you encounter it in radio equipment. Knowledge of how a choke input filter acts can in itself be valuable, for a choke input filter is used extensively in transmitter power packs and in the high-voltage power packs of special radio apparatus, even though rarely used in radio receivers.

A comparison of your choke and condenser input curves in Graph *32DC* should show that the d.c. output voltage is lower for choke input than for condenser input. This is explained by the fact that with choke input, there is no input condenser to hold up the voltage in between the pulses of the rectifier tube output. The choke and output filter condenser merely serve to remove a.c. components from the rectifier tube output.

Voltage Regulation. With a condenser input connection, the voltage regulation of the entire power pact was figured out to be 14% when using the N. R. I. values. Examination of the N. R. I. curve for choke input in Graph *32DC* reveals that the d.c. output voltage at no load is 410 volts, and at a 25-ma. load is about 345 volts. This makes a difference of 65 volts; dividing 65 by 410, then multiplying by 100, gives about 16% as the voltage regulation for choke input. This indicates that essentially the same voltage regulation is obtained for either choke or condenser input.

The curves in Graph *32DC* represent the voltage regulation characteristics of the entire power pack, including the power transformer. If a sufficiently large power transformer were used, so that the a.c. secondary voltage of the transformer remained constant for all of the load values employed in this experiment, the choke input filter would be found to have better voltage regulation than the condenser input filter at high load current values.

Wave Form Considerations. We must not overlook the fact that we are dealing with an a.c. voltage which does not have the usual sine wave characteristics. When we connected a cathode ray oscilloscope to the output of the rectifier tube in the d.c. power pack used in the N. R. I. laboratory, we obtained on the oscilloscope screen a wave form pattern essentially like that shown in Fig. 23, having very nearly a square wave shape.

The heavy solid lines in Fig. 23 represent the instantaneous voltage being applied by the rectifier tube to the input of the filter. When one set of vibrator contacts closes (point *a* in Fig. 23), the voltage builds up quickly to a peak value (*b*), then drops gradually during the time the contacts are closed. When this set of contacts opens (*c*), the voltage drops suddenly again down to zero (*d*) and remains at zero until the spring steel reed in the vibrator has carried the moving contact over to the other fixed contact. At the end of this short interval (*e*), the voltage builds up suddenly again to a peak value (*f*) and the entire cycle of operation is repeated.

The time interval *t* existing between the opening of one set of contacts and the closing of the other set is an important characteristic of a vibrator. If this time interval could be eliminated entirely, the wave form would have only a small sawtooth pattern across the top, and the average voltage would be almost equal to the peak voltage.

In a good vibrator, the time *t* occupies only about 10% of the total time for a cycle; the average voltage is then only slightly lower than the peak voltage, and a d.c. power pack employing the vibrator delivers a d.c. voltage which is very close to its high a.c. voltage. Thus, for comparable no-load conditions in Experiments 32DC and 33DC, the N. R. I. values indicate a no-load *a.c.* voltage of 460 volts and a no-load *d.c.* voltage of 440 volts.

When the rectifier tube is feeding into a normal *condenser input filter,* the input filter condenser tends to maintain its charge during time intervals *t,* thereby raising the valleys in the wave form of Fig. 23, and making the instantaneous voltage follow the dotted-line curves across these valleys. In other words, an input filter condenser can make up for deficiencies in the vibrator.

When a *choke input filter* is used, there is nothing at the filter input to bridge over the valley occurring during time interval *t,* and consequently the voltage fed into the filter has a decided a.c. ripple. The choke coil and output filter condenser eventually filter out most of this ripple, but the d.c. output voltage for choke input is pulled down by these valleys. This explains why choke input gives a lower d.c. output voltage than does condenser input.

Increasing the load current reduces the d.c. output voltage for choke input as well as for condenser input; the increased current boosts the voltage drops in the transformer, rectifier tube and choke coil, thereby reducing the voltage available for the load.

Although you are dealing with voltages having square wave forms, essentially the same effects would be observed in an a.c. power pack having sine wave voltages.

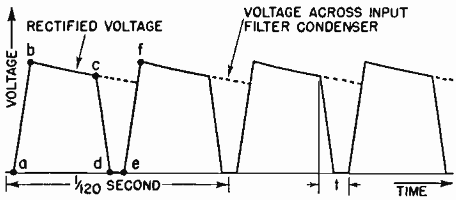


FIG. 23. The heavy solid lines in this diagram represent the wave form of the rectified voltage provided by the vibrator transformer and rectifier tube in a d.c. power pack employing full-wave rectification, when there is no load whatsoever on the rectifier tube. A condenser input filter system bridges across the valleys in this wave form, as indicated by the dotted lines.

Instructions for Report Statement No. 34DC. In this experiment, you demonstrated a number of important characteristics of radio receiver power packs. Among other things, you learned that the opening or removal of the input filter condenser changes your filter circuit from condenser input to choke input, thereby causing a change in the d.c. output voltage.

To test your understanding of what you measured and studied in this experiment, you are asked in Report No. 34DC to specify whether the d.c. output voltage increases, decreases or remains the same when the input filter condenser of a typical radio receiver power pack opens up while normal load current is being supplied (equivalent to changing from condenser input to choke input). Place a check mark after the answer you consider correct. There is only one correct answer, and it applies to a.c. power packs as well as to vibrator power packs like yours.

EXPERIMENT 35 DC

***Purpose:* To demonstrate that even though the a.c. filter input voltage for a choke input increases with load, the choke coil and output filter condenser effectively remove the a.c. ripple from the d.c. output voltage.**

Step 1. To measure the a.c. filter input voltage and the a.c. ripple voltage at the d.c. output terminal of your power pack for a choke input connection, first prepare the N.R.I. Tester for a.c. voltage measurements and remove the load from output terminals *4* and *5* of the power pack. Be sure the lead is still disconnected from condenser terminal *23* so as to give choke input.

Set the power pack chassis on its back side, locate the 50,000-ohm bleeder resistor which is connected across the input of the filter system (see Fig. *2* to verify this), measure the a.c. voltage across this resistor (place the black clip on the grounded resistor lead, going to transformer terminal *19,* to minimize chances of shock), and record your result in Table *35DC* as the a.c. filter input voltage in volts for no load.

Measure the a.c. ripple voltage at output terminals *4* and *5* for no load (black clip goes to *4*, which is grounded). If the pointer appears to flicker around the zero position when using the V range, simply record zero in Table *35DC* for the a.c. ripple voltage in volts at the d.c. output terminals under no-load conditions.

Step 2. To measure the a.c. filter input voltage and the a.c. ripple output voltage of your power pack when using a choke input connection and a 10,000-ohm load, first connect your four 40,000-ohm resistors in parallel to d.c. output terminals *4* and *5* of the power pack in the manner previously described, being sure the resistor leads do not touch the chassis.

Measure the a.c. voltage across the 50,000-ohm bleeder resistor, and record your result in Table *35DC* as the a.c. filter input voltage in volts for a 10,000-ohm load.

Measure the a.c. voltage at d.c. output terminals *4* and *5* for the same 10,000-ohm load, and record your result in Table *35DC* as the a.c. voltage in volts at the d.c. output terminals.

LOAD IN OHMS	A.C. FILTER INPUT VOLTAGE IN VOLTS		A.C. VOLTAGE IN VOLTS AT D.C. OUTPUT	
	YOUR VALUE	N.R.I. VALUE	YOUR VALUE	N.R.I. VALUE
NO LOAD		39		0
10,000		81		0

TABLE 35DC. Record your results here for Experiment 35 DC, in which you measure the a.c. voltages at the filter input and filter output while your d.c. power pack is connected for full-wave rectification and choke input, first for no load and then for a 10,000-ohm load on the power pack.

Discussion: The measurements which you have just made should show definitely that the a.c. filter input voltage increases as load is applied. The N.R.I. values do show this, for the a.c. voltage at the filter input increased from 39 volts to 81 volts when the 10,000-ohm load was connected to the power pack. In both cases, however, the a.c. voltage at the d.c. output terminals was so low that it had to be recorded as zero.

Obviously, the choke coil and output filter condenser must provide highly effective filtering action in order to reduce the 81-volt a.c. filter input voltage to a value so low it cannot be read on the meter. Let us consider in detail the actions occurring in our filter circuit when choke input is employed, to see just how this filtering is provided.

Filter Circuit Analysis. The filter circuit for choke input is shown in Fig. *24*, with power pack load R shown connected directly across output filter condenser C_2 as it is during normal power pack operation. The a.c. filter input voltage e_i causes alternating current to flow through choke coil L and the parallel combination of R and C_2. As will later be shown, the reactance of C_2 at the a.c. frequencies in question is so small with respect to the resistance of R that the shunting effect of R upon C_2 can be neglected. The input a.c. voltage therefore flows through L and C_2 in series, with the a.c. voltage drop across each of these parts being determined by the reactance of that part. The higher the reactance, the higher will be the a.c. voltage drop.

If the reactance of choke coil L is high with respect to the reactance of output filter condenser C_2, most of the a.c. voltage will be dropped across L, and the ripple reduction factor of our filter circuit will be high. Let us compute the reactances of these two parts, keeping in mind that for a 120-cycle vibrator system and full-wave rectification, the fundamental ripple frequency is about 240 cycles. In these formulas, C must be in mfd., L in henrys, and f in cycles.

$X_L = 6.28 \times f \times L$
$X_L = 6.28 \times 240 \times 10$
$X_L = 15{,}100$ ohms, reactance of choke coil.

$X_C = 1{,}000{,}000 \div (6.28 \times f \times C)$
$X_C = 1{,}000{,}000 \div (6.28 \times 240 \times 10)$
$X_C = 1{,}000{,}000 \div 15{,}100$
$X_C = 66$ ohms, reactance of output condenser.

With an output filter condenser reactance of only 66 ohms at the fundamental ripple frequency, it should be clear that even the smallest load resistance we use (10,000 ohms) will not materially affect the combined impedance of C_2 and R.

The ripple reduction factor of this filter circuit is the ratio of coil reactance to output filter condenser reactance ($X_L \div X_C$). Dividing 15,100 by 66 gives 230 as the ripple reduction factor. Now we can readily see that even with an input a.c. voltage of 81 volts, the output a.c. voltage will be so low that it cannot readily be measured; dividing 81 by 230 gives about .35 volt a.c. as the full-load ripple voltage drop across the output condenser. This is the a.c. ripple voltage acting upon the load, and could hardly be detected with the N. R. I. Tester.

Since the ripple reduction factor is determined only by the frequency, the choke coil value and the output filter condenser value, it remains the same for full load as for no load. This means that for a no-load input a.c. voltage of 39 volts, the a.c. ripple output will be .17 volt. The a.c. ripple output voltage thus increases with load.

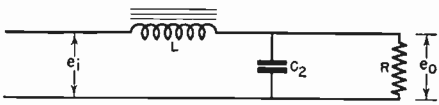


FIG. 24. Circuit diagram for the choke input filter system employed in Experiment 35DC. Resistor *R* represents the external power pack load.

Now let us consider why the N. R. I. value of a.c. filter input voltage rose from 39 volts to 81 volts when a 10,000-ohm load was placed on the power pack. Fig. *25A* shows an elementary schematic diagram of this full-wave rectifier circuit with its choke input filter system X_L-X_C and 10,000-ohm load R. (the 50,000-ohm bleeder resistor in your power pack can be omitted from this analysis since it has no effect on the a.c. filter input voltage under consideration.)

Since the reactance of output filter condenser X_C at the fundamental ripple frequency is very low in comparison with the resistance of R and the reactance of X_L, we can consider X_C to be essentially a short-circuit path for the alternating currents under consideration. The a.c. voltage drop across choke coil X_L will be equal to the reactance of this coil multiplied by the alternating current value, and this a.c. drop across X_L will be essentially equal to the a.c. filter input voltage since X_C is a short-circuit path. We can assume that the reactance of X_L remains essentially constant at all normal load values, and consequently we arrive at the important conclusion that *the a.c. filter input voltage will increase when the alternating current through the choke coil increases;* likewise, the a.c. filter input voltage will decrease when the alternating current through the choke coil decreases.

If only resistance load R were connected to the secondary winding and rectifier tube, the voltage acting in the circuit would have the wave form shown in Fig. *25B,* and the circuit current would have this same wave form. When a choke input filter system is employed, however, we must also consider the d.c. voltage which exists across the charged output filter condenser X_C. At any instant of time, the net voltage available on the rectifier tube, allowing only a small portion near the peak of each voltage pulse to swing the plate of the rectifier tube positive and produce current flow. The resulting alternating current flowing through the choke coil is very low in magnitude, and consequently the a.c. filter input voltage is correspondingly low for no-load condition.

When a 10,000-ohm load is placed on the power pack, the d.c. output voltage drops due to the increased voltage drops in the rectifier tube, choke coil and transformer. With a lowered condenser voltage, more of each voltage pulse swings the rectifier tube plate positive, as shown in Fig. *25D,* and the a.c. component of the rectifier tube current becomes higher than for the no-load condition. As a result, the a.c. filter input voltage for a 10,000-ohm load (Fig.

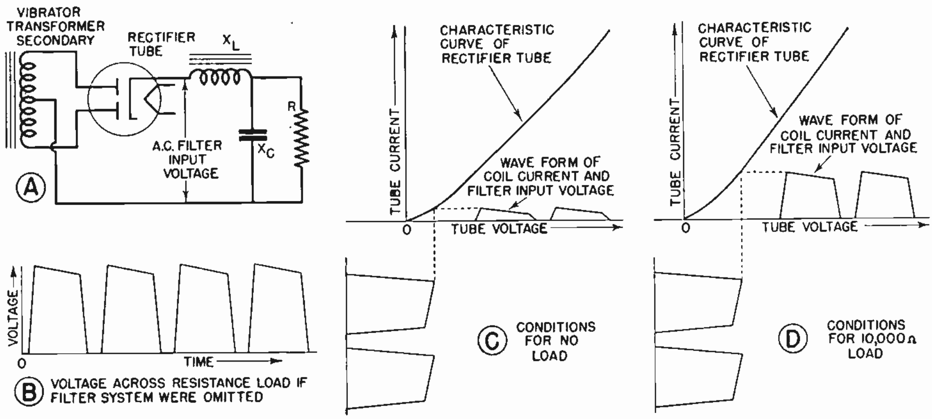


FIG. 25. These diagrams and the corresponding discussion in Experiment 35DC explain why the a.c. filter input voltage is higher for full load than for no load when your d.c. power pack is connected for choke input and full-wave rectification.

to send current through the choke coil is equal to the difference between the condenser voltage and the voltage being produced by the secondary winding and rectifier tube. The current flowing through the choke coil at each instant thus depends upon the total impedance of the circuit and the net voltage in the circuit. Let us now consider how this d.c. voltage across the condenser affects the current flowing through the rectifier tube and choke coil.

Under no-load conditions (with R omitted in Fig. *25A*), the d.c. voltage across the condenser will be almost equal to the peak value of the voltage shown in Fig. *25B,* so that only a small portion near the peak of each voltage pulse serves to send current through the circuit. This no-load condition is shown in Fig. *25C*; the condenser voltage acts somewhat like a negative bias

25D) is definitely higher than the a.c. filter input voltage for no-load (Fig. *25C*), just as you determined by actual measurement.

Instructions for Report Statement No. 35DC. In the discussion of this experiment, it was pointed out that most of the a.c. voltage at the filter input was dropped across the high impedance of the choke coil. For this report statement, you will verify this explanation.

With a choke input connection and with a 10,000-ohm load connected to output terminals *4* and *5* of your power pack, measure the a.c. voltage between terminals *13* and *14* of the choke coil. Make a note of your measured voltage value on the margin of this page, compare it with the value you recorded in Table *35DC* as the a.c. filter input voltage for a 10,000-ohm load, then turn to the last page of this experiment and place a check mark after the answer which corresponds to your conclusion.

EXPERIMENT 36DC

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

Step 1. To convert your power pack circuit for half-wave rectification, simply disconnect the lead from transformer terminal *18* and ground it temporarily to terminal *19.* The lead should still be disconnected from condenser terminal *23*, to give a choke input filter connection, and the four 40,000-ohm resistors should still be connected in parallel to output terminals *4* and *5* to give a 10,000-ohm load.

Measure the d.c. voltage between output terminals *4* and *5,* and record your result in Table *36DC* as the d.c. output voltage in volts for half-wave rectification, choke input and a 10,000-ohm load.

Measure the a.c. voltage between output terminals *4* and *5*, and record your result in Table *36DC* as the a.c. ripple output voltage in volts. The meter pointer will swing erratically up and down scale, so you will have to estimate the average value about which it swings.

Discussion: A comparison of the d.c. output voltage value you recorded in Table *36DC* for half-wave rectification with that which you recorded in Table *34DC* for full-wave rectification and the same 10,000-ohm load should show definitely that *half-wave rectification gives lower d.c. output voltage.* The N.R.I. value for half-wave rectification is actually 100 volts lower than for full-wave rectification. This means that when half-wave rectification is employed in a radio circuit, the power transformer secondary voltage must be higher than would be required with full-wave rectification to secure a given d.c. output voltage.

Comparison of the a.c. ripple output voltage values measured for half-wave rectification (Table *36DC*) and full-wave rectification (Table *35DC*) for the same 10,000-ohm load condition should show that half-wave rectification gives much higher a.c. ripple output voltage than does full-wave rectification. Thus, the N.R.I. value is 3.5 volts for half-wave rectification and essentially zero volts for full-wave rectification.

CIRCUIT USED	D.C. OUTPUT VOLTAGE IN VOLTS		A.C. OUTPUT VOLTAGE IN VOLTS	
	YOUR VALUE	N.R.I.	YOUR VALUE	N.R.I.
HALF WAVE, CHOKE INPUT, 10,000 Ω LOAD		230		3.5

TABLE 36DC. Record your results here for Experiment 36DC, in which you measure the d.c. output voltage and the a.c. ripple output while your d.c. power pack is connected for half-wave rectification and choke input, with a 10,000-ohm load.

Computation of Ripple Reduction Factor. With the 240-cycle fundamental ripple frequency of full-wave rectification, the reactance of the choke coil was computed as 15,100 ohms (Experiment 35DC) and the reactance of the condenser was 66 ohms. Half-wave rectification cuts the fundamental ripple frequency in half, thereby cutting the choke coil reactance in half to give 7,550 ohms, and doubles the reactance of the condenser so as to give 132 ohms. The ripple reduction factor now becomes 7,550 divided by 32, which is 57.

In Experiment 35DC, dealing with full-wave rectification, the ripple reduction factor was computed to be 230. Dividing 230 by 57 gives approximately 4, showing that the same filter circuit is only about one-fourth as effective for half-wave rectification as for full-wave rectification. This is one factor which makes the hum output (the a.c. ripple output) higher for half-wave rectification. The filter is still highly effective for harmonics of the ripple frequency, however, so that the hum *output* is essentially due to the fundamental frequency and is essentially a sine wave.

The second factor which makes half-wave rectification give higher a.c. ripple output is the increased a.c. voltage which is present at the filter input with this type of rectification. Although this could be proved with higher mathematics, such a procedure is unnecessary. Careful inspection and comparison of the wave forms for full-wave and half-wave rectification in Fig. *26* should make it clear that there is more a.c. in the half-wave rectified voltage than in the full-wave rectified voltage. You will now learn how to verify this by actual measurements.

Instructions for Report Statement No. 36DC. In Experiment 35DC, you measured the a.c. voltage at the filter input for a 10,000-ohm load when full-wave rectification was employed, and obtained a value comparable to the N.R.I. value of 81 volts for this same measurement. For Report Statement No. 36DC, you will make this same measurement for half-wave rectification.

With your power pack still connected for half-wave rectification, with the 10,000-ohm load connected to d.c. output terminals *4* and *5*, and with the lead on terminal *23* still disconnected to give choke input, measure the a.c. voltage across the 50,000-ohm bleeder resistor in your power pack (remember that the black clip must go on the grounded resistor lead).

Compare the measured voltage value with that which you recorded for a 10,000-ohm load in Table *35DC*, then turn to the last page and place a check mark after the answer in Report Statement No. 36DC which applies to your conclusion.

EXPERIMENT 37DC

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

Step 1. To tune the choke coil in your power pack approximately to resonance, take a .25-mfd. paper condenser (Part *3-2A*), connect it in parallel with the choke coil underneath the power pack by means of temporary soldered lap joints, but leave all other connections exactly as before. Be sure the 10,000-ohm load is still connected to d.c. output terminals *4* and *5*.

Measure the a.c. voltage at output terminals *4* and *5*, and record your result in Table *37DC* as the a.c. ripple output voltage for a tuned choke, half-wave rectification, choke input and a 10,000-ohm load.

Discussion: In Experiment 30DC, you found that a .25-mfd. condenser gave approximate resonance when connected in parallel with the 10-

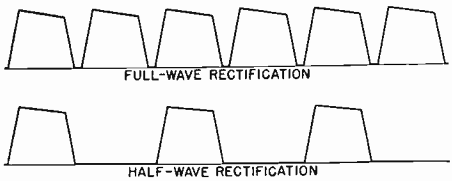


FIG. 26. Wave forms of the rectified voltages provided by the vibrator transformer and rectifier tube of your d.c. power pack for full-wave and half-wave connections when there is no load on the rectifier tube.

henry choke coil. A comparison of the N.R.I. values in Tables *36DC* and *37DC* for the a.c. ripple output voltage indicates that tuning the choke coil approximately to the fundamental ripple frequency of 120 cycles reduces the a.c. ripple voltage to about one-half its former value in the case of half-wave rectification and choke input. The coil-condenser combination must therefore have about twice the impedance of the coil alone.

We know that when a coil is tuned to resonance by connecting a suitable capacity value across it, the impedance of the combination is increased by an amount equal to the Q factor of the coil at the fundamental frequency. Apparently, then, the Q factor of the 10-henry choke coil is at least 2.

Tuning of the filter choke coil is by no means a complete solution to the filtering problem in a half-wave rectifier or even in a full-wave rectifier, but it does improve the filtering sufficiently to warrant its use in some radio receiver power packs and some transmitters.

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

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

Instructions for Report Statement No. 37DC. Although there are many radio applications in which a condenser may be changed appreciably in value without affecting circuit conditions, this is not true in the case of the condenser used for tuning the choke coil in a power pack filter circuit. For this report statement, you will demonstrate this fact by placing across the choke coil a higher capacity than that required for resonance at the fundamental ripple frequency.

With your power pack connected exactly as it was for Step 1 in Experiment 37DC (with half-wave rectification, choke input, a 10,000-ohm load, and one .25-mfd. condenser connected across the choke coil terminals), increase the shunt capacity across the choke coil to .5 mfd. by placing your other .25-mfd. condenser (Part *3-2B*) in parallel with the .25-mfd. condenser already across the choke coil terminals. Do this by soldering the condenser leads together with lap joints just as you did in a previous experiment.

CIRCUIT USED	A.C. RIPPLE OUTPUT VOLTAGE IN VOLTS	
	YOUR VALUE	N.R.I. VALUE
HALF WAVE, CHOKE INPUT, 10,000Ω LOAD, TUNED CHOKE		1.8

TABLE 37DC. Record your result here for Experiment 37DC, in which you measure the a.c. ripple output of your power pack while it is connected for half-wave rectification, choke input, a choke coil tuned by a .25-mfd. condenser, and a 10,000-ohm load.

Measure the a.c. voltage at output terminals *4* and *5* with the .5-mfd. capacity in the circuit, compare your measured value with that which you recorded for the a.c. ripple output voltage in Table *37DC* when the capacity was only .25-mfd., and answer Report Statement No. 37DC.

Finally, disconnect the two .25-mfd. condensers from the choke coil, remove the 10,000-ohm load from output terminals *4* and *5*, and disconnect two of the 40,000-ohm resistors from the parallel-connected group.

EXPERIMENT 38DC

Purpose: **To demonstrate that two identical filter circuits connected in cascade give a much higher ripple reduction factor than one filter circuit alone.**

Step 1. To remove the entire internal filter circuit from your power pack in preparation for this experiment, disconnect from choke coil terminal *13* the lead which goes to output terminal *5*, then disconnect from choke coil terminal *14* the lead which goes to rectifier tube socket terminal *8*. Now connect together with a temporary soldered hook joint the two leads which you just disconnected, and arrange the leads so the joint cannot touch any terminals or parts. Rectifier tube socket terminal *8* is now connected directly to output terminal *5*. Leave all other connections as they were for the previous experiment, so that you still have half-wave rectification. The circuit which you now have in your d.c. power pack is shown in schematic form in Fig. *27A*.

Step 2. To measure the a.c. filter input and output voltages for one R-C filter, take a 40,000-ohm resistor (Part *3-6A*) and a .25-mfd. condenser (Part *3-2A*) and connect them in series to d.c. output terminals *4* and *5* of your power pack, as indicated for R_1 and C_1 in Fig. *27A*.

Measure the a.c. voltage between output terminals *4* and *5*, and record your result in Table *38DC* as the a.c. filter *input* voltage in volts for one R-C filter.

Measure the a.c. voltage across C_1 (Fig. *27A*), and record your result in Table *38DC* as the a.c. filter *output* voltage in volts for one R-C filter.

Step 3. To measure the a.c. filter input and output voltages for two R-C filter circuits connected in cascade, first take another 40,000-ohm resistor (Part *3-6B*) and another .25-mfd. condenser (Part *3-2B*) and connect them in series across the .25-mfd. condenser C_1 of your first R-C filter circuit, so as to give the arrangement shown in Fig. *27B*. Use temporary soldered joints throughout.

Measure the a.c. voltage between output terminals *4* and *5*, and record your result in Table *38DC* as the a.c.

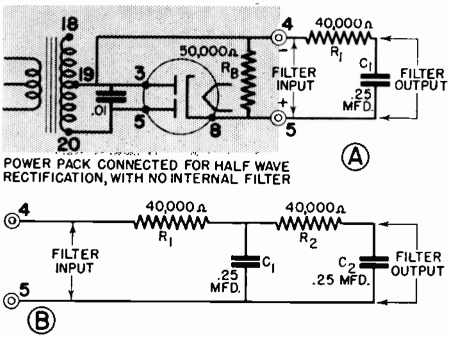


FIG. 27. Schematic circuit diagram for Experiment 38DC, in which you first connect one R-C filter to the output terminals of your power pack as shown at *A* while the power pack is connected as indicated in this diagram, then connect two similar R-C filters in cascade as shown at *B*.

filter *input* voltage in volts for two R-C filters.

Measure the a.c. voltage across C_2 (Fig. *27B*) and record your result in Table *38DC* as the a.c. filter *output* voltage in volts for two R-C filters.

Discussion: The ripple reduction ratio of a filter circuit is equal to the a.c. filter input voltage divided by the a.c. filter output voltage. On the basis of the N.R.I. values recorded for Step 2 in Table *38DC*, the ripple reduction ratio for a single R-C filter circuit is equal to 141 divided by 16.5, which is about 8.5. Similarly, the ripple reduction ratio for two R-C filter circuits is 141 divided by 2, or approximately 70 on the basis of N.R.I. values.

With sine wave voltages, the ripple reduction ratio of two filter sections would be equal to the ripple reduction ratio of one section multiplied by the ripple reduction ratio of the other section. With a square-wave voltage such as you have, however, the first filter section (the one connected directly to power pack output terminals *4* and *5*) provides almost complete suppression of harmonics, so that essentially a pure sine wave voltage is passed on to the second filter section. The ripple reduction ratio for the first filter section may therefore be higher than for the second section, even though the two are identical electrically.

STEP	CIRCUIT	A.C. FILTER INPUT VOLTAGE IN VOLTS		A.C. FILTER OUTPUT VOLTAGE IN VOLTS	
		YOUR VALUE	N.R.I.	YOUR VALUE	N.R.I.
2	ONE R-C FILTER		141		16.5
3	TWO R-C FILTERS		141		2.0

TABLE 38DC. Record your results here for Experiment 38DC, in which you measure input and output a.c. voltages first for one R-C filter, then for two R-C filters connected in cascade, while your power pack is connected for half-wave rectification with a 50,000-ohm internal bleeder resistor but with no internal filter system.

Close agreement between computed and measured values is impossible in this experiment, for the continual flickering of the meter pointer makes accurate meter readings difficult to obtain, especially for low values on the *AC* scale. In addition, harmonic frequencies make the results different from those for sine wave voltages, and normal tolerances of up to 20% in resistor values make computations have errors as high as 20%.

R-C Filter Computations. In a single R-C filter section, the voltage drop across each element of the filter will be proportional to the resistance or reactance of that part. If there is an a.c. voltage drop of 1 volt across the .25-mfd. condenser (which has a reactance of 5,300 ohms at the fundamental ripple frequency of 120 cycles), the voltage drop across the 40,000-ohm resistor will be higher by the factor 40,000 ÷ 5,300, which is about 7.5. In other words, for each volt across the condenser, there will be 7.5 volts across the resistor.

By drawing a vector diagram for these voltages in the manner shown in Fig. *28*, so that the 1-volt drop across the condenser is at right angles to the 7.5-volt drop across the resistor, then adding these two voltages to secure the resultant vector, we find that an input a.c. voltage of about 7.6 volts is required for each volt dropped across the condenser. In other words, the 40,000-ohm, .25-mfd. R-C filter has a theoretical ripple reduction ratio of 7.6, and two sections would have a *theoretical* ripple reduction ratio of 7.6 × 7.6, which is about 58. The N.R.I. value of 70 is sufficiently close to this computed value, considering the many factors which affect the accuracy of computed and measured values.

Instructions for Report Statement

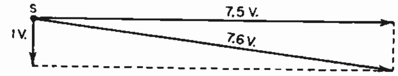


FIG. 28. Vector diagram based upon the N.R.I. values obtained for the single R-C filter circuit which you employ in Step 2 of Experiment 38DC.

No. 38DC. In this experiment, you measured the a.c. filter output voltage values for a single R-C filter and for two R-C filters in cascade. Now suppose that instead of connecting two filters in cascade as indicated in Fig. *27B*, you formed a single R-C filter from these parts by connecting the two 40,000-ohm resistors in series to give 80,000 ohms, and by connecting the two .25-mfd. condensers in parallel to give .5 mfd. Do you think this arrangement would work just as well as the cascade arrangement?

For this report statement, you will answer this question yourself. Do this by disconnecting the first .25-mfd. condenser (C_1 in Fig. *27B*) and placing it in parallel with the other .25-mfd. condenser (C_2). Leave the resistors connected as they are in Fig. *27B*. You now have 80,000 ohms in series with .5 mfd., across output terminals *4* and *5*.

Measure the a.c. voltage across the .5-mfd. capacity, compare this measured a.c. filter output voltage value with the output values you recorded in Table *38DC* for one and two R-C filters respectively, then answer Report Statement No. 38DC.

EXPERIMENT 39DC

Purpose: **To demonstrate the effectiveness of a resistor-condenser filter (usually called an R-C filter) in reducing the a.c. ripple voltage which acts on the load.**

Preliminary Discussion. In Fig. *29A* is shown a typical audio amplifier circuit such as might be found connected to a power pack like yours in an actual 6-volt radio receiver. The terminals marked *B—* and *B+* in this diagram would go to the *B—* and *B+* terminals respectively of the power pack.

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

Resistor R_1 and condenser C_1 in Fig. *29A* form a filter which effectively prevents power pack a.c. ripple from entering the plate circuit. The a.c. voltage between the *B—* and *B+* terminals in Fig. *29A* is divided between C_1 and R_1, with most of the a.c. voltage being dropped across R_1. In designing a circuit like this, the reactance of C_1 is made very low in comparison to the resistance of R_1, so that only a negligibly small a.c. voltage is developed across C_1 for application to the plate circuit.

With your power pack, you can readily duplicate the conditions existing in the circuit of Fig. *29A*, and demonstrate to yourself the effectiveness of a resistor-condenser filter in preventing power pack hum (or a.c.

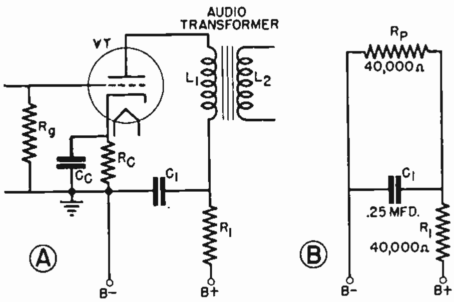


FIG. 29. **Schematic circuit diagram of a typical vacuum tube stage *(A)*, and equivalent circuit diagram for this vacuum tube stage as used in Experiment 39DC.**

ripple) from entering a vacuum tube circuit. It is not necessary to use the entire vacuum tube circuit shown in Fig. *29A* for this experiment, because we can satisfactorily duplicate this circuit with two resistors and a condenser arranged as shown in Fig. *29B*. Here C_1 and R_1 are the same as in Fig. *29A*, but R_P is a 40,000-ohm resistor which essentially duplicates the total plate circuit resistance of a typical vacuum tube circuit (such as a circuit having a plate voltage of 250 volts and a plate current of 6.25 ma., corresponding to a total circuit resistance of $250 \div .00625$, or 40,000 ohms).

By setting up the circuit shown in Fig. *29B*, connecting the *B—* and *B+*

terminals of the circuit to the corresponding terminals of your power pack, and measuring the a.c. ripple voltage at the input of the filter in your power pack, at the d.c. output terminals of your power pack and finally across equivalent load resistor R_P (across the output of external filter $R_1 - C_1$), you can prove to yourself that the external filter is effective in reducing the ripple voltage at the load.

Step 1. To prepare your apparatus for demonstrating the effectiveness of an external resistor-condenser filter, first break the connection between rectifier tube socket terminal *8* and output terminal *5,* then restore the connection between output terminal *5* and choke coil terminal *13,* and restore the connection between rectifier tube socket terminal *8* and choke coil terminal *14.* Leave your power pack connected for *half-wave rectification* (the lead from socket terminal *3* still going to terminal *19*), and leave the filter circuit still connected for *choke input* (with the lead still removed from condenser terminal *23*).

Connect your four 40,000-ohm resistors and a .25-mfd. condenser to output terminals *4* and *5* in the manner shown in Fig. *30,* so as to give the equivalent R-C and vacuum tube circuit of Fig. *29B* along with a 20,000-ohm load on the power pack. Use temporary soldered joints.

Step 2. To check the performance of the internal power pack filter and the external R-C filter, first measure the a.c. voltage across the 50,000-ohm bleeder resistor in your power pack. Use a wooden or cardboard box to support the external resistors and condensers while the chassis is resting on its back side for this measurement. Record your result in Table *39DC* as the a.c. ripple voltage in volts at the input of the power pack filter (across the 50,000-ohm bleeder resistor).

Measure the a.c. voltage at output terminals *4* and *5*, and record your result in Table *39DC* as the a.c. ripple voltage in volts at output terminals *4* and *5* (this is at the output of the power pack filter and is also at the input of the external R-C filter).

Measure the a.c. voltage across .25-mfd. condenser C_1, and record your result in Table *39DC* as the a.c. ripple voltage in volts at the output of the external R-C filter.

Discussion: In the previous experiment you demonstrated that an R-C filter can be used in place of a conventional choke coil filter system in a power pack to reduce the a.c. ripple voltage. The use of resistors having high ohmic values is undesirable in the power pack, however, because it also reduces the d.c. output voltage and limits the current which can be drawn from the power pack. For example, with two R-C filters connected in cascade according to the arrangement used in Experiment 38DC, a resistance of approximately 80,000 ohms has been inserted in series with the load circuit of the power pack. With a load current of only 2 ma., the d.c. voltage drop across the filter resistance would be 80,000 × .002, which is

NATURE OF MEASUREMENT	YOUR VALUE	N.R.I. VALUE
A.C. VOLTAGE IN VOLTS AT INPUT OF POWER PACK FILTER (ACROSS 50,000Ω BLEEDER)		150
A.C. RIPPLE VOLTAGE IN VOLTS AT INPUT OF FILTER $R_1 - C_1$ (AT TERMINALS 4 AND 5)		2.3
A.C. RIPPLE VOLTAGE IN VOLTS AT OUTPUT OF FILTER $R_1 - C_1$ (ACROSS R_P)		0

TABLE 39DC. Record your results here for Experiment 39DC, in which you make a.c. voltage measurements which enable you to determine the ripple reduction factor of the choke input filter system in your power pack and the ripple reduction factor of an external R-C filter system used between the power pack and a 40,000-ohm load resistor. In this experiment, the power pack is connected for half-wave rectification and choke input.

160 volts, and the d.c. output voltage would be reduced by this amount. For these reasons, a choke coil is generally used in a power pack when maximum values for both d.c. output voltage and output current are required.

When a power pack is capable of furnishing a much higher d.c. voltage than is required by a particular vacuum tube stage, an external R-C filter can be used for the dual purpose of reducing this d.c. voltage and providing additional reduction in the a.c. ripple voltage. Since this practice is employed extensively in radio receiver circuit design, you are dealing in this experiment with a highly practical filtering arrangement.

Computations made in Experiment 38DC showed that the theoretical ripple reduction factor for an R-C filter having a resistance of 40,000 ohms and a capacity of .25 mfd. was approximately 7.6; dividing the 2.3-volt N.R.I. value for the a.c. input voltage of the R_1-C_1 filter by 7.6 gives a voltage so close to zero that it cannot be read on the meter.

Comparison of the N.R.I. values for the a.c. input and output voltages of the power pack filter shows clearly the effectiveness of this filter. Thus, dividing 150 by 2.3 gives a ripple reduction factor of 65 for the filter circuit in the power pack. When an external R-C filter is used in addition, the total ripple reduction will be 7.6×65, or approximately 495.

A.F. Filtering Action. An R-C filter in a vacuum tube stage also serves to prevent a.f. signals in the plate circuit from entering the power pack and traveling from there to other circuits where undesirable regeneration or degeneration might be produced. Thus, filter condenser C_1 in the vacuum tube circuit of Fig. *29A* has a reactance which is low in comparison to the total impedance of the signal path through vacuum tube *VT*, coil L_1 and the parallel combination of cathode resistor R_C and C_C, and hence only a small portion of the total available a.f. voltage exists across C_1 to feed back into the power pack.

R_1 in Fig. *29A* acts with the output filter condenser in the power pack as an R-C filter for a.f. signals traveling in this op-

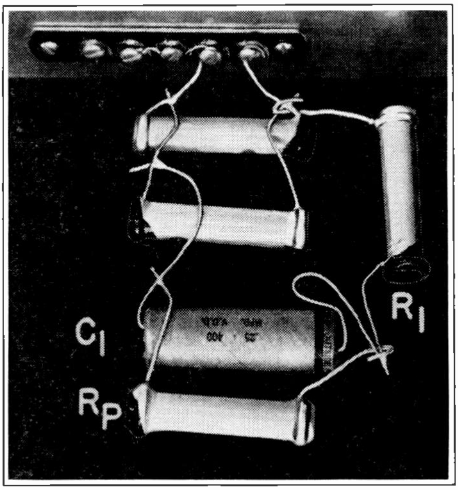


FIG. 30. Suggested method of connecting to the d.c. output terminals of your power pack a 20,000-ohm load and an arrangement of two resistors and a condenser (*R_1, R_P* and *C_1*) which duplicate the effect of a typical audio amplifier stage having an R-C filter and a total plate circuit resistance of 40,000 ohms.

STEP	CIRCUIT DATA	A.C. VOLTAGE IN VOLTS AT FILTER INPUT		A.C. RIPPLE VOLTAGE IN VOLTS AT FILTER OUTPUT		D.C. OUTPUT VOLTAGE IN VOLTS	
		YOUR VALUE	N.R.I. VALUE	YOUR VALUE	N.R.I. VALUE	YOUR VALUE	N.R.I. VALUE
1	NO RESISTORS IN SERIES WITH FILTER CONDENSERS		3.7		0		300
2	18,000Ω IN SERIES WITH INPUT FILTER CONDENSER		138		2.7		220
3	18,000Ω IN SERIES WITH OUTPUT FILTER CONDENSER		4.2		3.6		300

TABLE 40DC. Record your results here for Experiment 40DC, in which your power pack is connected for half-wave rectification and condenser input, with a 10,000-ohm load across the d.c. output terminals.

posite direction toward the power pack. The reactance of the output filter condenser is usually quite low at audio frequencies (is less than 200 ohms), while R_1 is generally higher than 10,000 ohms in value, so that the ripple reduction factor for a.f. signals traveling toward the power pack is considerably higher than 50.

Instructions for Report Statement No. 39DC. This experiment proves conclusively that an R-C filter connected between the power pack and its load will reduce the a.c. ripple voltage which reaches the load. But what effect does insertion of an R-C filter between the source (the power pack) and the load (resistor R_P in Figs. *29B* and *30*) have upon the value of the d.c. voltage applied to the load? By making two simple d.c. voltage measurements, you can check this effect yourself and at the same time secure the answer to Report Statement No. 39DC.

With your parts still connected as shown in Fig. *30*, first measure the d.c. output voltage between terminals *4* and *5* of your power pack and make a notation of its value in the margin of this page or elsewhere. Next, measure the d.c. load voltage across 40,000-ohm load resistor R_P, compare your two measured values, and answer Report Statement No. 39DC.

Unsolder R_1, R_P and C_1 in Fig. *30*, but leave the other two 40,000-ohm resistors connected to the d.c. output terminals.

EXPERIMENT 40DC

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

Step 1. To secure voltage data with your power pack connected for half-wave rectification, condenser input and a 10,000-ohm load, first connect to condenser terminal *23* by a temporary soldered joint, the free lead from choke coil terminal *14* so as to secure a condenser input filter again. Leave your power pack connected for *half-wave rectification,* and place a 10,000-ohm load (four 40,000-ohm resistors in parallel) across output terminals *4* and *5*.

Measure the a.c. voltage across the 50,000-ohm bleeder resistor, and record your result in Table *40DC* as the a.c. voltage in volts at the filter input for Step 1, in which a normal condenser input filter system is used.

Measure the a.c. voltage at output terminals *4* and *5*, and record your result in Table *40DC* as the a.c. ripple voltage in volts at the filter output for Step 1.

Measure the *d.c. voltage* at output terminals *4* and *5*, and record your result in *Table 40DC* as the *d.c. output voltage* in volts for Step 1.

Step 2. To secure voltage data with an 18,000-ohm resistor in series with the input filter condenser, first remove the lead from condenser terminal *23,* connect one lead of an 18,000-ohm resistor (Part *1-16*) to this condenser terminal, and connect the other resistor lead to the lead just disconnected from *23*, as shown in Fig. *31A*. Adjust the resistor position so its leads do not touch other terminals or parts.

Measure the a.c. voltage across the 50,000-ohm bleeder resistor, and record your result in Table *40DC* as the a.c. voltage in volts at the input of the filter for Step 2, in which 18,000 ohms is in series with the *input* filter condenser.

Measure the a.c. voltage at output terminals *4* and *5*, and record your result in Table *40DC* as the a.c. ripple voltage in volts at the output of the power pack filter for Step 2.

Measure the d.c. voltage at output terminals *4* and *5*, and record your result in Table *40DC* as the d.c. output voltage in volts for Step 2.

Step 3. To secure voltage data with an 18,000-ohm resistor in series with the output filter condenser, first remove the 18,000-ohm resistor from the power pack circuit and reconnect the lead from choke coil terminal *14* directly to condenser terminal *23*. Now disconnect the lead from condenser terminal *24*, connect one lead of the 18,000-ohm resistor to condenser terminal *24*, and connect the other resistor lead to the wire which you just unsoldered from terminal *24*. This places the 18,000-ohm resistor in series with the *output* filter condenser, as shown in Fig. *31B*.

Measure the a.c. voltage across the 50,000-ohm bleeder resistor, and record your result in Table *40DC* as the a.c. voltage in volts at the input of the filter for Step 3, in which 18,000 ohms is in series with the *output* filter condenser.

Measure the a.c. voltage at output terminals *4* and *5*, and record your result in Table *40DC* as the a.c. ripple voltage in volts at the output of the power pack filter for Step 3.

Measure the d.c. voltage at output terminals *4* and *5*, and record your result in Table *40DC* as the d.c. output voltage in volts for Step 3.

Discussion: For your first step in this experiment, you simply secure a.c. and d.c. voltage values for normal operation of your power pack when connected for half-wave rectification, condenser input and a 10,000-ohm load. The N.R.I. values for Step 1 indicate a very low a.c. filter input voltage of only 3.7 volts. The filter system suppresses this a.c. input voltage so effectively that the a.c. ripple voltage at the d.c. output terminals is essentially zero.

For comparison purposes, you also make a d.c. output voltage measurement; the N.R.I. value for this is 300 volts, indicating that half-wave rectification gives a lower d.c. output voltage than the 360-volt N.R.I. value obtained for full-wave rectification under the same conditions in Experiment 32DC.

In Step 2, you introduce an 18,000-ohm resistor in series with the input filter condenser, to duplicate the entirely possible condition whereby this electrolytic filter condenser has dried out and become equal to a condenser in series with a resistor. The N.R.I. values for this condition (Step 2 in Table *40DC*) show the extremely high a.c. filter input voltage of 138 volts, with an a.c. ripple output of 2.7 volts. By dividing 138 by 2.7, we find that the defective condenser input filter system is giving a ripple reduction factor of about 50, which is not enough to keep the a.c. ripple at a satisfactorily low value at the d.c. output terminals.

We also see that the defective input filter condenser causes lowering of the d.c. output voltage from 300 volts to 220 volts. These figures indicate that in an actual radio receiver, drying out of the input filter condenser can cause serious hum accompanying the radio program, along with lowered output volume, loss of sensitivity and distortion due to the lowered d.c. output voltage.

When the 18,000-ohm resistor is placed in series with the output filter condenser in Step 3 to simulate drying out of this condenser, the N.R.I. value of 4.2 volts for the filter input a.c. voltage shows clearly the effectiveness of a good output filter condenser in suppressing a.c. components of the rectified voltage. The corresponding a.c. ripple output measurement for this condition is 3.6 volts, however, indicating that drying out of the output filter condenser makes this section of the filter system just about useless. The choke coil provides only a small amount of ripple suppression.

The 300-volt N.R.I. value of the d.c. output voltage in Step 3 indicates that the output filter condenser has no effect whatsoever upon the d.c. output voltage. Actually, you can disconnect the output filter condenser completely without affecting the d.c. output voltage.

Filter Circuit Computations. At 120 cycles (the fundamental ripple frequency for a half-wave rectifier circuit), the reactance of a 10-mfd. condenser is about 132 ohms. The insertion of an 18,000-ohm resistor in series with a 132-ohm capacitive reactance makes the combination essentially resistive, having a total impedance slightly higher than 18,000 ohms. The total impedance of the output filter condenser is now higher than the 7,500-ohm impedance of the choke coil at this fundamental frequency, making the ripple reduction factor for the output filter condenser and choke coil less than 1.

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

Instructions for Report Statement No. 40DC. In this experiment, you made measurements in which only one filter condenser at a time was defective. Another condition which is encountered just about as often in actual practice is that in which both filter condensers become partially defective.

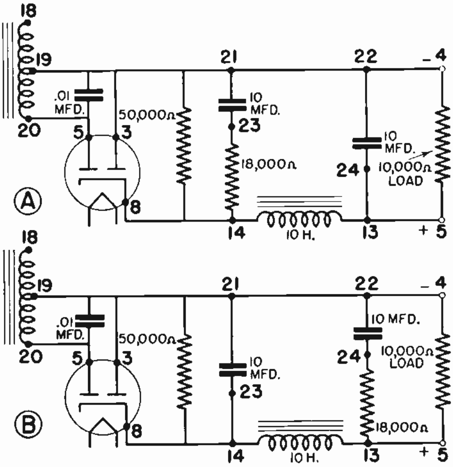


FIG. 31. Schematic circuit diagrams for Experiment 40DC, in which you duplicate the effects of dried-out electrolytic filter condensers by inserting an 18,000-ohm resistor in series with each filter condenser in turn and measuring the resulting a.c. filter input and output voltages.

When conditions are such as to cause drying out of condensers, both electrolytic filter condensers will generally be affected. You can duplicate this condition in your power pack simply by inserting a 1,000-ohm resistor in series with each of the electrolytic filter condenser sections.

Remove the 18,000-ohm resistor which is still connected into your power pack circuit, then take two 1,000-ohm resistors (Parts *3-5A* and *3-5B*), connect one between condenser terminal *23* and the lead which normally goes on this condenser terminal, and connect the other between condenser terminal *24* and the lead from choke coil terminal *13* which normally goes on terminal *24*. Leave the power pack connected for *half-wave rectification.*

Measure the a.c. voltage at output terminals *4* and *5* while the 10,000-ohm load is still connected to your power pack, and record your result in Report Statement No. 40DC.

Restoring Power Pack Connections. Finally, remove the two 1,000-ohm resistors and restore your original power pack circuit, by connecting the lead from choke coil terminal *14* to condenser terminal *23* with a permanent soldered hook joint, and connecting the lead from choke coil terminal *13* to condenser terminal *24* with a permanent soldered hook joint. Restore full-wave rectification by removing from transformer terminal *19* the lead going to rectifier tube socket terminal *3*, and connecting this lead to transformer terminal *18* by means of a permanent soldered hook joint. If you desire, you can now convert all other temporary hook joints in your power pack to permanent hook joints by squeezing the hooks with long-nose pliers while keeping the solder molten with your soldering iron.

To be sure you have rewired your power pack correctly, check it carefully against the pictorial wiring diagram in Fig. *8*, then check its operation by measuring the d.c. output voltage at terminals *4* and *5* under no-load conditions, after first removing the 10,000-ohm load from the d.c. output terminals. This measured value of voltage should correspond to that which you recorded for Step 2 in Table *31DC*.

NOTICE: The d.c. power pack which you built according to instructions in this manual is electrically equivalent to the a.c. power pack built by students having access to 115-volt, 60-cycle a.c. power.

The instructions given in the remaining manuals for using the power pack will therefore apply both to the d.c. and a.c. versions. The illustrations will show the a.c. version, in which only terminals *3* and *4* are connected together with bare wire.

Remember, however, that *output terminals 2, 3 and 4 on your power pack are to be left connected together by the length of bare wire, exactly as instructed in this manual,* even though the a.c. power pack shows only terminals *3* and *4* connected together. (In the d.c. power pack, omission of the connection between terminals *2* and *3* might allow vibrator "hash" to enter filament circuits and cause noise when you build the superheterodyne receiver and other receiver circuits.)

Remember also that during all work with your d.c. power pack, an external ground connection should be made to terminal *2, 3* or *4*.

After completing an experiment and carrying out the instructions at the end, fill in the information asked for in the corresponding report statement on the next page, or make a check mark like this √ *with* pencil in the box *following* what you consider to be the correct answer. PLACE NAME, ADDRESS AND STUDENT NUMBER ON REVERSE SIDE OF LAST PAGE.

REPORT STATEMENTS—RADIO KIT 4 RK-DC

Report Statement No. 28DC: When I shunted a .5-mfd. capacity across 1,000-ohm resistor R_1, the a.c. voltage measured across resistor R: *increased* ☐; *decreased* ☐; *remained the same* ☐.

Report Statement No. 29DC: When I cut in half the a.c. voltage applied to the series resonant circuit of Fig. *18C*, the a.c. voltage across the condenser: *was doubled* ☐; *was cut in half* ☐; *remained the same* ☐.

Report Statement No. 30DC: When I inserted a 2,000-ohm resistance in series with the 10-henry choke coil (Fig. *19B*), the a.c. voltage across resistor R: *increased* ☐; *decreased* ☐; *remained the same* ☐.

Report Statement No. 31DC: The no-load d.c. output voltage was ....volts when the storage battery voltage was..................volts.

Report Statement No. 32DC: When my power pack is delivering its rated current of 25 ma., the d.c. output voltage is..................volts.

Report Statement No. 33DC: Comparison of the no-load a.c. voltage values I measured across half the vibrator secondary indicates that the true no-load value is: *higher than* ☐; *lower than* ☐; *the same as* ☐ the value obtained with the rectifier tube in its socket.

Report Statement No. 34DC: If the *input* filter condenser of a typical radio receiver power pack should open up, the d.c. output voltage will: *increase* ☐; *decrease* ☐; *remain the same* ☐; *drop to zero* ☐.

Report Statement No. 35DC: The a.c. voltage across the choke coil was: *much higher than* ☐; *much lower than* ☐; *essentially the same as* ☐ the a.c. filter input voltage for choke input and a 10,000-ohm load.

Report Statement No. 36DC: The a.c. filter input voltage for half-wave rectification, choke input and a 10,000-ohm load was: *much higher than* ☐; *much lower than* ☐; *essentially the same as* ☐ the a.c. filter input voltage for full-wave rectification, choke input and a 10,000-ohm load.

Report Statement No. 37DC: Increasing the value of the condenser used for tuning the choke coil from .25 mfd. to .5 mfd. makes the a.c. ripple at terminals *4* and *5*: *increase* ☐; *decrease* ☐; *remain the same* ☐.

Report Statement No. 38DC: The a.c. filter output voltage which I measured for an 80,000-ohm, .5-mfd. R-C filter was: *the same as for one R-C filter* ☐; *in between the values for one and two R-C filters* ☐; *the same as for two R-C filters* ☐; *higher than for two R-C filters* ☐.

Report Statement No. 39DC: When an R-C filter is inserted between the power pack and a load, the d.c. *load* voltage is: *higher than* ☐; *the same as* ☐; *lower than* ☐ the power pack d.c. output voltage.

Report Statement No. 40DC: With half-wave rectification, a 10,000-ohm load, and a 1,000-ohm resistor in series with each filter condenser, the a.c. ripple voltage at d.c. output terminals *4* and *5* was.................volts.

(See Reverse Side)

REPORT ON EXPERIMENTS 28 TO 40

RADIO DEMONSTRATION KIT 4RK-DC

As soon as this report is submitted, it will be carefully corrected, graded and returned to you, with your grade marked in the square at the right.

Grade for 4RK-DC

Fold Along This Line

Explanation of Grading Method. A check mark (√) made with colored pencil in the right-hand margin alongside a report statement indicates your answer is correct. A cross (X) made with colored pencil in this same position indicates that your answer is not correct; in this case, the correct answer wil be checked by the instructor. Study the experiment again, and repeat parts of it if necessary.

Grades "A," "B" and "C" are *passing,* and mean that you have satisfactorily completed this series of experiments in your practical demonstration course. A grade of "D" indicates that you have not yet mastered this series of experiments. Whenever a grade of "D" is given, you are expected to restudy carefully the experiments which gave trouble, and perform them over again if necessary.

	← NAME
	← ADDRESS
	← CITY AND STATE
	← STUDENT NUMBER

Fold Along This Line

IMPORTANT INSTRUCTIONS

Fill in your name, address and student number *plainly* in the spaces above, using a pencil, a typewriter or rubber stamp. *Do not use ink.*

Mail this report to National Radio Institute, 16th and U Streets, N. W., Washington, D. C., *along with one of your regular lessons,* after you have performed all of the experiments in this manual and have answered all of the report statements on the other side of this sheet.

Your next radio demonstration kit will be sent when you complete the required number of lessons, *provided you have sent in this report.* The next kit cannot be shipped until you send in this report, because we must know that you have progressed sufficiently to be ready for more advanced experiments.

Detach by Cutting Along This Line. Do Not Tear Off.

D.C. AND SINGLE-PHASE A.C. GENERATORS AND MOTORS

36CH-1

YOU ARE STARTING YOUR ADVANCED COURSE

This book is the FIRST LESSON of your Advanced Specializing Course

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NATIONAL RADIO INSTITUTE
EST. 1914
WASHINGTON, D.C.

IMPORTANCE OF POWER SUPPLIES IN RADIO COMMUNICATIONS

The first few lessons in your Communications Course deal with motors and generators for the simple reason that the power supplies in many radio installations depend partly or entirely upon rotating machinery for their operation. Partial or complete failure of power is just as serious as failure of a radio circuit; in fact, even the most modern radio installation is no more dependable than its power supply.

Generators and motors are employed in practically every commercial radio transmitter installation, whether on land, on sea or in the air. Although the present trend is toward elimination of rotating machinery in the main power supplies for broadcast transmitters in this country, at least one generator, driven by a gas or diesel engine, must be available for emergency use if the station is to be kept on the air during power line failures.

The man entrusted with the operation and maintenance of a radio installation must know how to keep every part of that installation operating at maximum efficiency, and must know how to make speedy adjustments and repairs in emergencies. This does not mean that you as a radio operator will be called upon to design and build motors and generators, but you will be expected to know their underlying principles.

These first books in your Communications Course are intended to give you a general knowledge of how generators convert mechanical energy into electrical energy and how motors convert electrical energy into mechanical energy. These are important books, and contain a great deal of information in highly condensed form, so study them slowly and carefully.

J. E. SMITH.

NATIONAL RADIO INSTITUTE

WASHINGTON, D. C.

1941 Edition

A LESSON TEXT OF THE N. R. I. COURSE
WHICH TRAINS YOU TO BECOME A
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(REGISTERED U. S. PATENT OFFICE) (REGISTERED U. S. PATENT OFFICE)

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D.C. and Single-Phase A.C. Generators and Motors

Dynamo-Electric Machinery in Communications

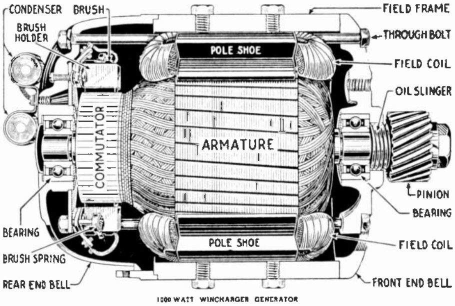
IN all radio installations, whether on land, sea or air, the power supply system employed is of paramount importance—so important that often the very safety of life may depend upon its operation. No radio installation can be more reliable than its power supply, hence it is just as important for the competent radio operator to understand the fundamentals of power supply systems as it is to familiarize himself with the principles of radio transmitting and receiving equipment.

While the use of dynamo-electric machinery at fixed land radio stations is gradually being limited to emergency use only, such machinery must always remain an essential portion of the power supply system in most mobile radio stations, such as in ships, aircraft and automobiles. Any treatment of the subject of power supplies must, therefore, include a discussion of generators and motors. This lesson will deal with the fundamentals of direct-current generators and motors and single-phase, alternating-current generators and motors, so that you will know how to operate these units efficiently and will be able to make simple repairs in case of emergency.

Fundamental Concepts

An electric generator is a machine which converts mechanical energy into electrical energy. In a dynamo-electric generator the mechanical energy usually rotates a system of conductors through a magnetic field, producing at the terminals of the system of conductors an electric voltage which will send current through an externally connected load and thus supply the load with electrical power.

An electric motor is a machine which converts electrical energy into mechanical energy. In a dynamo-electric motor the flow of current through a system of conductors placed in a magnetic field is converted into a motion of these conductors about a shaft. Mechanical power is thus made available at the shaft.



Courtesy Wincharger Corp.

Cut-away diagram showing construction of a 1000-watt, 32-volt d.c. generator. This unit is made by the Wincharger Corp., Sioux City, Iowa, for use in wind-driven charging systems for 32-volt farm power plants. This construction is typical of all small d.c. generators. The two condensers suppress sparking at the brushes and thereby prevent radio interference. This particular unit employs a gear drive to the propeller shaft.

Direction of Magnetic Lines of Force

In both types of dynamo-electric machines we have electric circuits, magnetic circuits and motion. The source for a magnetic circuit is generally an electromagnet, in order to make the magnetic field as powerful as possible. The electric circuit, since it carries current, has a magnetic field associated with it (independent of the main magnetic field). We are, therefore, fundamentally interested in the direction of flow of the magnetic lines of force associated with the flow of electrons through an electrical conductor. This relationship is given in Fig. *1A*. The lines of magnetic force correspond in direction to those flowing out of a north magnetic pole and into a south magnetic pole.

Figure *1B* shows a second and perhaps simpler way to remember this relationship between electron flow and magnetic lines of force. If you imagine that you are grasping the electrical conductor in your *left* hand in such a way that your thumb points in the direction of *electron* flow, your fingers will be curled around the wire with the tips pointing in the direction of the magnetic lines of force.

Law of Induced Voltage

A second important relationship is that which tells the magnitude and direction of the voltage produced when

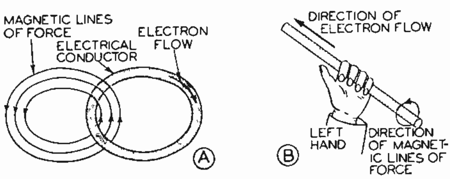


FIG. 1. Direction of magnetic lines of force around a conductor carrying a flow of electrons.

a conductor is moved through a magnetic field. Figure *2A* shows a permanent magnet having a north and a south pole close to each other; between the poles is a strong magnetic field acting in the direction of the arrows. A conductor is placed in this magnetic field, and its ends are connected to an instrument which measures the magnitude and direction (polarity) of the voltage induced in the wire. (It is assumed that the instrument requires a very minute current for its operation, in order that we can consider the conductor to be without an appreciable load.)

When the wire is moved from front to back at a speed of, say, one inch per second, the instrument will show that an electrical pressure (voltage) has been developed in a given direction along the conductor. When the motion of the wire is reversed (that is, moved from back to front between the pole faces), the instrument will read in the other direction, indicating that the direction of the e.m.f. induced in the conductor has been reversed. When the conductor is moved twice as fast, the instrument reading will double. When the conductor is moved five times as fast, the instrument will show that five times the original value of voltage is produced. When the length of the conductor exposed to the magnetic field is reduced by one-half and the conductor moved across the field at the original speed, the original induced voltage will be reduced to one-half.

When the density of the magnetic flux is made ten times that of the original value by substituting an electromagnet for the permanent magnet, and the conductor is moved across this field at the original speed (one inch per second), the voltage indicated by the instrument will be ten times that for the permanent magnet. When the wire is moved across this stronger field ten times as fast as at first, the induced voltage in the conductor will be one hundred times (10×10) the original value.

If these experiments are repeated with the magnet turned upside-down, so the south pole is above the north pole, the instrument readings will be the same in magnitude as for corresponding previous tests, but will be in opposite directions (reversed polarities).

If the experiments are repeated with three conductors connected in series, as in Fig. *2B*, the voltage indicated by the instrument will be three times the value originally obtained. The use of ten conductors in series will give ten times the voltage induced in a single conductor. If three, five or ten conductors are connected in parallel, however, there will be no increase in the total induced voltage in any case; here we would simply have the effect of one large wire equal in cross-section to the sum of the cross-sections of all of the parallel wires. The series connection is essential in order to obtain addition of the voltages induced in the individual conductors.

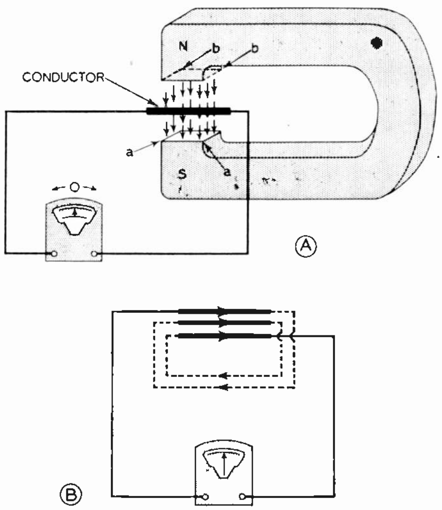


FIG. 2. Diagrams illustrating the law of induced voltage for a conductor which is moved across a magnetic field.

When one, three, five or ten conductors in series are moved diagonally across the field from rear edge *bb* of the north pole to front edge *aa* of the south pole at the original speed (one inch per second), the induced voltages are materially lower than for the corresponding cases where the lines of force were cut perpendicularly. When the conductors are moved parallel to the lines of force (from one pole straight up to the other), *no* voltage will be induced in the conductors.

The conclusions from all of the foregoing experiments may be summarized as follows: The voltage induced in a system of conductors moving in a magnetic field depends upon four factors: *1. The number of conductors in series; 2. The magnetic flux density* (the lines of force per unit cross-sectional area of the magnetic field); *3. The speed of the conductors perpendicular to the lines of force; 4. The length of the conductors in the magnetic field.*

This relationship between the induced voltage and the other factors may be unified into a very simple concept by referring to Fig. *3*, in which conductor *C* of length *L* (inches) is moved at a speed *S* (inches per second) across a magnetic field having flux density *B* (lines per square inch).

The runners on which the conductor moves are metallic and serve to complete the circuit to the voltmeter. In one second the conductor sweeps across the magnetic field a distance of *S* inches, and thus passes over an area in the magnetic field equal to $L \times S$ square inches. The strength of the magnetic field is *B* lines of force per square inch, hence the area covered has a total of $B \times L \times S$ lines of force. Since we have shown that the induced e.m.f. depends upon the flux density, the length of the conductor and the speed of the conductor across the field, we can now see that the induced e.m.f. depends upon the *total number of lines of force cut per second.* If there are a number of conductors connected in series, each conductor will develop the same voltage and the voltages will add since the conductors are in series.

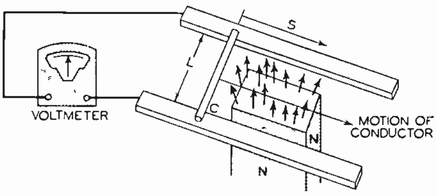


FIG. 3. The voltage induced in the moving conductor *C* in this simple circuit depends upon the total number of lines of force cut by the conductor per second, provided that this cutting changes the number of lines of force through the closed loop. The general rule is: The voltage induced in a closed loop moving in a magnetic field depends upon the *rate of change of flux linkages* through the loop.

Let us look at this induced-voltage relationship in a more technical manner. Think of the electrical circuit in Fig. *3* as a closed loop expanding in area due to the motion of the conductor. As the area of the loop increases, the loop links with more and more lines of force (the number of lines of force through the loop increases).

The value of the induced voltage depends upon how much change occurs (in a given unit of time) in the number of lines of magnetic force linking the loop or, as is often said, the induced voltage depends upon the *rate of change* of the lines linked by the loop. An example will clarify this; assume that at a given instant 1,000 lines of force pass through the loop, that one second later 2,000 lines link with the loop, and that two seconds later 3,500 lines link with the loop. The change in the flux lines linking the loop was 1,000 during the first second and 1,500 during the next second, and hence the *rate of change* of flux linkage was 1,000 per second during the first second and 1,500 per second during the next second. The induced voltage would be proportional to 1,000 during the first second and to 1,500 during the next second. If there were more than one turn in the loop, the *rate of change* of flux linkage would be the same for each turn, and each loop would have a voltage induced in it. The total induced e.m.f. would be the sum of these voltages.

When the number of flux linkages is *increasing,* the induced voltage has one direction. When the number of flux linkages is *decreasing,* the polarity of the induced e.m.f. is reversed. This latter case obviously corresponds to the case where the direction of motion of the conductor *C* of Fig. *3* is opposite to that shown in the illustration. Reversing the direction in which the flux passes through the coil without changing any other factors will reverse the polarity of the induced e.m.f.

Force on a Current-Carrying Conductor in a Magnetic Field

The third important relationship which we must consider deals with the magnitude and direction of the mechanical force exerted on a conductor which carries current and is located in a magnetic field. This can be explained quite simply with the aid of the diagrams in Fig. *4*. The uniform magnetic field between the north and south poles of a magnetic system is shown in Fig. *4A*. The magnetic field around a conductor is shown in Fig. *4B* for the case where the electrons are flowing away from you (into the paper).

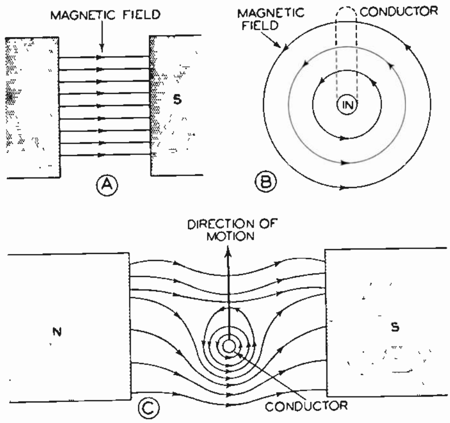


FIG. 4. Direction of motion of a current-carrying conductor in a magnetic field when electron flow through the conductor is away from you (into the paper).

Figure *4C* shows what happens when the conductor of Fig. *4B* is placed in the magnetic field of Fig. *4A*. The resultant magnetic field is obviously a composite of the two individual magnetic fields. Note that the lines of force under the conductor are compressed, because they are all in the same direction and *add.* Above the conductor, the two sets of lines of force are in opposite directions and subtract, causing a thinning of the flux.

We can visualize what happens if we imagine the lines of force to be hundreds of very thin rubber bands. Beneath the conductor they are depressed, and there is a strong urge for them to straighten out. This creates an upward mechanical force on the conductor. This upward force is actually on the field of the conductor (which cannot be separated from the wire) rather than on the conductor itself. Remember this important fact: When electrons are sent through a wire which is at right angles to magnetic lines of force, the *wire will be moved at right angles to both the direction of electron flow and the direction of the magnetic line of force.*

The force acting on a current-carrying conductor in a magnetic field will increase with increases in the magnetic flux density, in the length of the conductor exposed to the magnetic field and in the magnitude of the current flowing through the conductor; this is the fundamental principle of the electric motor. If the conductor rotates about a shaft, as is generally the case in the electric motor, the force on the conductor will exert on the shaft a rotating twist known as *mechanical torque*. The magnitude of the mechanical torque produced by an electric motor depends upon the force on the conductor and upon the distance of the conductor from the shaft.

Energy Laws for Generators and Motors

A more general consideration of the fundamental concepts involved in the operation of electrical generators and motors is now possible. Consider the case of the generator first. In Fig. *5A* suppose that the conductor is moved in direction *A* across the magnetic field; this, as we know, induces a voltage in the conductor. If we connect an external circuit having resistance *R* to the ends of the conductor, the induced voltage *E* will send an electron flow *I* through the conductor. The value of this current will be equal to the induced voltage divided by the circuit resistance ($I = E/R$).

The question is, what will be the directions of the induced voltage and of the current produced by this voltage? The answer is given by Lenz's law, which is derived from the natural law that energy can neither be created nor destroyed.

The voltage (E) which is induced in a conductor moving through a magnetic field will be in such a direction that the flux produced by the resulting circuit current (I) will tend to oppose the *change of flux linkages* which produced the induced voltage.

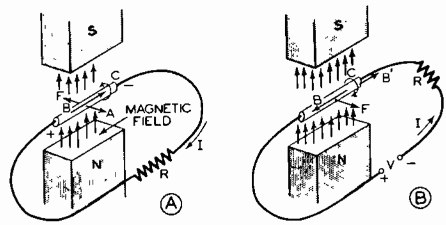


FIG. 5. These diagrams serve to illustrate Lenz's law, which tells the direction of the induced voltage in a dynamo-electric machine.

Let us apply Lenz's law to the conditions set forth in Fig. *5A*. Since the motion of the conductor here is such as to decrease the flux linking the loop (decrease the flux linkages), the induced voltage in the conductor and the flow of electrons through it will be in such a direction that the flux produced by the resulting current will tend to increase the main flux inside the loop. The flux produced by the conductor will therefore have direction *C*. The direction* of the induced voltage and the direction of the electron flow will therefore be as shown by arrow *B*, in which the arrow points to the negative terminal of the conductor. (This can be verified by referring to Fig. *1B;* place your left hand over the conductor with your fingers pointing in direction *C*, and your thumb will then be pointing in direction *B*.)

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*In this lesson, the "direction" of the induced voltage is the direction in which that voltage will force *electrons* through the circuit.

Now we have a conductor carrying current and moving in a magnetic field. The magnetic field of the conductor superimposed on the original magnetic field will cause a compression of the lines of force on the right of the conductor and a rarefication of the lines of force on the left of the conductor. There will thus be a mechanical force produced in the direction F, *opposing* the original motion of the conductor through the magnetic field. To keep the conductor moving, it is necessary to overcome this opposing force. This means that it is necessary to expend mechanical power in order to generate electrical power. This is the reason why Lenz's law for the direction of the induced e.m.f. was referred to as a special case of the law of conservation of energy.

As the load on a generator increases (as I increases due to reduction of R), the amount of power required to overcome the opposing force increases. Actually the mechanical power required to keep the conductor in Fig. *5A* moving is greater than the power needed to overcome this opposing force (and hence greater than the electrical power produced) by an amount necessary to overcome frictional and other losses.

Now consider the case of the motor. Referring to Fig. *5B*, assume that a voltage V is sending an electron flow through the conductor in direction B; the value of this current will be $I = V/R$ when the conductor is not moving. The magnetic field set up around the conductor by this current will be in direction C and will interact with the main magnetic field to produce a mechanical force acting on the conductor in direction F, which is *at right angles* to both the direction of electron flow and the direction of the magnetic lines of force. The conductor will start moving in this direction, thereby decreasing the number of lines of force threading the loop. According to Lenz's law, a voltage E_a will now be induced in the conductor, in such a direction as to tend to cause a current to flow which will increase the number of flux linkages. This voltage will obviously have the direction B'; it will therefore oppose the original electron flow B, and reduce the force on the conductor.

The induced voltage in the case of a motor is always opposite to the direction of the externally-applied voltage, and is therefore termed a *back e.m.f.* Because of this back e.m.f. E_a, the current flowing through the conductor in Fig. *5B* is reduced ($I = \frac{V - E_a}{R}$) and the force on the conductor is accordingly reduced. To maintain a given force on the conductor and hence a given mechanical torque at the shaft about which the conductor is rotating, the applied voltage V must be increased enough to give the required value of current. This is again a case of the conservation of power; to generate mechanical power, it is necessary to expend enough extra electrical power to make up for the losses in the machine.

The facts discussed in this section may be summarized as follows:

1. Generator Action. If a conductor is located in a magnetic field and is acted upon by a mechanical force in such a manner that the conductor is made to cut lines of force, the induced e.m.f. will have such a direction that the resulting current will react with the magnetic field so as to set up a mechanical force in opposition to the driving force. Mechanical energy is converted into electrical energy.

2. Motor Action. If a conductor is located in a magnetic field and is carrying a current provided by some source of electrical energy, the resulting force will tend to produce motion of the conductor in such a direction that the induced e.m.f. will oppose the original flow of the current. Electrical energy is converted into mechanical energy.

Generator and motor action are entirely reversible; a good generator may act as a motor, and vice versa.

Simple Single-Phase A.C. Generator

The elementary alternating-current generator shown in Fig. *6A* has two poles, *N* and *S,* produced by an electromagnet. A rheostat inserted in the field circuit serves to control the strength of the electromagnet. Between the field poles, a loop of wire called the *armature* is rotated mechanically about an axis. The armature is generally wound in an iron frame-work (not shown) which serves to reduce the reluctance* of the complete magnetic circuit and thereby increase the total flux. As the armature loop is rotated, a voltage is generated in a manner to be described later. Two slip ring-and-brush assemblies serve to transfer this voltage to the external circuit (to the terminals marked *A.C.*). The slip rings are generally of copper, while the brushes are made either of copper or carbon.

The magnitude of the voltage generated in the armature loop at each instant while it is being rotated may be considered in terms of the change in the flux threading the loop. Figure *6B* shows how the generated voltage varies during one complete revolution of the loop. At position *A* we have maximum flux linkage through the loop, but a small angular change in loop position produces only a negligible change in the flux linkage; the induced voltage at position *A* is therefore zero. This same condition exists after the loop has rotated through 180 degrees (position *E*) and through 360 degrees (position *I,* which is the same as position *A*).

At positions *C* and *G* the loop is parallel to the lines of flux, and the flux linkage is therefore zero. A small angular change in loop position produces a marked change in the flux linkages, however; the induced voltage is therefore a maximum at positions *C* and *G*.

The direction of the induced voltage at any position may be determined by applying Lenz's law. Consider position *H* in Fig. *6B,* which corresponds to the coil position shown in Fig. *6A*. Since the coil is rotating in the direction of

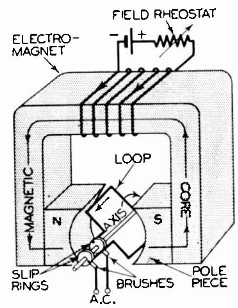


Fig. 6A. An a.c. generator in its simplest form has one coil of wire revolving in the magnetic field produced by an electromagnet.

increasing flux linkage, the flux produced around the conductors by the induced current must *oppose* the main field. The directions of the induced voltages in the conductors are then as shown by the arrows in Fig. *6A*. Note that the voltages induced in the two conductors of the armature loop are additive. Further increase in voltage may be obtained by increasing the number of turns in the loop winding, as shown in Fig. *6C*.

It will be seen from Fig. *6B* that the induced voltage is alternating in nature, and passes through a complete cycle of variations during each revolution of the armature coil. Hence, to produce a frequency of 60 cycles per second (universally employed in U.S.), the armature of this simple a.c. generator must revolve 60 times per second or 3,600 times per minute (3,600 r.p.m.). It is possible to reduce this speed re-

*The opposition which a magnetic circuit offers to the passage of a magnetic field is known as reluctance.

quirement by increasing the number of poles in the field structure. If four poles are used, with adjacent poles of opposite polarity, each revolution of the armature will produce two complete cycles of variation in the induced voltage. The speed for 60 cycles per second need now be only 30 revolutions per second or 1,800 r.p.m. In general, the relationship between the frequency f, the number of poles P and the revolutions per minute n may be expressed by the following simple formula:

$$f = \frac{P \times n}{120}$$

For two poles and 3,600 r.p.m.:

$$f = \frac{2 \times 3{,}600}{120} = 60 \text{ cycles per sec.}$$

For four poles and 1,800 r.p.m.:

$$f = \frac{4 \times 1{,}800}{120} = 60 \text{ cycles per sec.}$$

It is important to know that the induced voltage of an a.c. generator which produces a given frequency is independent of the number of poles used. A consideration of the examples in the preceding paragraph will show why this is true. A two-pole a.c. generator sweeps a coil through the flux of one pole in half a revolution at the speed of 3,600 r.p.m., while a four-pole a.c. generator sweeps a coil through the flux of one pole in one-fourth of a revolution at a speed of 1,800 r.p.m. The coils on both machines thus cut through the flux of one entire pole in exactly the same time. The maximum rate of change of flux is therefore the same for a two-pole generator as for a four-pole generator, and the maximum induced voltages must likewise be the same. A similar analysis for other generators would show that the value of the induced voltage in a single loop of an a.c. generator is the same for a given frequency regardless of the number of pairs of poles employed. The number of armature turns and the strength of the magnetic field are obviously the important factors which control the magnitude of the induced voltage.

The field of a simple a.c. generator is generally excited from an external d.c. source, which may be a small d.c. generator called the exciter, employed especially for this purpose.

Most a.c. generators are multipolar. For power outputs up to 20 kilowatts, the field structure is generally stationary and the armature rotating. For greater generated powers, the following two factors make it more desirable for the field to be rotating and the armature to remain stationary: *1.* The current-handling requirements of the slip rings and brushes are very much reduced, as the exciting power required for the field is only a few per cent of the generated power; *2.* Higher voltages may be handled more readily by a stationary armature.

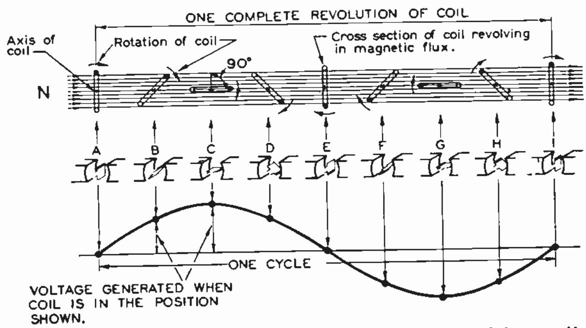


Fig. 6B. When a coil of wire is rotated at constant speed in a uniform magnetic field, the voltage generated will vary in the sine-wave manner shown here.

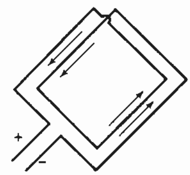


Fig. 6C. Two turns give twice the induced voltage.

Figure 7 shows a single-phase alternator (a.c. generator) with a stationary armature and a six-pole revolving field. Note that the direct current for exciting the field is brought in on the slip rings. The stationary armature

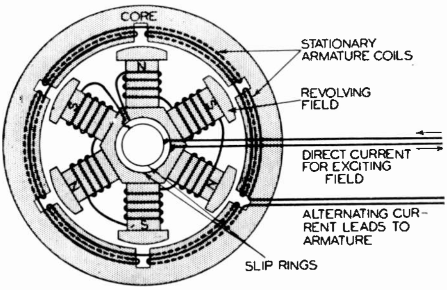


Fig. 7. Diagram of an a.c. generator having a 6-pole revolving field and a stationary armature.

winding consists of a number of multi-turn coils connected in series. As a pole passes a coil, the flux associated with the pole sweeps through the coil, changing the flux linkages of the coil and thereby inducing in it a voltage. The connections to alternate coils are reversed, in order that the induced voltages will be additive when poles of opposite polarity pass them. For a 60-cycle frequency, a speed of 1,200 r.p.m. is required for the field structure.

A Simple D.C. Generator

Purpose of the Commutator. So far, we have considered only the production of alternating current by means of a generator. Dynamo-electric generators are also employed to produce direct or continuous currents. It must be understood, first of all, that the voltages set up in the various armature conductors of a generator are always alternating, no matter how the armature is wound. It is impossible to wind a generator armature in such a manner that direct current can be obtained from the terminals of the armature coil. It is necessary to employ some device which will always keep the direction of current flow in the external circuit in one direction, even though the current reverses in the armature coil or loop. This device, known as the *commutator* of a d.c. generator, *mechanically and periodically reverses the connections between the armature conductors and the load, so that the voltage applied to the load is always in the same direction.*

A simple d.c. generator is shown in Fig. *8A*. The two segments of the simple commutator are connected to opposite ends of the armature loop. The segments are made of copper and are rigidly fastened to the armature shaft by means of suitable insulating material. The operation of the commutator in converting a.c. into d.c. may be understood by reference to Fig. *8B*. In this illustration, conductors *a* and *b*, which form the simple armature loop, are shown embedded in slots in the armature core. (As indicated previously, this core is used to lower the reluctance of the magnetic circuit.) The lead from conductor *a* of the armature loop is connected to armature segment *1*, and the lead from conductor *b* of the armature loop is connected to commutator segment *2*.

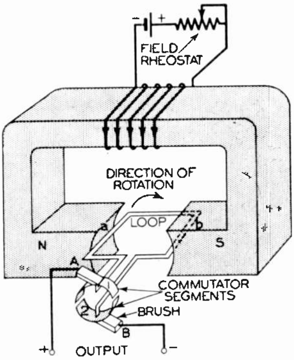


Fig. 8A. Simple d.c. generator.

When the armature loop in Fig. *8A* is rotated, voltages are induced in it exactly as in the case of the simple a.c. generator. The induced voltage is zero at positions *A*, *E* and *I*, and is a maximum at positions C and G, as indicated in Fig. *8B*. The polarity of the *induced* voltage at position G is the opposite of that of position C, as may be determined by applying Lenz's law. The voltage induced in the armature loop will therefore vary with armature position in the sine-wave manner represented by curve A-C-E-G-I in Fig. *8B*. As the armature approaches position E (where the induced voltage

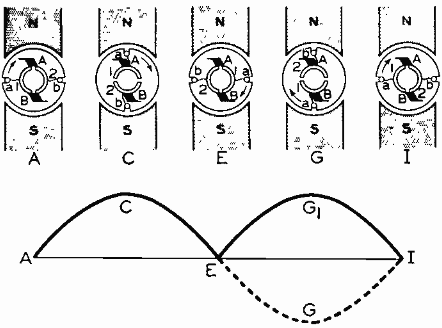


FIG. 8B. Output voltage curve for a simple d.c. generator.

drops to zero), brushes A and B (which connect to the external circuit and which have been passing over segments *1* and *2* respectively) approach the opposite segments. At position E each brush contacts both segments. After position E has been passed, brush A contacts segment *2*, and brush B contacts segment *1*. Thus you can see that although the armature voltage reverses in polarity at position E, the connections of the armature to the external load are also reversed at this point, so that the voltage applied to the external load still has the same direction. This is the process of commutation. The variation of the voltage applied to the load is as shown by curve A-C-E-G_1-I, and is a pulsating direct voltage instead of the alternating voltage generated in the armature loop.

It is important to note that at the instant of reversing the brush connections to the commutator, the armature loop is short-circuited by the brushes. This occurs at the point when the induced voltage is practically zero, however, so sparking at the commutator is minimized.

Armature Windings

The pulsating voltage (and current) delivered by the simple d.c. generator of Fig. *8A* is of little practical value. Commercial direct-current applications require much more uniform voltage and current. The manner in which this is accomplished will now be considered.

Referring to Fig. *8C*, let curve *1-3-5* represent the pulsating voltage delivered by the simple d.c. generator of Fig. *8A*. A second armature coil, placed at right angles to the first coil and operating in conjunction with a second commutator-and-brush assembly, would produce the pulsating voltage represented by curve *2-4-6* of Fig. *8C*. If we add together the voltages delivered by the two sets of commutators, the resultant or total e.m.f. will be represented by curve E; clearly there is much less fluctuation in amplitude in this voltage than in either of the component voltages.

In direct current generator practice, a large number of loops called *winding*

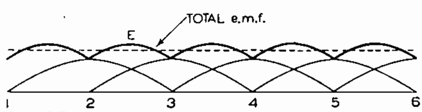


FIG. 8C. Output voltage E of a d.c. generator having two sets of commutators.

elements are distributed around the armature and are connected in special sequence to arrange for even more complex addition of the component voltages, thereby insuring a practically uniform output voltage. The winding sequences employed are referred to as *lap* and *wave* windings. Winding elements for these two types of windings are shown respectively at Figs. *9A* and *9B*. The essential difference is that in the lap winding, opposite ends of a coil connect to *adjacent segments on the commutator,* while in the wave winding, opposite ends of a coil connect to *diametrically-opposite commutator segments.* Although only single-turn winding elements are shown in Figs. *9A* and *9B,* it is customary to use several turns per element, particularly when high voltages are required. In the next few paragraphs you will learn that the total generated d.c. voltage is affected by the number of turns per winding element and by the number of winding elements connected in series around the armature (between the positive and negative brushes).

A photograph of typical multi-turn lap-wound coils appears in Fig. *10A.* The loops are made up in a jig, then fitted into slots in an armature of the type shown in Fig. *10B.* One coil fits into slots numbered *1* and *6,* with its leads connected to commutator segments *b* and *c;* another coil fits into slots numbered *3* and *8,* with its leads connected to commutator segments *c* and *d,* and so on around the armature.

Now let us consider the complete armature winding in Fig. *10B.* It is a

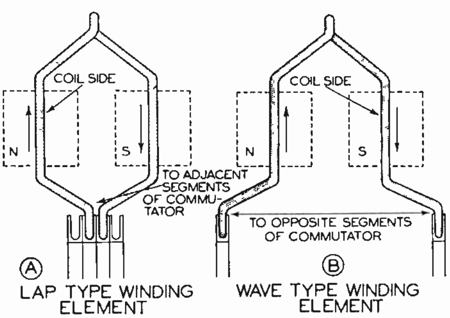


FIG. 9. Types of winding elements.

lap-type winding for a two-pole d.c. generator. The small circles in the armature slots represent the conductors of the winding elements. The dotted lines from the commutator segments to the conductors represent the connections back of the armature, and these wires normally lie on a cylindrical face forming an extension of the armature core, but of somewhat smaller diameter. The solid lines represent the connections between conductors in front of the armature, and lie on a similar cylindrical surface forming an extension of the armature

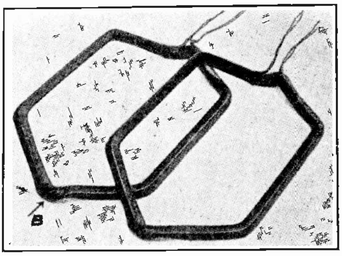


FIG. 10A. Typical multi-turn lap-wound coils. The special twist which allows the coils to fit close together is indicated at *B.*

core at the rear. The small dots and crosses in the circles representing the conductors indicate the directions of the voltages induced in the conductors at the particular armature positions shown. A dot signifies that the induced voltage would tend to force electrons *out of* the conductor (toward you and away from the commutator), and the cross indicates an induced voltage which is forcing electrons into the conductor (away from you and toward the commutator). Figure *10B* is for the particular armature position shown; the induced voltages in any one conductor will naturally reverse in direction at each half-revolution of the armature in this case.

Starting from brush *B,* let us trace the electron flow paths through the winding until brush *A* is reached. Note that there are two parallel paths, as follows:

Path *1:* From brush *A* to commutator segment *c,* into *6,* out of *6* and across to *1,* out of *1* to *b,* into *4,* out of *4* and across to *11,* out of *11* to *a,* into *2,* out of *2* and across to *9,* out of *9* to *f,* and then to brush *B.*

Path *2:* From brush *A* to commutator segment *c,* into the back end of conductor *3*, out of the front end of *3* and across to *8*, out of *8* to *d*, into *5*, out of *5* and across to *10*, out of *10* to *e*, into *7*, out of *7* and across to *12*, out of *12* to *f*, and then to brush *B*.

Since it is somewhat difficult to visualize complete paths from brush to brush in a cross-sectional picture diagram like that in Fig. *10B*, it is customary for designers of electrical machinery to employ a developed type of diagram like that in Fig. *10C*. This is for the identical armature winding shown in Fig. *10B*, and is obtained by imagining that the cylindrical surfaces of the armature, commutator, etc., are unrolled and placed on a flat surface with the poles underneath in the proper positions. The two poles and two brushes are considered to be fixed as to position, with the windings and the commutator segments sliding past them in the direction of rotation.

Let us trace the two electron flow paths between brushes *B* and *A* in Fig. *10C*, then figure out why the induced voltages have the directions shown.

Path *1* is easily traced now: *A* to *c* to *6* to *1* to *b* to *4* to *11* to *a* to *2* to *9* to *f* to *B*. Path *2* is: *A* to *3* to *8* to *d* to *5* to *10* to *e* to *7* to *12* to *f* to *B*. Note that there are three complete winding elements in each of the electron paths.

Consider first the winding element formed by conductors *1* and *6*; this is approaching maximum flux linkage in both Figs. *10B* and *10C*, and the induced voltage in this element is approaching zero since a small movement causes very little change in flux. Commutator segment *b* is approaching brush *A;* a slight additional rotation brings *b* to *A*, short-circuiting this winding element preparatory to reversing its connections to the brushes.

While winding element *1-6* of path *1* is approaching zero voltage, winding elements *4-11* and *2-9* are producing quite high induced voltages. Since these three winding elements are in series, and are connected in such a way that the voltage is in the same direction at all points along the circuit (you can verify these directions by applying Lenz's law), the voltage between the brushes will be the sum of the three different values of induced voltage. As the armature revolves, the voltages in the individual coils (winding elements) will vary in a sine-wave manner, but the sum of these three induced voltages will vary only a small amount. Path *2* is in parallel with path *1* between the brushes, and produces the

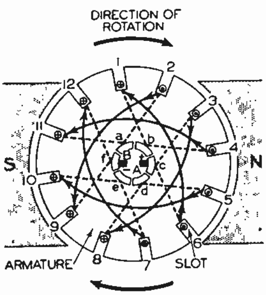


FIG. 10B. Cross-section view of simple two-pole d.c. generator, looking from the end *opposite the commutator*. *A* and *B* are brushes, while *a, b, c, d, e* and *f* are commutator segments.

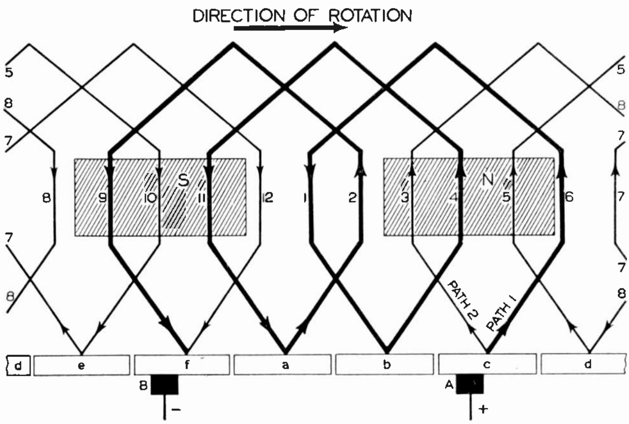


FIG. 10C. Developed diagram of a simple two-pole lap-wound d.c. generator. Arrows indicate directions of induced voltages (directions of electron flow) through the armature.

same essentially-constant output voltage at the brushes. This gives very nearly a pure d.c. voltage; by placing more winding elements on the armature, an even steadier output d.c. voltage can be secured.

The voltage induced in a winding element reverses each time the sides of this element arrive at the neutral zones between poles. In a d.c. generator the connections to a winding element must, therefore, be reversed each time the element arrives at a neutral zone. The winding element must be short-circuited by a brush before its connections can be reversed, and consequently we must provide an adequate number of brushes, located at the proper points on the commutator, to accomplish this short-circuiting and reversal of connections.

Only two brushes are needed for two-pole d.c. generators, regardless of whether they employ a lap winding or a wave winding. By considering this brush problem now for a four-pole d.c. generator, we can arrive at important general conclusions which will apply to d.c. generators having any number of poles and employing either a lap winding or a wave winding.

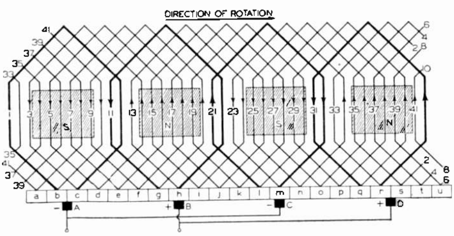


FIG. 11A. Developed lap winding.

The developed lap winding for a four-pole d.c. generator is shown in Fig. *11A*. The four winding elements, which are in or approaching the neutral zones between poles and must therefore be short-circuited by brushes when the armature is rotated a small amount in the direction of rotation, are shown in heavy lines. As you can see, brush *A* is already shorting commutator segments *b* and *c*, thereby short-circuiting the first of these winding elements (having conductors *1* and *12*). A small amount of additional rotation will bring commutator segment *g* in contact with brush *B*, short-circuiting the second winding element (having conductors *11* and *22*). Still further rotation will bring segments *l* and *m* in contact with brush *C*, shorting the third winding element (having conductors *21* and *32*). Finally, segments *q* and *r* will contact brush *D*, shorting the fourth winding element (having conductors *31* and *42*). We obviously cannot use less or more than four brushes for this four-pole lap-wound d.c. generator. Our general conclusion is that *with a lap winding we must have as many brushes as there are poles.*

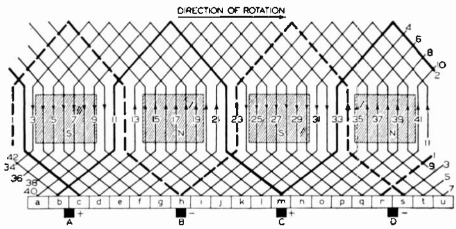


FIG. 11B. Developed wave winding.

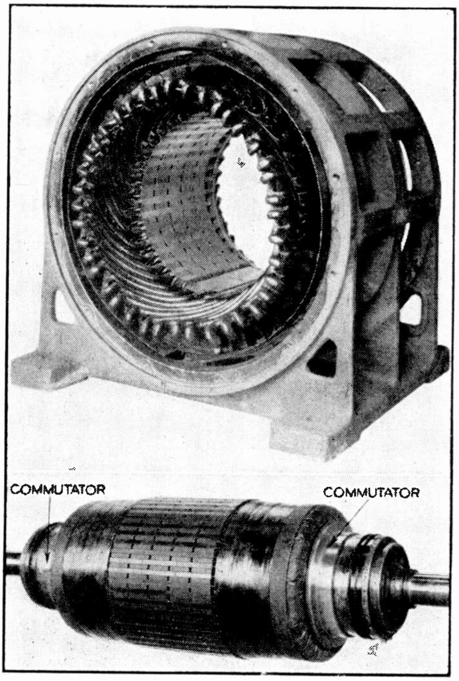
A developed wave winding for a four-pole d.c. generator is shown in Fig. *11B*. The winding elements which are in neutral zones and must therefore be short-circuited by brushes are shown here in heavier lines. A careful study of this diagram will show that brush *A* is shorting commutator segments *b* and *c*, and is therefore shorting two winding elements connected together in series, one having conductors *11* and *22*, and the other having conductors *33* and *2*. Brush *D* is short-circuiting the other two winding elements which are in neutral zones, for these are connected together in series between commutator segments *r* and *s* (one winding element has conductors *1* and *12,* and the other has conductors *23* and *34*). We thus have short-circuiting of four windings with only two brushes in the case of a wave winding. Brushes *B* and *C* may be used if individual short-circuiting of winding elements is desired; in this case, brush *C* would be connected to brush *A,* and brush *B* would be connected to brush *D.* Our general conclusion is that *only two brushes are required regardless of the number of poles in a wave-wound d.c. generator.*

A lap winding is often called a *parallel* winding, for a simple lap winding always has as many parallel paths through the armature between the output terminals as there are poles. A wave winding is often called a *series* winding, for a simple wave winding has only two parallel paths through the armature between generator terminals regardless of the number of poles.

The Effect of Armature Reaction on Commutation in a D.C. Generator

Figure *12A* shows the magnetic field produced by the field poles of a d.c. generator when the armature is stationary (no generated voltage). The field is symmetrical and practically uniform since the armature now acts only as a portion of the main magnetic circuit, with the armature core tending to reduce the reluctance of the complete system. When the armature of a d.c. generator is rotating, the electron flow through the conductors could be as shown in Fig. *12B* for the direction of rotation indicated. If we could remove the main magnetic field temporarily under this condition, the magnetic field produced by electron flow through the rotating armature windings would be as shown in Fig. *12B.* When both magnetic fields exist simultaneously, as they do in a d.c. generator, the armature flux naturally affects the field flux to some extent, depending upon the relative strengths of the two fields. The result of this reaction between the two fluxes is a redistribution of flux lines, as shown in Fig. *12C;* this effect is referred to as *armature reaction.*

Rotation of the armature in a generator seems to pull the field magnetism around with it, or to stretch it out of place *in the direction of rotation.*



Courtesy General Electric Co.

Field (stator) and armature (rotor) of a General Electric CY-98 d.c. generator capable of delivering 100 kilowatts of power at 15,000 volts d.c. The windings on the inside of the field structure are all compensating windings, fitting into slots in the faces of the two field poles. They completely hide the main field pole windings in this view. The armature has two sets of windings, each generating 7500 volts; the two commutators, one at each end of the armature, each serve one of these windings. In this way each brush handles only 7500 volts, reducing the tendency toward sparking. The two sets of brushes are connected in series externally to give the full 15,000 volts.

Because of this, the strongest part of the magnetic field is not where it was when the armature was stationary—it has moved to one side in the direction of rotation. This displacement naturally takes place equally at each field pole, and the amount of displacement is largely determined by the load.

Mention has already been made of the fact that brushes must be so placed that they will short commutator segments whose conductors are in the zero field between poles. Now it is reasonable to believe that when the field is distorted or changed as just described, the amount of field distortion will have to be considered in setting the brushes. According, the brushes in a d.c. generator should be moved away from the dead-center position* *in the direction of armature rotation* to minimize sparking at the brushes. The distance from dead center is determined by the amount of field distortion.

In practice, brushes are actually set even farther in the direction of rotation, so that a small voltage of the same polarity which the neutral coil is about to have induced in it is set up in the coil. This small voltage operates to overcome the effect of self-inductance in the coil; this self-inductance tends to maintain in the coil during short-circuit a current having the same direction as that flowing in the coil prior to short-circuit. Advancing the brushes slightly beyond the true neutral thus tends to prevent sparking at the brushes.

Reentrancy of Windings

In all of the windings treated so far, if we started with conductor *1* and traced through the windings (regardless of the direction of induced voltage) we would pass through *all* the conductors before reaching conductor *1* again. These windings are known as *single-reentrant windings*. It is possible to arrange the windings so that they are double-reentrant, triple-reentrant, etc. Double-reentrant windings are obtained by sandwiching two windings of the same kind (lap or wave) on a single armature. Each winding has its own commutator segment, the two sets of segments being interleaved. The brushes must be of sufficient width (at least twice the width of a commutator segment) to provide for short-circuiting of a winding element in each winding at the neutral zones. If we started with conductor *1* and traced through the winding, we would pass through only half the conductors before reaching conductor *1* again.

Triple-reentrant windings are obtained by sandwiching three windings of the same kind on a single armature and interleaving three corresponding sets of commutator segments. The brushes must now be at least triple width.

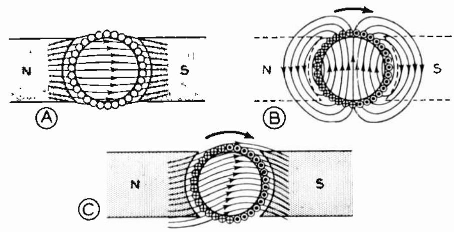


FIG. 12. Distortion of the main magnetic field due to armature reaction.

Winding Pitch and Commutator Pitch

The *winding pitch* is the number of sides of winding elements which are passed over in connecting one conductor to another on the armature. *Front pitch* refers to the connections at the front or commutator end of the armature winding, and *back pitch* refers to the connections at the back end. In Fig. *11A*, conductor *1* connects to conductor *12* at the rear, and hence the back pitch is +11; conductor *12* connects to conductor *3* at the front, and hence the front pitch is —9. (The conductor to which a connection is made is always counted when determining pitch.) The signs refer to the direction of progression of the winding around

*The "dead center" position of a brush is the position it would be placed at if there were no distortion of the field flux by armature reaction.

the armature. A + sign indicates progress in the direction of rotation, while a — sign means progress opposite to the direction of rotation. Since this is a lap winding, the winding laps back over itself and there is a negative progression at the front end. In Fig. *11B*, a wave winding, both the front and back pitch are +11.

The *commutator pitch* refers numerically to the spacing of the commutator segments to which the two terminals of a winding element are connected. In Fig. *11A* the commutator pitch is +1, in Fig. *11B* it is +11.

Armature Windings for Single-Phase A.C. Generators

In Fig. 7 was shown a rotating field and stationary armature of an a.c. generator. The type of winding shown on the armature is known as the *chain* type. The lap winding is also generally used for the armatures of a.c. generators (whether of the rotating-field or rotating-armature types). The stationary armature (rotating-field type) requires slip rings only for the field connections.

When a lap winding is employed on a stationary armature, the various winding elements are connected together in series in such a way that voltages will all be in the same direction at any instant of time. Voltages induced in adjacent coils will be out of phase, for when flux is changing at a maximum rate for one coil it will be changing at a lesser rate for adjacent coils. The voltages induced in the various coils are sine-wave in form but differ in phase, so they all add up to produce a sine-wave output voltage at the generator terminals.

Field Excitation for A.C. and D.C. Generators

As has already been mentioned, a direct current is required for field excitation of any generator. A.C. generators therefore require a separate d.c. source, usually a small d.c. machine called an exciter. A small a.c. generator can be made self-excited by employing a commutator on the rotating armature shaft to rectify part of the a.c. output for field excitation. D.C. generators, on the other hand, may be operated self-excited; since the armature suppies direct current, part of this current may be used to excite the field. As will be shown, all or part of the field coils may be in parallel or in series with the load, depending on the operating characteristics desired for the generator.

Operating Characteristics of the Single-Phase A.C. Generator

The factors defining the operating characteristics of a generator are: armature speed (S), induced armature voltage (E_a), armature current (I_a), field current (I_f), the terminal voltage applied to the external load (V_t), and load current (I_L). We have shown that for a constant output frequency, the voltage generated in a single-phase a.c. generator will vary directly with the strength of the magnetic field.

The terminal voltage (V_t) will be less than the generated voltage (E_a) by a voltage drop in the armature (I_aZ_S, where Z_S is the impedance of the generator during operating conditions). This voltage drop is caused by the flow of current through an armature winding having both resistance and reactance. The resistance is the ohmic resistance of the winding. The reactance is the sum of the inductive (or self) reactance of the armature and a fictitious reactance which takes into account the effect of armature reaction. The term "Z_S" is called the *synchronous impedance* and includes both the resistance and the total reactance of the armature.

Assuming that the armature speed remains constant, the *induced* voltage will remain constant regardless of the load current. However, the voltage drop in the armature will increase as the load current increases, since I_L and I_a are identical (a series circuit). The terminal voltage V_t (equal to $E_a - I_aZ_S$) will therefore decrease as the load current increases.

The term *voltage regulation* (expressed in per cent) is often used as a figure-of-merit of a generator. It defines *the per cent drop in terminal voltage when changing from no-load to full-load conditions.*

The terminal voltage of an a.c. generator may be kept constant by increasing the field current (and hence the flux) as the load current increases. In this way E_a is increased just sufficiently to make up for the increased voltage drop in the armature as load current increases. This may be done manually by means of a field rheostat, or automatically by means of relays which are operated by the load current and serve to control the amount of resistance in the field circuit.

Figure *13* shows how the induced voltage of an a.c. generator varies with the current flowing through the field windings. During normal operation the field current is set on an essentially linear portion of the curve, close to the point of magnetic saturation, so that an increase or decrease in field current causes a corresponding variation in the induced voltage. At zero field current, there is still some residual magnetism in the field magnets, hence the induced voltage does not drop down to zero. Near maximum field current, the magnetic flux, and hence the induced voltage) does not increase linearly with the field current because of magnetic saturation of the field structure.

Operating Characteristics of the D.C. Generator

The induced voltage (E_a) of a d.c. generator has been shown to vary directly with the number of winding elements per path in the armature, with the flux per pole, with the number of pairs of poles, and with the armature speed. Since the d.c. generator is self-excited, variations in load current will cause variations in the field current and thereby affect the strength of the field flux. This in turn will affect the terminal voltage of the generator.

Figure *14A* shows the electrical connections for what is known as a shunt generator. For convenience the armature is represented by the commutator

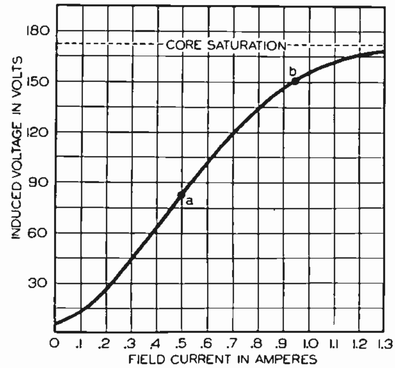


FIG. 13. Characteristic curve of an a.c. generator. Up to point *a* on the curve, increases in field current produce proportional increases in magnetic field strength and in induced voltage; above point *a*, magnetic saturation of the iron pole pieces and the armature core begins, so that given increases in field current produce less and less increase in the induced voltage. The saturation effect is not serious up to about point *b*, hence the region between *a* and *b* is usually selected as the operating range for field current. Complete saturation exists when the iron structure cannot hold any more magnetic lines of force; under this condition, additional increases in field current cause no further increases in magnetic field strength or induced voltage, and we are getting the maximum possible induced voltage (the value corresponding to the dotted line labeled *CORE SATURATION*).

and brush assembly (since the brushes form the external connections to the armature), and a coil is used to represent the field. windings. Note that the field is connected in parallel (shunt) with the load, hence the name "shunt generator." It will be obvious that for this connection the armature current will be equal to the sum of the load current and the field current ($I_a = I_L + I_f$). The terminal voltage in this case will be the induced voltage minus the voltage drop in the resistance of the armature winding ($V_t = E_a - I_aR_a$). The terminal voltage will decrease somewhat as load current increases, first because of the increased I_aR_a drop in the armature and secondly because this reduction in terminal voltage in turn causes a reduction in field current and hence in the generated voltage E_a. The variation of the terminal voltage with load current for this type of machine is shown by curve *a* in Fig. *14D*.

Figure *14B* shows the electrical connections for a series generator. The field winding is connected in series with series field coils and providing the correct relationship between the strengths of these fields, it is possible to obtain a practically *flat voltage characteristic, so there will be negligible variation in the terminal voltage as load is varied.* A machine employing this combination of field windings is called a *compound generator*. The electrical connections of a compound generator as shown in Fig. *14C,* and the manner in which the terminal voltage varies with load current is portrayed by curve *b* in Fig. *14D*. By adjusting the relative strengths of the two field windings it is

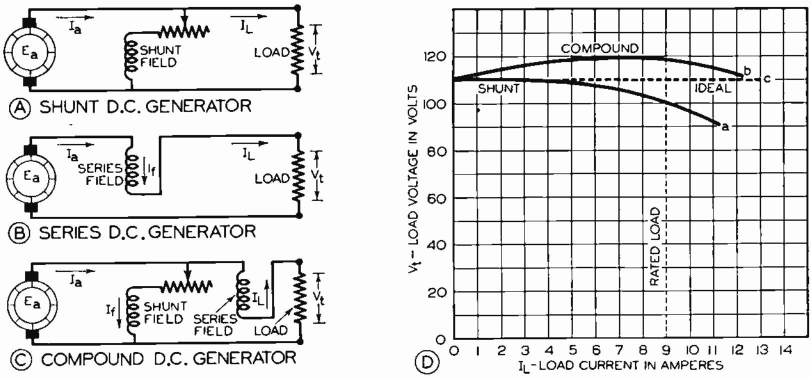


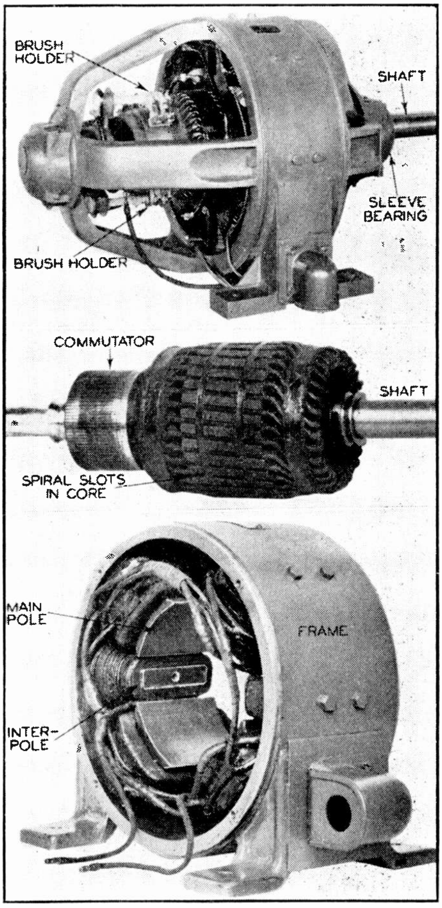
FIG. 14. Field connections for shunt, series and compound d.c. generators, together with output voltage—output current characteristic curves for shunt and compound d.c. generators.

the armature, hence the name "series generator." This type of generator has very little application in modern practice. Since the field current is equal to the load current, it is apparent that the induced voltage will vary widely with the load current. Figure *13* expresses the nature of this variation, showing that in a series generator the induced voltage increases with load current. The terminal voltage will be less than the induced voltage by the IR drops in the armature and the series field.

We thus see that it is possible to have the terminal voltage decrease as load is applied (the shunt generator), or increase as load is applied (the series generator). By combining shunt and possible to make the voltage rise somewhat with load (*the over-compounded generator*) or drop slightly with load (*the under-compounded generator*).

It is of interest to consider how self-excited shunt or compound generators build up their generated voltages. When the armature is first rotated, the only induced voltage is that due to the residual magnetism of the field structure. Assuming no-load conditions, this small voltage will send a small current through the shunt field. If the armature is revolving in the proper direction, the polarity of the induced voltage will be such that the field due to this small field current will assist the residual field. The induced armature voltage is thus further increased, and it in turn increases the field current and the total field again. This process continues until the I_fR_f drop in the field coils is equal to the generated voltage E_a; we then have steady-state conditions, and the generated voltage will remain constant at this value until the field resistance R_f or the speed is changed.

The same building-up phenomena occurs in a series generator, but only when a load is applied. A series gen-



Courtesy General Electric Co.

Top: This type CD General Electric four-pole d.c. motor, available with either shunt or compound-wound field coils, is typical of general-purpose d.c. motors larger than 3 h.p. in size. Center: Armature of the above motor. Bottom: Field structure of a type B General Electric d.c. motor, available in sizes from ½ h.p. at 1750 r.p.m. up to 10 h.p. at 3500 r.p.m. There are four main poles, and two interpoles to improve commutation.

erator will not build up its magnetism under no-load conditions, for current cannot flow through the field coil until a load is connected to the generator.

Efficiency of Generators

The efficiency of a generator is equal to the ratio of the electrical power developed to the mechanical power supplied to it, expressed in per cent. For a self-excited generator, the mechanical power input must equal the electrical power output plus the resistance (I^2R) losses in the field and armature windings, plus eddy current and hysteresis losses in the armature core, plus frictional and windage losses. For example, if a generator delivers 10 amperes at 100 volts (1,000 watts) and the sum of all its losses is 100 watts, the mechanical power delivered to it will be the mechanical equivalent of 1,100 watts. The generator efficiency is $1000 \div 1100$, which is 0.909 or 90.9%.

The D.C. Motor

The d.c. motor is essentially a d.c. generator to which electrical power is supplied, causing it to rotate and to deliver mechanical power at its shaft. The principle underlying motor action was explained in connection with Fig. *4*. The generation of a back e.m.f. as the armature rotates in the magnetic field was demonstrated in the text associated with Fig. *5B*. While these explanations were for a single conductor carrying current in a magnetic field, it is evident that they are applicable to armatures of the types described in connection with Figs. *10* and *11*.

Consider the lap-wound armature shown in Fig. *10C* (reproduced as Fig. *15* for convenience). Assume that an external voltage (V_t) is applied between brushes A and B. Let the polarity of the brushes be kept the same as they were when the machine was a generator, so that the positive lead is connected to A and the negative lead to B. Electron flow through the armature winding will then be in the directions indicated by the arrows at the right of the conductors. The magnetic lines of force produced by these electron flows will be in the directions indicated by the curved arrows under the conductors. It will be seen that for conductors over the face of the south pole (where the main field is away from you), the field set up by the current in the conductors opposes the main field at the right of the conductors and strengthens the main field at the left of the conductors; the result is a force tending to pull these conductors to the right. For conductors over the face of the north pole (where the main field is out of the paper, towards you), exactly the same conditions apply. The main field thus exerts a force on each

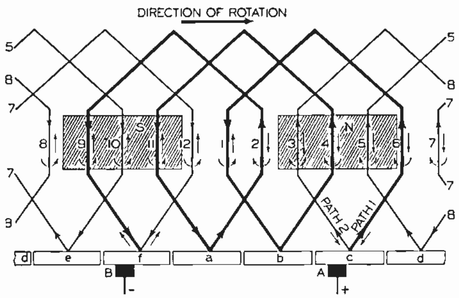


FIG. 15. Developed diagram of a simple lap-wound d.c. motor. Arrows alongside wires indicate direction of electron flow. Arrows on wires indicate direction of induced voltage (back e.m.f.). Curved arrows under conductors indicate directions of magnetic lines of force produced by the conductors.

armature conductor in the same direction, moving the armature to the right. The total force which tends to rotate the armature about the shaft is equal to the sum of the forces on the individual conductors.

Armature Current in a D.C. Motor. With the armature rotating in the direction shown, there is induced in each of the conductors a voltage which, in the absence of an externally-applied voltage, would tend to force electrons in the directions shown by the arrows on the conductors. The induced voltages oppose the externally-applied voltage, and the armature current is therefore equal to the difference between the two voltages divided by the ohmic resistance of the armature $\left(I_a = \frac{V_t - E_a}{R_a}\right)$. Note that for a motor the terminal voltage is greater than the induced voltage, whereas for a generator it is less than the induced voltage. The armature current in a d.c. motor is a maximum value at the instant of starting (when E_a is zero). Armature current decreases as a d.c. motor comes up to operating speed, because rotation of the armature induces in its conductors a voltage (E_a) which partially opposes the applied voltage.

Since the force on the armature conductors varies directly with the main flux (Φ) and the armature current (I_a), the torque developed at the armature shaft also varies with these two factors. The mechanical power P delivered by the shaft is proportional to the torque T times the speed S of the shaft ($P = K \times T \times S$). Now let us see what governs the speed of the motor.

First we will consider the shunt motor, electrical connections for which are shown in Fig. *16A*. Since the terminal voltage is constant (we assume a constant-voltage external source), both the field current and the flux are independent of the current supplied to the machine. (Actually, armature reaction reduces the flux slightly as armature current goes up due to an increased mechanical load.) When the machine is in equilibrium, the torque due to the interaction of the field and armature currents will be just sufficient to supply the required torque at the shaft at a given speed. Now suppose that the mechanical load is heavily increased. The armature slows down somewhat and (since Φ remains essentially constant) the induced voltage E_a is reduced. The difference between V_t and E_a increases, allowing a greater flow of armature current, and this in turn increases the torque. A new speed is finally reached, at which the torque is again sufficient to handle the mechanical load.

Actually, the armature speed change required to handle the complete range of load conditions from no-load to full-load is quite small, since a small change in the difference voltage ($V_t - E_a$),

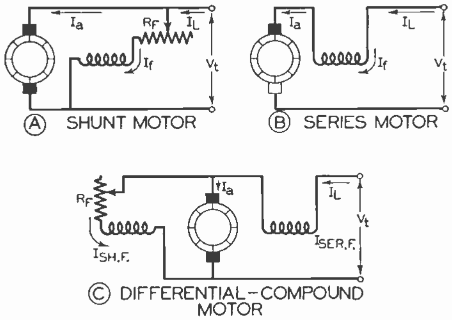


FIG. 16. Electrical circuits for three types of d.c. motors.

caused by a small change in induced voltage E_a, results in a large change in the current through the low-resistance armature windings. The shunt d.c. motor is usually considered a constant-speed machine.

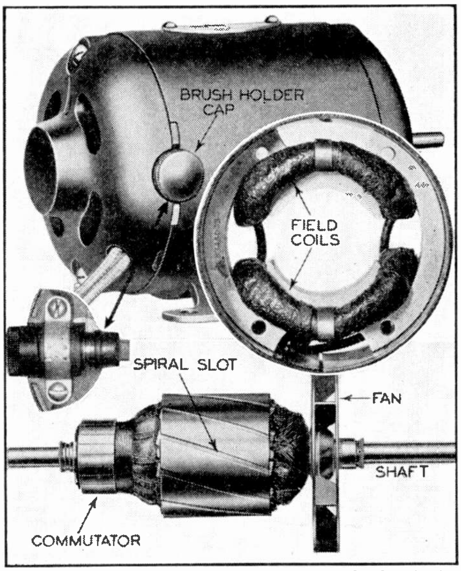
Suppose now that it is desired to increase the speed of rotation. Field rheostat R_F is adjusted to reduce I_f and hence Φ. E_a now decreases and I_a increases. The torque increases and the machine speeds up. A new speed is finally attained at which the torque due to armature current I_a

$$(I_a = \frac{V_t - E_a}{R_a})$$

is just sufficient to handle the mechanical load. It is obvious that, other conditions being fixed, the speed of a shunt motor increases as the field current is decreased, and vice versa.

Next consider the case of the series motor, the electrical circuit for which is given in Fig. *16B*. Since the field and armature currents are identical, an increase in the mechanical load is accompanied by an increase in both the armature current and the strength of the magnetic field. To reduce the induced voltage (in order to accommodate the increased armature current), the speed of the armature must decrease very much more than if the field strength had remained constant. For this reason the series motor is essentially a variable speed machine, with the speed decreasing as the mechanical load is increased.

If by accident, the strength of the magnetic field of a d.c. motor should be materially reduced (by opening the field circuit of a shunt motor, or by shorting turns in the field coils of a series motor), the armature speed will increase unduly in an attempt to generate sufficient back e.m.f. (E_a) to



Courtesy General Electric Co.

General Electric type P fractional-horsepower series motor for universal a.c.-d.c. operation. Both the field core and the armature core are made of high-quality laminated steel. The two brushes, on opposite sides of the armature, are connected in series with the two field poles. A fan at one end of the armature cools the motor by blowing air through ducts around the windings. Note that the laminations on the armature are stacked to give spiral slots; this construction tends to smooth out minor fluctuations in motor speed. These motors are also made with straight slots, which give better commutation (less sparking at the brushes) and more torque, but have a slightly fluttering speed characteristic. Universal series motors are used chiefly for high-speed applications where the load is directly connected and duty is intermittent, such as in small fans and blowers and in portable electric appliances. The speed of a series motor decreases rapidly as load is applied, so that full-load speed is only about 60% of no-load speed.

limit I_a to the value required by the mechanical load. This means that if the field circuit of a shunt-excited d.c. motor is opened while the motor is driving a very small load, the speed will increase rapidly until centrifugal force tears apart the armature and wrecks the motor; in engineering slang, the motor will "run away." This is also the case for the series motor when started under no-load conditions. The armature current requirement is then small, so that the field current (and flux) is accordingly low; the speed will increase to a very high value as already explained. Series motors are

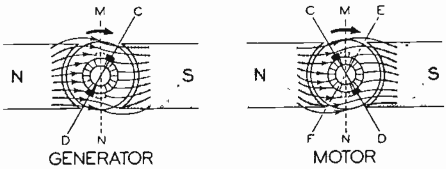


FIG. 17. Brushes are shifted from the center position *MN* in the manners shown here to compensate for armature reaction in d.c. generators and motors.

usually geared to their loads (as in street railway applications), so that no-load starting may not accidentally occur.

If it is desired to keep the speed of a motor constant within quite narrow limits independent of the load, the slight drop in speed with load may be compensated for in a shunt motor by the addition of a series field connection so as to oppose the main shunt field. This is called a *differential-compound motor* and its circuit is given in Fig. *16C*. The flux produced by the series field coil increases with load, thereby decreasing the main field. E_a is thereby reduced sufficiently to accommodate the increased armature current without a reduction in armature speed.

The direction of rotation of any series d.c. motor, shunt d.c. motor or universal a.c.-d.c. motor may be reversed by reversing the direction of electron flow through the armature winding, or by reversing the polarity of the field. If both are reversed, such as by reversing the polarity of the applied voltage, the direction of rotation will not change. These facts can be verified by referring to Fig. *15*.

Commutation in D.C. Motors

The subjects of armature reaction and of means for obtaining proper commutation are equally as important for motors as for generators. You will recall that in a generator the armature pulls the field along with it to a certain extent; in other words, the armature distorts the field. In a motor this distortion is in the opposite direction; the armature pushes the field backwards, if we consider the armature as moving forward. Adjustment to compensate for this field distortion (armature reaction) is made by shifting the brushes to points where no sparking occurs. Figure *17* shows the difference between generator and motor armature reaction, and how brushes are set to compensate for it in each case. Generator brushes are shifted from the center in the direction of rotation until no sparking occurs; motor brushes are shifted opposite to the direction of rotation until there is no sparking.

Most motors are designed to operate in only one direction. In this case brush setting is a compartively simple matter. But it is not so easy to solve the problem of brush position in a reversible d.c. motor. It is physically impractical to reset the brushes each time the motor is reversed, and consequently the brushes of reversible motors are set at their neutral positions, and means are provided for proper commutation.

By placing in the faces of the field poles a number of conductors equal to the number of conductors on the armature and connecting these field pole conductors in series with the armature, we can produce an extra magnetic field which is equal in strength to the magnetic field created by the armature conductors. By making proper connections to the field pole conductors (known as *compensating windings*), the two magnetic fields can be made to oppose and cancel each other. The result is uniform distribution of the main field flux regardless of the direction of armature rotation.

In order to secure proper commutation in a reversible d.c. motor, some means must be provided for counteracting the self-inductance of the armature conductors. The brushes must be kept just midway between the poles, and cannot be shifted to accomplish this purpose, so reversible d.c. motors generally have small *interpoles,* located between the main poles. The small magnetic fields produced by these interpoles induce currents in the conductors which, at the instant of commutation, oppose the currents due to the self-inductance of the armature winding. Current in each coil is thus forced to zero the instant before that coil is shorted by a brush, and sparking is eliminated. The interpole windings are connected in series with the armature.

In small reversible motors, the compensating windings are sometimes omitted and the interpoles are relied upon for proper commutation and the elimination of sparking. Because they are in series with the armature, armature reaction is taken care of automatically and this self-adjustment varies with the load. Figures *18A* and *18B* show the positions of compensating windings and the interpoles. It will be seen from Fig. *18B* that the interpole is of such polarity as to extend the influence of that main pole which the armature conductor is just leaving. The voltage induced in the short-circuited coil thus has the same polarity as if the brushes had been set backwards. When the direction of rotation of the motor is reversed (by reversing the armature current), the polarity of the interpoles is also reversed, so that again their effect is equivalent to setting the brushes back from the neutral zones.

Efficiency of Motors

The efficiency of a motor is equal to the ratio of the mechanical power developed to the electrical power supplied to it from the line. The mechanical power is expressed in horsepower (abbreviated h.p.; 1 h.p. = 746 watts). The electrical power input is expressed in kilowatts (abbreviated kw.; 1 kw. = 1,000 watts). Part of the electrical power is used up in the I^2R losses in the field and armature windings, in hysteresis and eddy current losses in

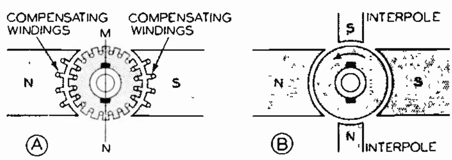


Fig. 18. Locations of compensating windings and interpoles in reversible d.c. motors.

the armature core, and part of the mechanical power developed is used up in frictional and windage losses; only the remainder is available as useful mechanical power output. If the input power is 1,100 watts, of which 100 watts goes for losses, the power available for mechanical work is 1,000 watts or 1.34 h.p. The efficiency is

$$\frac{1{,}000}{1{,}100} = 0.909 = 90.9\%.$$

The A.C. Single-Phase Motor

A.C. Operation of a Series D.C. Motor. In the study of the d.c. motor, it was shown that if both the polarity of the field and the direction of the armature current were reversed, the direction of rotation of the motor would remain the same. This means that if an a.c. voltage is applied to the terminals of a series d.c. motor, as indicated in Fig. *19,* it will still operate. Each time the voltage (and hence the line current) reverses, both the field and the armature current will reverse, and the armature will continue to rotate in the same direction. Such operation is not very efficient, however, because of high hysteresis and eddy current losses in the massive magnetic system due to the flow of alternating current through the field winding.

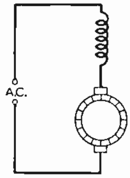


Fig. 19. A.C. series motor.

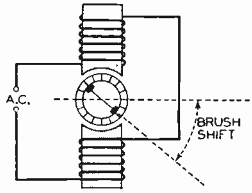


Fig. 20. A.C. repulsion motor.

In industrial applications where it is desired to operate a motor on either a.c. or d.c., the series motor is adapted to such operation by special design of the magnetic system to reduce losses. The armature core and component parts of the field structure are built up of thin sheets (laminations), the natural oxide coatings of which reduce eddy currents to a minimum. The universal motors used for driving remote controls on radio receivers, vacuum cleaners, fans, winding machines, etc., are often of the series type.

The A.C. Repulsion Motor. Suppose that the armature of an ordinary d.c. motor is placed between an a.c.-excited field structure, as shown in Fig. *20*. Let the armature brushes be short-circuited and be advanced beyond the neutral zone by 10 to 20 degrees. At each half-cycle of the applied a.c., the polarity of the field poles reverses, causing a reversal in the magnetic flux through the armature. The changing flux through the short-circuited armature coil induces in this coil a current which sets up its own field practically along the axis of the brushes. This field interacts with the main field to produce rotation of the armature. When the main field reverses, the induced current in the armature reverses, so that the direction of rotation of the armature remains the same. This is an *a.c. repulsion motor.* This type of motor is used extensively for low-power applications, because of its appreciable starting torque.

The Simplified A.C. Generator as a Synchronous Motor. Now assume that an a.c. voltage is applied to the stationary armature winding of a two-pole rotating-field type a.c. generator, as indicated in Fig. *21*. The rotating field is still supplied with direct current through slip rings, just as in the a.c. generator. The current through the stationary armature winding reverses every half-cycle, and consequently the polarity of armature poles X and Y reverses every half-cycle. At one instant, X will be north and Y south; a half-cycle later, X will be south and Y north, so X and Y are called a.c. poles. Consider a moment when X is south; it will then attract the north field pole, while Y (being north) will attract the south field pole. With the field in the

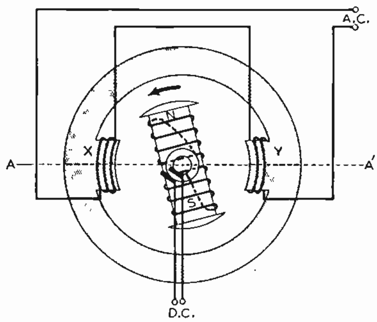


Fig. 21. A simplified a.c. synchronous motor.

position shown, it will rotate in a counter-clockwise direction until it lines up in the position AA'. Now assume that X and Y reverse polarity. Nothing will happen. The field structure is in a dead-center position and cannot be rotated by changes in the polarity of X and Y.

Assume, however, that somehow the field structure is brought up to such speed that it travels just beyond the dead-center position AA' by the time X and Y reverse their polarity. The a.c. poles now repel the field structure, keeping it rotating in the original direction. Assume, further, that the rotor speed is just right so that (after another half-revolution) S will be just beyond X (and N will be just beyond Y) when the a.c. poles reverse again. X is now south and Y north, and the force of repulsion continues to keep the rotor (field poles) turning in the original direction. The rotor speed necessary to make this action continuous is called the *synchronous speed.* Once the rotor is brought up to this speed (say by an external drive), the latter drive may be disconnected, since the mechanical inertia of the rotor will then carry it over the dead spot AA' at each half-revolution. This is the principle of the synchronous motor.

It is not always convenient to start the motor up externally. Other means must be sought. For small synchronous motors of the type used in electric clocks, turntable drives, etc., manual spinning of the rotor to carry it over the dead spot is sometimes sufficient. In motors of the type to be described in the next section, a long, quick pull of a cord coiled tightly about the shaft serves the same purpose. Larger motors require other treatment, which will be discussed in following sections.

Minimum-Reluctance Type Synchronous Motor. An interesting development of single-phase synchronous motors, particularly adaptable to use where very small mechanical power is required, is shown in Fig. *22A*. The four-pole rotating system is nothing more than an annealed-steel rotor without windings, mounted on a shaft. This motor operates on the principle of minimum magnetic reluctance. The rotor poles tend to take positions which will make the reluctance of the field magnet structure a minimum, and consequently the rotor poles tend to line up with the field poles.

With alternating current flowing through the field pole windings, the strength of a field pole increases from zero to a maximum and drops down to zero again once for each half-cycle. If field current is increasing at the instant when the rotor is in the position shown in Fig. *22A*, the gradually increasing flux at field pole M will produce a gradually increasing force tending to bring rotor pole W in front of field pole M; at the same time, pole Y will be pulled toward field pole N.

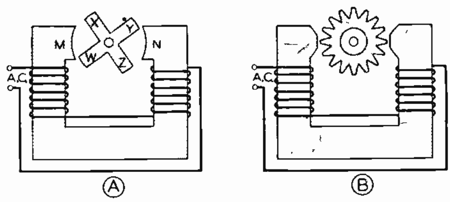


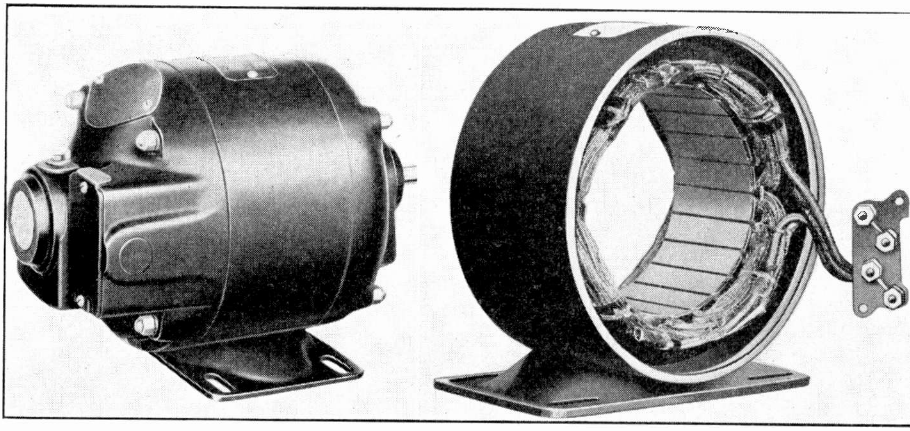
FIG. 22. Minimum-reluctance type synchronous motors.

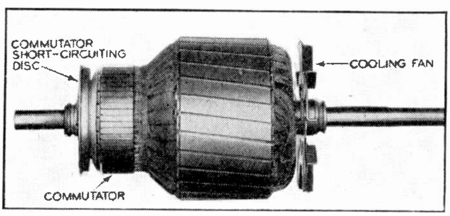
Poles W and Y will line up with poles M and N when the alternating current reaches its peak value, and the reluctance of the magnetic path will then be a minimum. Now, as the alternating current drops down to zero and reverses its direction for the next half-cycle, there will be no further force tending to rotate the armature. Obviously this type of motor is not self-starting.

If a minimum-reluctance type synchronous motor like that shown in Fig. *22A* is brought up to synchronous speed manually, the rotor will have sufficient momentum so that pole W will coast beyond field pole M. The farther beyond M the rotor pole gets, the less will be the attraction between the two poles, for the flux at M is now decreasing, and the force on W depends upon both the field strength and the distance between the poles. When the flux at M reverses and begins increasing in value again, pole Z will be closer than pole W to M, and we have a force which tends to keep the rotor rotating in the same direction. This same analysis applies to the toothed sixteen-pole rotor shown in Fig. *22B*. In each case, the amount of rotor rotation during each half-cycle is equivalent to the distance between two adjacent rotor poles.

The speed of minimum-reluctance type motors like those shown in Fig. *22* is calculated just as if the poles were employed in a synchronous motor thus *lowers the speed.*

Motors of this type have many interesting applications. As already indicated, the motors employed in clocks and constant-speed phonograph turntable drives are of this type. The national frequency standard maintained at the National Bureau of Standards employs a synchronous motor of this type in a clock operating from a submultiple of its 100-kilocycle crystals.





Courtesy General Electric Co.
General Electric type RSA single-phase repulsion-induction a.c. motor. This unit starts as a repulsion motor, with the brushes short-circuited to give high starting torque. When operating speed is reached a centrifugal device automatically forces a short-circuiting disc against the ends of commutator bars, shorting them all together. The unit then operates as a squirrel-cage single-phase induction motor having desirable constant-speed characteristics. These motors are used extensively to drive watercooling pumps in radio stations, to drive woodworking machinery, and for other applications requiring fractional-horsepower motors with high starting torque and essentially constant speed.

electromagnets. If f is the frequency, P the number of poles and n the revolutions per minute, then $n = \frac{120f}{P}$. This is the same simple relation used for determining the frequency of an a.c. generator. Thus, for the four-pole rotor and a 60-cycle supply, the speed is $n = \frac{120 \times 60}{4} = 1{,}800$ r.p.m. For the sixteen-pole rotor on the same supply, the speed is $n = \frac{120 \times 60}{16} = 450$ r.p.m. Increasing the number of rotor poles The frequency used is 1,000 cycles per second, and the clock speed is 1,200 r.p.m. The number of teeth (poles) on the rotor is $P = \frac{120f}{n} = \frac{120 \times 1{,}000}{1{,}200} = 100$. A minimum-reluctance type a.c. motor will revolve in the direction in which it is initially started manually.

The Revolving Field. Suppose that two sets of a.c. poles were used in Fig. *21,* the second set being placed between X and Y and having an independent set of windings as shown in Fig. *23.* Now if the connections to coils L and

M are made through a condenser (C) and the connections to coils X and Y are made through a resistor (R), the a.c. currents in the two sets of coils can be made to have equal peak values and be approximately 90 degrees out of phase. The two a.c. fields will therefore be at right angles to each other and 90 degrees out of phase. Figure *24* shows a series of drawings each with two vectors at right angles to each other, representing the space separation of the two fields. Vector *1* represents the a.c. field produced by windings X-Y in Fig. *23*, and vector *2* the a.c. field produced by windings L-M. The 90-degree phase difference of the two fields is represented by the fact that one vector is zero when the other is a maximum, and vice versa. Note that field *1* is a maximum in one direction at A, is nearly zero in this same direction at C, and is a maximum in the opposite direction at E. Field *2* is nearly zero at A, a maximum in the same direction at C, and nearly zero again at E.

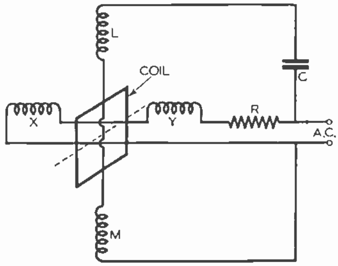
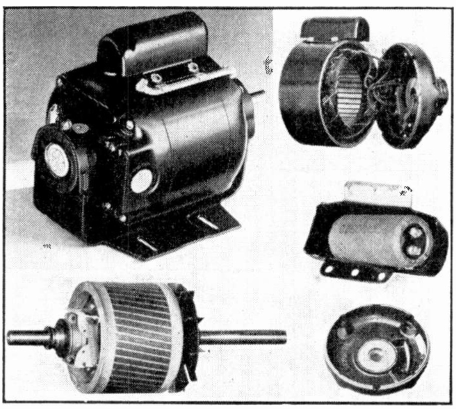


FIG. 23. Split-phase connection employed to produce a revolving magnetic field.



Courtesy General Electric Co.

These photographs show a typical split-phase a.c. induction motor and its component parts (General Electric type KH fractional-horsepower motor). These motors employ a dry electrolytic condenser (shown at the right center and usually mounted on top of the motor) to produce 90° out-of-phase fields for starting purposes. When operating speed is reached, a centrifugal device mounted on the armature releases the pressure against contacts inside one of the end castings, thereby disconnecting the starting condenser. The unit then runs as a true constant-speed single-phase induction motor. Capacitor-start induction motors provide high starting torque with relatively low starting current. They are widely used for air conditioning and cooling machinery in radio stations, for water systems, for oil burners and for a host of other low-power applications. The squirrel-cage rotor has a one-piece cast aluminum winding. Reversing the connections to the starting winding reverses the direction of rotation, for an induction motor rotates in whichever direction it is started.

If we add the two vectors in each of the cases shown in Fig. *24*, we obtain a resultant vector (R) of *constant amplitude* but of *continuously changing direction*. This indicates that the magnitude of the resultant field is constant but that the field revolves continuously about the armature shaft as a center.

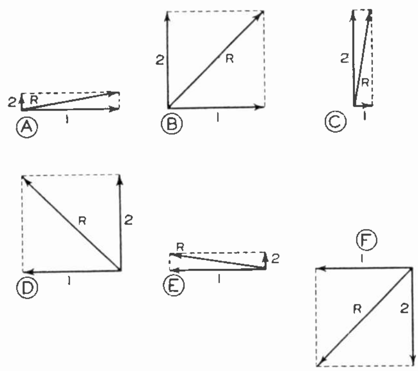


FIG. 24. The magnetic fields produced by coils at right angles to each other are shown as *1* and *2*. Since the coils are fed 90° out of phase, *1* will be a maximum when *2* is zero, and vice versa. Since each field varies cyclically we have the conditions shown in *A* to *F*. If the net field is determined by addition, taking phase into account, we get the resultant *R*, which revolves at constant strength and therefore represents a revolving field.

It is as if a field structure of the type forming poles N and S in Fig. *21* actually revolved physically.

Now refer back to Fig. *24*. The conditions depicted between A and E correspond to a half-cycle of the a.c. voltage applied to the field windings. The resultant vector (R) representing the resultant field has gone through one-half a revolution during that time. The revolving field therefore rotates at synchronous speed, making one revolution per cycle per pair of poles. Here,

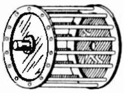


FIG. 25. Rotor of an induction motor, without the steel laminations.

the number of poles making up each split phase is of importance. Thus, in the example of Fig. *23*, $n = \frac{120f}{P} = \frac{120 \times 60}{2} = 3{,}600$ r.p.m.

We have just shown how we may obtain a magnetic field revolving in space even though the field coils producing it are stationary. This is called a *revolving field.* The winding arrangement of the field coils is called a *split-phase connection.* Let us see how it can be used.

The Split-Phase Induction Motor. If a short-circuited coil is in the field structure of Fig. *23,* the revolving field, passing this coil, changes the flux threading it and induces a voltage. The voltage sets up a current in the short-circuited coil which, by Lenz's law, tends to oppose the field producing it. The result is a force on the coil which rotates it in the direction of the revolving field. If the coil should catch up to the field (i.e., rotate at synchronous speed), there would no longer be any change of flux threading it. The force on it would reduce to zero and it would tend to slow down. It slows down until its torque is sufficient for whatever mechanical load is applied to its shaft. This is the principle of the split-phase circuit so widely used for starting induction motors.

Once a split-phase induction motor is brought nearly up to synchronous speed, it is no longer necessary to have two fields 90° out of phase with each other in the stationary armature. The reason is simply that the rotor itself is now producing its own magnetic field (due to the change in flux linkages through the shorted rotor coils as they rotate in the oscillating field produced by alternating current flowing through one pair of stationary armature poles), and this rotor-produced magnetic field reacts with the stationary oscillating field to produce *a revolving magnetic field* which is essentially constant in strength. This is the true induction motor action.

A rotor-produced revolving field exists in all induction motors once they are brought up to synchronous speed by some means, and in most cases is the only revolving field used to maintain rotation at full load. The starting circuit is disconnected by a centrifugally-operated switch as soon as a certain speed is reached; in Fig. *23* this switch would open the condenser circuit, leaving only the main poles X and Y to produce an oscillating stationary field. These two main windings would be distributed around the armature to equalize the torque.

The difference between the speed of the revolving field and the speed of the rotor in an induction motor is called the slip. Increasing the load on an induction motor slows down the rotor slightly, thereby increasing the slip and

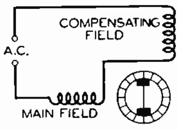


FIG. 26. Circuit of an a.c. repulsion-induction motor.

producing the increased rotor currents necessary to handle the extra load. The slip cannot be more than about 5% of the synchronous speed, if rotation is to be maintained; when the increase in load is so great that slip exceeds this value, the motor stops.

In commercial induction motors, a large number of short-circuited loops are employed on the armature, to secure more uniform torque. A typical rotor is shown in Fig. *25*. Speed may be controlled by inserting resistors in series with the rotor loops; this is possible when the rotor is made up of coil elements which are connected to slip rings on the rotor shaft. The greater the resistance, the lower the speed.

A.C. Repulsion-Induction Motor. A d.c. motor may act as a combination repulsion-induction a.c. motor. It starts as a repulsion motor with the brushes short-circuited; as it approaches synchronous speed, the short between the brushes is automatically opened, giving an induction motor. Instead of shifting the brushes to one side as shown in Fig. *20*, the brushes are usually left at neutral and a compensating field is used to provide a 90-degree out-of-phase field, as indicated in Fig. *26*. This provides the off-neutral field required to give starting torque. When the armature gets up to nearly full speed (synchronous minus slip), the brushes are raised by a centrifugal device, and at the same time all the segments on the commutator are shorted. The action from now on is that of an induction motor.

Self-Starting Synchronous Motor. A single-phase synchronous motor may be made self-starting. A split-phase a.c. field connection is employed for obtaining a revolving field, and short-circuited coils are embedded in the d.c. field structure (at poles *N* and *S* in Fig. *21*) to provide an auxiliary armature. The machine starts as a split-phase induction motor. As it comes up to nearly synchronous speed, the d.c. magnetic system locks into step with the revolving field and rotates at synchronous speed.

TEST QUESTIONS

Be sure to number your Answer Sheet with the *number* appearing on the front cover underneath the title of this text.

Place your Student Number on every Answer Sheet.

Never hold up one set of lesson answers until you have another ready to send in. Send each lesson in by itself before you start on the next lesson. In this way we will be able to work together much more closely, you'll get more out of your Course, and you will receive the best possible lesson service.

1. What four factors control the voltage induced in a system of conductors moving in a magnetic field?
2. What is the purpose of the commutator in a d.c. generator?
3. In what direction from the dead-center position should the brushes of a d.c. generator be moved in order to minimize sparking?
4. How can a small a.c. generator be made self-excited?
5. What is meant by the term "voltage regulation" in connection with a generator?
6. Why are series and shunt field coils sometimes used together in a d.c. generator?
7. Why does the armature current in a d.c. motor decrease as the motor comes up to operating speed?
8. What will happen if the field circuit of a shunt-excited d.c. motor is opened while the motor is driving a very small load?
9. Will the direction of rotation of a series d.c. motor be reversed if the polarity of the applied voltage is reversed?
10. What happens to the speed of a synchronous motor when the number of rotor poles is increased?