DE FOREST'S TRAINING, INC.

LESSON BINDER

2533 N. ASHLAND AVE. CHICAGO, ILL.

DE FOREST'S TRAINING, INC.

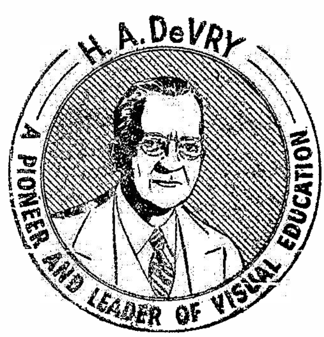
LESSON BINDER

2533 N. ASHLAND AVE. CHICAGO, ILL.

DE FOREST'S
TRAINING, Inc.

INTRODUCTION

Founded 1931 by



1-26812

A Training Program such as follows this introduction, is beneficial in two entirely different respects, one of which is seldom mentioned and may never have occurred to you.

First, you have enrolled for this program to gain essential knowledge of Radio and Electronics. Knowledge which gives you a thorough understanding of the operating principles yet is practical enough to assist you in obtaining a position in this field.

Second:- As you study the descriptions and explanations of the Lesson assignments, you will obtain the benefits of a training in Character Building. Whether you realize it or not, it requires a considerable amount of Ambition, Determination and Self Management to plan and maintain your own schedule of Study.

There is no instructor at your elbow, giving you definite daily assignments, there is no definite fixed hour at which some one else says you must report and you have no visible classmates to keep up with. You are on your own and it requires real ability to do a good job at being your own boss.

You will find many distracting influences, every one of which will tend to delay your study program. There will be parties, dates, dances and movies, any one of which may offer more immediate enjoyment than the same time spent in study. Naturally, we do not suggest or recommend that you give up all of your social activities and pleasures but, by deciding definitely and quickly whether or not you can afford to participate in the various events as they occur, you will be developing that all important character trait of making decisions.

After you have made a decision you may be persuaded to change it. This persuasion may originate in others or yourself but, every time you overcome it, you will be developing your determination.

The very fact that you have started this training program proves you have ambition and, in the business world of today that means you hope to rise to a good position which may carry the responsibility of directing the efforts of others.

What better training could you possibly obtain than in directing your own efforts? What better experience could you make than in laying out a study program for yourself and making sure that you carry it out to completion?

EXPERIENCE VS. TRAINING

As the words, "Training" and "Experience" are commonly used, they sometimes have but little difference in meaning therefore

we want to explain them in greater detail. For example, when any employees are hired by an organization, for even a simple routine job, they are "trained" by being shown all the details of the work. Then, after 12 months on the same job, they have a year of "Experience".

While these are the common uses of the words, in reality, all the experience was gained during the period of learning the details of the work. Doing the same thing, over and over in the same way, does not add to your experience. To gain real experience you must do something new or different. However, by doing the same things over and over, you train your mind and body to complete the necessary operations in the shortest time and with the least effort. Thus, everyone who claims years of "Experience" along certain lines, really means they have had years of "Training".

We assume your hands are already well trained to obey your mind and the object of these assignments, with their examinations, is to train your mind. Every principle, action or unit we explain, provides you with experience; and making use of these explanations by answering questions, solving problems, or performing practical work, provides you with training.

There is a great difference between training the mind and the body. An animal, with little if any mind, can be trained to perform difficult tricks. At a given command, he makes certain body movements for which he receives a reward, usually his favorite food. All the thinking has been done by the trainer, the animal merely carries out his ideas.

There are great variations in modern professions. For example, it is comparatively easy for a pianist to learn to read printed music and know exactly how each printed note should be played. However, it requires years of practice to train the fingers to respond instantly and reproduce the music the printed notes convey to the mind.

In Radio and Electronics conditions are reversed as it requires comparatively little practice to train the hands properly. The real job is in training the mind.

PLAN OF YOUR TRAINING

To learn to play the piano, you start training your fingers by practicing scales and gradually advance to more difficult exercises. We follow the same general plan by first explaining the general principles which apply particularly to Radio and Electronics, showing how each can be applied to your everyday work.

Perhaps you have already learned these first principles, but do not think a study of the early Lessons will be a waste of

time. We give you only those explanations which are necessary for a full understanding of your later work. Most of our students, including numbers of college graduates, appreciate these early assignments because they realize their value.

You may not always see why we spend time on details that apparently have little to do with Radio, but remember, we are interested only in your final success which depends entirely on the knowledge you gain. We want you to get over the ground, just as quickly as possible, without missing anything, the lack of which may cause trouble later on.

We know what problems you are going to meet and every detail we explain will be necessary to your future work. Therefore, when you are studying Ohm's Law or other simple subjects which you feel you already know, or which seem to have no bearing on Radio, don't forget that this entire training has been carefully and completely planned to enable you to really learn the work in the shortest possible time.

The first assignments are easy but don't make the mistake of going over them in a hurry or thinking you know everything they contain. The explanations of each advance assignment are based on the previous Lessons therefore, the first section of the training forms the foundation for all that follows. You cannot build a substantial or permanent house without a good foundation and the same is even more true of your training.

HOW TO STUDY

Set aside a certain convenient time for study every day and make up your mind to permit nothing to interfere. Let your relatives and friends know that, during this hour, you are not to be disturbed. Regular study will bring the quickest progress and we have little respect for the student who puts off studying today with the excuse that more time will be spent in study tomorrow.

First, fold out the illustration pages and referring to them when necessary, read your Lesson over carefully before looking at the questions. Then begin, one by one, to answer the questions in order. If some question seems impossible to answer, finish all the others you can and then read the Lesson again. If, after reading a lesson several times, you are still unable to answer some question or solve a problem, write to our Instruction Department, stating clearly just what you cannot understand, and they will be glad to give you additional explanations.

Don't give up without a real attempt. The invention of the Radio tube was not just an accident and its problems were solved only after years of study and experiment. While we don't expect you to study years, or even days, on one problem,

you'll find solving a difficult one, without asking for help, the finest training possible.

DON'T BECOME DISCOURAGED

Worth while training -- training that will qualify you for the more interesting and better opportunities in Radio cannot be acquired in a week or a month. This is fortunate because, if by taking a few weeks training, anyone could hold down a good job in this newer industry, then thousands would qualify themselves for it and the field would be crowded.

It requires backbone to achieve success. At times, when the lessons seem difficult, you'll feel like neglecting your study hour. At other times, you will want to lay aside your Lessons in favor of movies or some other amusement. Make up your mind that you are going to become a success in this work -- that you are not going to yield that determination to any other consideration. Your Lesson record will soon show whether you have the necessary backbone and the needed "stick-to-it" will power.

MECHANICS OF HOME STUDY

The last page of each Lesson, following the illustrations, is a sheet containing questions for you to answer. Usually, there is plenty of room for you to write your answer in the space below each question. In fact, we want you to follow this plan because short, concise answers are the best.

Detach this sheet from the Lesson, carefully write, or print your name, address and registration number in the spaces provided. Your registration or "Student Number" is extremely important and should be written plainly, not only on your examinations, but on every page of every letter you send us. This number identifies your correspondence in case of damage in the mail or accidental separation of the pages. To answer the question, "How many advance Lessons have you now on hand?", simply count the number of Lessons you have received but not studied and write that number in the space provided. Then, write in your answers to the questions.

When you have two of these question sheets finished, place them in one of the small, self-addressed envelopes and mail to us. Always send us, for grading, two question sheets at a time. If you send more, it may delay the mailing of advance Lessons because they are released only as your answers show the former Lessons have been completed. When you finish one set of Lesson questions, lay it aside until you have finished the next one.

Our training is designed to meet the requirements of the busy individual forced to study during leisure time. We do not

restrict your progress or expect you to finish any certain number of Lessons each month. You may study at a rate of speed best suited to your personal convenience but make sure you understand each Lesson before advancing to the next.

On its arrival here, each question sheet will be carefully graded by a competent instructor who will check mark (√) each answer if correct or satisfactory, or question mark (?) it if wrong or doubtful. In some cases he may allow half (1/2) credit. The examination will then be graded and returned with a duplicate sheet with the correct answers. By this method, you are able to compare your answers with ours and accurately check any mistakes you may have made. These question and answer sheets also form a valuable ready reference.

Do not become impatient if your graded examinations are not returned for several days. Make allowances for delay in the mail, both ways, our five day week of mail receipts, the time required for careful grading and the maintainence of our records, not only of your grades but your eligibility for advance study material. While waiting, go ahead and study the next advance Lesson, or if you are not clear on some points, review the earlier Lessons.

Our system of grading is simple. We use the words "Excellent", "Good" and "Fair" or their abbreviations, and the tabulation below indicates the approximate numerical value of a graded examination paper.

Ex+ = 97 - 100	Good+ = 87 - 89	Fair+ = 77 - 79
Ex = 94 - 96	Good = 84 - 86	Fair = 75 - 76
Ex- = 90 - 93	Good- = 80 - 83	

All examinations which do not warrant a grade of 75 are returned to you, with suggestions, in order that you may have an opportunity to raise your mark before the grade is entered on our records. Should you receive a returned question sheet, marked "Please Correct and Return", go over the Lesson and suggestions carefully. As you will have only one opportunity to revise your answers, make what corrections you can and then return your test to us for final grading.

If, for any reason, you feel that it is necessary to write for service on any of your study material, always be sure to indicate the exact Lesson, with identification, such as FDM-5, TRA-7---, in addition to placing your name, student number and correct address on your communication.

WHAT THIS TRAINING WILL DO FOR YOU

This Training will prepare you for work in Radio and other Electronic apparatus which requires the use of vacuum tubes.

As more trained people are needed, your services will become of greater value.

Our plan is to train you and then help you find a position in which you will have the best personal advantages. At your command is a staff of instructors anxious to help you with your studies as well as with problems which may arise in your later work. As a student, you have enlisted our services in helping you to become successful in this work.

We are sincerely and intensely interested in your progress and are depending on you to do your part, not only by conscientious study but by giving us every opportunity of helping you.

DE FOREST'S
TRAINING, Inc.

METHODS OF SOLVING PROBLEMS

Founded 1931 by

RADIO FUNDAMENTALS

METHODS OF SOLVING PROBLEMS

Arithmetic ---------------------------------- Page 1
Addition ------------------------------------ Page 2
Subtraction --------------------------------- Page 3
Multiplication ------------------------------ Page 5
Division ------------------------------------ Page 7
Fractions ----------------------------------- Page 8
Addition of Fractions ----------------------- Page 9
Subtraction of Fractions -------------------- Page 11
Multiplication of Fractions ----------------- Page 11
Division of Fractions ----------------------- Page 12
Decimals ------------------------------------ Page 13
Addition and Subtraction of Decimals ----- Page 14
Multiplication of Decimals ------------------ Page 14
Division of Decimals ------------------------ Page 15
Square Root --------------------------------- Page 17
Practice Problems --------------------------- Page 20
Answers to Practice Problems ---------------- Page 24

* * * * *

"The best advice, as it appears to me, is old and simple. Get knowledge and understanding. Determine to get the most possible out of yourself by doing, to the best of your power, useful work that comes your way. There are no new recipes for success in life. A good aim, diligence, honest work and a determination to succeed, will win out every time."

-- James J. Hill

As quite a large number of students, starting the study of Radio and Electronics, have been out of school for a number of years, it is only natural for them to be somewhat "rusty" in certain subjects. Although the explanations of this program have been arranged to correct this condition as rapidly and easily as possible, we expect some assistance may be of benefit in regard to certain details and therefore want you to feel free to ask questions at any time.

This training does not include subjects such as Spelling, Grammar and Penmanship therefore any "rustiness" along these lines can be worn off gradually. However, there are some explanations and problems which require an immediate understanding and use of arithmetic.

For this reason, the explanations of this Lesson, which start way back in "Kindergarten", are given only as a review or "Refresher" for those students who find it necessary. If you are familiar with the subject, ignore this Lesson but, if you are "rusty" on the proper method of handling Fractions, Decimals and so on, study the Lesson carefully and then keep it handy for future reference.

Instead of the usual examination which is sent in for grading, this Lesson has a number of "Practice Problems" covering the main operations of arithmetic. These problems are not a part of your required program and need not be returned for grading. However, if you feel a review of arithmetic will be beneficial, we urge you to work all of these practice problems and check your answers with those given on the last page. Then, if you feel that further explanations are needed, we will be glad to extend our regular consultation service in regard to them.

ARITHMETIC

The whole subject of Arithmetic is based on the figure "1" which is called a unit or unity. It can be added, indicated by the sign "+", it can be multiplied, indicated by the sign "x", it can be divided, indicated by the sign "÷" and can be subtracted as shown by the sign "-". The sign "=" means "is equal to" or "the result is".

Should we take two units and add them, we can write it as $1 + 1 = 2$. Adding a unit to 2, we have $2 + 1 = 3$, or we can write $1 + 1 + 1 = 3$. By adding one more unit each time, we arrive at the figures 4, 5, 6, 7, 8 and 9. These, with 1, 2 and 3 are called the digits which, with the number "0" called zero, include all the digits used for writing any number. You will notice that each one of these digits is just 1 larger than the one before it. Thus: $6 + 1 = 7$, $7 + 1 = 8$ and so on.

Should we add 1 to 9, the result will be 10, which requires two digits. Here again, we can add units and 10 + 1 = 11, 11 + 1 = 12 and so on up to 19, when 19 + 1 = 20. In every case where two digits are used, the one on the left represents the groups of ten units and the one on the right represents the number of single units.

Take the number 76 for instance, the 7 represents seven groups of ten units and the 6 represents 6 single units. The entire number is read as seventy-six. This same method is carried out for each extra digit which is used and, for a large number such as 3246358, we split it up as follows:

MILLIONS	HUNDRED THOUSANDS	TEN THOUSANDS	THOUSANDS	HUNDREDS	TENS	UNITS
3	2	4	6	3	5	8

and read it as three million, two hundred and forty-six thousand, three hundred and fifty-eight.

ADDITION

To show you how the units are handled, suppose we add 4 and 5. We know that 4 equals 1 + 1 + 1 + 1, and can think of 5 + 4 the same as 5 + 1 + 1 + 1 + 1. We can easily find the result by remembering that 5 + 1 = 6, 6 + 1 = 7, 7 + 1 = 8 and 8 + 1 = 9. In this way, we have used the four units by adding them to 5, one by one, to reach the answer of 9.

After very little practice, this can be done quite easily, without stopping to count the units. The usual plan is to place the numbers under each other and then add -- thus:

2	6	1
4	8	6
7	3	5
5	9	7
18	26	19

To add larger numbers, they are written one above the other, taking care to place the units exactly over each other. For example, to add the following numbers we write them as shown below.

```
4329
   7
 246
1857
----
6439
```

Notice here, the units at the right of each number form a vertical line or column, the digits which represent groups

of 10 units are also in a vertical line or column and the same is true of the digits which represent groups of 100 units and 1000 units.

A line is drawn below the bottom number and the units are added first. Starting at the top

$$9 + 7 + 6 + 7 = 29$$

The "9" of this addition is written directly below, or in the units column and the "2", which represents two groups of ten units, is either actually or mentally placed above the 10 units column. This is usually thought of as "2" to carry".

Next, we add the groups of 10 units, including the 2 carried over, and have

$$2 + 2 + 4 + 5 = 13$$

Following the plan already explained, the "3" is written directly below or in the "10" column and the "1" is carried over to the next left hand, or hundreds column.

The hundreds are then added, including the "1" carried over, for a total of

$$1 + 3 + 2 + 8 = 14$$

This time, the "4" is written in the "100" column and the "1" carried over to the "1000" column. Adding the thousands and including the "1" carried over, we have

$$1 + 4 + 1 = 6$$

The "6" is placed in the "thousands" column and completes the addition. Reading the full answer, we have six thousand, four hundred and thirty-nine.

Notice here, the same general plan is followed all the way through and, starting at the right hand units column, we work toward the left.

SUBTRACTION

To subtract numbers, the process of addition is reversed. In other words, we want to find out how much larger one number is than another. Suppose we want to subtract 5 from 8, and write the problem as $8 - 5 = ?$ We know that $8 = 5 + 1 + 1 + 1$, and taking the 5 away, we have $1 + 1 + 1 = 3$. Thus we can say that $8 - 5 = 3$.

For larger numbers, the idea is exactly the same but the value of the different digits which make up a large number must be kept in mind. For example, to subtract 3789 from 5842, we can write the numbers the same as for addition. Thus:-

```
 5842
 3789
 ----
```

Starting at the right hand side in the units column, we have to subtract 9 from 2 but, as 9 is larger than 2, we can not very well make the subtraction. We know however, that the next digit to the left shows the number of groups of 10 units therefore, we can take one group of 10 units and add it to the 2 and think of the number as

```
 5 8 3 12
 3 7 8  9
 --------
        3
```

We can easily subtract 9 from 12 for the result of 3, which we write underneath the 9 and below the line. To continue, we subtract the next left digits, which represent the groups of 10, and find that 8 is to be subtracted from 3. This is about the same as subtracting 9 from 2, so that, as before, we borrow a group of 100 from the next left column and think of the number as

```
 5 7 13 12
 3 7  8  9
 ---------
      5  3
```

Here we subtract 8 from 13 and write the answer, which is 5, under the 8.

In the next column to the left, we subtract 7 from 7 which, of course, leaves nothing or 0. This is written under the 7.

In the last left column, we subtract 3 from 5 and as 5 - 3 = 2, we write the 2 under the 3. The complete subtraction is,

```
 5842                 5 7 13 12
 3789     done as     3 7  8  9
 ----                 ---------
 2053                 2 0  5  3
```

To check, or prove, the answer, we remember that subtraction is finding out how much larger one number is than another so that, if 5842 is 2053 larger than 3789, 3789 + 2053 should equal 5842. Add it up yourself and see if we are right.

MULTIPLICATION

Multiplication is really a form, or quick way of adding numbers which are equal. Suppose we want to find the sum of four sixes. We can write them down and add, 6 + 6 + 6 + 6 = 24. However, you may still remember the multiplication tables you learned in school and know that six times four is twenty-four. Just to brush up your memory, we have the following table, giving all products from 1 x 1 to 12 x 12.

Starting at the upper left of the table, you will find the digit 1, and reading over to the right, 1, 2, 3, 4 and so on up to 12. Then reading down from the 1, again you will find the digits 2, 3, 4 and so on up to 12. To use the table, it is necessary to use both sets of figures. For example, suppose you want to know how much 8 x 7 is equal to.

1	2	3	4	5	6	7	8	9	10	11	12
2	4	6	8	10	12	14	16	18	20	22	24
3	6	9	12	15	18	21	24	27	30	33	36
4	8	12	16	20	24	28	32	36	40	44	48
5	10	15	20	25	30	35	40	45	50	55	60
6	12	18	24	30	36	42	48	54	60	66	72
7	14	21	28	35	42	49	56	63	70	77	84
8	16	24	32	40	48	56	64	72	80	88	96
9	18	27	36	45	54	63	72	81	90	99	108
10	20	30	40	50	60	70	80	90	100	110	120
11	22	33	44	55	66	77	88	99	110	121	132
12	24	36	48	60	72	84	96	108	120	132	144

Start at the upper left, with 1, and go down to 8. Then over to the right to the column with "7" in the top line. The number is 56 and thus, 8 x 7 = 56.

You can work this the other way also by starting at 1 and going down to 7, then over to the column with 8 in the top line. Again you will find that 56 is the answer.

In general, to find the product of any two numbers up to 12 x 12, go down the left hand column to one of them, then over to the right to the column which has the other one in the top line.

Instead of 6 + 6 + 6 + 6 = 24 we can write 6 x 4 = 24. This we read as six times four equals 24 and call 24 the product.

To multiply larger numbers and still use the Table, we can secure an answer as follows: To find the product of 6 times 76, we write

$$\begin{array}{r} 76 \\ \underline{6} \\ 456 \end{array}$$

Starting at the right, we first multiply 6 x 6 and from the Table , see that 6 x 6 = 36. The six we write below the line under the 6 and the 3 we carry over to add to the next multiplication. Now we multiply 7 x 6 which is 42 and adding the 3, which we carried over, have a total of 45 which we write to the left of the 6 making the answer 456.

For still larger numbers, the same idea is carried out by starting at the right and every time a multiplication is completed, the right hand figure of the product is written and the remaining figures carried over to add to the next product.

To multiply a number by 10, a "0" is simply placed to the right of it. Thus 10 x 476 = 4760. To multiply by 20, first multiply by 2 then add a 0 to the right of the product. This idea is carried out in all cases where either number to be multiplied ends in one or more zeros. To multiply 628 by 1000, simply add the 000 to 628 so that 628 x 1000 = 628000.

Suppose you want to multiply 478 by 26. 26 is made up of 20 and 6 so that you first multiply 478 by 6 which gives 2868. Then you multiply 478 by 20 which gives 9560. The 2868 is added to the 9560 like this

$$\begin{array}{r} 2868 \\ \underline{9560} \\ 12428 \end{array}$$

giving the answer. In practice, it is customary to combine the multiplication and addition and omit the last 0 as it makes no difference. The complete problem can be written

$$\begin{array}{r} 478 \\ \underline{26} \\ 2868 \\ \underline{956} \\ 12428 \end{array}$$

When a number is multiplied by itself, the product is called the square of the number. For example, 3 x 3 = 9 and 9 is the square of 3, usually written 3^2.

Multiplying a number by itself three times, the product is called the cube of the number. Thus 3 x 3 x 3 = 27, the cube of 3, and usually written 3^3. These products are known as the Powers of the number and the small figure at the upper right, known as an "Exponent" shows how many times the number is multiplied by itself.

DIVISION

When the process of multiplication is reversed, the operation is called "Division". By division, you can find out how many times one number is contained in another. For all small numbers, the multiplication table gives the correct results.

By the table, you see, for instance, that 3 x 5 = 15, and know that 3 goes into 15, 5 times, or 5 goes into 15, 3 times. Using the division sign, 15 ÷ 5 = 3, or 15 ÷ 3 = 5.

This method works out easily with the smaller numbers but, to divide larger numbers, a somewhat different method is used. For example, suppose we are required to divide 4488 by 17. In other words we want to find out how many times 17 goes into 4488. The number to be divided, such as 4483 in this example, is called the "Dividend", the number by which the dividend is to be divided, such as 17 in this example, is called the "Divisor" and the answer, or result obtained by the division, is called the "Quotient".

The problem can be written as

```
17 ) 4488 (264
     34
     ---
     108
     102
     ---
       68
       68
       --
```

To begin, we estimate how many times 17 goes into the first two left hand figures, "44". As 2 times 17 is 34 and three times 17 is 51, we place a 2 in the right hand bracket for the first number of the answer. Then we multiply 17 by 2, which is 34, and write it under the 44. Subtracting 34 from 44 there is 10 left over and the next right hand figure of the dividend is brought down and written to the right of the 10, making it 108. Then we repeat our first step and, estimating that 17 will go into 108 about six times, we put a 6 as the second number of the answer.

Multiplying 17 x 6 gives us 102, which is written under the 108, and subtracting these numbers, leaves 6. The next right hand figure of the dividend is then brought down and written to the right of the 6 making it 68. We now think that 17 will go into 68 about four times and write the 4 down as the third figure of the answer. Multiplying again, we find that 4 times 17 is 68 and, as subtracting here leaves nothing for the remainder, the division is finished.

To prove the answer and check the work, we will multiply the quotient, 264, by the divisor, 17.

```
 264
  17
1848
264
4488
```

The product is the original divident of 4488 so that the division must be correct.

Of course, all problems in dividion will not work out like this and often leave a remainder.

Suppose, for example, that we want to divide 537 by 19. The figures are put down and the work is done exactly the same as in the former example, giving us

```
19) 537 (28
    38
    157
    152
      5
```

That leaves a remainder of 5 which is less than the divisor 19 so that the 28 is not a complete answer. To complete the problem, we must also divide the remainder 5 by the divisor 19 but, instead of doing any work, we simply write 5/19 making the correct answer 28-5/19.

The 5/19 is called a fraction, and to continue, we will explain how they can be added, subtracted, divided and multiplied.

FRACTIONS

Proper Fractions are those figures which represent quantities less than 1. Let us take a dollar for example. It can be divided in many different ways such as 100 cents, 10 dimes, 4 quarters or 2 half dollars. A cent, a dime, a quarter or a half are each a certain part or fraction of a dollar. To write a half dollar in fractional form it would be $\frac{1}{2}$ or 1/2 and the upper or first figure is the Numerator while the lower or last figure, is the Denominator. As it takes four quarters to make a whole, each quarter is equal to 1/4 or one fourth of a dollar, each dime is equal to 1/10, or one tenth, and each cent is equal to 1/100, one one hundredth of a dollar.

Now you know that five dimes is equal to fifty cents, two quarters or one half and written in fractions we have

$$5/10 = 50/100 = 2/4 = 1/2$$

The first fraction represents the dimes because each dime is 1/10 of a dollar and five dimes is 5/10. The 50/100 represent

the pennies because each cent is equal to 1/100 of a dollar and so on. Looking at the fraction 5/10 = 50/100, you can see that to make the 5/10 equal to 50/100, both the numerator and denominator have been multiplied by 10. The same is true of 1/2 = 2/4 but in this case, the numerator and denominator of 1/2 were multiplied by 2.

Because this relation is always true we can state the rule that, when the numerator and denominator of a fraction are both multiplied by the same number, the value of the fraction does not change.

This being true, we can also go the other way and say that when the numerator and denominator of a fraction are both divided by the same number, the value of the fraction does not change. For example, using this rule and dividing both the numerator and denominator of 5/10 by 5 we get 1/2. Following this plan and dividing 50/100 by 50 we get 1/2 or dividing 2/4 by 2 we again get 1/2. Then as 5/10 equal 1/2 and 50/100 equal 1/2, and 2/4 equal 1/2 you can easily see that

$$5/10 = 50/100 = 2/4 = 1/2$$

The one exception to this rule is the value of zero. Any number multiplied by zero is equal to zero thus, multiplying the numerator and denominator of a fraction by zero would result in the expression of zero divided by zero such as

$$\frac{5 \times 0}{10 \times 0} = \frac{0}{0}$$

a result which has no definite numerical meaning.

In much the same way, dividing by zero has no definite meaning. It is assumed that any number, divided by zero, will result in a quotient of infinity. That is, zero goes into any number an unlimited number of times and therefore the operation has no finite numerical meaning.

ADDITION OF FRACTIONS

Fractions can be added just like whole numbers but first must be multiplied or divided until they all have the same denominator. Suppose you want to add 7 pennies, 3 dimes, and a quarter. You know at once that the answer is 62 cents but, what you really do in your mind is to add

$$7/100 + 3/10 + 1/4 = 62/100$$

By first making them all have the same denominator, 7 pennies equal 7/100, 3 dimes equal 30 cents, or 30/100 and a quarter equals 25 cents or 25/100 of a dollar. Then you have

$$7/100 + 30/100 + 25/100 = 62/100$$ of a dollar or 62 cents.

To add any fractions, it is first necessary to reduce them all to a common denominator which is any number that can be divided exactly by all the denominators. For example, to add 1/4 + 2/3 + 1/6, the denominators are 4, 3 and 6 which, when multiplied, give a product of 4 x 3 x 6 = 72 for the common denominator. As 72 divided by 4 = 18, 72 divided by 3 = 24 and 72 divided by 6 = 12 the problem can be written

$$\frac{1 \times 18}{4 \times 18} + \frac{2 \times 24}{3 \times 24} + \frac{1 \times 12}{6 \times 12} = \frac{18}{72} + \frac{48}{72} + \frac{12}{72}$$

with the common denominator of 72, the problem can be continued as

$$\frac{18 + 48 + 12}{72} = \frac{78}{72}$$

Inspection of this fraction shwos both 78 and 72 are divisible by 6 therefore the fraction can be reduced to

$$\frac{78 \div 6}{72 \div 6} = \frac{13}{12}$$

Going back to the original problem, the denominators can be divided into their factors and written as

$$(2 \times 2) \times (3) \times (3 \times 2) = 72$$

Here we see that the factors (2 x 2 x 3) include all those needed for any one of the denominators and decide that 2 x 2 x 3 = 12 is the smallest number all the denominators will divide into exactly and is therefore the lowest common denominator. As 4 goes into 12 three times, we multiply 1/4 x 3/3 = 3/12. 3 goes into 12 four times therefore 2/3 x 4/4 = 8/12 and as 6 goes into 12 two times, then 1/6 x 2/2 = 2/12. Now we can add

$$3/12 + 8/12 + 2/12 = 13/12$$

As the denominator of a fraction shows how many parts the unit has been divided into, then 13/12 would give us one entire unit of 12 parts and one left over so that we could write 13/12 = 1-1/12. This we read as thirteen twelfths equal one and one twelfth. Whenever the numerator is larger than the denominator we call it an improper fraction because it is greater than 1. Thus the fraction 7/4 can be written 1-3/4 because 1 equals 4/4.

To change an improper fraction into a whole number and a proper fraction we divide the numerator by the denominator. Thus: 29/7 = 29 divided by 7 which is 4-1/7.

In the same way, a whole number and a proper fraction can be changed into an improper fraction by multiplying the whole number by the denominator and then adding the result to the numbrator. Thus 6-2/5 = 6 x 5/5 + 2/5 = 30/5 + 2/5 = 32/5.

SUBTRACTION OF FRACTIONS

To subtract fractions, the process of addition is just reversed. Referring to money again, suppose you had two quarters and wanted to give away three dimes. First you would have to make change, and receive five dimes for the two quarters. Then you could give the three dimes away and have two left. Remembering that a dime is 1/10 of a dollar, in fractions, here is what you did.

2/4 - 3/10 = ?

You know that 2/4 = 1/2 so that you had to subtract three tenths from one half or, 1/2 - 3/10. When you made change, you turned the 1/2 into 5/10 which, as you already know, did not change its value, to make the problem

$$\frac{5}{10} - \frac{3}{10} = \frac{2}{10}$$

As in addition, you first changed the fractions until they had the same denominator but then subtracted the numerators, the result being the numerator of the answer. The denominator of the answer remained the same as that of the fractions subtracted.

To show you how these steps are followed we will subtract 2/7 from 3/4. First we reduce to a common denominator which, in this case, is 4 x 7 or 28. Then, 3/4 equals 21/28 and 2/7 = 8/28. Subtracting, 21/28 - 8/28 = 13/28.

MULTIPLICATION OF FRACTIONS

To multiply fractions we proceed somewhat differently than in multiplying whole numbers. When a fraction is multiplied by a whole number, we multiply the numerator only and do not change the denominator. Thus 1/4 x 3 = 3/4, because if you had a quarter of a dollar and we had three times as much, we would have three quarters.

To multiply one fraction by another we simply multiply the numerators for the numerator of the answer and then multiply the demoninators for the denominator of the answer.

Instead of using the "x" sign, we often write the word "of" between the fractions. Suppose you had 60 cents and we had

2/3 as much. Now 60 cents is 6 dimes or 6/10 of a dollar and we have 2/3 of 6/10. Multiplying the numerators, 2 x 6 = 12, and multiplying the denominators, 3 x 10 = 30, therefore we have 12/30 of a dollar. We can divide both numerator and denominator by 3 to arrive at the answer 4/10 or 4 dimes as the amount of our money. The 4/10 could be reduced further to 2/5 by dividing both numerator and denominator by 2.

To multiply several fractions we proceed in exactly the same way. To find out how much 5/12 x 9/21 x 14/25 equals, we think of it as

$$\frac{5 \times 9 \times 14}{12 \times 21 \times 25}$$

Before multiplying however, we can save quite a lot of work by splitting the numbers into smaller ones. We know that 3 x 3 is 9 and 2 x 7 = 14 therefore, we will write the numerator as 5 x 3 x 3 x 2 x 7. For the denominator 3 x 2 x 2 = 12, 3 x 7 = 21 and 5 x 5 = 25. The whole problem then can be written as

$$\frac{5 \times 3 \times 3 \times 2 \times 7}{3 \times 2 \times 2 \times 3 \times 7 \times 5 \times 5}$$

Instead of multiplying both numerator and denominator by the same figures, we cross out, or cancel, those above and below the line that are alike. The first 5 of the numerator and the first 5 of the denominator are crossed off, then the first 3 of the numerator and first three of the denominator and so on until the fraction is reduced to

$$\frac{\quad}{2 \times 5}$$

With no number left in the numerator, we assume a factor of 1 to have

$$\frac{1}{2 \times 5} = \frac{1}{10}$$

DIVISION OF FRACTIONS

To divide a fraction by a whole number, the denominator is multiplied by the number and the numerator is not changed, thus 3/4 divided by 5 equal 3/20. This is easy to prove because 3/4 equal 15/20 and five times 3/20 also equal 15/20.

To divide one fraction by another, we simply invert the divisor and multiply. Thus 2/3 ÷ 4/5 is changed to 2/3 x 5/4 which equal 10/12 or 5/6.

Any whole number can be written as a fraction by putting 1 as the denominator. Thus 4 = 4/1 but as 4/1 = 8/2 = 12/3 = 16/4 we can change any whole number into a fraction with any denominator we wish.

DECIMALS

If you should pick up a newspaper and see some shoes advertised for $3.65 you would read the price as three dollars and sixty-five cents. You know, however, that a cent is one one-hundredth of a dollar so that the price might be written $3-65/100. $3-65/100 is a fraction but $3.65 is a decimal.

We want you to think of decimals as fractions whose denominators are 10 or 10 multiplied by itself any number of times. 10 x 10 = 100, 10 x 10 x 10 = 1000 and so on. Instead of writing them as ordinary fractions, however, we use exactly the same idea as we do in the whole numbers. You will remember that, starting with the figure 1, the next column to the left showed the tens, the next to the left the hundreds and so on. Notice here, that each time we go to the left with a figure, we really multiply the number by 10. Thus 10 is ten times 1, 100 is ten times 10, 1000 is ten times 100.

The decimals are exactly the same but start to the right of 1, with the decimal point always next to and at the right of the units. Thus .1 is read one-tenth because the figure is at the right of the decimal point. The number .01 is read one one-hundredth because it is in the second column to the right of the decimal point. Going to the right of the decimal then, the figures in the first column are the tenths, in the second column the hundredths, and the third column the thousandths and so on. Carrying this plan further

Hundred Thousands	1 0 0, 0 0 0.
Ten Thousands	1 0, 0 0 0.
Thousands	1, 0 0 0.
Hundreds	1 0 0.
Tens	1 0.
Units	1.
Tenths	.1
Hundredths	.0 1
Thousandths	.0 0 1
Ten Thousandths	.0 0 0 1
Hundred Thousandths	.0 0 0 0 1

You will notice the 1, or unity, is at the center and the decimal point, included with it, is at the right. Going to the left, each column represents a number ten times greater while, going to the right, each column represents a fraction ten times smaller.

Another way you can think of decimals is this. For the decimal fraction .347, the 347 is the numerator and the denominator is the figure 1 with as many zeros after it as there are figures in the numerato. . In this case, there being three figures. the denominator is 1000.

When they are at the right of the figure, the zeros make no difference to the value of a decimal, thus .5 is five-tenths, .50 is fifty hundredths, .500 is five hundred thousandths. From our former explanations, you know that 5/10 = 50/100 = 500/1000.

When the zeros appear at the left of the figures, they make a big difference as .5 equal 5/10, .05 equal 5/100 and .005 is five thousandths. To determine the value of the denominator in this case, we count the number of figures to the right of the decimal whether they are zeros or not.

ADDITION AND SUBTRACTION OF DECIMALS

Decimals are added and subtracted just like whole numbers but, when writing them down, we must be careful to have all of the decimal points exactly under each other. For example, if we add .6 + .039 + 1.02 we will write

$$\begin{array}{r} .600 \\ .039 \\ \underline{1.020} \\ 1.659 \end{array}$$

The last zeros, to the right, are not necessary but make the addition a little easier to see.

In the subtraction of decimals, we follow exactly the same method as in subtracting whole numbers but, in writing down the figures, it is always well to include the extra zeros as we did in the addition above. For example to subtract .012 from .02 we write

$$\begin{array}{r} .020 \\ \underline{.012} \\ .008 \end{array}$$

MULTIPLICATION OF DECIMALS

To multiply decimals, we simply forget the decimal point and go ahead just as if they were whole numbers. However, when we have the answer, we start at the right and count off as many numbers, or places, as the sum of the number of places in both the numbers which were multiplied.

For example, to multiply 56.4 by .28, we write them down as in ordinary multiplication.

```
  56.4
   .28
  4512
 1128
15.792
```

After we find the answer, 15792, we simply count one figure to the right of the decimal in 56.4 and two to the right in .28. Then 1 + 2 = 3 and, starting at the right of the answer, we count off three placed and locate the decimal at the left of the 7, making the result 15.792. To follow this plan, sometimes it is necessary to add zeros but the rule still holds good. For example, suppose we multiply .002 by .07.

```
 .002
  .07
.00014
```

Here you see the first answer is 14, but as .002 has three places and .07 two, the answer requires five places to the right of the decimal. As there are but two figures, we add the three zeros and the correct answer is .00014.

DIVISION OF DECIMALS

As in multiplication, decimals are divided just like whole numbers, no attention being paid to the decimal point until we have the answer. Then, starting at the right as before, we point off as many places as those in the dividend exceed those in the divisor.

For example suppose we divide 44.0572 by 18.7. As already explained we will have

```
18.7) 44.0572 (2.356
      374
       665
       561
       1047
        935
        1122
        1122
```

Checking back on our explanation, the dividend 44.0572 has four decimal places while the divisor, 18.7 has but one. Then as four is three larger than one, the answer, or quotient, will have three places making it 2.356. When the

dividend and divisor have the same number of decimal places, the answer has none — like this

```
.039 divided by .003 =     .003) .039 (13
                                  3
                                   9
                                   9
```

giving us the whole number 13 for the answer. Should the dividend not have as many decimal places as the divisor, we simply add as many zeros, to the right of the decimal, as are needed.

30.5 divided by .125 will be worked out by just adding two zeros making 30.5 into 30.500. Notice that this does not change its value.

```
.125) 30.500 (244
      250
        550
        500
          500
          500
```

As both the dividend and divisor have the same number of decimal places the answer has none and is 244.

About the only other case that will bother you is where the divisor is larger than the dividend, such as 17 divided by 68. Here, we put a decimal to the right of the dividend and add as many zeros as are needed. In this example, we add two and the dividend becomes 17.00. Notice again that this does not change its value.

```
68) 17.00 (.25
    136
     340
     340
```

Our first answer is 25 but as the dividend has two more decimal places than the divisor, there will have to be two places in the quotient making it .25.

By following this method, any fraction can be changed into a decimal. Thus:

$$3/4 = 3 \div 4 = 3.00 \div 4$$

```
4) 3.00 (.75
   28
    20
    20
```

Therefore, we find that 3/4 equal .75. As a check, we know .75 = 75/100 and dividing both numerator and denominator by 25, we find 75/100 = 3/4.

SQUARE ROOT

As mentioned earlier in this Lesson, when a number is multiplied by itself, we say it is "squared" and indicate the process by writing the number with an exponent "2". In the form of an equation,

$$6^2 = 6 \times 6 = 36$$

which is read as six squared equals six times six, equals thirty-six.

This is a common form of problem found in many electrical calculations but one which causes no particular difficulty as it involves nothing but simple multiplication. The table, given earlier in this Lesson, includes all squares of whole numbers from 1 x 1 to 12 x 12.

However, it is an equally common problem to arrive at a value, such as the "36" in the example just given, and be required to find the number of which it is the square. This process, known as finding the square root of a number, is indicated by the radical sign, "$\sqrt{}$" and reversing the former example,

$$\sqrt{36} = 6$$

which is read as, the square root of thirty-six equals six.

To illustrate, we will assume a problem in which we find

$$E = \sqrt{729}$$

and therefore know the value of voltage "E" is equal to the square root of 729.

To solve the problem, we go ahead much like long dividion in arithmetic but first write down the number 729 and, starting from the right, draw a line after the second number like this, 7/29.

Next, we look at the left figure, which in this case is 7, and think of the largest square that will be less, or go into it. We know that 2 x 2 is 4 and 3 x 3 is 9 therefore the square of 2 is the largest that will go into 7. So we write 2 as the first figure of our answer and the problem now looks like

) 7/29 (2

The square of 2 is written under the 7, subtracted from it and the next group of two figures brought down like this

```
 ) 7/29  (2
   4
   ---
   329
```

We then multiply the answer, that we have so far, by 2 and use that as the first figure of the next divisor like this

```
   ) 7/29  (2
     4
     ---
4)   329
```

Now we see that 4 goes into the 32 of the 329 exactly 8 times but, as the divisor will have a second figure, decide 8 will be too large therefore write 7 in as the second figure of the answer and also as the second figure of the divisor, giving us

```
   ) 7/29  (27
     4
     ---
47)  329
```

The 47 is then multiplied by the 7 of the answer, being written under the 329 and subtracted from it. As there is no remainder, the answer 27 is complete and the square root of 729 is 27. The complete problem will look like this

```
   ) 7/29  (27
     4
     ---
47)  329
     329
     ---
```

These same steps are followed for all numbers but, when there is a decimal point, it is necessary to start from it and work both ways when dividing the number into groups of two figures.

To show you how this works out, suppose we extract the square root of 844.484. Starting from the decimal point and dividing the number into groups of two figures, we have

8/44./48/40

The "0", added to the right-hand group, does not change the value of the number but simply completes the last group. Following the steps explained above, the problem works out as follows.

```
     ) 8/44./48/40 (29.06
        4
   49) 4 44
       4 41
  580)   3 48

 5806)   3 48 40
         3 48 36
               4
```

Notice here, the third number of the answer is "0" because with any number added, the trial divisor "58" will be greater than the remainder "348". In a case of this kind, we place a "0" in the answer, add a "0" to the trial divisor, bring down the next group of two figures and go ahead with the steps already explained.

Checking the problem, you will find there is a single figure in the answer for each group of two figures in the original number. Therefore, as the original number has two groups of figures to the left of the decimal the answer has two single figures to the left of the decimal.

Because some units of electrical measure are comparatively large, the components used in Radio circuits are of small value and thus it is often necessary to extract the square root of a four or five place decimal. To illustrate a problem of this kind, suppose we want to find the square root of .00025.

Our first step is to start at the decimal point and divide the number into pairs of figures, making it .00/02/50. The last "0" does not change the value of the number but completes the third group of two figures.

Looking at the groups, the one next to the decimal point contains two zeros therefore the first figure of the answer will be zero with the decimal to the left, like this

```
.00/02/50 (.0
```

As this first step contains nothing but zeros, the next pair of numbers is inspected and the problem is started as already explained. In this case, with the number "02", the nearest perfect square is 1, therefore we write "1" under the 02 and another "1" in the answer, as shown below.

```
.00/02/50 (.01
     1
```

Then we subtract the "1" from the "2", as in ordinary division, and bring down the next pair of figures to make the problem

```
   .00/02/50 (.01
        1
        1 50
```

Following the usual steps, the answer is doubled and written in as the first number of the trial divisor, the second number of which is estimated and written in the divisor and the answer to make the problem

```
   .00/02/50 (.015
        1
    25) 1 50
        1 25
          25
```

To provide a third number in the answer, we assume a group of two zeros follows the group of "50" in the original number and proceed in the usual way.

```
  .00/02/50/00 (.0158
       1
  25)  1 50
       1 25
  308)   25 00
         24 64
            36
```

The work can be continued by adding pairs of zeros until the answer has the desired number of decimal places but, for ordinary problems, three figures usually provide sufficient accuracy.

In all square root problems, it is easy to check the work because, as the answer should be the square root of the original number, the answer can be multiplied by itself and the result should equal the original number.

For the example just given, we found the square root of .00025 was .0158 and, as .0158 x .0158 is .00024964 our answer is but .00000036 less than the original number.

PRACTICE PROBLEMS

The following problems have been included as a part of this Lesson to provide a ready means of practice for those students who require it. To make the information complete, the answers to all the problems are given on a separate page.

Our suggestion is that you work the problems first and then check your answers with those which are given. In this way, you will obtain the greatest benefit from the work.

These problems need not be sent in for grading but we will be glad to send complete details on any of them which you may find difficult

PRACTICE PROBLEMS

Do Not Send In For Grading

Answers on Page 24

1. (a) 2 + 6 + 7 + 3 + 9 = 27
   (b) 746 + 5 + 2416 + 40 = 3207
   (c) 17 + 594 + 4 + 31,567 = 32182
   (d) 600 + 78 + 2567 + 758 + 9 = 4012
   (e) 3006 + 435 + 74 + 6782 = 10297

2. (a) 63 – 45 = 18
   (b) 462 – 63 = 399
   (c) 7525 – 6735 = 790
   (d) 837 – 492 = 345
   (e) 5864 – 962 = 4902

3. (a) 49 x 7 = 343
   (b) 63 x 14 = 882
   (c) 592 x 38 = 22,124
   (d) 746 x 258 =
   (e) 3926 x 547 = 192,468

4. (a) 153 ÷ 9 = 17
   (b) 184 ÷ 23 = 8
   (c) 4564 ÷ 326 = 14
   (d) 59 ÷ 7 = 6 5/7
   (e) 382 ÷ 21 = 18 2/21

5. (a) 2/5 + 9/15 = 1
   (b) 1/2 + 2/3 + 5/6 = 2
   (c) 1/3 + 1/4 + 1/6 = 3/4
   (d) 7/4 + 3/5 + 2/3 = 3 1/60
   (e) 3-1/3 + 2-3/4 + 1-4/7 =

6. (a) 3/4 – 2/5 = 7/20
   (b) 4/7 – 2/9 = 22/63
   (c) 2/3 – 5/8 = 1/24
   (d) 3-3/4 – 2-1/7 =
   (e) 5-4/9 – 3-2/11 =

7. (a) 2/3 x 3 = 2
   (b) 3 x 1/8 = 3/8
   (c) 2-1/2 x 3/5 =
   (d) 3-7/8 x 4/3 =
   (e) 3/4 x 4/5 x 5/6 =

PRACTICE PROBLEMS (Continued)

Do Not Send In For Grading

Answers on Page 24

8. (a) 3-1/2 ÷ 7/8 =
   (b) 3 ÷ 1/4 = 12
   (c) 1/4 ÷ 3 = 1/12
   (d) 4-3/4 ÷ 1-1/2 =
   (e) 7/8 ÷ 3/4 =

9. (a) 2.45 + .06 + 38.4 + 7.1 = 48.01
   (b) 29.6 + .008 + .2 + 14.06 = 43.868
   (c) .01 + .002 + .125 + .00025 = .13725
   (d) 5.07 + 1.2 + .0001 + 6.002 = 12.2721
   (e) 10.00 + .001 + 1.01 + .10= 11.111

10. (a) 4.6501 - .006 = 4.6441
    (b) .001 - .00025 = .00075
    (c) 8.8043 - 8.7942 = .0101
    (d) 29.004 - 19.005 = 9.999
    (e) .0025 - .00025 = .00225

11. (a) 32.4 x .005 = .1620
    (b) .02 x .0005 = .0001
    (c) 2.5 x 6.02 x 3.04 = 45.172
    (d) .05 x .02 x .001 = .000001
    (e) 6823. x .0001 = .6823

12. (a) 32.4 ÷ .005 = 6480.
    (b) .02 ÷ .0005 = 40.
    (c) 2.5 ÷ 6.25 = .4
    (d) .001 ÷ .05 = .02
    (e) .25 ÷ 250 = .001

13. (a) $\sqrt{1849}$
    (b) $\sqrt{466.56}$
    (c) $\sqrt{3850.2025}$ =
    (d) $\sqrt{.001}$ =
    (e) $\sqrt{.0005}$ =

ANSWERS TO PRACTICE PROBLEMS

1. (a) 27
   (b) 3207
   (c) 32,182
   (d) 4012
   (e) 10, 297

2. (a) 18
   (b) 399
   (c) 790
   (d) 345
   (e) 4902

3. (a) 343
   (b) 882
   (c) 22,496
   (d) 192,468
   (e) 2,147,522

4. (a) 17
   (b) 8
   (c) 14
   (d) 8-3/7
   (e) 18-4/21

5. (a) 1
   (b) 2
   (c) 3/4
   (d) 3-1/60
   (e) 7-55/84

6. (a) 7/20
   (b) 22/63
   (c) 1/24
   (d) 1-17/28
   (e) 2-26/99

7. (a) 2
   (b) 3/8
   (c) 1-1/2
   (d) 5-1/6
   (e) 1/2

8. (a) 4
   (b) 12
   (c) 1/12
   (d) 3-1/6
   (e) 1-1/6

9. (a) 48.01
   (b) 43.868
   (c) .13725
   (d) 12.2721
   (e) 11.111

10. (a) 4.6441
    (b) .00075
    (c) .0101
    (d) 9.999
    (e) .00225

11. (a) .1620
    (b) .00001
    (c) 45.752
    (d) .000001
    (e) .6823

12. (a) 6480
    (b) 40
    (c) .4
    (d) .02
    (e) .001

13. (a) 43
    (b) 21.6
    (c) 62.05
    (d) .0316
    (e) .02236

DE FOREST'S
TRAINING, Inc.

LESSON FDM - 1
RADIO SYSTEMS

Founded 1931 by

RADIO FUNDAMENTALS

LESSON FDM-1

RADIO SYSTEMS

Radio Energy ------------------- Page 1
Transmission and Reception ------ Page 2
Antennas ------------------------ Page 3
Frequencies vs. Wavelength ------ Page 3
Radio Measurements -------------- Page 5
Units of Frequency Measure ------ Page 5
The Radio Spectrum -------------- Page 5
Radio Receivers ----------------- Page 6
Tuning -------------------------- Page 7
Radio Receiver Chassis ---------- Page 8
Radio Receiver Dials ------------ Page 9

* * * * *

Some people fail because they never begin. More people fail because they never finish. Stick-to-it-ive-ness wins oftener than genius or luck. You may make mistakes, others may misjudge you. You may be tired and discouraged. But, if you stick, by and by everything and everybody will give way to you.

If you have principles, they will do you no good unless you stick to them. If you do not stick to your friends, you do not deserve friends. If you do not stick to your job, you cannot make a success of it and find a better one. In a troubled and anxious time of the Civil War, General Grant said, "I will fight it out on this line if it takes all summer." Let that be your motto.

-- Dr. Frank Crane

RADIO SYSTEMS

It is a very common, everyday experience for most of us to simply turn a switch or push a button on our Radio and, in a few seconds, enjoy the music of our favorite orchestra even though it may be playing hundreds of miles away. Perhaps you have marveled at this "magic" of Radio which travels through space, without wires, and lets you hear the music as soon as the audience in the Broadcasting Studio where the orchestra is playing.

Being interested in this subject, no doubt you have looked underneath a Radio and may have wondered how such a "rat's nest" of wires and gadgets can pull your favorite programs out of the air. That, by the way, is the purpose of this Training Program -- To tell you and show you just "what makes the wheels go around" in Radio and Electronic Equipment -- To explain the principle which may govern the actions of the many "gadgets" which go to make up the various Radio and Electronic devices.

Once you understand these principles and some of their practical applications, you will have a good foundation to build on and will have made a good start to qualify for the more skilled and profitable work in the Radio and Electronic field.

RADIO ENERGY

It has been said that, "With a good start a race is half won" so, let's start at the very beginning with a few general ideas about this world in which we live.

The "stuff" which makes up all the things we know, such as the soil, rocks, water and trees in the country as well as the bricks, stones and pavements of the city is known technically as "Matter".

As a general definition, we can say that Matter is anything which occupies space and thus you can see it will include our clothes, our food, our furniture and even our bodies. The definition makes no exceptions and covers all solids, such as wood, stone, metals and cloth, all liquids such as gasoline and water as well as the lighter substances, such as air, which are known generally as "gas".

In addition to "matter", there are a number of important natural forces which we call "energy". No doubt you are familiar with the common use of the word but, for this training, we want you to think of energy as the ability to do work. Not exactly the kind of work for which you receive a pay check, but work in a more technical sense.

For example, by heating water in the boiler of a railroad Locomotive, you can produce steam which will pull a heavy train, a job that, under ordinary conditions, the original cold water could not do. That is why we say it is the Heat Energy, added to the water, which has the ability to do work.

There are other common forms of energy, such as light and sound, and any work you do with your muscles can be classed as mechanical energy. What interests us most in this training program is Electrical energy because, without it there would be no Radio.

Most of our modern machinery is mainly useful in converting energy from one form to another. For example, the heat energy of the exploding gasoline vapor, inside the cylinder of an automobile engine, is converted to mechanical energy which drives the car. Electrical energy, passing through the common electrical lamp bulb, is converted into both light and heat energy.

When you talk into the ordinary telephone, the muscular energy of the vocal chords in your throat is converted to sound energy which enters the mouthpiece and is converted into electrical energy. This electrical energy travels along the wires to the other end of the line where it is converted back to sound energy which can be heard by the listener.

In Radio, the general idea is much the same but, instead of using wires to connect the speaker and listener, a special form of electrical energy is employed to carry the messages through space. We want you to think of this as Radio Energy or, because it carries the messages from one point to another, as a Radio "Carrier".

TRANSMISSION AND RECEPTION

In general, all complete Radio systems can be divided into two main parts.

One: The apparatus which converts the sound energy to electrical energy and, by means of a "Carrier", sends or transmits the messages through space. This part of the system is the "Transmitter" and its complete assembly is known as a "station". The common Broadcast stations are therefore classed as Radio Transmitters or Transmitting Stations.

Two: The apparatus which receives the transmitted carrier energy and converts it back to sound. This part is the "Receiver".

The Radio Transmitter, in turn, can be divided into two general parts. First, the apparatus which converts the sound or other

signals into electrical energy and second, the apparatus which generates the "Carrier".

While Radio receivers are a common household article, Radio Transmitters are soldom seen by the public and therefore, in Figures 2 and 3, we show views of a medium sized Federal Marine Model such as is used on ships. Figure 2 shows the general appearance of the unit ready for operation while, in Figure 3, the doors have been opened to expose the various parts.

ANTENNAS

In order to start the carrier energy on its journey through space, the transmitting station has an "Antenna".

As shown in Figure 1, these are made in many forms, shapes and types and, for transmitting stations, they range all the way from a simple vertical rod, to complicated arrays of masts with wires strung in between.

Antennas are also required for Radio Receivers but, in general, they are much smaller and simpler than those of the Transmitting stations. In fact, many modern Receivers have the antenna built inside the cabinet, thus eliminating the need of an outdoor installation.

FREQUENCIES VS. WAVELENGTH

All Radio transmitters produce or "generate" the Carrier, which was mentioned above, and now we want to explain the characteristics which make it possible for the many Radio Transmitters and Broadcast Stations to operate at the same time without interfering with each other.

By methods which we will explain later, the transmitter feeds the Radio carrier energy to the antenna in a series or stream of pulses. Each of these pulses causes a distrubance which spreads out at the speed of light in the space around the antenna.

As these pulses follow each other in rapid and regular order, the energy which leaves the antenna is often thought of as being a form of waves and the action is compared to that which occurs when a pebble is dropped in a pool of still water. Little waves start at the point the pebble strikes the water and travel away in a series of widening circles.

Thinking of the Radio carrier energy in somewhat the same way, we are interested in the speed at which the waves travel, the number of waves which pass in a given time and the distance from the crest of one wave to the next.

This may sound somewhat complicated but, in reality, a little simple arithmetic will bring out all the important points. To make the details easy to follow, suppose we imagine that several shiploads of airplanes are being landed and assembled at a small port and are to be flown to their destination, several hundred miles away. The only available airport is so small that but one plane can take off at a time.

The planes are all alike, with a speed of 300 miles per hour, and a schedule has been arranged which allows one to take off every minute. At the end of one hour, the first plane will be 300 miles away but, as the planes take off at one minute intervals, there will be 60 planes in the air.

With 60 planes spaced equally over a distance of 300 miles, they must be 5 miles apart because 300 divided by 60 equals 5. However, if you were standing anywhere along their line flight, the planes would pass you at the rate of one per minute.

Let's go over the picture again quickly. A steady stream of airplanes take off from the airport at the rate of one per minute and, travelling at 300 miles per hour are spaced 5 miles apart. In a more technical way, we can say the planes leave the airport at a "frequency" of 60 per hour. This is also the "frequency " at which the planes pass over any point of their flight.

We frequently read of "waves" of bomber planes and, thinking of each plane in the example above as the crest of a wave, we will have a wavelength of 5 miles. Thus we have the three important factors in regard to the planes of this example.

1. Speed of 300 miles per hour.
2. Frequency of 60 per hour.
3. Wavelength of 5 miles.

To calculate the relationship between these three, you will find --

1. The Frequency equals the speed divided by the wavelength.
2. The Wavelength equals the speed divided by the frequency.

Using the values given above, the Frequency is equal to the speed of 300 divided by the wavelength of 5 for a value of 60.

The Wavelength is equal to the speed of 300 divided by the frequency of 60 for a value of 5.

RADIO MEASUREMENTS

Exactly the same plan is used for the measurement of the Radio Carrier Energy but, as its speed is enormously high, different units of measure are employed. Distances are measured in "Meters", a unit of the metric system, which equals about 39 of our inches or approximately 3 1/4 feet.

Frequencies are measured in "cycles", a word that applies to any series of events which occur over and over again in regular order. Each complete pulse of Radio energy which leaves the Transmitting antenna is considered as one cycle.

For our airplane example, we found a frequency of 60 per hour but, because of the high speed of Radio energy, its frequencies are measured in "cycles per second". Even on this basis, the ordinary frequencies run into large numbers and therefore we use larger units as shown by the following table.

UNITS OF FREQUENCY MEASURE

1,000 Cycles = 1 Kilocycle - (kc)
1,000,000 Cycles = 1 Megacycle - (mc)
1,000 Kilocycles - (kc) = 1 Megacycle - (mc)

We have mentioned the enormous speed of Radio Carrier Energy and can tell you now that it will travel completely around the world about seven times in one second. It is because of this high speed that we can talk to distant parts of the World by Radio, without any noticeable pauses in our conversation.

In actual numbers, this speed is equal to 300 million meters a second and, as explained for the airplane example, every frequency has a corresponding wavelength. Here again, we use the relationship explained for the airplane example but now, the speed is 300 million meters per second, the Frequency is measured in cycles per second and the wavelength is measured in Meters. Thus, for Radio Energy, we can state: --

1. The Frequency (in cycles per second) equals 300 million divided by the Wavelength (in meters).
2. The Wavelength (in meters) equals 300 million divided by the Frequency (in cycles per second).

There are two important points to remember here. First -- there is a corresponding wavelength for every frequency and. Second -- the higher the frequency, the shorter the wavelength.

THE RADIO SPECTRUM

By methods we will explain the later Lessons, it is possible to control the frequency of a Radio transmitting station and

all frequencies, between 10 Kilocycles and 30,000 Megacycles, are known as the Radio Spectrum. The Federal Communications Commission assign or "allocate" a definite frequency to every transmitting station so that each one has its place and can operate without causing interference with other stations.

Starting at the low frequency end, all values between 10 Kilocycles and 30 Kilocycles are known generally as very low frequencies, abbreviated, (VLF). From 30 K.C. to 300 K.C., they are called "Low" frequencies, abbreviated (LF).

The frequencies between 300 K.C. and 3000 K.C. are known as "Medium", abbreviated "MF." and here we find the Broadcast Band which extends from 545 K.C. to 1600 K.C. As practically all of our Broadcast stations operate in this band it is the one known best to the general public.

To simplify the writing of frequency values, above 3000 K.C., the unit megacycle is used and transposing, 3000 K.C. is equal to 3,000,000 cycles which, in turn is equal to 3 megacycles. All of the present classes or bands of frequencies are summarized in the following table.

Frequency Range	- Name	-Abbreviation
10 KC to 30 KC	-Very Low	- VLF
30 KC to 300 KC	-Low	- LF
300 KC to 3000 KC	-Medium	- MF
3 MC to 30 MC	-High	- HF
30 MC to 300 MC	-Very High	- VHF
300 MC to 3000 MC	-Ultra High	- UHF
3000 MC to 30,000 MC	-Super High	- SHF

The frequencies from the 1600 Kilocycle end of the Broadcast Band up to 30 Megacycles are sometimes called "Short Waves". The corresponding wavelengths for these frequencies are from 187 meters to 10 meters and certain groups of frequencies are known as the "49 Meter Band", the "19 Meter Band" and so on.

The values from 30 megacycles up are commonly classed as "Ultra Short Waves" and include that part of the Radio Spectrum in which some of the later Radio developments are designed to operate. The proper use of these has been of greatest aid in our war effort, and apparently will be of increasing importance in the future days of peace.

RADIO RECEIVERS

To complete any system of communication, the transmitted messages must be received and you are no doubt familiar with

the common types of Radio Receivers such as portables, table models, consoles and radio-phonograph combinations as shown in Figure 4.

Starting at the top left, we have a small portable type which, by means of self contained batteries, can be operated anywhere without external connections.

Below the Portable, we show a small table model which plugs into the house lighting system but is small enough to be readily moved from room to room.

Next is a somewhat larger table model while at the bottom we show a large console type, usually considered as a piece of furniture.

At the top of the right hand side, is an illustration of a table type combination which includes a Radio Receiver and Phonograph. This type of Receiver is quite popular because, with a library of records, any desired music can be enjoyed.

Next below is another small table model, of the semi-portable type, similar to the one at its left.

Going to the right of the page again, you will see a "Chair-side" type of radio console, the name of which suggests its use.

At the bottom is an illustration of a console type of Radio Phonograph combination. Many models of this type are equipped with automatic record changers so that 12 or more records can be played, one after the other, without any attention from the listener.

TUNING

Looking at all of these receivers, you will notice that each has a prominently placed "Tuning Dial", by means of which the desired station can be selected. From our former explanation, we can tell you now that "Tuning" a radio simply means that you are making adjustments so that it will respond to the frequency of the Transmitting station you desire to hear.

You will find, round, square, oval and oblong dials in a great variety of patterns but, in every case, there is a pointer, or marker. Together with a scale, the pointer makes it possible for you to tune to some definite number which, in most cases, refers to the frequency or wavelength to which the receiver will respond.

RADIO RECEIVER CHASSIS

To give you a better idea of their general construction, for Figure 5 we show a Radio Receiver Chassis removed from its cabinet but with the tuning dial and control knobs in place.

This dial is known as a "Slide Rule" type because the pointer moves straight across the scale and readings are taken on the same general plan as those of the slide rules used by engineers.

In this case, the vertical pointer moves from side to side, as the control knob is turned, and you will notice the dial has three scales.

The top scale, marked "Broadcast" in the center and with the letters "KC" near each end has printed numbers from 550 to 1600. This checks exactly with our former explanation and the numbers indicate the frequencies of the Broadcast Band in Kilocycles. If you want to listen to a Broadcast station with a Frequency of 820 K.C. you simply turn the tuning knob until the pointer is opposite 820 on the Broadcast Scale.

The middle scale is marked "Short Wave", has the letters "MC" near each end and is numbered from 6 to 18, which means the receiver will tune the short wave band with frequencies from 6 megacycles to 18 megacycles.

In order to select these different bands, one of the knobs operates a "Band Switch" and the panel of the receiver carries markings to show which band is in use.

Notice here, the short wave values are given in frequencies but, using the methods explained in the earlier part of this Lesson, you can readily determine that 6 MC. is equivalent to a wavelength of 50 meters while 18 MC. is equivalent to a wavelength of 16.6 meters. On this particular scale, certain wavelength values, in meters, are printed below the megacycle scale.

To convert these frequencies to their corresponding wavelengths we make use of the relationship that Wavelength equals the speed divided by the Frequency. The speed is always 300 million meters and, with a frequency of 6 MC., which is 6 million cycles we divide the 300 million by 6 million to find a wavelength of 50 meters.

In the same way, for a frequency of 18 MC., we divide the speed of 300 million meters by the frequency of 18 million cycles to find the wavelength of 16.6 meters.

The bottom scale is uniformly divided from 100 to 0 and has no definite reference to frequency or wavelength. However, it

is useful in locating certain favorite stations or for retuning stations whose frequency is not definitely known. On some models, a scale of this type is used as an extra sensitive tuner, ofter called "Band Spread".

RADIO RECEIVER DIALS

A somewhat similar dial is shown in Figure 6 but this has only a single scale from 42 MC. to 50 MC. This is the band once used by the new Frequency Modulation stations but its general action is exactly as explained for Figure 5. Keep this dial in mind as we will have more to say about Frequency Modulation a little later.

Going ahead to Figure 7, we show a rotating type of dial pointer and want you to remember that, when the upper part moves to the right, the lower part moves to the left. The scale is divided into two parts, the upper half marked "Kilocycles" and the lower half marked meters.

The Kilocycles scale is marked from 55 to 155 but you can readily see that, by adding a zero to each printed number, the scale would read from 550 K.C. to 1550 K.C. and cover the Broadcast Band.

In the position shown, the pointer indicates a little less than 70 on the K.C. scale and a little less than 450 on the meter scale. If you care to figure it out, you will find 680 K.C. is the equivalent of 441 meters and therefore the dial of Figure 7 is reasonably accurate.

The dial of Figure 8 is quite similar to that of Figure 7 but is designed for the Broadcast and Short Wave Bands. Here again, the Broadcast scale is numbered from 55 to 160 but, by adding a "0", we can readily read it as 550 K.C. to 1600 K.C. and this it checks with the dials of Figures 5 and 7.

The short wave band is in (MC) megacycles, from 3.0 to 6.5 and opposite the numbers, 6.5 and 6.0, there is a bar marked "49M" which means 49 meters. As 6.0 M.C. is equivalent to 50 meters and 6.5 M.C. is equivalent to 46 meters, the 49 Meter band will be in between these two points.

Near the top center, just below 4.0 M.C. and extending toward 3.5 M.C., there is another bar, marked "Amateur", as these frequencies are in the 80 Meter band allocated to Radio Amateurs.

Adjoining the "Amateur" is another Band, allocated for the use of Aviation service and therefore, this part of the dial is marked "Aircraft".

No matter what their size or shape, all Radio Dials are marked on this same general plan and, after reading the explanations of this Lesson, we want you to examine the dial of every Radio Receiver you see. Compare its markings with the explanations and illustrations of the Lesson and, if possible, tune in one or two Broadcast or other stations whose frequencies you know.

Most newspapers list the frequencies of all local stations and you will find it quite interesting to tune a Radio according to the listed frequencies. Remember however, all dials are not entirely accurate and you will find some which are badly in need of calibration, an adjustment we will take up later on.

Now that we have told you how to read the dial of a Radio Receiver, for our next Lesson we are going to give you details on the common forms of Electrical energy, most of which play an important part in the operation of all complete Radio systems.

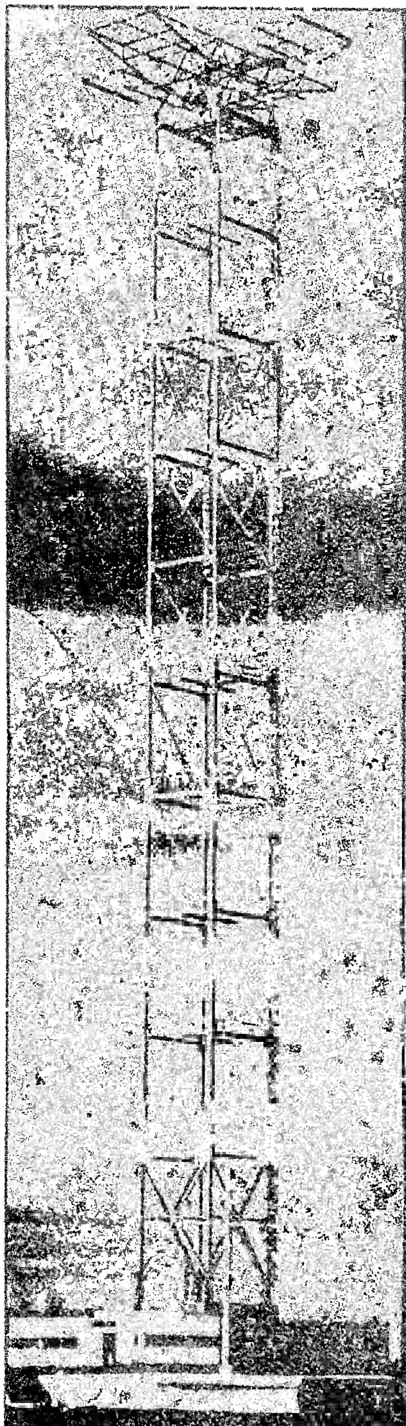
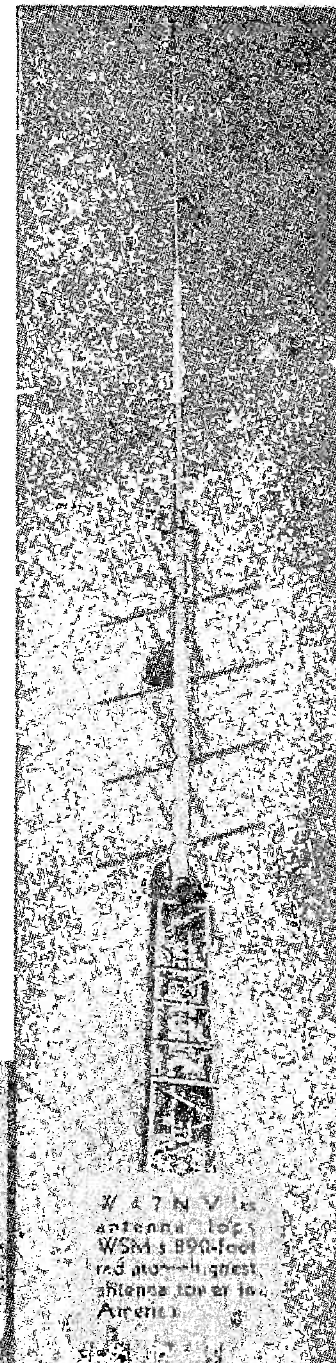
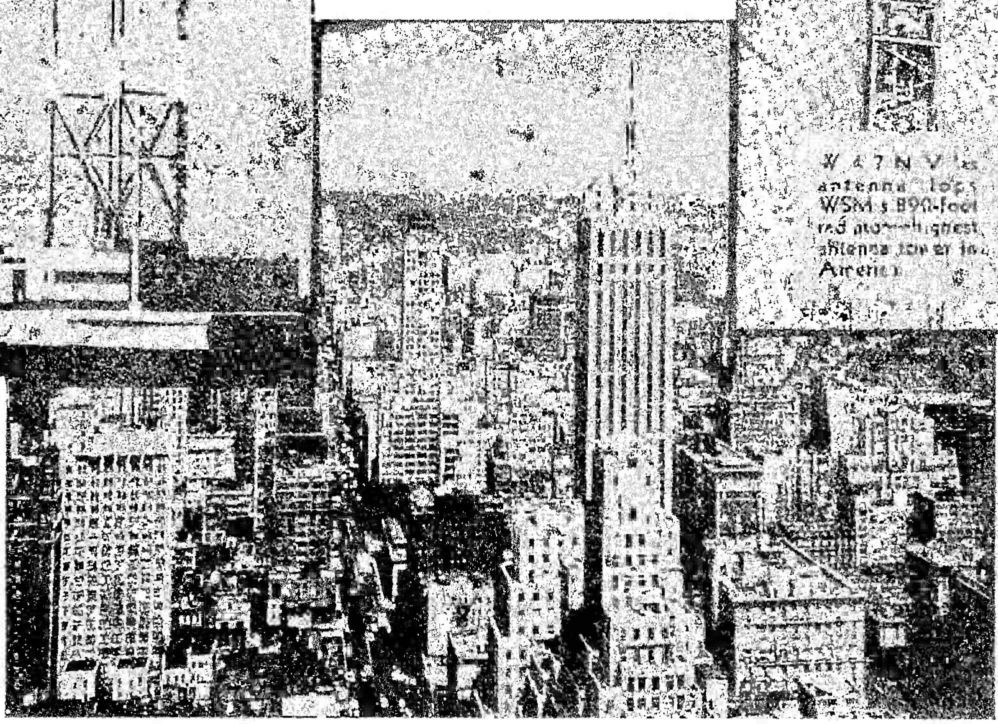


FIGURE 1





DU MONT TELEVISION TRANSMITTER W2XWV, AT 515 MADISON AVENUE, NEW YORK CITY

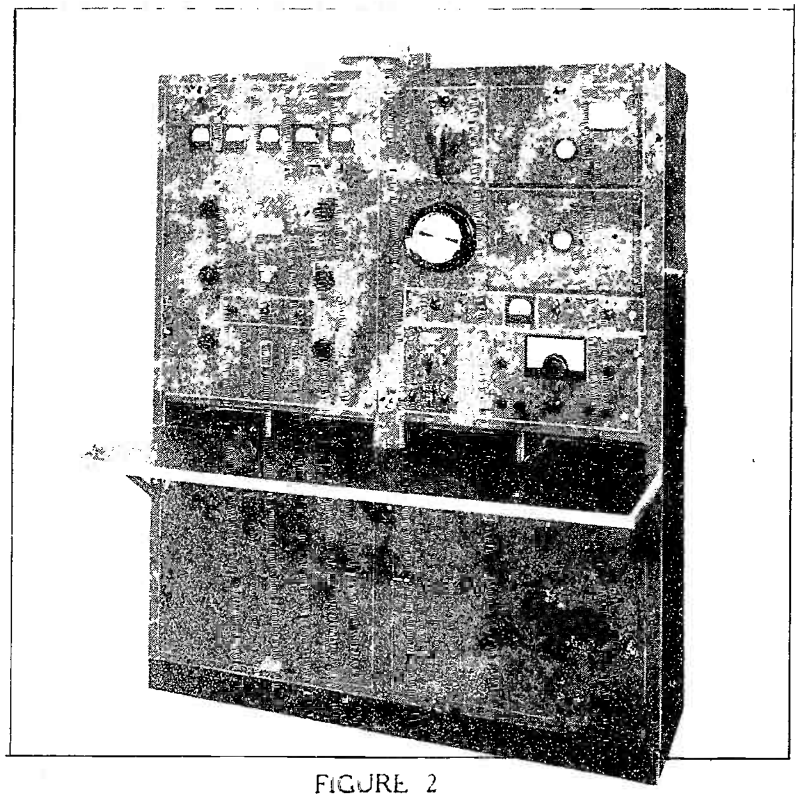


FIGURE 2

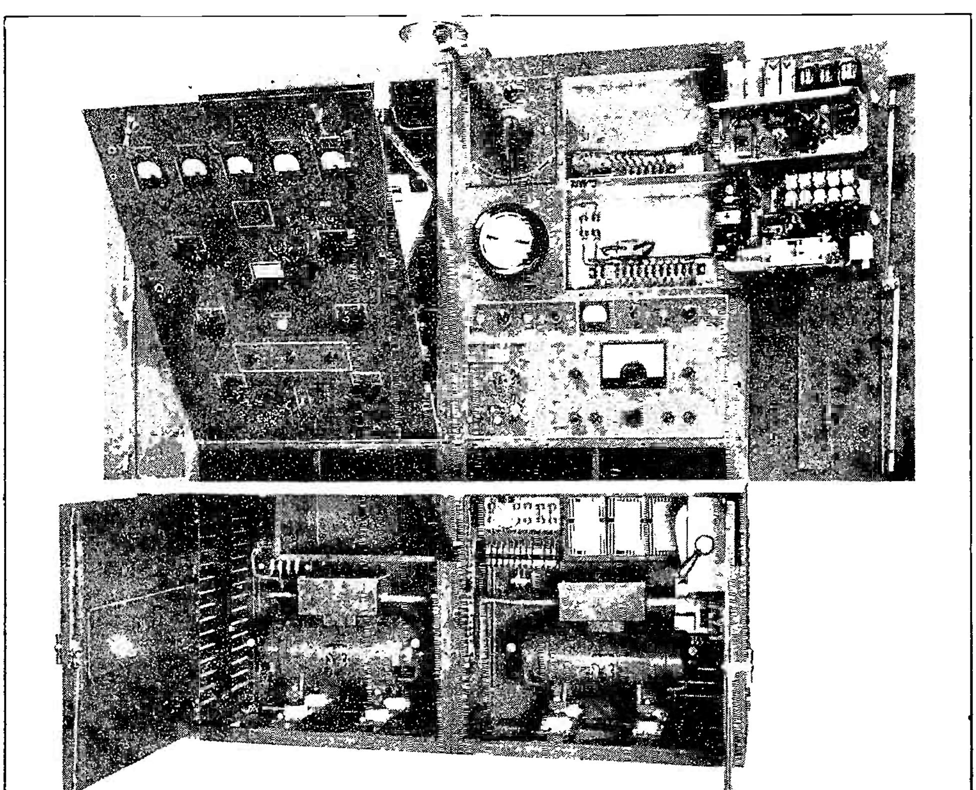


FIGURE 3

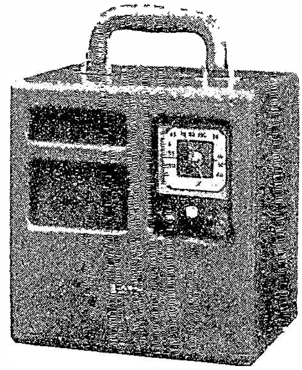
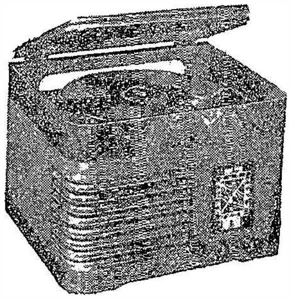
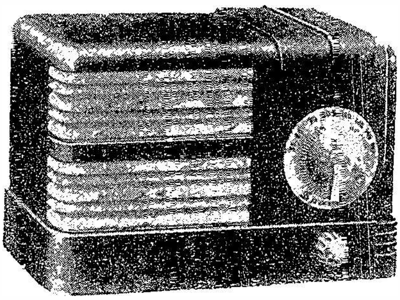
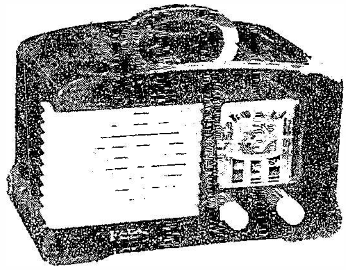
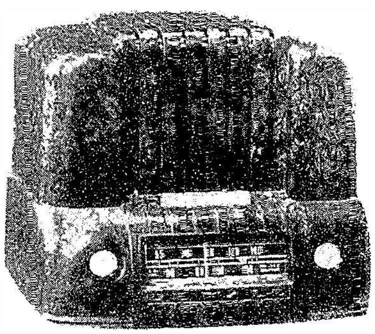
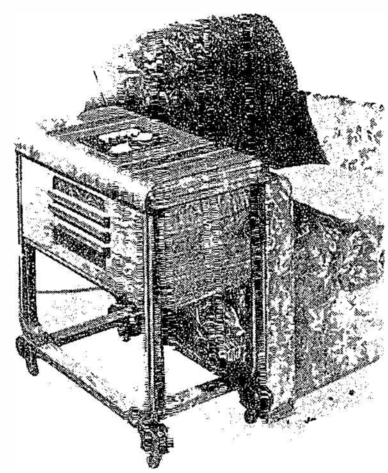
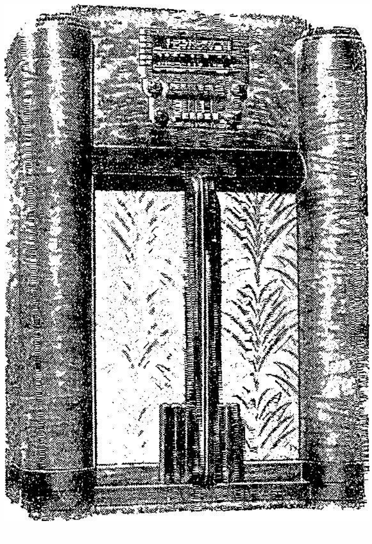
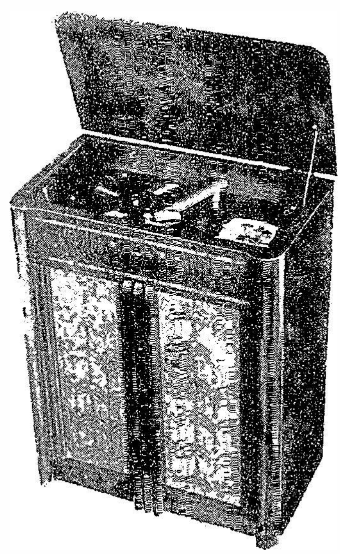





FIGURE 4

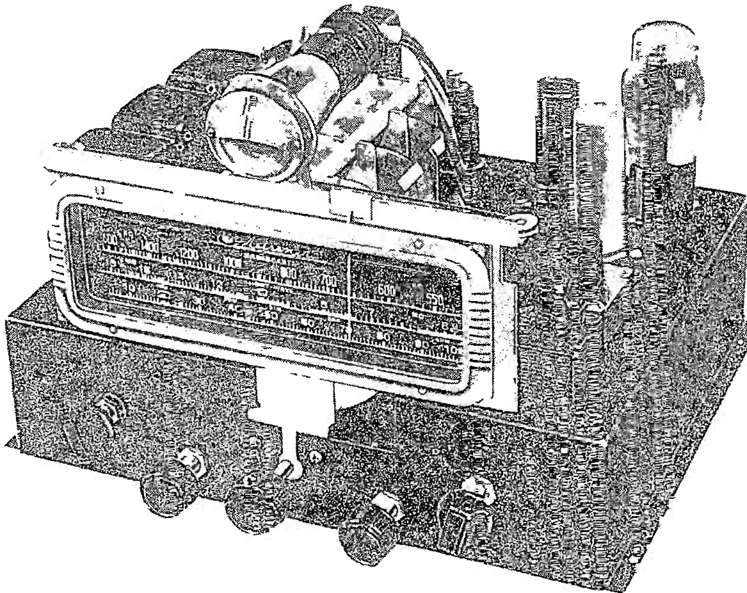


FIGURE 5

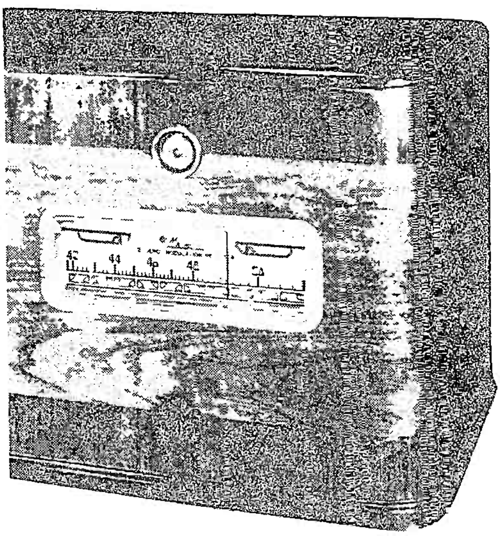


FIGURE 6

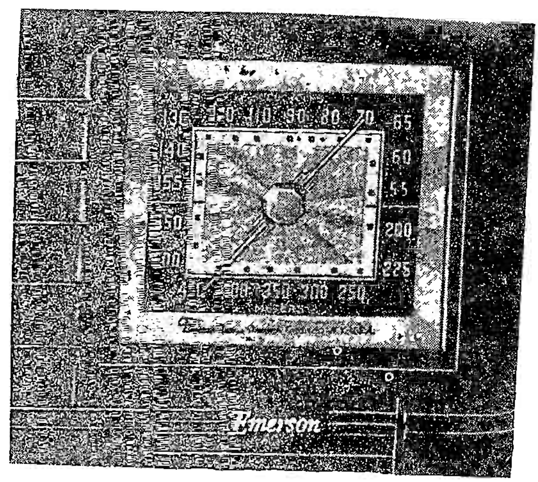


FIGURE 7

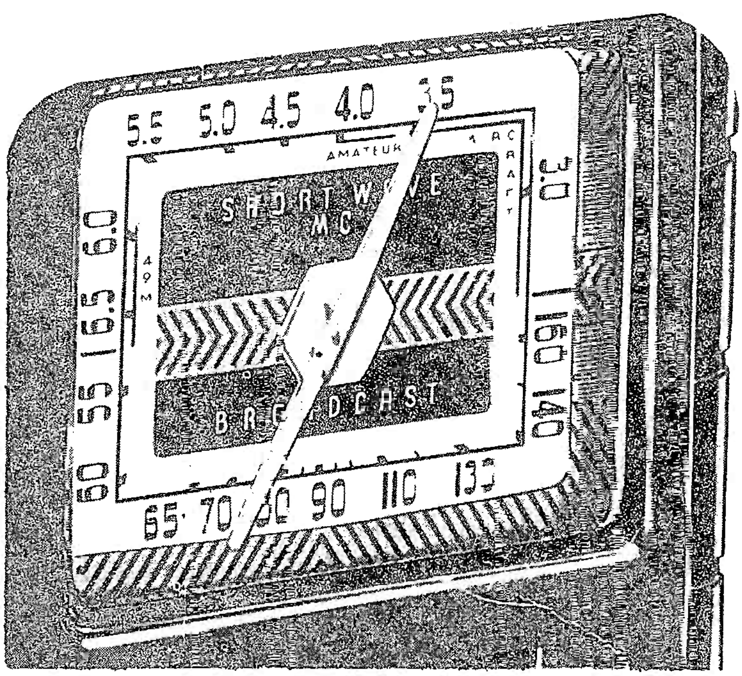
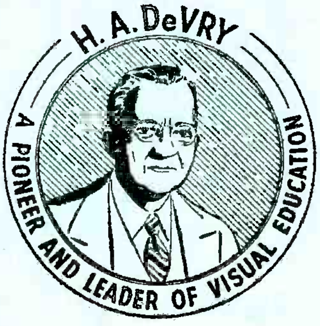


FIGURE 8

DE FOREST'S
TRAINING, Inc.

LESSON FDM - 2
FORMS OF ELECTRICITY

* * Founded 1931 by * *



RADIO FUNDAMENTALS

LESSON 2

FORMS OF ELECTRICITY

First Electrical Action -------- Page 1
Dr. Gilbert's Work ------------- Page 1
Early Idea of Electricity ------ Page 1
Franklin's Kite ---------------- Page 2
The First Battery -------------- Page 2
Magnetism ---------------------- Page 3
The "Lodestone" ---------------- Page 3
Electricity vs. Magnetism ------ Page 3
Electro-Magnets ---------------- Page 4
Induction ---------------------- Page 4
Ohm's Law ---------------------- Page 4
Discovery of the Motor --------- Page 4
Progress of Electricity -------- Page 5
What is Electricity ------------ Page 5
Forms of Electricity ----------- Page 6
Atmospheric Electricity -------- Page 7
Plan of Training --------------- Page 7

- - - -

Nothing is impossible; there are ways that lead to everything, and if we had sufficient will we should always have sufficient means. It is often merely for an excuse that we say things are impossible.

— La Rochefoucauld

FIRST ELECTRICAL ACTION

While there is no definite record of when it was first noticed, as far backas 200 B.C. we find mention of the fact that amber, when rubbed, had the power to attract and repel light objects such as straw and dry leaves. From this fact, the word Electricity is derived from the Greek word meaning amber.

The ancients also knew something of the influence of electricity on the human body but, all through the Middle Ages, there was practically nothing done in the way of experiment or investigation until the time of Dr. Gilbert, who died early in the 17th century.

DR. GILBERT'S WORK

He seems to have been the first man to investigate the knowledge of the ancients and experiment with their ideas to give him general credit as being the founder of the modern science of electricity. From his work, it was discovered that, besides amber, various other substances, when rubbed, had the power to attract, not only straws and leaves, but also metals, stone, wood and liquids. The strength of this power was different for different materials.

From these small beginnings, other experimenters took up the work and, at this time, we want to mention briefly a few of the most important men. Notice their names very carefully because they are words you will use constantly as you advance with your studies.

So far then, about all that was known concerning electricity was the fact that, by rubbing, various substances could be made to attract other objects and were said to be electrified.

Experiments along these lines were conducted by a number of men, some of whom used pads, or cushions for rubbing, while others made up cylinders which could be revolved, thus giving a steadier action. In this connection, Sir Isaac Newton was the first to use a glass globe.

EARLY IDEA OF ELECTRICITY

In 1792, Gray made the very important discovery that some substances would, while others would not, carry this electricity from one object to another. This really was the beginning of our present knowledge of conductors and insulators. The general idea at that time seemed to be that electricity was some sort of a fluid and many attempts were made to collect or bottle it. One of these containers, the Leyden Jar, must be remembered as it did hold an electrical charge and certain forms of it are still in use today.

FRANKLIN'S KITE

Everyone has heard the story of Benjamin Franklin and his kite, by which he proved that lightning was electricity. The kite was sent up as a storm approached but the experiment was not a success until the string got wet. Then he was able to draw sparks from a key, tied to the end of the string.

Contrary to popular belief, the kite was not "struck" by lightning, in the ordinary sense of the word. Instead, the wet string provided a path by which the electrical charges of the storm cloud, in which the kite was flying, could discharge to the earth.

For his own safety, Franklin used a length of silk ribbon between his hand and the kite string but, with the sparks he drew from the key, he was able to produce practically all of the electrical effects known at that time. Therefore, his proof was complete, Lightning was Electricity.

In the many earlier experiments, it had been established that there were two kinds or types of electrification. Without any particular technical reason, Franklin suggested that the electrification which results on glass, when it is rubbed with silk, be called "Positive" while the electrification which results on sealing wax, when rubbed with flannel, be called "Negative".

This is usually considered as Franklin's most important work because the terms were adopted universally and are still in use today although, according to modern theory, they should have been reversed. Keep these terms in mind as we will have more to say about them.

THE FIRST BATTERY

The next important discovery came in 1790 when Luigi Galvani proved that the contact of metals and chemicals produced electricity. Working on this idea, Alessandro Volta developed his "Voltaic Pile" about ten years later.

This pile was made up of alternate disks of different metals, such as copper and zinc, separated by pieces of paper or cloth soaked in a liquid such as weak sulphuric acid. This arrangement produced electricity, by the action of the chemicals on the metal and, thought to be something different, it was named Voltaic or Galvanic in honor of the experimenters.

The voltaic pile was really the first battery and, as more startling results could be produced with it, most experimenters turned their attention to Voltaic or Galvanic electricity.

strength of the current, but reached some certain value and would not go higher.

ELECTRO-MAGNETS

The next step was the discovery that a very strong magnet could be made by winding a coil of wire around a piece of iron and sending an electric current through the wire. As long as there was current in the wire, the iron center, or core of the coil, would act like a magnet. This same method is in use today in nearly every kind of electrical apparatus and the assembly of the coil and core is called an electro-magnet.

INDUCTION

The name of Faraday now comes into the story as in 1821 he succeeded in making a wire, carrying an electric current, revolve across the ends of a magnet. This we might call the first electric motor but it was over fifty years later before the idea was put to practical use.

His next great discovery came about ten years later when he found that, under certain conditions, an electric current in one wire would cause a similar current in another although they were not connected. Also, by moving a magnet past a wire, he could cause an electric current in the wire. These actions are called Electro-Magnetic Induction and most of the electricity in use today is produced by this method.

OHM'S LAW

While Faraday was conducting his experiments in Induction, Dr. Ohm had been working on the theory of Galvanic electricity. He introduced the terms Electro-Motive-Force, Intensity of Current and Resistance, showing their relation to each other. The law he worked out, known as Ohm's Law, will play a very important part in your studies.

Even though the results of all these experiments were well known, Electricity was still little more than a plaything and it was not until 1864, that the present day dynamo was really invented. Then, at the Vienna Exposition of 1873, several of these early dynamos were on exhibition.

DISCOVERY OF THE MOTOR

Purely by accident, some one picked up the two wires from one of the machines, being driven by a steam engine, and connected them to another dynamo which was standing idle. The idle dynamo at once started to run and so our present day electric motor came into existance.

strength of the current, but reached some certain value and would not go higher.

ELECTRO-MAGNETS

The next step was the discovery that a very strong magnet could be made by winding a coil of wire around a piece of iron and sending an electric current through the wire. As long as there was current in the wire, the iron center, or core of the coil, would act like a magnet. This same method is in use today in nearly every kind of electrical apparatus and the assembly of the coil and core is called an electro-magnet.

INDUCTION

The name of Faraday now comes into the story as in 1821 he succeeded in making a wire, carrying an electric current, revolve across the ends of a magnet. This we might call the first electric motor but it was over fifty years later before the idea was put to practical use.

His next great discovery came about ten years later when he found that, under certain conditions, an electric current in one wire would cause a similar current in another although they were not connected. Also, by moving a magnet past a wire, he could cause an electric current in the wire. These actions are called Electro-Magnetic Induction and most of the electricity in use today is produced by this method.

OHM'S LAW

While Faraday was conducting his experiments in Induction, Dr. Ohm had been working on the theory of Galvanic electricity. He introduced the terms Electro-Motive-Force, Intensity of Current and Resistance, showing their relation to each other. The law he worked out, known as Ohm's Law, will play a very important part in your studies.

Even though the results of all these experiments were well known, Electricity was still little more than a plaything and it was not until 1864, that the present day dynamo was really invented. Then, at the Vienna Exposition of 1873, several of these early dynamos were on exhibition.

DISCOVERY OF THE MOTOR

Purely by accident, some one picked up the two wires from one of the machines, being driven by a steam engine, and connected them to another dynamo which was standing idle. The idle dynamo at once started to run and so our present day electric motor came into existance.

We have mentioned these various experiments only to give you an idea of the comparatively simple discoveries which have led to important developments, all of which will be fully explained in the later lessons. Except as a matter of Historical interest, the details of these experiments have no particular value and therefore we will go ahead without further delay.

PROGRESS OF ELECTRICITY

Our present systems of electric lighting did not begin until after the dynamo was a commercial success and are therefore only about 75 years old, yet today, you will find electric lighting in practically every nook and corner of the world. Although Morse invented the telegraph in 1835, it was very slow in becoming popular, and it was not until 1875 that Bell invented his telephone. Today, the country is a network of telephone and telegraph lines and we think nothing of talking clear across the country from New York to San Francisco.

More recently, the service has been extended across the Atlantic Ocean and you can now sit in your own home and talk to people in London or Paris.

Many other discoveries have been made, many are still being made and with the time and effort being put into electrical and electronic work, no one can even guess what the future will produce. The rapid growth of Television, Sound and Radio in the past few years is a good illustration of the possibilities in this field.

When you stop and think that the entire science of electricity, as we know it, is only about 100 years old, we feel sure you will agree that perhaps the most important discoveries are still to come.

WHAT IS ELECTRICITY

In spite of all that has been learned, no one really knows just what electricity is. It is not a liquid, solid or a gas and thus we usually think of it as a form of energy.

By definition, energy is the ability or capacity, to do work. For example, it is your muscular energy that makes you able to do various kinds of physical labor. When you light a fire and the fuel is burning, it gives off heat energy which can be used for various kinds of work, such as boiling water and making steam. If the steam is used to run an engine, then the heat energy of the fire is carried to the engine by means of the steam, and turned into mechanical energy.

You may think that the steam itself is a form of energy but you know if the water is boiled in an open pan, the steam simply rises into the air. However, if we confine it and hold it under pressure, then it will transmit the heat energy which produced it.

Electricity can be explained in much the same way because, when put under pressure, it will carry energy from one place to another.

As a common example, we can take the mechanical energy of a waterfall and, by means of a water wheel and dynamo, turn it into electrical energy. The electrical energy can then be carried along wires to some distant factory and, by means of a motor, be turned back into mechanical energy.

It really does not make much difference just what it is because we do know how to make use of electricity and in its common useful forms speak of it as a form of energy or a force.

FORMS OF ELECTRICITY

According to its motion, the common forms of electricity are classed as follows:

1. Electricity at rest - Static
2. Electricity in motion - Current
3. Electricity in vibration - Radiant

Static electricity is that form which is produced by friction. A substance when rubbed, is said to have a static charge. Nowadays, we also speak of the atmospheric disturbances heard over the radio as static.

Current electricity is that form in most common use and is always in motion. It is the form of electricity that passes through or along the wires, lights our lamps and operates our telephones, motors and so on.

Radiated electricity is that form in which the current vibrates back and forth, or oscillates, very rapidly, taking the form of waves like those of Radio, X-Rays, and Cosmic Rays.

Magnetism is sometimes described as a form of electricity that rotates around a magnet. It is commonly produced with an electro-magnet by means of current electricity.

As originally named by Franklin, you will also hear the terms positive and negative applied to electricity. By positive electricity we simply mean that point or part of an electri-

fied body having a higher energy from which it flows to a point of lower energy or level.

An easy way to think of this is to remember that water always flows from a higher to a lower level. Positive and negative are used in electricity like high and low are used for water. Electricity flows from positive to negative. Don't let these terms confuse you, because even though the positive were closer to the floor, or lower than the negative, Electricity would still flow from positive to negative.

This statement is an apparent contradiction to the generally accepted "Electron Theory" but, as we will explain in the later Lessons, for the most practical work the actual direction of an electrical current is not of major importance.

The older idea of current from positive to negative is still in common use commercially and circuits are traced on this plan. Therefore, we will follow this method in the early explanations, taking up the Electron Theory later on after you have learned the basic actions and rules. In this way, you will be able to understand both Theories, without the confusion which would arise should we attempt a complete discussion at this time.

ATMOSPHERIC ELECTRICITY

There is also a certain amount of free electricity in the air, although very little is known about it, but we have all seen the electricity that is present during a thunderstorm. The Northern Lights are another effect of this atmospheric electricity. Then, as we will explain later, the earth itself is a huge magnet, so you see there is electricty all around us, not only in the machines that men have made, but in nature itself.

PLAN OF TRAINING

Before going ahead with the next Lesson, we would like to give you an idea as to our plan of training. In the early Lessons, you will find that we spend considerable time on the fundamentals and principles of electricity and magnetism. This may seem unnecessary detail but, from experience, we have found that it is the only way you can obtain a thorough knowledge of Radio and other Electronic application. In other words, you must have a good foundation if you expect to build a lasting career in the electronic field.

Also, you will find the explanations of these early Lessons are written around battery operated units. This is done for two reasons. First, all the common forms of Radio tubes are

fundamentally direct current units and the, so-called, A.C. equipment merely contains additional circuits to provide the required direct current from the A.C. supply. Thus, by showing batteries as a direct current supply, both the circuits and explanations can be made much simpler.

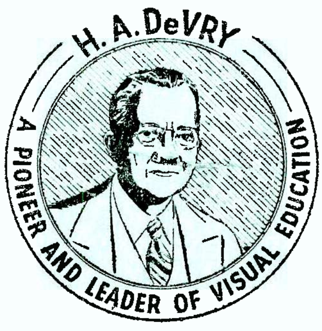
Second, by looking in most any Radio catalog, you will find there is a great amount of battery operated equipment being sold for mobile installations and portable units as well as in rural communities.

In general then, we want you to be patient enough to obtain a good understanding of fundamentals, after which, we can assure you, the later Lessons contain complete explanations on various A.C., D.C. and Universal types of Radio and other Electronic equipment.

DE FOREST'S
TRAINING, Inc.

LESSON FDM - 2
FORMS OF ELECTRICITY

* * Founded 1931 by * *



RADIO FUNDAMENTALS

LESSON 2

FORMS OF ELECTRICITY

First Electrical Action ——— Page 1
Dr. Gilbert's Work ——— Page 1
Early Idea of Electricity ——— Page 1
Franklin's Kite ——— Page 2
The First Battery ——— Page 2
Magnetism ——— Page 3
The "Lodestone" ——— Page 3
Electricity vs. Magnetism ——— Page 3
Electro-Magnets ——— Page 4
Induction ——— Page 4
Ohm's Law ——— Page 4
Discovery of the Motor ——— Page 4
Progress of Electricity ——— Page 5
What is Electricity ——— Page 5
Forms of Electricity ——— Page 6
Atmospheric Electricity ——— Page 7
Plan of Training ——— Page 7

- - - -

Nothing is impossible; there are ways that lead to everything, and if we had sufficient will we should always have sufficient means. It is often merely for an excuse that we say things are impossible.

— La Rochefoucauld

FIRST ELECTRICAL ACTION

While there is no definite record of when it was first noticed, as far backas 200 B.C. we find mention of the fact that amber, when rubbed, had the power to attract and repel light objects such as straw and dry leaves. From this fact, the word Electricity is derived from the Greek word meaning amber.

The ancients also knew something of the influence of electricity on the human body but, all through the Middle Ages, there was practically nothing done in the way of experiment or investigation until the time of Dr. Gilbert, who died early in the 17th century.

DR. GILBERT'S WORK

He seems to have been the first man to investigate the knowledge of the ancients and experiment with their ideas to give him general credit as being the founder of the modern science of electricity. From his work, it was discovered that, besides amber, various other substances, when rubbed, had the power to attract, not only straws and leaves, but also metals, stone, wood and liquids. The strength of this power was different for different materials.

From these small beginnings, other experimenters took up the work and, at this time, we want to mention briefly a few of the most important men. Notice their names very carefully because they are words you will use constantly as you advance with your studies.

So far then, about all that was known concerning electricity was the fact that, by rubbing, various substances could be made to attract other objects and were said to be electrified.

Experiments along these lines were conducted by a number of men, some of whom used pads, or cushions for rubbing, while others made up cylinders which could be revolved, thus giving a steadier action. In this connection, Sir Isaac Newton was the first to use a glass globe.

EARLY IDEA OF ELECTRICITY

In 1792, Gray made the very important discovery that some substances would, while others would not, carry this electricity from one object to another. This really was the beginning of our present knowledge of conductors and insulators. The general idea at that time seemed to be that electricity was some sort of a fluid and many attempts were made to collect or bottle it. One of these containers, the Leyden Jar, must be remembered as it did hold an electrical charge and certain forms of it are still in use today.

FRANKLIN'S KITE

Everyone has heard the story of Benjamin Franklin and his kite, by which he proved that lightning was electricity. The kite was sent up as a storm approached but the experiment was not a success until the string got wet. Then he was able to draw sparks from a key, tied to the end of the string.

Contrary to popular belief, the kite was not "struck" by lightning, in the ordinary sense of the word. Instead, the wet string provided a path by which the electrical charges of the storm cloud, in which the kite was flying, could discharge to the earth.

For his own safety, Franklin used a length of silk ribbon between his hand and the kite string but, with the sparks he drew from the key, he was able to produce practically all of the electrical effects known at that time. Therefore, his proof was complete, Lightning was Electricity.

In the many earlier experiments, it had been established that there were two kinds or types of electrification. Without any particular technical reason, Franklin suggested that the electrification which results on glass, when it is rubbed with silk, be called "Positive" while the electrification which results on sealing wax, when rubbed with flannel, be called "Negative".

This is usually considered as Franklin's most important work because the terms were adopted universally and are still in use today although, according to modern theory, they should have been reversed. Keep these terms in mind as we will have more to say about them.

THE FIRST BATTERY

The next important discovery came in 1790 when Luigi Galvani proved that the contact of metals and chemicals produced electricity. Working on this idea, Alessandro Volta developed his "Voltaic Pile" about ten years later.

This pile was made up of alternate disks of different metals, such as copper and zinc, separated by pieces of paper or cloth soaked in a liquid such as weak sulphuric acid. This arrangement produced electricity, by the action of the chemicals on the metal and, thought to be something different, it was named Voltaic or Galvanic in honor of the experimenters.

The voltaic pile was really the first battery and, as more startling results could be produced with it, most experimenters turned their attention to Voltaic or Galvanic electricity.

MAGNETISM

Before going any further with the development of electricity, we will have to mention the subject of magnetism. Like electricity, the name Magnetism comes from a Greek word that was used for a certain kind of iron ore. This ore had the remarkable power of attracting pieces of iron and, after being rubbed on the ore, a piece of iron then had the power to attract other iron and was said to be magnetized.

Just who first discovered this action is not known but while the ancient Greeks and Romans knew about it, no practical use was made of it. Finally, some one noticed that when a piece of this ore was hung so that it could turn freely, it would always stop when pointing North and South.

THE "LODESTONE"

The sailors used this action to guide them when out of sight of land and the ore came to be called "Lead-Stone" or lodestone. The ordinary magnetic compass of today works on exactly the same idea except that, instead of a lodestone, a magnetized steel needle is mounted on a pivot.

The action of the lodestone in attracting pieces of iron was so much like that of a rubbed piece of amber attracting pieces of straw, that most of the early experimenters had been looking for a connection of some sort between electricity and magnetism.

ELECTRICITY vs. MAGNETISM

However, it was not until 1820 that Prof. Oersted found the electric current of a voltaic pile, or galvanic battery, when made to pass through a platinum wire, acted on a compass needle placed below the wire. Instead of pointing North and South, the needle would always turn crosswise to the wire.

In that same year, Biot and Savart, two French physicists working on Oersted's discovery, showed that the current in the wire produced magnetism which varied with the strength of the current. Thus, Oersted's arrangement of a magnetic compass and a current carrying wire was converted into an electrical measuring instrument which is known as a "Galvanometer". Some of our present types of electric meters operate on this same general principle.

This same year, it was also discovered that an electrical current had the power to magnetize iron and steel. Lenz and Joule, two other experimenters, went a little further and found that the magnetization of iron did not keep on increasing with the

strength of the current, but reached some certain value and would not go higher.

ELECTRO-MAGNETS

The next step was the discovery that a very strong magnet could be made by winding a coil of wire around a piece of iron and sending an electric current through the wire. As long as there was current in the wire, the iron center, or core of the coil, would act like a magnet. This same method is in use today in nearly every kind of electrical apparatus and the assembly of the coil and core is called an electro-magnet.

INDUCTION

The name of Faraday now comes into the story as in 1821 he succeeded in making a wire, carrying an electric current, revolve across the ends of a magnet. This we might call the first electric motor but it was over fifty years later before the idea was put to practical use.

His next great discovery came about ten years later when he found that, under certain conditions, an electric current in one wire would cause a similar current in another although they were not connected. Also, by moving a magnet past a wire, he could cause an electric current in the wire. These actions are called Electro-Magnetic Induction and most of the electricity in use today is produced by this method.

OHM'S LAW

While Faraday was conducting his experiments in Induction, Dr. Ohm had been working on the theory of Galvanic electricity. He introduced the terms Electro-Motive-Force, Intensity of Current and Resistance, showing their relation to each other. The law he worked out, known as Ohm's Law, will play a very important part in your studies.

Even though the results of all these experiments were well known, Electricity was still little more than a plaything and it was not until 1864, that the present day dynamo was really invented. Then, at the Vienna Exposition of 1873, several of these early dynamos were on exhibition.

DISCOVERY OF THE MOTOR

Purely by accident, some one picked up the two wires from one of the machines, being driven by a steam engine, and connected them to another dynamo which was standing idle. The idle dynamo at once started to run and so our present day electric motor came into existance.

We have mentioned these various experiments only to give you an idea of the comparatively simple discoveries which have led to important developments, all of which will be fully explained in the later lessons. Except as a matter of Historical interest, the details of these experiments have no particular value and therefore we will go ahead without further delay.

PROGRESS OF ELECTRICITY

Our present systems of electric lighting did not begin until after the dynamo was a commercial success and are therefore only about 75 years old, yet today, you will find electric lighting in practically every nook and corner of the world. Although Morse invented the telegraph in 1835, it was very slow in becoming popular, and it was not until 1875 that Bell invented his telephone. Today, the country is a network of telephone and telegraph lines and we think nothing of talking clear across the country from New York to San Francisco.

More recently, the service has been extended across the Atlantic Ocean and you can now sit in your own home and talk to people in London or Paris.

Many other discoveries have been made, many are still being made and with the time and effort being put into electrical and electronic work, no one can even guess what the future will produce. The rapid growth of Television, Sound and Radio in the past few years is a good illustration of the possibilities in this field.

When you stop and think that the entire science of electricity, as we know it, is only about 100 years old, we feel sure you will agree that perhaps the most important discoveries are still to come.

WHAT IS ELECTRICITY

In spite of all that has been learned, no one really knows just what electricity is. It is not a liquid, solid or a gas and thus we usually think of it as a form of energy.

By definition, energy is the ability or capacity, to do work. For example, it is your muscular energy that makes you able to do various kinds of physical labor. When you light a fire and the fuel is burning, it gives off heat energy which can be used for various kinds of work, such as boiling water and making steam. If the steam is used to run an engine, then the heat energy of the fire is carried to the engine by means of the steam, and turned into mechanical energy.

You may think that the steam itself is a form of energy but you know if the water is boiled in an open pan, the steam simply rises into the air. However, if we confine it and hold it under pressure, then it will transmit the heat energy which produced it.

Electricity can be explained in much the same way because, when put under pressure, it will carry energy from one place to another.

As a common example, we can take the mechanical energy of a waterfall and, by means of a water wheel and dynamo, turn it into electrical energy. The electrical energy can then be carried along wires to some distant factory and, by means of a motor, be turned back into mechanical energy.

It really does not make much difference just what it is because we do know how to make use of electricity and in its common useful forms speak of it as a form of energy or a force.

FORMS OF ELECTRICITY

According to its motion, the common forms of electricity are classed as follows:

1. Electricity at rest - Static
2. Electricity in motion - Current
3. Electricity in vibration - Radiant

Static electricity is that form which is produced by friction. A substance when rubbed, is said to have a static charge. Nowadays, we also speak of the atmospheric disturbances heard over the radio as static.

Current electricity is that form in most common use and is always in motion. It is the form of electricity that passes through or along the wires, lights our lamps and operates our telephones, motors and so on.

Radiated electricity is that form in which the current vibrates back and forth, or oscillates, very rapidly, taking the form of waves like those of Radio, X-Rays, and Cosmic Rays.

Magnetism is sometimes described as a form of electricity that rotates around a magnet. It is commonly produced with an electro-magnet by means of current electricity.

As originally named by Franklin, you will also hear the terms positive and negative applied to electricity. By positive electricity we simply mean that point or part of an electri-

fied body having a higher energy from which it flows to a point of lower energy or level.

An easy way to think of this is to remember that water always flows from a higher to a lower level. Positive and negative are used in electricity like high and low are used for water. Electricity flows from positive to negative. Don't let these terms confuse you, because even though the positive were closer to the floor, or lower than the negative, Electricity would still flow from positive to negative.

This statement is an apparent contradiction to the generally accepted "Electron Theory" but, as we will explain in the later Lessons, for the most practical work the actual direction of an electrical current is not of major importance.

The older idea of current from positive to negative is still in common use commercially and circuits are traced on this plan. Therefore, we will follow this method in the early explanations, taking up the Electron Theory later on after you have learned the basic actions and rules. In this way, you will be able to understand both Theories, without the confusion which would arise should we attempt a complete discussion at this time.

ATMOSPHERIC ELECTRICITY

There is also a certain amount of free electricity in the air, although very little is known about it, but we have all seen the electricity that is present during a thunderstorm. The Northern Lights are another effect of this atmospheric electricity. Then, as we will explain later, the earth itself is a huge magnet, so you see there is electricty all around us, not only in the machines that men have made, but in nature itself.

PLAN OF TRAINING

Before going ahead with the next Lesson, we would like to give you an idea as to our plan of training. In the early Lessons, you will find that we spend considerable time on the fundamentals and principles of electricity and magnetism. This may seem unnecessary detail but, from experience, we have found that it is the only way you can obtain a thorough knowledge of Radio and other Electronic application. In other words, you must have a good foundation if you expect to build a lasting career in the electronic field.

Also, you will find the explanations of these early Lessons are written around battery operated units. This is done for two reasons. First, all the common forms of Radio tubes are

fundamentally direct current units and the, so-called, A.C. equipment merely contains additional circuits to provide the required direct current from the A.C. supply. Thus, by showing batteries as a direct current supply, both the circuits and explanations can be made much simpler.

Second, by looking in most any Radio catalog, you will find there is a great amount of battery operated equipment being sold for mobile installations and portable units as well as in rural communities.

In general then, we want you to be patient enough to obtain a good understanding of fundamentals, after which, we can assure you, the later Lessons contain complete explanations on various A.C., D.C. and Universal types of Radio and other Electronic equipment.

QUESTIONS

How many advance Lessons have you now hand?______________

Print or use Rubber Stamp.

Name ______________________________ Student No. __________

Street ____

City ____________________________ State __________

1. What simple act demonstrates the oldest known electrical action?

2. What was Benjamin Franklin's important work?

3. Who invented the first electric battery?

4. What was the first use made of Magnetism?

5. What was Oersted's important discovery?

6. How is an Electro-Magnet made?

7. What is Static Electricity?

8. What is Current Electricity?

9. What is meant by Positive Electricity?

10. According to Benjamin Franklin's theory, what is the direction of an electric current?

DE FOREST'S
TRAINING, Inc.

LESSON FDM - 3
CURRENT ELECTRICITY

. . Founded 1931 by . .

RADIO FUNDAMENTALS

LESSON FDM-3

CURRENT ELECTRICITY

The Action of Water - - - - - - - - - - - - - - - - -	Page 1
Four Things to Remember - - - - - - - - - - - - - -	Page 1
Action of the Valve - - - - - - - - - - - - - - - - -	Page 1
Water Pressure - - - - - - - - - - - - - - - - - - -	Page 2
Current, Pressure and Resistance - - - - - - - - -	Page 2
Electrical Conductors - - - - - - - - - - - - - - - -	Page 2
Electrical Insulators - - - - - - - - - - - - - - - -	Page 2
Comparing Electricity with Water - - - - - - - - -	Page 3
A Simple Electrical Path - - - - - - - - - - - - - -	Page 3
The Electric Circuit - - - - - - - - - - - - - - - - -	Page 4
Units of Measure - - - - - - - - - - - - - - - - - - -	Page 4

# # # # # #

Thank God every morning when you get up that you have something to do that day which must be done, whether you like it or not. Being required to work, and forced to do your best, will breed in you temperance and self control, dilligence and strength of will, cheerfulness and content, and a hundred virtues which the idle never know.

— Charles Kingsley

As far as the operation of Radio and other Electronic equipment is concerned, you will be interested mainly in current electricity because that is what operates the tubes and other parts. In fact, it is the common form of electricity which lights the lamps in your home or along your street, drives the street cars, operates your telephone, rings your door bell and performs many other useful duties.

To make the action of a current of Electricity a little easier to understand, we are going to compare it to a stream or current of water. Remember, these explanations are used only to give you the idea, and must not be carried too far or used to explain all electrical actions.

THE ACTION OF WATER

Let us look at Figure 1 for a minute and imagine that although water is so scarce that we can not afford to lose any, we want to operate the water wheel which is placed in a catch basin.

By operating the pump, the supply tank can be partly filled with water but, if the valve is closed, none of it can get out. You will notice that the tank is palced somewhat higher than the water wheel so that, when the valve is opened, a stream of water will flow out of the tank and from the end of the pipe. As it falls, it strikes the paddles on the water wheel and causes it to revolve.

To keep the wheel turning, it will be necessary to pump the water from the catch basin back up into the supply tank. With but a very small amount of water, it would be necessary to keep the pump going all the time in order to keep the wheel in motion.

FOUR THINGS TO REMEMBER

There are four things that we want you to notice and remember about this outfit. First:- None of the water is used up in running the wheel, it is simply pumped into the tank and allowed to run down over the paddles. Second:- There is a continuous path for the water to travel around. Third:- If the valve is closed, the wheel will not run even though the supply tank is full of water. Fourth:- The pump must be kept working in order to keep the wheel turning.

ACTION OF THE VALVE

Suppose now that the wheel had to be run very slowly. We would open the valve just a little way until there was enough water flowing to give the desired speed. This can be explained by saying that the small opening at the valve makes

it harder for the water to get out, or offers resistance to the flow of water. Along the same line, you can see that the more the valve was opened, the less resistance there would be to the flow of water and the current through the pipe would be greater.

WATER PRESSURE

There is another thing that you may not have thought about. The water in the return pipe will not run the wheel unless we first pump it up into the tank. What have we done? Certainly the water has not been changed, but has merely been pumped to a higher level and naturally, will try to run back down whenever it gets the chance.

This push of the water in trying to get out of the tank can be thought of as Pressure, and the higher the tank is above the wheel, the greater the pressure will be. If the water fell only one foot before it hit the paddles, the wheel would not turn very fast but, if it fell six feet before striking the paddles, it would have more force and turn the wheel a great deal faster.

CURRENT, PRESSURE AND RESISTANCE

We find then that, in order to operate even such a simple outfit as shown in Figure 1, a CURRENT of water is required and, to produce the current, the water must have PRESSURE. Even with pressure, the amount of current will depend on the opening of the valve, or the RESISTANCE to its passage.

Checking up in Figure 1, we have a path for the water, a pump for putting the water into the tank and giving it pressure and a current of water to make the water wheel run. To a great extent, this is exactly what happens in an electrical path or circuit.

ELECTRICAL CONDUCTORS

Unlike water, electricity will travel through, or on most anything to some extent, but there are certain things that will carry, or conduct, it much better than others. Those are called "Conductors", and in general, include all of the metals such as copper, iron, steel, lead and aluminum.

ELECTRICAL INSULATORS

Other things, that do not conduct electricity well, are called "Insulators". They include rubber, porcelain, certain kinds of oil, shellac, mica and air. Then there are a lot of manufactured insulating compounds such as bakelite and fibre.

COMPARING ELECTRICITY WITH WATER

In order to put electricity to work, first of all we must build a path, making it like a circle and using some metal, such as copper, for the electricity to travel on or through. To prevent it from getting away from its path, we put an insulator around the circle.

A SIMPLE ELECTRICAL PATH

In the electrical path of Figure 2, the pump and tank of Figure 1, are replaced by a battery of two ordinary dry cells. Instead of the pipe and a catch basin, there is a wire for the path. A switch takes the place of the water valve and a small electric motor replaces the water wheel.

While these two paths are much alike, in some ways they are different. To shut off the water, the valve was to be closed but, to break the electrical path, the switch has to be opened.

Then, as long as there is water in the supply tank of Figure 1, the water wheel can be run but, in the electrical path of Figure 2, the motor will not run unless the path is entirely completed from the battery, through the motor and switch and back to the battery again.

This battery of dry cells produces an electrical pressure which, when the switch is closed, forces an electrical current through the motor and causes it to run. The current is not used up but passes through the motor and back to the battery again. If you will just think for a minute that electricity has a speed so great that its action is almost instantaneous, you will easily understand why we can not, as in the case of the water, pump up a supply and let it run down. The electric current goes around this path so fast that it is impossible to store it up and it comes back from the motor to the battery in exactly the same amount that it goes from the battery to the motor.

To compare this action with the arrangement of Figure 1, we will imagine the supply tank has been taken away and the pump has been moved over so that the water from its spout will fall directly on the paddles of the water wheel. Under these conditions, the current of water from the catch basin to the pump would be exactly the same as that from the pump to the water wheel.

As the pump does not actually produce, or "make" any water, it can deliver only as much as it receives through the return pipe and thus, the current of water would be the same in all parts of Figure 1. No water is lost or used up and the pump merely raises it to a higher level to produce the pressure which causes the water to flow.

THE ELECTRIC CIRCUIT

The general idea of the arrangement of Figure 2 is much the same because, with the switch closed, there is an endless path for the electricity. In this path there is a device for producing an electrical pressure - the battery. There is something to open and close the path - the switch, and there is something to change the electricity into a useful form — the motor. A set up of this kind is called an ELECTRICAL CIRCUIT.

While the switch can not be partly closed, like the valve of Figure 1, still the switch, wires and motor offer resistance to the free flow of electricity. If we want to think of both Figures 1 and 2 as circuits, we find that they have very nearly the same conditions to work under.

In the operation of each circuit, there are three very important things to remember, Pressure, Current and Resistance. From what has been said, you can easily see that they depend more or less on each other. If, in Figure 1, there was no pressure, there would be no current and nothing would happen. Even with pressure, if the valve was closed, the resistance would be so great that there would still be no current. Therefore it is clear that the current depends both on Pressure and Resistance.

UNITS OF MEASURE

To measure the conditions in the water circuit, the pressure will be so many "pounds", just like the air pressure in an automobile tire or the steam pressure in a boiler. The current of water will be "gallons per minute", but here we have to stop because there is no unit for measuring the resistance of water pipe.

In the electrical circuit, the pressure will be measured in "VOLTS". With electricity always in motion, it is not necessary to say "Per-Minute" every time, because the current is measured in "AMPERES" which includes time. The resistance of the electrical circuit is very important and is measured by a unit called the "OHM".

The whole action of Figure 2 can be summed up by saying that an electrical pressure of so many volts forces an electrical current of so many amperes through a circuit which has a resistance of so many ohms.

Be sure you have these three units straight in your mind because they are really the foundation for all the work to follow and apply wherever electricity is used. They are so important that they are named after the men who discovered their

actions. Try and think of each one separately because each one is different and distinct. For example - When the switch of Figure 2 is open, the dry cells still retain their Voltage, but there is no current in the circuit. Should the dry cells run down and lose their voltage, there would be no current in the circuit even though the switch was closed, because there would be no pressure to force it through.

The resistance of the circuit depends on how it is built and what it is made of. It must not be confused with either the voltage or the current.

For example, part of the operating requirements of an electronic tube may be listed as "Filament Volts — 6.3", "Filament Amperes — .3". That simply means the filament is made of wire, the size, length and matérial of which offers enough resistance to allow a current of .3 ampere at an electrical pressure of 6.3 volts.

As the filament is placed inside a glass bulb and can not be adjusted, you can think of its resistance as remaining unchanged. Then, to check up with what we have already said, with no voltage there would be no current. If the voltage was less than 6.3, the current would be less than .3 ampere.

At 6.3 volts, there is .3 ampere which heats the filament to the correct temperature and allows the tube to operate properly. However, if the voltage was more than 6.3, the current would be more than .3 ampere, the filament would become too hot and the life of the tube would be shortened.

Now that you have been introduced to this all-important subject of CURRENT ELECTRICITY and the electrical measuring units known as the VOLT, AMPERE and OHM, you are really beginning to get down to "brass tacks" in your study of Radio and Electronics.

Remember — any building or institution that is to <u>endure</u> must have a solid foundation. So it is with life — and so it is with a career in Radio and Electronics.

What we are doing in these early Lessons is to build for you, step by step, a safe ... enduring FOUNDATION in the fundamentals of Radio and Electronics. The progress you later make in this field is going to depend to a considerable extent on the soundness of this foundation.

Be sure you <u>understand</u> each Lesson thoroughly before moving ahead to the next. Do this — and there's no reason why you should not come through with colors flying — and a bright future ahead of you.

We are not going to take up your time with unnecessary details and, in the next Lesson you will find a great deal of practical information on "Resistors", perhaps the most numerous component of Radio and other Electronic circuits.

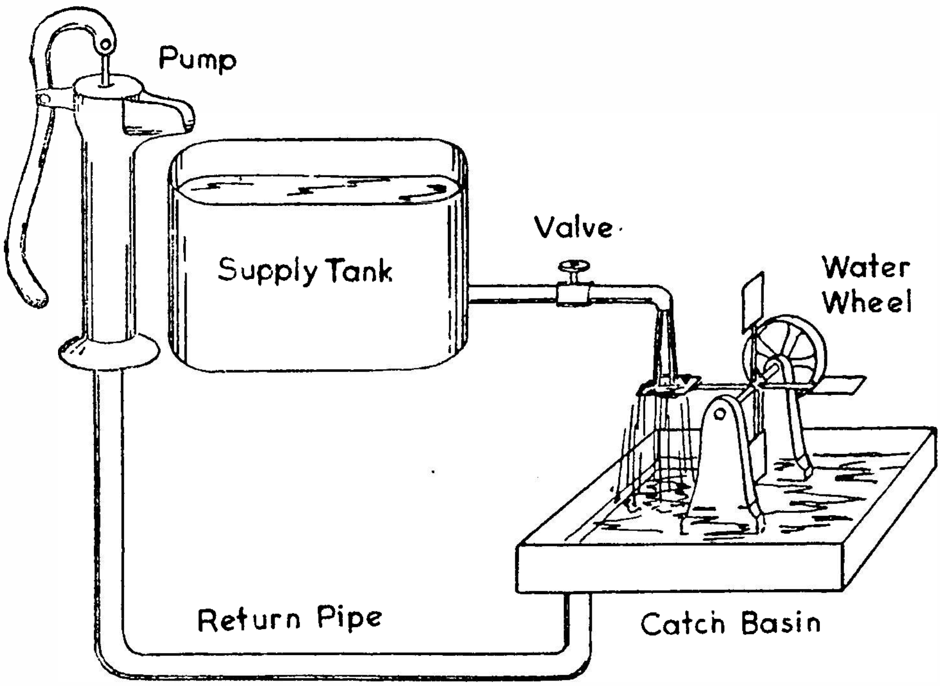


FIGURE 1

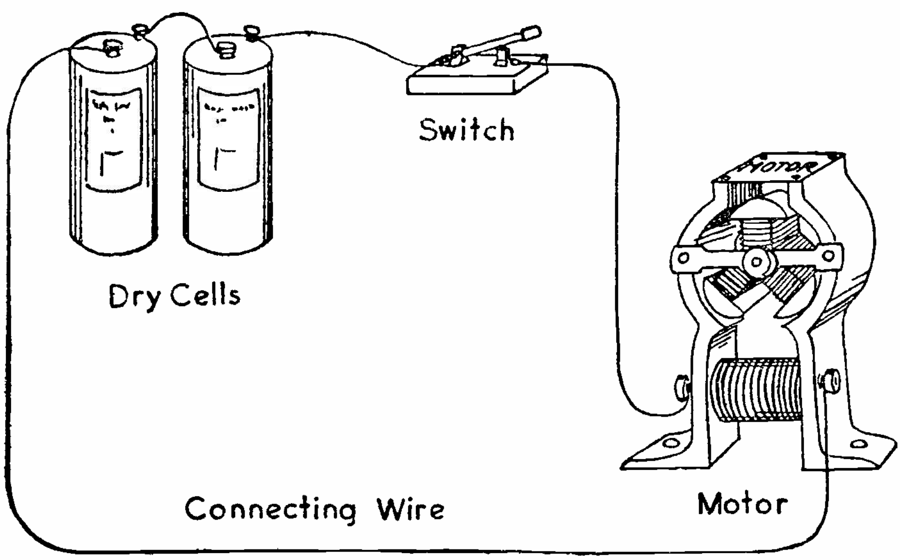


FIGURE 2

DE FOREST'S
TRAINING, Inc.

LESSON FDM - 4
RESISTORS

. . Founded 1931 by . .

RADIO FUNDAMENTALS

LESSON FDM-4

RESISTORS

Carbon Resistors ---------------- Page 1
Insulated Carbon Resistors ------ Page 3
Metallized Resistors ------------ Page 3
Wire Wound Resistors ------------ Page 3
Variable Resistors -------------- Page 4
Color Codes --------------------- Page 6
Axial Type Color Code ----------- Page 7
Tolerance ----------------------- Page 8
Methods of Installation --------- Page 8

* * * * *

RESOLVE:

To cultivate a cheerful spirit, a smiling confidence and a soothing voice. The sweet smile, the subdued speech, the hopeful mind, are earth's most potent conquerors, and he who cultivates them becomes a very master among men.

— Hubbard

RESISTORS

In our explanation of the electrical circuit, we emphasized the need for conductors and in describing the Electrical units of measure, we showed the relationship between voltage, current and resistance.

Reviewing briefly, you will remember that Voltage is the electrical pressure which forces Current through a circuit while Resistance is a quality of the material in the circuit which opposes, or tries to prevent, the current. Thus, for any given voltage, it is possible to regulate the current by inserting the desired amount of resistance in a circuit.

There are other actions, which we will take up later, that make it necessary to insert definite values of resistance in a circuit in order to obtain some desired action. Therefore in many Radio and other Electronic Circuits, various amounts of resistance are intentionally included although the connecting wires usually have the lowest possible resistance.

Because of this condition, most Radio and Electronic apparatus contains a comparatively large number of component parts, each made with a definite value of resistance. These units are called "Resistors" and are of several common types. Before going into the details of their construction, we want you to look at Figures 2 and 3 on the illustration page at the end of this Lesson.

These illustrations are approximately actual size and, in general, resistors are cylindrical in shape with a connecting wire on each end. At first glance, they may look something like a small firecracker but electrically, they have a definite electrical resistance which is measured in ohms.

CARBON RESISTORS

One common type of resistor is composed of a "Mix", made up of a conducting material and a filler or binder. The conductor is usually carbon or graphite while the filler is clay, rubber or bakelite. The binders and fillers are insulating material and therefore, by combining them with the proper amount of conducting material, the resulting "Mix" will have the proper range of resistance.

After the mix has been made, it is usually moulded into the form of a solid rod and given a heat treatment. The rod is then cut into suitable lengths and connecting wires are attached to the ends.

There are many methods of attaching these wires but, at this time, we are interested only in their position. In Figure 2,

the connecting wires are at right angles to the rod, or body of the resistor and therefore they are known as a "Radial" type.

In Figure 3, the connecting wires extend straight out from the center of the ends of the body and therefore these are known as "Axial" types.

Because of the conductor material used in the mix, all units made by this general method are known as "Carbon" Resistors. They are quite small in size and made in values from several ohms up to several million ohms.

In Figures 2 and 3, we show different sizes of resistors but want you to remember that their resistance value depends only on the composition of the mix. Almost any resistance value can be had in any of the sizes.

The difference in size is needed to allow different values of current to be carried safely. As you will soon learn, an electrical current heats the conductor which carries it and, the larger the current, the greater the heating effect. As the larger resistors have more surface from which to radiate or dissipate the heat, they can carry larger currents.

This ability to dissipate heat is measured in "watts", an electrical unit for Power and, as shown in Figure 3, the largest resistor is rated at 2 watts, the middle size at 1 watt and the smallest at 1/2 watt. Let us remind you again, each of these sizes are made in the same values of resistance, measured in ohms.

Although complete details will be given in the later Lessons, we want to mention here that for any resistor, its maximum rated current, in amperes, is equal to the square root of the value obtained by dividing its size, in watts, by its resistance, in ohms.

Following this plan for the resistors of Figure 3, and assuming each one has a resistance of 100 ohms, the maximum rated current for the 1/2 watt size is .07 ampere, for the 1 watt, .1 ampere and for the 2 watt, .14 ampere.

You need not worry about the details of these calculations as the example is given mainly to illustrate that there is a definite relationship between the current carrying ability, the size in watts and the resistance, in ohms.

From an electrical standpoint, the largest size would be satisfactory in any circuit the smaller sizes would serve but, for economy in cost and space, the smaller sizes are used wherever possible.

INSULATED CARBON RESISTORS

When several ordinary carbon resistors are installed quite close to each other, as is often the case, there is a possibility they may shift in position and touch each other or the metal chassis base on which they are mounted. When a contact of this kind is made, it provides an unwanted electrical path or, what is commonly known as a "short".

To prevent a condition of this kind, many carbon resistors are now made on the plan of Figure 1, which shows the construction used by "Centralab", the Central Radio Laboratories. Here, the conductor rod is in the center of a ceramic sleeve while the connecting wires, at each end, are embedded in a moulded bakelite cap.

The bakelite and the ceramic, which is a material similar to that of "China" dishes, are both insulators and thus, the conducting material of the resistor can not come in contact with other parts. Insulated resistors are quite popular because less care is needed for their installation and, should they shift sufficiently to touch another resistor or other part, no electrical disturbance would result.

METALLIZED RESISTORS

The resistors of Figure 3, made by the International Resistance Co., "IRC", while similar to the carbon type in appearance and size, have an entirely different construction. The conducting material consists of a thin coating of metal which is sprayed on the outer surface of a small glass rod.

This rod is then enclosed in a ceramic or bakelite tube, on the general plan of Figure 1, to complete the assembly. This type is known as a "Metallized" resistor and is manufactured in both the Radial and Axial Types.

WIRE WOUND RESISTORS

Because of its low electrical resistance, copper is used for most kinds of wire but there are other metals, also classed as combining two or more of these metals, the resulting alloy has a fairly high resistance and yet is classed as a conductor. Wires, made of these alloys, are used for resistor elements and heating units.

Common alloys of this type are composed of various mixtures of nickel, chromium and iron and are sold under different trade names such as "Nichrome". This is the the type of wire used for the heating elements in flat irons, toasters and similar appliances.

For Radio work, resistance wire is used to make resistors, similar to the carbon types we have explained. In general, these "Wire Wound" resistors have lower values of resistance or are designed to carry larger values of current.

As shown in Figure 4, the resistance wire is wound on a form, usually of ceramic material, connections are made at each end and the complete assembly is covered with insulating material. This outer covering is usually a ceramic or vitreous material which is baked on at high temperature to make the finished unit sturdy, well insulated and moisture proof.

For Figure 5, we show two examples of wire wound resistors and you will notice that, in general, they resemble the carbon types. However, they are larger and, while the largest carbon types are usually rated at 2 watts, the smallest wire wound types are generally rated at 5 watts.

Electrically, both types are installed on the same plan but mechanically, due to their larger size and weight, the wire wound types require more support.

VARIABLE RESISTORS

All of the resistors we have described so far, have some definite value and are constructed to maintain this value with practically no change. Thus, no matter what their type, they are classed as "Fixed" resistors.

In certain applications, it is desirable to vary the amount of resistance, in order to control the current or voltage of a circuit, and therefore it is necessary to install a "Variable" Resistance.

For Figure 6 we show a Yaxley wire wound variable resistance which is known as a rheostat. The resistance wire is wound on a flat form and then bent into a circular shape which is mounted in the housing. A shaft is mounted centrally in the housing and a contact arm is fastened to its inner end. As shown in the views of Figure 7, the shaft is extended so that a knob or dial can be attached to its outer end.

The electrical circuit is quite simple and, looking at Figure 6, the left hand terminal is connected to one end of the resistance wire coil. The right hand terminal connects to the arm and the circuit is through the arm to its point of contact with the resistance wire and through the wire to the left hand terminal. As the shaft is turned, the arm moves and the contact slides along the coil of resistance wire. The electrical circuit, always from the contact arm to the end terminal will contain more or less resistance, depending on the position of the contact arm.

You can readily see that if the contact arm was turned counter clockwise until it touched the end terminal, there would be no resistance wire in the circuit. However, if the arm was turned clockwise until the contact was all the way around to the other end of the coil, all of the resistance wire would be in the circuit between the two terminals.

A variable resistance of this type, with two terminals, is known as a Rheostat but, to increase its utility, it is common practice to add a third terminal which connects to the other end of the resistance wire. In views A and B of Figure 7, you will see the three terminals and an arrangement of this kind, while still a variable resistance, is known as a "Potentiometer" or "Pot" for short.

Like the fixed resistors, there are "Wire Wound" and "Carbon Type" variable resistors. The general construction of the wire wound types is shown in Figure 6 and Figure 7-D. For the carbon type, with the general appearance of Figure 7-A, the resistance strip is of the same general shape as the wire wound but it is coated with a carbon compound which has the desired resistance value. Michanically, the construction is similar to that of Figure 6 but the contact arm, or shoe, slides on the inner surface of the resistance strip as the shaft is turned.

Like the fixed resistors, variable wire wound resistances are usually of lower resistance values or larger current carrying capacity. The carbon types are of higher resistance values with lower current carrying capacity.

Potentiometers, like that shown in Figure 7-A, are commonly used for Radio Receiver Volume and Tone Controls, while the wire wound type of Figure 7-D will be found in Power Supplies, Radio Transmitters and other apparatus where larger currents are in use.

To conserve space and also reduce the number of controls, it is common practice to install a switch on the back, as shown in Figure 7-B. Electrically, this switch is entirely separate from the Potentiometer but mechanically, both are controlled by the same shaft.

In many Radio Receivers for example, the Volume Control and the "OFF-ON" switch are controlled by the same knob. The switch operates at one end of the knob's rotation and thus has little effect on the normal operation of the volume control.

For somewhat more complicated circuits, where it is desired to vary two resistances in some fixed relation to each other, the assembly of Figure 7-C is installed. Electrically, it

consists of two entirely separate potentiometers, like that of Figure 7-A but mechanically, the same shaft controls the position of both contact arms.

You will find variable resistances, mainly of the potentiometer type, used in a great majority of Radio control circuits. Later on, we will take up their circuits and actions but now, want you to think of them only as a unit, the resistance of which can be varied.

COLOR CODES

Due to the large number of fixed resistors, necessary in most Radio and other Electronic apparatus, some method of rapid identification had to be devised. As we explained earlier in this Lesson, the size of a carbon type resistor is determined by its "Wattage" rating and not by its resistance value.

Therefore, for rapid identification of the resistance values, all standard resistors of this general type are "Color Coded". We have shown this code in Figure 8 and first want you to notice the ten colors, each of which represents some number from 0 to 9 inclusive.

Check these over carefully as they form the basis for the entire code. Black represents "0", Brown represents "1", Red represents "2" and so on. We suggest you memorize the first six at least because they are in most common use.

At the top of Figure 8, we show a standard, Radial type of carbon resistor and, as shown by the arrows, it has three colors. —

First - the body color
Second - the end color
Third - the dot color.

In some cases, the dot extends all around the body in the form of a band.

The colors are "read" in the order given and, substituting the corresponding number for the color, gives the value of the resistance in ohms. Notice here, the "dot" column of the table is read as the number of zeros which follow the first two numbers.

For example, suppose the resistor at the top of Figure 8 had a Red body, a Green end and an Orange dot. Looking at the table you will see that red means 2, green means 5 while orange, shown as 3, means three zeros in the dot column.

In the form of a table the colors are read as --

Red	Green	Orange
2	5	000

and when we write the numbers close together, the value is 25,000 ohms.

Following this plan, and checking with the table, you will readily see that any value, from 1 ohm up to 99,000,000,000 ohms can be represented. To illustrate, we list a few more examples in the following table --

Body		End		Dot		Ohms
Green	(5)	Black	(0)	Brown	(0)	500
Violet	(7)	Green	(5)	Orange	(000)	75,000
Yellow	(4)	Violet	(7)	Yellow	(0000)	470,000
Orange	(3)	Black	(0)	Green	(00000)	3,000,000

In some cases, two of the colors may be alike and therefore the finished resistor will actually show but one or two colors, instead of three. However, the plan of reading remains exactly the same. The following examples illustrate several combinations of this kind.

Body		End		Dot		Ohms
Red	(2)	Red	(2)	Red	(00)	2,200
Orange	(3)	Green	(5)	Orange	(000)	35,000
Brown	(1)	Yellow	(4)	Yellow	(0000)	140,000
Blue	(6)	Blue	(6)	Green	(00000)	6,600,000

For values less than 100 ohms or more than 10 ohms, the dot is black to indicate that no zeros are added to the first two numbers. For values less than 10 ohms, the body and dot are both black, so that the end color is the only one read.

Body		End		Dot		Ohms
Green	(5)	Black	(0)	Black	(None)	50
Red	(2)	Green	(5)	Black	(None)	25
Black	(0)	Gray	(8)	Black	(None)	8
Black	(0)	Blue	(6)	Black	(None)	6

AXIAL TYPE COLOR CODE

A slight variation of the method explained above, is now in use on axial type carbon resistors, as illustrated at the bottom of Figure 8. Here, all of the colors are in the form

of bands and the body color has no significance as far as the code is concerned.

Checking on Figure 8, you will notice the bands are closer to one end of the resistor and we read them by starting with the band closest to the end. The colors represent the same values and are read in the same way as for the radial type.

TOLERANCE

In the manufacture of fixed resistors, their electrical resistance will vary somewhat, due to slight differences which can not be avoided. When completed, the resistors are usually sorted and then coded according to their accuracy.

For example, a "1000 ohm" resistor might actually measure 920 ohms or 1060 ohms but would still operate satisfactorily in many Radio circuits. This variation of actual resistance from the marked resistance is known as the "Tolerance" and stated in percentage.

In the example given above, 10% of 1000 ohms is 100 ohms and thus both the 920 ohm and the 1060 ohm resistor would be within 10% of their rated value. On this basis, any resistor from 900 ohms to 1100 ohms is considered as a 1000 ohm resistor with a tolerance of 10%.

To indicate this tolerance, a fourth color code band appears on both the radial and axial type resistors and, as shown by the table of Figure 6, "Gold" indicates 5%, "Silver" indicates 10% while with no fourth band, the tolerance is 20%.

As you may suspect, the more accurate the resistance value, the more expensive the resistor. For ordinary commercial Radio equipment, 10% tolerance is satisfactory, for low priced "Bargain" equipment, 20% tolerance is usually good enough. For real quality equipment, 5% tolerance is common while for measuring instruments, it is customary to use "Precision" resistors with a tolerance of 1% or less.

METHODS OF INSTALLATION

As you will learn later, many circuits of Radio and other Electronic apparatus require one or more resistors in order to establish the desired electrical conditions. Therefore, the various types illustrated in Figures 1 to 7 must be mounted mechanically so that the proper electrical connections can be made.

N

In the conventional types of construction, all of the larger circuit components are mounted mechanically on a sheet metal chassis which is shaped to form a substantial base and drilled to provide openings of the required size in the desired locations. In most cases, these larger units are mounted on top of the base while their electrical connections extend through to the under side.

As shown for the variable resistors of Figure 7, the electrical connections at most of those units are in the form of mechanically rigid and electrically insulated lugs, the outer end of which is shaped to readily accomodate a connecting wire. With lugs of this general type on the larger units, resistors like those of Figure 2 and 3 are installed by looping the ends of their connecting wires through the holes in the end of the lugs and completing the joint by soldering.

By this method, often known as "point to point" wiring, the connecting wires provide mechanical support as well as electrical connections for the resistor.

For larger types, like those of Figures 4 and 5, the weight is too great to be supported by the connecting wires, therefore, the resistor is installed mechanically by means of brackets or clamps although the electrical connections are made as explained for the smaller types at Figures 2 and 3. In some cases, the terminal lugs of the larger units are l located so that the lugs of the larger size resistors can be soldered directly to them. When this condition occurs, no other mechanical supports are needed.

Variable resistors like those of Figures 6 and 7 are mounted on the same general plan as the larger components. As shown in Figure 7A, the operating shaft extends through a threaded bushing which is mounted rigidly on the body of the unit. Installation is made by mounting the unit inside with the bushing and shaft extending out through a hole in the chassis base. A nut is then placed on the outer end of the bushing and tightened to provide a rigid mechanical mounting.

There are endless arrangements for these parts, depending on the type of assembly but, in every case, the general idea is the same. The resistors must be supported mechanically and connected electrically in the proper circuit.

In addition to the resistors, all of the various parts are connected by wires, therefore, for our next Lesson, we will explain the measurement of wire and the common types of insulation.

N

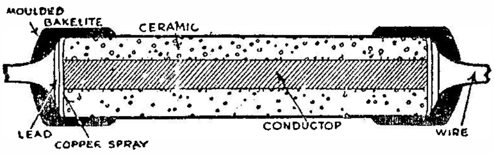


FIGURE 1

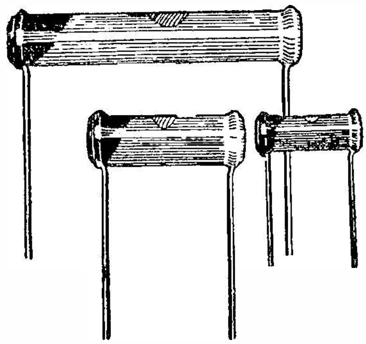


FIGURE 2

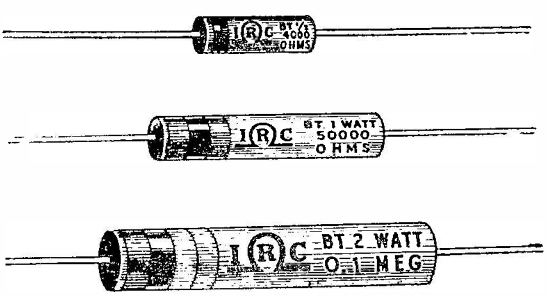


FIGURE 3

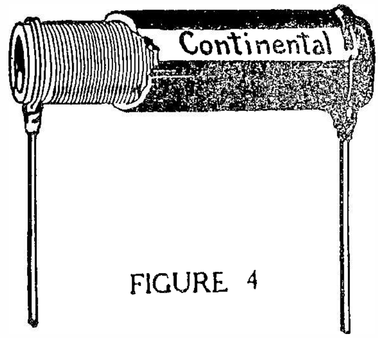


FIGURE 4

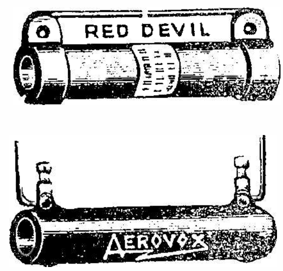


FIGURE 5

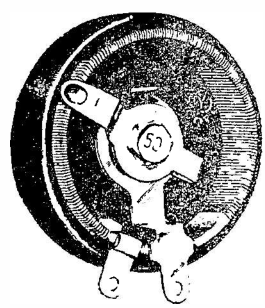


FIGURE 6

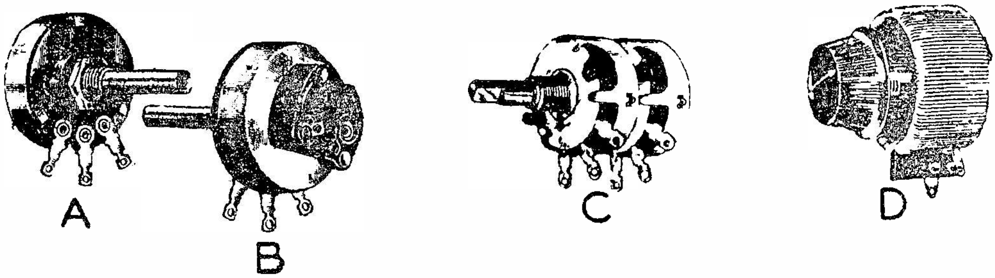
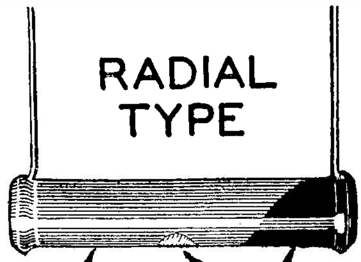


FIGURE 7

FDM-4



CODE	BODY	END	DOT	Tolerance
Black	0	0	None	
Brown	1	1	0	
Red	2	2	00	
Orange	3	3	000	
Yellow	4	4	0000	
Green	5	5	00000	
Blue	6	6	000000	
Violet	7	7	0000000	
Gray	8	8	00000000	
White	9	9	000000000	
Gold				5%
Silver				10%
None				20%
	BAND 1	BAND 2	BAND 3	BAND 4

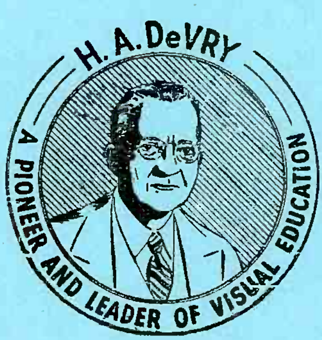
AXIAL TYPE

FIGURE 8

DE FOREST'S
TRAINING, Inc.

LESSON FDM - 5
WIRE MEASUREMENT

• • Founded 1931 by • •



RADIO FUNDAMENTALS

LESSON 5

Wire Measurement

Common Use of Wire ---------------------- Page 1
Common Wire Materials ------------------ Page 1
Action of Pipe in Water System --------- Page 2
Effect of Size ------------------------- Page 2
Area and Resistance -------------------- Page 3
Effect of Material --------------------- Page 3
Effect of Length ----------------------- Page 3
Comparison of Wire and Pipe ------------ Page 3
The Mil -------------------------------- Page 4
The Circular Mil ----------------------- Page 4
Effect of Area - Length - Material ----- Page 4
Changes with Temperature --------------- Page 5
Brown and Sharpe Gauge ----------------- Page 5
Use of B and S Table ------------------- Page 5
Common Examples ------------------------ Page 6
Stranded Wires ------------------------- Page 7
Bare Wire ------------------------------ Page 8
Magnet Wire ---------------------------- Page 9
Single Conductors ---------------------- Page 10
Double Conductors ---------------------- Page 11
Removing Insulation -------------------- Page 13
Cabling -------------------------------- Page 13
Copper Wire Table ---------------------- Page 16

* * * * *

From the chin down, no one is worth much more than a dollar or two a day. Even what you do with your hands depends for its value on the amount of sense you use. You can train and improve your mind as well as your fingers. Mental laziness is the most common disease.

-- Dr. Frank Crane

WIRE AND WIRE MEASUREMENT

In our explanation of a simple Electrical circuit, we emphasized the need of an endless path and can tell you now that all circuits, no matter how complicated, require the same general methods of connection.

Naturally, we think of the units we use, such as a lamp, motor speaker, or Radio tube as the most important part of an Electrical circuit but remember, they will not operate unless properly connected to a source of Electrical energy or pressure.

To carry this Electrical Energy from the source to the unit in use, there must be a path or circuit which, in most cases is made of wire. For this Lesson therefore, we are going to tell you about the different types of wire and give you a working knowledge of the common wire measurements.

COMMON USE OF WIRE

You have seen a good many telegraph poles with wires strung on them, you have seen telephone, electric light and power wires almost everywhere you went but, did you ever stop to think that each and everyone of those wires is a part of some electrical circuit?

Wires from the telephone exchange to your home make a circuit that you can send your voice over. Wires from the Electric Company, stretching in all directions, carry electricity to every home, shop and office where it is used. In fact, this whole country is one huge network of wires.

Perhpas one of the biggest advantages of electricity is that it can be carried from the place where it is produced, almost any distance, over small wires with very little loss.

COMMON WIRE MATERIALS

As we told you in a former Lesson, all materials will carry, or conduct, electricity to some extent and are called conductors or insulators only according to how well or how poorly they act as a conductor.

Made mainly to be used to carry electricity, naturally we want a wire to be as good a conductor as possible, Although nearly all metals are classed as conductors, to be practical, we will consider only those metals which are commonly used for making wire.

Lead, Steel, Nickel, Platinum, Aluminum and Bronze, or combinations of two or more of these are in general use, but Copper is, by far, the most common conductor.

ACTION OF PIPE IN A WATER SYSTEM

To give you a good working idea of the general action of wire, we will again compare an electrical circuit with a water system. To begin, suppose that you had a tank of water with an outlet pipe at the bottom and, to control the flow of water, you had a valve put in the pipe. Also imagine the valve is quite close to the tank but the pipe is ten or twelve feet long.

With a tank full of water, opening the valve will, of course, let a stream of water run out of the end of the pipe. The more you open the valve, the more water there will be running through the pipe but, even with the valve wide open, only a certain current of water will run out. There are several things that control this action and, from our former explanations, you know that the current of water will depend greatly on the pressure in the tank. For this Lesson however, we will take up the action of the pipe itself.

EFFECT OF SIZE

It is hardly necessary for us to tell you that, with the valve wide open, the smaller the pipe, the smaller the current of water and the larger the pipe, the larger the current of water. We can explain this action in one way by saying, the larger the pipe, the less resistance it offers to the flow of water.

Pipe is usually measured by its "diameter", which means the largest distance across the inside but, as the water is carried by the entire pipe, we must consider its cross section area which is usually measured in square inches.

The idea here is the same as used to measure all surfaces. For example, the usual 9 x 12 living room rug is 9 feet wide and 12 feet long but, to find its area, we multiply 9 x 12 for a value of 108 square feet.

The same plan is used to find the cross section area of the inside of the pipe, which can be considered as the circle you see when you look at its end. The details by which these areas are calculated are not important just now therefore, we want you to remember only that the area of a pipe will vary as the square of its diameter.

To square any number, we simply multiply it by itself and thus 2 times 2 is equal to 2 squared or four. Three times three is equal to three squared or nine and so on.

AREA AND RESISTANCE

You can readily see that it is the cross section area of a pipe which determines the amount of water it can carry and therefore, we can say that the larger pipe must offer less resistance because it can carry more water. However, as stated above, the area of a pipe varies as the square of its diameter and, thinking of its resistance, it will also vary with the square of the diameter but in the opposite way, the larger the pipe, the smaller the resistance.

In technical language, opposite actions of this kind are called "inverse" which means, "opposite to" or "upside down". Using this word, as a general rule we can state, -- The resistance of a pipe varies inversely as the square of its diameter.

EFFECT OF MATERIAL

The resistance of a pipe will also vary somewhat with the material it is made of and whether it is rough or smooth. The smoother the pipe, the less resistance it will offer.

EFFECT OF LENGTH

You can also easily understand that, the longer a pipe, the more resistance it will offer, because the water will have to go further in order to get through it.

To sum up all of the above, the resistance of a water pipe will vary.

1. Inversely as the square of its diameter.
2. With the material it is made of.
3. With its length.

COMPARISON OF WIRE AND PIPE

Like water pipe, most of the wires used to carry electricity are round or cylindrical, and also similar in other ways but, in using wires, we have to pay particular attention to their resistance and ability to carry current.

Being round like water pipe, the resistance of the ordinary wire varies inversely as the square of its diameter. As all wire in common use is quite small, when measured in inches, it would be a whole lot of trouble to figure out its diameter and area in fractions of an inch or square inch therefore, we use much smaller units of measure.

THE MIL

For the first unit, we take one, one thousandth of an inch and call it a "Mil". With this in mind, you can easily change inches to mils by multiplying the inches by 1000. In the same manner, you can change mils to inches by dividing the mils by 1000. To multiply a number by 1000 you simply move its decimal point three places to the right while, to divide by 1000, you move the decimal point three places to the left. Whenever we talk about the diameter of ordinary wire, we say it is so many "mils".

THE CIRCULAR MIL

Again, like the water pipe, it is the cross section area of a wire that determines its resistance and ability to carry current but, for convenience in comparing areas, we use a unit, the "Circular Mil" which is the area of a circle with a diameter of one mil.

Here again, the area of the wires vary as the square of their diameters but, using the circular mil as a unit of measure, the area of any wire, in circular mils, is equal to the square of its mil diameter.

EFFECT OF AREA

Like a water pipe, the resistance of a wire is inversely as the square of its diameter but here, as the circular mil area is equal to the square of the mil diameter, the resistance will be inversely as the circular mil area.

EFFECT OF LENGTH

Again like the water pipe, the longer the wire, the more resistance it will have. A wire two feet long will have twice the resistance of a like piece one foot long.

EFFECT OF MATERIAL

One thing more, by which the wire and pipe can be compared, is the material they are made of. We have already told you that different materials offer different resistances to a current of electricity and naturally, in building the ordinary electrical circuit, we want to use a metal, or conductor, that has the lowest possible resistance.

While silver is perhaps the best known conductor of electricity, copper is so good, and so commonly used, that we usually take it as a starting point for figuring the resistance of other metals.

CHANGES WITH TEMPERATURE

Temperature is one condition, concerning the wire, that does not affect the water pipe. Whenever a current of electricity passes through a conductor, it heats it. As the temperature of a conductor changes, its resistance changes also. The amount of this change of resistance, with a change of temperature, varies greatly with different metals and while in some cases it must be taken into consideration, for ordinary work it is not as important as the other things we have been talking about.

To sum up all of the above, we can say that the resistance of a wire will vary.

1. Inversely as its circular mil area.
2. With the length.
3. With the material.
4. With the temperature.

BROWN AND SHARPE GAUGE

Don't worry for a minute that you will not be able to remember all these figures that we have been giving you because very few people ever try to, but instead, keep a table handy and refer to it whenever necessary.

While there have been quite a few different systems of wire measurement, the Brown and Sharpe Gauge is the most common one in use for copper wire in this country.

USE OF BROWN AND SHARPE TABLE

The Copper Wire table at the end of this Lesson will give you all the information you will need about the various sizes which are in common use. You will notice that there are eight columns, the first one at the left being labeled "Gauge No.". This is the number electricians mean when they talk about a number 16 or a number 18 wire. These numbers start at 0000 and end at 40, and the larger the number the smaller the wire.

The second column, from the left, is the "Mil Diameter", which you will remember is the same as thousandths of an inch. Thus, a Gauge No. 10 wire has a diameter of 101.9 mils which is equal to .1019 inch.

The third column, from the left, is the "Area in Circular Mils" and is the square of the mil diameter. You may notice that this does not work out exactly in all cases in the table but that is because the diameter of the wire is not given closer than hundredths of a mil.

The fourth column, from the left, shows the weight in pounds, per 1000 feet of the different sizes, without insulation.

The fifth column, from the left, is very much like the fourth column but is turned around and gives the number of feet of bare wire in a pound.

The last three columns list the resistance of the various sizes of pure copper wire in the number of "Ohms per Foot", number of "Feet per Ohm", and number of "Ohms per Pound".

To use the wire table, you read down the left hand column to the Gauge No. you want and then read across to the right for the value you desire.

For example, suppose you want to find the weight of Gauge No. 20 wire; which is usually called "No. 20" and written #20. Going down the left column to 20 and then, over to the right to the fourth column, we find the value of "3.09". As the top of this column states, "Weight in lbs. per 1000 ft.", we know that 1000 ft. of No. 20 wire weighs 3.09 pounds.

All of the values in the table may be read by the same general plan and, reading across for a No. 30 wire, we see it has a diameter of 10.03 mils, an area of 100.5 circular mils, a weight of .30 pound per thousand feet and it requires 3287 ft. to weigh one pound.

From the last three columns we find a No. 30 wire has a resistance of .1030 ohm per foot, it requires .707 ft. of wire for a resistance of one ohm while a pound of this size, has a resistance of 338.6 ohms.

A table of this kind eliminates all calculations and, as explained above, you can read off any of the commonly used values for the ordinary sizes of copper wire.

COMMON EXAMPLES

There are hundreds of different uses for this table as you will very soon find out. For example, suppose you had a coil or roll of wire and wanted to know how many feet it contained. As it would be quite a job to unroll and measure it, you simply find the size of the wire and weigh the roll. Then turning to the table, you go down the column, "Feet per Pound", until you are opposite the size of the wire, where you find the number of feet per pound. To complete the problem, you multiply this number by the weight of the roll of wire in pounds.

Suppose someone asked you how many number 20 wires it takes to equal the area of one number 10. You can turn to the table,

go down the first column to 10, then across to the third column where you find the number 10380. Repeating these steps and going down to number 20 in the first column and over to the third column again, you find the number 1022. You can easily see that ten times 1022 is 10220 which is just about equal to 10380, stated as the circular mil area of the number 10 wire.

You may be wondering how wire can be measured accurately when there is but a few thousanths of an inch difference in the diameter of various sizes, but, for this work, the average electrician carries what is called a wire gauge. These wire gauges are made in two popular designs. One is Circular in shape and has a ring of holes drilled around the outside. These holes are numbered the same as the wire sizes and, of course, are of the proper size.

To measure a piece of wire with a gauge of this type, you scrape off the insulation and then find the smallest hole the wire will go through. The number of this hole is the size of the wire.

The other model of wire gauge has a "V" shaped slot in the center and, at the proper place on the "V", the sizes are marked. With this gauge, the wire is pulled down in the "V", as far as it will go, and the mark it stops at is the size of the wire.

The Brown and Sharpe wire gauge applies to solid copper wire which, in general, is installed in all permanent circuits. The telephone, telegraph and electric power wires, which you see strung outdoors on poles, are usually of solid wire.

STRANDED WIRES

In order to make use of the low resistance of copper and yet have a proper size of wire which is flexible, it is customary to make up a conductor of a number of smaller solid wires. The smaller sizes of solid copper wire are quite flexible and by combining a number of them into a cable, the assembly is known as a stranded wire.

While copper is considered as a "soft" metal, and the usual sizes of solid copper wire can be bent quite easily, they are not flexible and therefore not suitable for portable or movable circuits, such as the cords on vacuum cleaners, bridge lamps, and other similar units which can be moved from place to place.

These smaller wires are twisted together, somewhat like the threads in a piece of string, and therefore each carries a part of the total current in the circuit in which they are connected. For example, the attachment cords, used for Bridge,

Table and Bed lamps, usually contain a No. 18 stranded wire. Actually the conductor is made up of sixteen No. 30 wires, to provide the required flexibility.

Referring to the wire table, you will find a No. 30 wire has an area of 100.5 circular mils while a No. 18 has an area of 1624 circular mils thus, sixteen No. 30 wires have a total area of 16 x 100.5 or 1608 circular mils which is approximately equal to the area of one No. 18 solid wire.

Most stranded conductors, of this general type, employ No. 30 wires and their number is varied to approximate the area of different sizes of solid wire as shown by the following table:-

Stranded Wire

Size	Composed of
No. 14 - - - - - - - -	41 No. 30 wires
No. 16 - - - - - - - -	26 No. 30 wires
No. 18 - - - - - - - -	16 No. 30 wires
No. 20 - - - - - - - -	10 No. 30 wires

For other purposes, where even greater flexibility is needed, still smaller wires are used, as shown by a few common sizes listed below:-

Flexible Cables

Size	Composed of	Use
No. 18 - - - -	41 No. 34 - - - -	Flexible cable
No. 20 - - - -	41 No. 36 - - - -	Test leads
No. 20 - - - -	65 No. 38 - - - -	Indoor antenna
No. 23 - - - -	20 No. 36 - - - -	Nonkink antenna

Checking in the wire table, you will find that the total area, of the given number of small wires, is approximately equal to the area of a solid wire with the same size number as that listed for the stranded wire. By following this arrangement, the solid and stranded wires have the same electrical specifications and therefore may be interchanged at will, the choice of solid or stranded wire depending entirely on the type of service for which it is to be used.

BARE WIRE

In our explanation of a simple electrical circuit, we told you the connecting wires had to be insulated in order to keep the electricity in its proper path. However, we also mentioned that "air" is a very good insulator therefore, a length of bare wire, strung through the open air, is very well insulated.

A common example of this type of installation is found in the many telegraph, telephone and electric power wires which are strung outdoors on poles. To make the insulation complete, the wires are usually supported at the poles by glass insulators and thus the entire wire and circuit is properly insulated although the actual conductor has no insulating material attached to it. Circuits of this kind must be well supported because the air insulation offers no protection if the wire comes in contact with any object.

MAGNET WIRE

In many Radio applications, copper wire is wound in coils of various sizes and shapes, on forms and spools. In most cases, the turns of the coils are wound quite tightly together and therefore, the wire itself must be insulated. Should the conductors of the different turns actually touch, or make contact with each other, the electricity would follow the shorter path, from one turn to the next, instead of passing through the entire length of the wire.

Because a condition of this kind provides a shorter path for the current, we call it a "short circuit" or "short" and it is to prevent this condition that insulation is placed on the wire.

The insulation on magnet wires is mainly of three materials, Enamel, Cotton and Silk. For the first of these, the bare Copper wire is run through a bath of special varnish to apply a thin coat of insulation on its outer surface. This coating is known as "Enamel" and the finished product as enameled wire.

Cotton is a fairly good insulator, when dry, and therefore, cotton threads, wound on the outside of a copper wire closely enough to completely cover the outer surface, form a layer of insulation. Magnet wire of this type is known as single cotton covered and often abbreviated as S.C.C.

When more insulation is needed, a second layer of cotton is wound over the first to produce, double cotton covered, (D.C.C.) magnet wire. In addition to its own insulating qualities, the cotton acts to keep adjacent wires apart and thus prevents them from touching.

On the smaller sizes of wire, silk is used instead of cotton as it can provide the same insulation in less space. Thus, like the cotton covered, we have single silk covered, (S.S.C.) and double silk covered, (D.S.C.), magnet wire.

In addition to these three general types, it is common practice to combine the enamel with the cloth covering to provide "cotton enamel", (C.E.) and "Silk Enamel", (S.E.) magnet wire.

The enamel has a better insulating action than the cloth but, a layer of cotton or silk wound over the enamel, provides protection against mechanical injury and also acts as a spacer between adjacent wires.

In general, the insulation of magnet wires is comparatively thin and, because the installation is permanent, the conductors are solid.

SINGLE CONDUCTORS

With the exception of the various types of magnet wires, which are usually wound up in coils by machinery, most of your work will be with conductors that are used to complete the circuits of various units and, to give you an idea of the variety of insulation found on the more common kinds of wire, for Figure 1 we show a few of the many types produced by the Belden Mfg. Co. of Chicago.

Starting at the upper left with No. 1, we have an illustration of a single conductor, stranded wire with a coating of rubber insulation. As both the stranded conductor and the rubber insulation are flexible, this is a general purpose type of wire and the rubber is easily removed for making electrical connections to the copper conductor.

As shown in types 1-A and 1-B, this same general type of wire is made with both stranded and solid conductors and with insulation of different thickness.

For many connections of Radio and Electronic equipment, instead of rubber, wire of this type is provided with a woven cloth insulation which will not unravel. The insulation fits rather loosely and can be readily pushed back, from a cut end, to expose the conductor. Because of this action, this type is known as "Push Back" wire. The commonly used sizes include the even numbers of wire, from 14 to 20 inclusive, while both solid and stranded conductors are available.

No. 2 illustrates a wire, similar to No. 1, but the rubber insulation is covered with a woven wire sleeve which forms a metallic shield. Shielding of this type has many applications as it not only protects the wire from mechanical injury but, as you will learn later, can be used to reduce interference, or what is commonly called "Static", when heard over a Radio receiver.

For No. 3, we again have the general type of No. 1 but the rubber is covered with a cloth braid and a metal shield is woven around the braid. The shield, in turn, is wrapped with cotton and a second coating of rubber placed on the outside.

Wire of this type is used for the flexible conductor which connects to a microphone and, because it is insulated on both the inside and outside, the shielding can act as a second con-ductor, as well as a shield.

When two electrical conductors are placed close to each other, like the wire conductor and shield of this type of wire, there is an electrical action between them which technically, is known as "Capacity". In many Radio Circuits this capacity is undesirable and it can be reduced by increasing the distance between the wire conductor and the outer shield.

The wires shown in 4, 5 and 6, are examples of "Low Capacity" cable and you will notice a greatly increased amount of insul-ation surrounding the wire conductor. No. 4 has the metal shield as the outer covering while No. 5 and No. 6 have a coating of rubber, outside the shield, to provide additional protection, especially against moisture.

No. 7 is a similar type but here, the insulation is in the form of beads, strung on the inner conductor. The material of these beads reduces the capacity effect still further and, a wire of this type is often called a "Coaxial Cable".

DOUBLE CONDUCTORS

There are many applications, such as the Floor and Table lamps already mentioned, where it is necessary to run two conductors from the source of electricity to the unit where it is to be used. To take care of the many variations of circuits of this type, a large number of "Double Conductor" wires and cables are available. In Figure 1, numbers 8 to 17 inclusive illus-trate a few of these types and we will simply list their specifications.

No. 8 - No. 22 Stranded conductor with a paper wrap covered with rubber. The rubber is of different colors or "color coded", so that each conductor may be readily identified. The two conductors are then twisted and covered with a weather proofed over-all cotton braid.

No. 9 - A parallel, all rubber insulated cord made up of two No. 18 stranded wires with a cotton wrap. The outer rubber covering is 1/64 of an inch thick and quite thin in the center so that the individual wires can be separated readily. This type of wire is commonly used for making connections to house lighting circuits.

No. 10 - A double conductor designed for connections to speak-ers or as a power supply. It consists of two No. 18 stranded wires with a cotton wrap. This, in turn, is covered with 1/64

inch of rubber, color coded as explained for illustration No. 8. These wires are twisted and, with cloth fillers, are wrapped with cotton and then given an over-all sheath of rubber.

No. 11 - The stranded conductors have a cellophane wrap covered with rubber. These wires are twisted and then covered with a weatherproofed over-all cotton braid.

No. 12 - The conductors are solid and have a double coating of enamel with a cotton wrap covered by color coded cotton braid. The wires are then twisted and covered with an over-all copper shield.

This is known as a "Shielded Twisted Pair" and, with no protection for the outer shield, is suitable only for inside use.

No. 13 - This double conductor cable is designed for use with microphones or similar units which can make use of the shield as a third conductor. Each stranded conductor is covered with rubber and a cloth braid is placed around both. This braid is covered with rubber over which is another braid. The shielding is placed over this second braid and it, in turn, is covered by a cotton wrap and an outer over-all layer of rubber.

No. 14 - This is similar to No. 13 but the stranded conductor is covered first by a celanese braid with an outer coating of color coded rubber. These two wires are twisted and, with fillers, are enclosed in a cotton wrap around which is the copper shield. The shield is then covered with a cotton wrap and a rubber sheath.

No. 15 - Here we have another type of microphone cable, similar to No. 14, but the wires are not twisted making it more adaptable for transmission lines in which the shielding is grounded.

No. 16 - This type is used mainly as a connection between the antennas and short wave receivers. The stranded wire has a cotton wrap covered by color coded, low capacity rubber. The wires are then twisted and covered with an over-all, weatherproofed cotton braid.

No. 17 - The variations between this wire and No. 16 above are mainly in the copper shield. The cotton wrap, color coded rubber wires are twisted and have a paper wrap, surrounded by the copper shield. An over-all weatherproofed cotton braid covers the shield.

No. 1 - You will notice there are three separate conductors in this assembly and, with the exception of the filler, its construction is like that of No. 15 above. Cable of this

type is used on microphone and similar circuits which require an additional conductor as well as a shield.

No. 19 - While similar to No. 18, here the amount of insulation has been reduced as the cable is designed for temporary indoor microphone circuits. Each stranded wire has a paper wrap, rubber and color coded cotton braid. These wires are twisted, or cabled, and covered with an over-all copper shield.

No. 20 - This three wire type is designed for speakers which require a third conductor. Each wire has a cotton wrap covered with color coded rubber. These are assembled with fillers and given an outer cotton wrap covered by an over-all rubber sheath.

REMOVING INSULATION

All of these different types are made up of the actual conductors, the shielding if used, and the insulation. The various layers of insulating materials provide both electrical and mechanical protection for the conductor metals.

No matter what the type of wire, a good metallic connection must be made to each conductor when it is used in an electrical circuit. Therefore, when working with any of these wires, it is very important that you completely remove the insulation without causing any injury to the metal conductor.

The rubber coverings are usually pulled or "stripped" off as it is rather difficult to cut through the rubber without partially cutting or "nicking" the wire itself.

Some cloth braids can be unraveled but, in cases where they must be cut, great care is necessary to cut through the braid only.

Shielding is really a braid made of metal threads and it is usually unraveled for a short distance after which the ends of its threads are twisted to form a stranded wire, used for making an electrical connection.

CABLING

On many Radio Communication units it is necessary to install a number of single conductor wires, more or less parallel to each other, for quite a distance. To keep all of these wires in place, to prevent them from shifting and also to improve the appearance of the work, they are bound together with waxed cord to form what is known as a cable. This system of lacing is called "Cabling" and while not at all difficult, there is a right and wrong way to do it.

Starting at the top of Figure 2, we have shown a section of a group of single conductor wires which have been cabled. The waxed cord is run parallel to the cable for an inch or two then wrapped around the cable and pulled tight.

Closely checking these loops, or stitches, you will notice that the part of the cord, parallel to the cable, is always next to the wires where the cords cross. This arrangement prevents the cord from slipping, even if the end is loose, and is known as a "Lock Stitch". In comparison, the wrong method is shown below the Lock Stitch and here, you will notice the cord, parallel to the cable, is outside at the point where the cords cross. This is known as the "Half Hitch" but it is not satisfactory as the entire cord will loosen if it is broken at any point.

To start a cabling job, a Figure eight knot is tied close to one end of the cord, pulled tight and drawn up against the first Lock Stitch, as shown in the "start" view of Figure 2. The short end of the cord, beyond the knot, is laced under the first two or three lock stitches and as each stitch is pulled tight, the cabling will hold in place.

The stiches should be placed every inch or two and at various places, certain wires may leave the cable while others may be added. As a general rule, a lock stitch should be made on both sides of these wires at the point they leave or enter the cable.

After the available length of the wire has been cabled, the job can be finished by making two or three lock stitches close together, as shown in the finish view of Figure 2.

To actually do this work, you first tie the Figure Eight knot and, after it is pulled tight, hold it in place on the wire with one thumb. Then, wrap the cord around the group of wires and bring the end back over the short end of the cord beyond the knot but thread it underneath the long end which you passed around the wires. The long end is then pulled tight and the stitch will hold in place.

The following stitches are made on the same general plan, the long end of the cord being drawn along with the wire and held, by your thumb, at the point the next stitch is to be made.

With a little practice you will find that this work is quite simple and will have no difficulty in locating the stitches exactly where you want them. If you care to practice, a bundle of pipe cleaners make a good substitute for the wires of our illustration.

In a complete electrical circuit, it is often necessary to make electrical connections between various wires, either to increase their length or to include other circuits. These connections are known as "splices" and to continue the subject of wires, the next lesson takes up the details of "Wire Splicing".

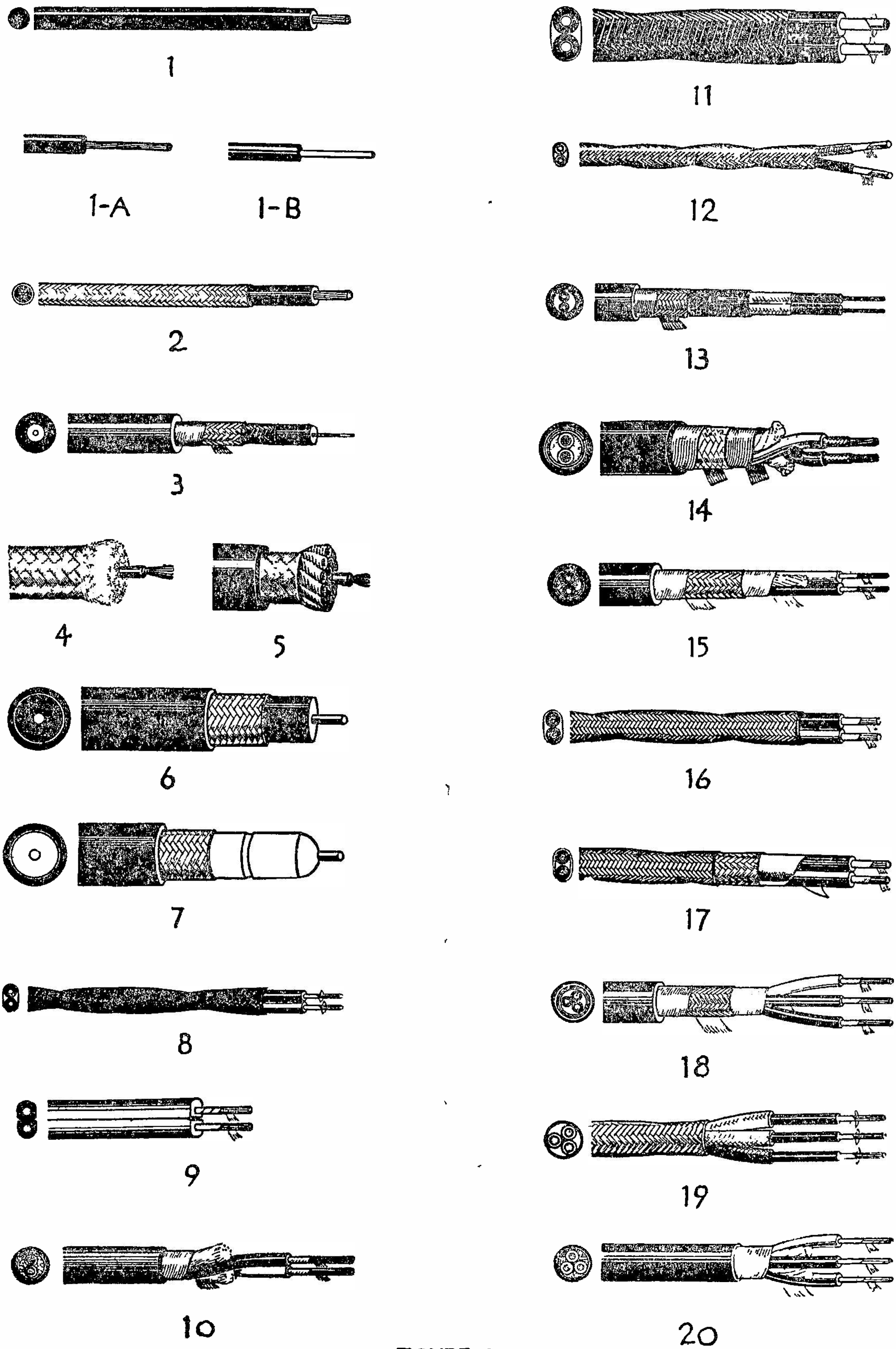


FIGURE 1

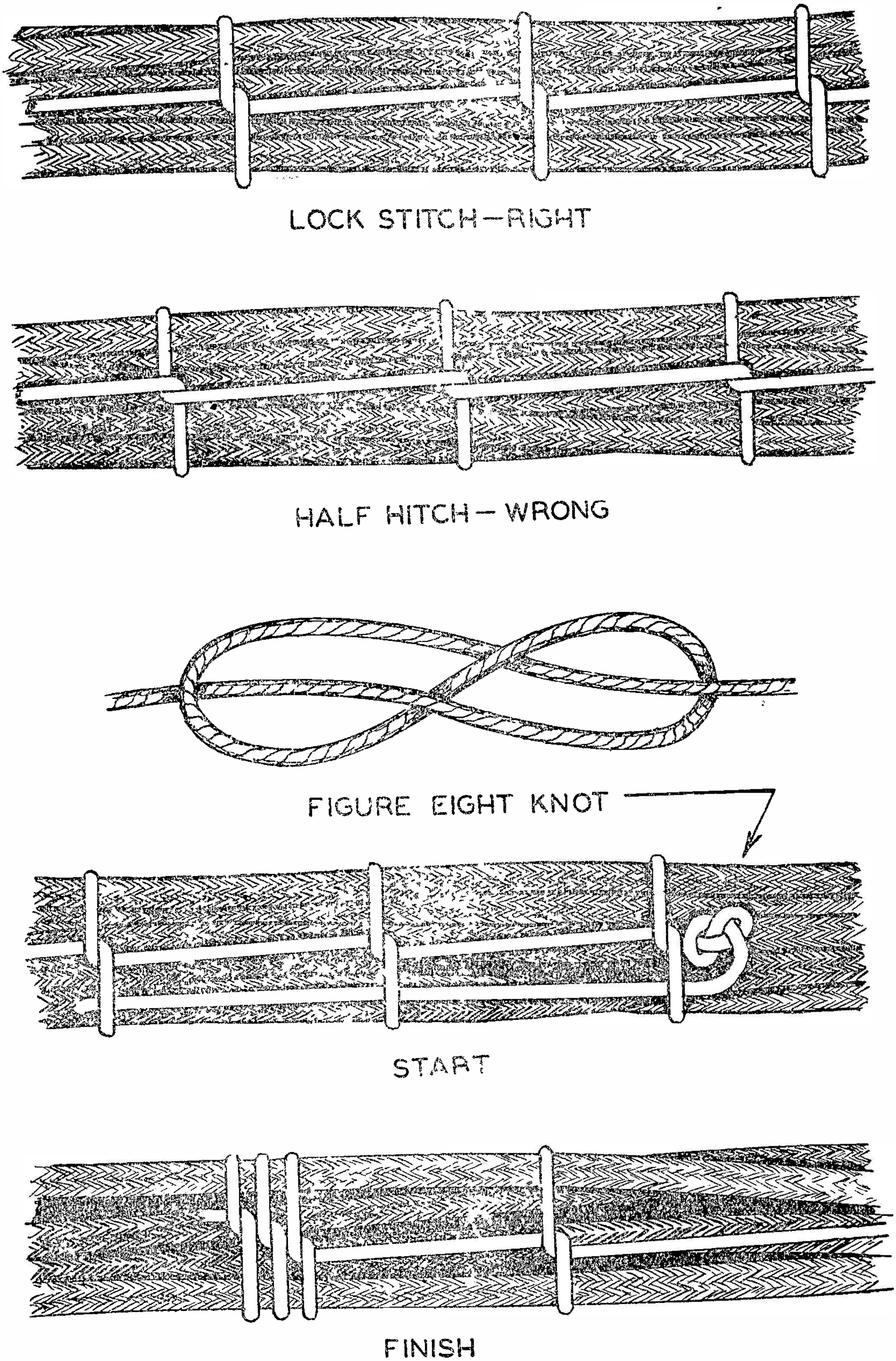

LOCK STITCH—RIGHT
HALF HITCH—WRONG
FIGURE EIGHT KNOT
START
FINISH

FIGURE 2

COPPER WIRE TABLE —B.&S.

Gauge No.	Diam. in. Mils.	Area in Circular Mils.	Weight in lbs. per 1000 feet	Feet per Pound	Resistance of Pure Copper in Ohms at 68° F.		
					Ohms per Ft.	Feet per Ohm	Ohms per lb.
0000	460.0	211600.	640.5	1.56	.0000489	20440.	.00007639
000	409.6	167800.	508.0	1.97	.0000617	16210.	.0001215
00	364.8	133100.	402.8	2.49	.0000778	12850.	.0001931
0	324.9	105600.	319.5	3.13	.0000981	10190.	.0003071
1	289.3	83690.	253.3	3.95	.0001237	8083.	.0004883
2	257.6	66370.	200.9	4.98	.0001560	6410.	.0007763
3	229.4	52630.	159.3	6.28	.0001967	5084.	.001235
4	204.3	41740.	126.4	7.91	.0002480	4031.	.001963
5	181.9	33100.	100.2	9.98	.0003128	3197.	.003122
6	162.0	26250.	79.46	12.58	.0003944	2535	.004963
7	144.3	20820.	63.02	15.87	.0004973	2011.	.007892
8	128.5	16510.	49.98	20.01	.0006271	1595.	.01255
9	114.4	13090.	39.63	25.23	.0007908	1265.	.01995
10	101.9	10380.	31.43	31.85	.0009972	1003.	.03173
11	90.74	8234.	24.93	40.12	.001257	795.5	.05045
12	80.81	6530.	19.77	50.58	.001586	630.5	.08022
13	71.96	5178.	15.68	63.78	.001999	500.1	.1276
14	64.08	4107.	12.43	80.45	.002521	396.6	.2028
15	57.07	3257.	9.86	101.4	.003179	314.5	.3225
16	50.82	2583.	7.82	127.9	.004009	249.4	.5128
17	45.26	2048.	6.20	161.3	.005055	197.8	.8153
18	40.30	1624.	4.92	203.4	.006374	156.9	1.296
19	35.89	1288.	3.90	256.5	.008038	124.4	2.061
20	31.96	1022.	3.09	323.4	.01014	98.62	3.278
21	28.46	810.1	2.45	407.8	.01278	78.24	5.212
22	25.35	642.6	1.95	514.2	.01612	62.05	8.287
23	22.57	509.5	1.54	648.4	.02032	49.21	13.18
24	20.10	404.0	1.22	817.6	.02563	39.02	20.95
25	17.90	320.4	.97	1031.	.03231	30.95	33.32
26	15.94	254.1	.77	1300.	.04075	24.54	52.97
27	14.20	201.5	.61	1639.	.05138	19.46	84.23
28	12.64	159.8	.48	2067.	.06479	15.43	133.9
29	11.26	126.7	.38	2607.	.08170	12.24	213.0
30	10.03	100.5	.30	3287.	.1030	9.707	338.6
31	8.928	79.71	.24	4145.	.1299	7.698	538.4
32	7.950	63.20	.19	5227.	.1638	6.105	856.2
33	7.080	50.13	.15	6591.	.2066	4.841	1361.
34	6.305	39.75	.12	8311.	.2605	3.839	2165.
35	5.615	31.52	.10	10480.	.3284	3.045	3441.
36	5.000	25.00	.08	13210.	.4142	2.414	5473.
37	4.453	19.83	.06	16660.	.5222	1.915	8702.
38	3.965	15.72	.05	21010.	.6585	1.519	13870.
39	3.531	12.47	.04	26500.	.8304	1.204	22000.
40	3.145	9.89	.03	33410.	1.047	.955	34980.

P4

DE FOREST'S
TRAINING, Inc.

LESSON FDM - 6
WIRE SPLICING

• • Founded 1931 by • •

RADIO FUNDAMENTALS

LESSON FDM-6

WIRE SPLICING

Soldering ---------------------------------- Page 1
Solder ------------------------------------- Page 1
Solder Flux -------------------------------- Page 2
Soldering Irons ---------------------------- Page 3
Tinning the Iron --------------------------- Page 3
Soldering Lugs ----------------------------- Page 4
Push-back Hook-up Wire --------------------- Page 5
Looped Connections ------------------------- Page 6
Wire Splicing ------------------------------ Page 7
Stripping the Wire ------------------------- Page 8
Stripping Small Wires ---------------------- Page 9
The Tap Splice ----------------------------- Page 9
Knotted Tap Splice ------------------------- Page 10
Western Union Splice ----------------------- Page 10
Fixture Splicing --------------------------- Page 11
Splicing Duplex Wire ----------------------- Page 11
Brittannia Joint --------------------------- Page 11
Stranded Wires and Cables ------------------ Page 12
Cable Taps --------------------------------- Page 12
Soldering Splices -------------------------- Page 12
Insulating Splices ------------------------- Page 13
Wire Ends ---------------------------------- Page 13
Importance of Wire ------------------------- Page 14

Success today may differ in substance from the success of 50 years ago, but there is no difference in time. Now, as before, knowledge, ability, industry, and determination are the essentials of success. The doors of achievement have never closed upon ability; on the contrary, they swing easier for it. Real ability, a capacity for doing things, never was so eagerly searched for as now, and never before commanded such rewards.

— Daniel Willard

SOLDERING

In our explanation of a simple electrical circuit, we emphasized that all conductors offer a very definite resistance to the passage of an electrical current. Therefore, it follows naturally that circuits should be constructed with as little resistance as possible.

Going further, you will remember that wire is used mainly to provide a path between the source of electrical energy and the unit in which it is to be used. That immediately brings up a problem of making a low resistance joint between the wire and the source as well as between the wire and the unit which consumes the electrical energy.

By tightly twisting two clean copper wires, a good electrical joint can be made but it is not reliable and, at the best, must be considered as a temporary connection. Even though the wires remain tightly twisted, their outer surfaces will corrode, or oxidize and, while copper is a good conductor, copper oxide is not.

Therefore, in a comparatively short time, a connection of this kind will develop an increase of resistance which will make it useless for Radio work. While mechanical clamping arrangements are used in some cases, practically all wire connections of Radio and other Electronic apparatus are soldered.

SOLDER

Solder is an alloy of two or more metals, mainly lead and tin which make it a soft, silvery white metal. It melts at fairly low temperatures and, when liquid, will cover or "coat" most other metals.

To solder a connection therefore, we simply flow a little liquid solder on the connecting wires and, as mentioned above, the solder will coat the outer surfaces of the wires and also run in between them so that the coating of one wire extends to the other.

When the solder cools and hardens, the wires are embedded in a solid sheath of solder which not only holds them tightly, but prevents their surfaces from corroding. In effect therefore, the soldered joint is a permanent solid connection and will carry a current of electricity with a minimum of resistance.

We want to emphasize here that, while a soldered joint acts electrically about the same as a solid piece of metal, solder is not mechanically strong. Therefore, always remember this rule:- Do not depend on the solder to support a wire mechanically or hold it in place.

Commercial solder is available in bars, or sticks of various sizes, and also as wire, which may be either solid or hollow. While made in the shape of wire, solder is not used like copper wire to carry electricity. Instead, as you will soon learn, wire solder makes a vonveniently shaped supply.

SOLDER FLUX

In all soldering work, cleanliness is perhaps the most important point to remember because solder will not stick to varnish, rust, paint, insulation, or dirt of any kind. The parts to be soldered are first cleaned mechanically, by filing or scraping but that is not enough and, to complete the cleaning, some sort of a chemical, called a "flux", is applied to the parts.

The flux acts to make the melted solder run freely and unite readily with the other metals and is needed for most soldering jobs. There are many kinds of "solder flux" on the market, made up in the form of sticks, pastes and liquids, each being expecially useful for certain types of work.

One general class of Solder Flux contins acid which acts to eat away the outer surface and expose the pure metal for contact with the solder. These are known generally as "Acid Flux" and are used on most non-electrical work such as metal tanks and the gutters installed along the eaves of houses.

For Radio work, Acid flux is not satisfactory because, after a joint has been soldered, small amounts of acid remain on the metal and cause corrosion. While not enough to weaken the joint mechanically, this corrosion will cause a variation of electrical resistance and, in a Radio Receiver, will produce "static" in the speaker.

As a general rule, never use Acid Flux for soldering the electrical connections of Radio apparatus.

Instead, all Radio joints are made with the help of "Non-Acid" or "Non-Corrosive" solder flux, most of which contains a mixture of rosin. When heated, the rosin will melt and clean the metal surfaces but it has no corrosive action and soldered joints, made with its help, are satisfactory from both a mechanical and electrical standpoint.

For most Radio purposes, the solder is made in the form of a hollow wire and the central opening is filled with Rosin flux. This is known as "Fluxed" or "Rosin Core" wire solder and is used almost universally.

SOLDERING IRONS

To solder two pieces of wire, they are first cleaned, usually by scraping, and then heated until the end of a piece of rosin core wire solder, when pressed on them, will melt and flow between them. The melted rosin completes the cleaning and allows the solder to adhere to the metal so that, as it cools, the solder hardens and completes the joint.

To heat the joint sufficiently to melt the solder, you will use a "Soldering Iron"; which really is not iron at all, but a piece of copper, mounted on a handle as shown in Figure 1-A on the illustration sheet at the end of this Lesson.

The working end of the copper is tapered, somewhat like a sharpened lead pencil, although the taper usually has but four sides or faces. Irons of this type are made in a number of sizes, graded by weight, such as 12 ounce, 1 lb., 2 lb., and so on. The larger sizes hold the heat longer and **are** for heavier work while the smaller sizes are more adaptable for Radio work.

To be of use, the iron must be heated and this can be done by means of a gasoline blow torch, or furnace, such as is used by plumbers and tinsmiths. In fact, irons of this type can be heated in almost any kind of a flame.

To simplify the heating, most soldering is now done with an "Electric Iron" of the type shown in Figure 1-B. It has the same type of copper tip, as explained for Figure 1-A, but it contains a heating element and works on the same idea as an electric flat iron toaster.

The main advantages of an electric soldering iron are that it can be used steadily, without becoming cold, and can be operated safely in places where the flame, used for heating an ordinary iron, would be dangerous.

Electric soldering irons are made in a wide variety of sizes and models and usually rated by the amount of Power they consume. Thus, you will hear them spoken of as 75 watt, 100 watt, or 200 watt irons. The size of the copper tip varies with the power rating and, for ordinary Radio wiring, a 75 watt or 100 watt iron is satisfactory.

TINNING THE IRON

When any piece of metal is covered by a thin coating of solder, it is said to be "Tinned". Much of the copper wire,

used in Radio work, is tinned before being covered with insulation as it is much easier to solder a "tinned" wire.

The same general idea applies to a soldering iron and, no matter what type it may be, the tip of the iron must be tinned before it can be used. Unless your iron is properly tinned, you will be unable to do good soldering.

To tin an iron, the faces of the tapered tip are first cleaned until they are smooth and bright. This can be done by filing scraping or the use of sandpaper. The iron is then heated and, when hot enough, some fluxed solder is melted on the tip.

At first, the melted solder may gather in globules but, as the flux runs in, the solder will flow to form a thin even coat on the tapered tip. A quick wipe with a piece of cloth will usually help this action.

Another method of tinning is to rub the tip of the heated iron on a lump of sal-ammoniac, to complete the cleaning, and then apply the solder.

No matter which method is used, the tapered faces on the tip of the iron must be covered with a thin even coat of solder before the job is done. When properly tinned, the iron is ready to use and while it must be kept hot enough to melt solder instantly, it must not be allowed to get too hot.

To make a quick test, and also to do good work, get into the habit of wiping the end of the iron with a rag before you start to work. This will remove any dirt or oxide that may have collected and, if the faces look smooth and white when wiped, you know the coat of solder is still there.

Should the iron become too hot, this coating will burn off and the tip will have to be tinned again before any soldering can be done. At no time should a soldering iron be allowed to get red hot because that temperature will remove all traces of the coating of solder and will burn holes or "pits" in the copper. When this occurs, the faces of the tip must be filed smooth and flat before they can be retinned.

Summing up, there are three main points for you to remember:-

First - The soldering iron must be hot and well tinned.
Second - The parts to be soldered must be clean and bright.
Third - A good soldering flux must be used.

SOLDERING LUGS

As practically all connections of Radio and other Electronic apparatus are soldered, different types of lugs have been

designed to help make good mechanical and electrical joints. In Figure 2, we show an assortment of several common types of "solder lugs" that generally are made of copper which has been tinned.

The two lugs at the left are employed when it is desired to make a soldered connection to a binding post or other screw terminal. To use them, the screw of the terminal, to which a connection is desired, is passed through the larger hole of the lug and the nut on the terminal tightened. That leaves the small hole of the lug open and a soldered connection is made to it. The only difference between these two lugs is that the large end of the lower one is made to act as a lock washer.

The other three lugs of Figure 2 are generally found as termimals on component parts of Radio apparatus. For example, the right and left lugs are quit commonly used as terminals on power transformers while the center lug is frequently employed as a terminal on various types of coils, volume controls and similar parts.

PUSH-BACK HOOK-UP WIRE

Fron your studies so far, you know that each part of a complete electronic device is usually connected to another by copper wire which is made in various diameters and with many different types of insulation. At this time, we are interested only in push-back hook-up wire, generally made up with insulation of two or more layers of braided cotton that completely covers the wire and has the general appearance shown at the top of Figure 3.

To expose the copper wire, it is only necessary to "push-back" the insulation from one end as shown by the center view of Figure 3. Here you see a solid copper wire conductor which, in most cases, is tinned to make soldering easier.

As shown at the bottom of Figure 3, the conductor may be "stranded" which means it is made up of a number of small diameter wires. The advantage of the stranded wire is that it is more flexible and thus does not break as easily as the solid wire. It has the disadvantage of being harder to work with because the ends have a tendency to fray.

In many cases, the exposed ends of stranded wire are tinned before a connection is made, in order to prevent fraying and also to insure the proper soldering of each individual wire in the conductor.

LOOPED CONNECTIONS

To complete our explanation of soldering, we will make use of the common type of connection which includes the lugs of Figure 2, the push-back wire of Figure 3 and pair of long nose pliers. Following common commercial practice, we will assume a "Lug" of Figure 2 is mechanically mounted on some component part and it is your job to connect a piece of wire to the lug.

First, you push back the insulation until about 1/2 inch of the wire is exposed and then, as shown in Figure 4, you grip the end of the wire with the tip of your long nose pliers.

Holding the wire in one hand and the pliers in the other, you twist the pliers and bend the end of the wire into the open hook of Figure 5-A.

You then remove the pliers and thread the end of the wire through the small hole in the lug, pulling it to the position of Figure 5-B.

After this has been done, you place the jaws of the pliers over the open end of the hook and, squeezing on the handles, pinch the loop tight as shown in Figure 5-C. The joint should now be fairly rigid but if not, the pliers can be used again to squeeze it tighter.

You will notice this plan provides a fairly good joint and any mechanical strain, or pull, will be carried entirely by the lug and the copper wire. To complete the joint, the parts must be soldered but usually, as both the lug and the wire are tinned, it will not be necessary to clean them by scraping.

With the soldering iron properly heated and tinned, one of the tapered faces is held directly below the joint and held firmly against it. The rosin core wire solder is then held on top of the joint, as shown in Figure 6-A, and as soon as the parts are heated, the flux and solder will melt and run smoothly over the joint.

The iron is then removed, the solder cools and hardens to give the finished work the general appearance of Figure 6-B. Notice, there is enough solder only to cover the joint smoothly.

Most beginners make the mistake of applying too much solder and not enough heat. Remember, the iron is used only to heat the parts and there is no reason to melt solder on to the tip. Also, only the solder in contact with the other metal parts is of benefit. Above all, make sure the parts are hot enough to actually melt the solder.

At first, you may be tempted to melt the solder on the iron and then allow it to flow on the comparatively cool parts. While a good looking joint can be made in this manner, the parts will not tin properly and the purpose of the solder will be defeated.

The result is a "cold soldered" joint which has a comparatively high and variable resistance to electricity. Joints of this type are particularly troublesome because they will cause erratic action in many circuits yet are rather difficult to locate by routine tests.

For Figure 6, we have shown a single wire and a single lug but, in a complete unit, there will be a number of lugs and several wires may be soldered to each. To illustrate this arrangement, for Figure 7 we show several lugs and connecting wires. Notice here, some of the lugs have two wires attached to them, others but one wire. One piece of wire is insulated, while the others are bare.

Figure 7 was drawn merely for illustration and you will notice every joint has been made like that of Figure 5. To complete the job, each of them must be soldered as shown in Figure 6.

Soldering is very simple process but you will find it requires practice to make a joint quickly and properly. After a few trials, you will learn to tell at a glance just when the parts are sufficiently heated, when the proper amount of solder has been applied and when it has tinned the parts complotly.

WIRE SPLICING

Although the big majority of your work in the Radio and Electronic field will deal with small diameter wires, proctically all of the various units must be supplied with electricity from some power source. This source may be a 6 volt battery or 110 volt power line but, in all cases, it must be connected by comparatively large diameter wires to the unit which is using the power. Therefore, the wires themselves become a very important part of the complete system and, in case you are called upon to do some power wiring, it is necessary for you to know how to make a "splice" or "tap" properly.

All work on standard lighting and power circuits must conform with the requirements of the Fire Underwriters Code, a Local or City Code and be inspected by local authorities before being put to use. The local codes vary in different parts of the country and, before doing any acutal electrical work on lighting or power circuits, it is always a good plan to consult your local authorities to determine their requirements on

electrical connections and installations. Due to the variations of local regulations, our explanations will all be according to the rules of the National Electrical Code.

In the National Electrical Code it states:-

> "Wires shall be so spliced or joined as to be mechanically and electrically secure without solder. The joints shall then be soldered, unless made with a splicing device, and shall be covered with an insulation equal to that on the wires."

Read that paragraph again because it is something you will need to know no matter what branch of electricity you follow. When you study it carefully, you will see that there are really three things you must learn.

First:- How to twist the wires so as to make a joint "mechanically and electrically secure".

Second:- How to solder.

Third:- What kind and how much insultation to put over the joints.

As you have probably gathered from your former Lessons, a great part of your work will be with wires and while most of them are copper, the insulation is of many kinds and sizes.

In addition to the common types of wire previously explained, for bell and alarm circuits we use annunciator wire which has an insulation made up of two or three layers of cotton twisted spirally around the copper wire, after which it is soaked in paraffin wax. For lighting and power circuits, the wire has a coating of rubber, covered with one or two layers of braid as shown in Figure 8-A.

In many jobs, where two wires are to be run, you will find a duplex wire or cable, made up of two single insulated wires bound together with a layer of braid, as in the sketch of Figure 8-B.

Then, you no doubt remember our earlier explanations of some of the many kinds of twisted cords, shown in Figure 8-C. The insulation on most of these consists of a coating of rubber, covered with some sort of a braid or weave. While the wire in the sketches of Figure 8-A and B is solid, that of the cords is made up of a number of smaller wires and is flexible.

STRIPPING THE WIRE

In order to make any kind of an electrical connection, joint or splice, your first job is to remove the insulation, which

we call, "stripping the wire". While this is a very simple operation, there is a right and wrong way to do it. You will find tools on the market, made specially for this purpose and while many of them are good, for all around work, a sharp pocket knife does about as well.

No matter how the insulation is removed, the copper wire must not be cut or nicked. If you use a knife, never run the sharp edge of the blade around the insulation and try to cut it off as in the sketch of Figure 9-A because, nine times out of ten, you will cut a nick around the wire making it break easily at that point. Even if it does not break, the nick will reduce the cross section area at that point and may cause trouble.

The better plan, shown in Figure 9-B, is to cut the insulation much the same as a lead pencil is sharpened, using the sharp edge of the knife blade, but being careful not to cut through to the copper. Then, after most of the insulation is whittled off, turn the blade over and, with the back, scrape the wire until it is clean and bright.

Many wires are tinned, so when scraping, be careful not to remove the thin coating of solder as it is put there to protect the copper and also makes the joints easier to solder.

STRIPPING SMALL WIRES

On smaller wires, and those having only silk and cotton for insulation, the best method is to pull the wire through a small piece of sandpaper held between the thumb and forefinger. Hold the sandpaper tightly against the wire and pull often enough to remove the insulation and leave the copper clean and bright.

You will also find wire, used mostly for coils, which has nothing but a coating of enamel for insulation. Here again, a piece of sandpaper will remove the insulation quickly and thoroughly.

THE TAP SPLICE

In the following explanations and Figures, we are going to show you the standard solid rubber covered wire used for Electric light and power circuits, but the same rules apply regardless of the kind of insulation. To begin with, we will suppose that you want to make a connection to a wire without cutting or breaking its circuit. This is the connection used for branch circuits and we call it a tap.

First, you locate the point on the unbroken, or running wire, where the tap is to be made, and strip off about two inches

of insulation. Next you strip about four inches off the end of the wire you are going to connect, making sure that both pieces of exposed wire are clean and bright.

Now, hold both wires firmly in one hand, in the position of Figure 10-A, and then twist the end of the tap wire around the running wire, forming the joint of Figure 10-B. While doing this, be sure that the wires do not twist or turn in your hand and that the turns around the running wire are not only tight, but close together. The last half turn or so can best be done with a pair of pliers.

For a solid joint, there should be at least five complete turns around the running wire and, to comply with the underwriters' requirements, the joint should be tight and solid at this time.

Some workers prefer to make the stripped end of the tap wire longer, wind up the five turns and then cut off the end. Others make the stripped end of the tap wire about the right length and use pliers to make the turns tight. You can try out both methods and use the one you can do best.

KNOTTED TAP SPLICE

In Figure 11 we show the Knotted Tap Splice which is an improvement over the tap of Figure 10 because the tap wire can not untwist. To make this joint, both wires are stripped as before and held tightly in the position of Figure 10-A. The first turn is then made around the running wire in one direction, the end brought back around the tap wire and the five turns made in the opposite direction. It is the first reverse turn that prevents the wire from untwisting.

WESTERN UNION SPLICE

Perhaps the most common method of joining the ends of two wires is what we call the Western Union Splice. Here, the ends of both wires are stripped for about five inches and then held firmly in the position of Figure 12-A. Notice that the wires cross about at the center of the stripped ends.

Making sure that the wires do not turn or slip, one end is given five close tight turns around the other making the joint look like Figure 12-B. Then, still holding the wires tight, the other end is given its five turns making the splice of Figure 12-C.

The ends of the twisted wires are then cut off short and forced down tight so they will not cut any insulation placed around them, making the finished splice of Figure 12-D.

FIXTURE SPLICING

There are many circuit conditions which require the splicing of wires of different sizes, such as the connections between fixtures and line wires where, instead of the Western Union, we make a Fixture Splice.

The wires are stripped for about 7 inches at the end and held firmly in the position of Figure 13-A. Notice here that the stripped ends cross at the center of one wire, usually the larger, but close to the insulation of the other. Holding them firmly in this position, they are given three complete twists around each other making the joint of Figure 13-B.

This part of the splice can be best done with a pair of pliers, but you must watch carefully to see that both wires twist equally. If the heavier wire stays straight, or nearly so, the twist will not hold.

After this twist is properly done, it is bend down along the longer end, as in Figure 13-C, after which both outer ends are twisted around the larger wire making the finished splice of Figure 13-D.

Here again, the ends are cut off short and forced down close to prevent them from cutting the insulation that will be put on.

SPLICING DUPLEX WIRE

To make a splice in both wires of a two conductor or Duplex Cable, the outer braid is stripped for 8 or 9 inches and the inner wires are cut so that one is six inches longer than the other. The ends are then stripped as before and a splice made between a long and short wire.

By this plan, the complete splice looks like Figure 14 and prevents any danger of the joints touching each other. This same plan is followed for all kinds of duplex wire and twisted cords where a double splice is to be made.

BRITTANNIA JOINT

To splice a wire which is too large or stiff to twist easily, another method called a "Bound" or Brittannia joint is used. The idea is shown in Figure 15 where the ends of the heavy wires are bent and overlapped for several inches.

A smaller size of bare tinned wire is wrapped around one of the heavy wires a few times and then wound tightly and closely over the entire overlap, finally being given a few last

turns around the other heavy wire. This binding holds the heavy wires tightly together and the bend or hook in their ends prevents them from slipping endwise.

STRANDED WIRES AND CABLES

While the smaller sizes of stranded wires are handled like the solid wires we have been explaining, the larger stranded cables are spliced and tapped by a different method.

To make a splice in a stranded cable, first strip the insulation and then, about half way along the stripped end, bind a few turns of small wire tightly around all the strands. About half the strands are then cut out of the center, close to the binding, and the remaining strands bend out. The cables are then brought together, as in Figure 16-A. and the outer strands twisted around much like the ends of the Western Union splice, making the finished joint of Figure 16-B.

CABLE TAPS

To make a tap splice with stranded cable, the job is started by stripping the wire the same as for an ordinary tap. The strands of the tap cable are then untwisted, half of them pulled one way and half the other, making a sort of a V.

The stripped part of the running cable is next placed in the bottom of the V, as in Figure 16-A, and each group of the tap cable strands given several twists around the running cable making the finished job of Figure 17-B.

SOLDERING SPLICES

Going back to the requirements of the Underwriter's Code, you can see that all of these joints and splices are made in such a way as to be both mechanically and electrically secure without solder but, to fulfill the second requirement, they must all be soldered.

If the stripping has been done properly, the soldering is very easy on the smaller solid wires as they will require but a small amount of flux, or soldering paste and a touch of a hot well tinned iron. When cored or fluxed solder is used, a hot iron is all that is needed.

Once more, let us warn you not to make the mistake of most beginners by trying to pile on a lot of solder because, unless the parts are hot and clean enough to tin all over, the solder will do little if any good.

INSULATING SPLICES

The third requirement of the Code was that the joint be covered with insulation equal to that of the wires. For this part of the work it is customary to use tape that comes in rolls, usually 3/4 of an inch wide and from one ounce to a half pound in weight.

As the ordinary insulation consists of rubber and cloth, there are two common kinds of tape, one made of rubber and the other of cloth impregnated with a sticky, waterproof, insulating compound. This kind we call Electricians or Friction tape.

For cloth covered wire, a layer of friction tape will give sufficient insulation but, for rubber covered wire, it is necessary to first put on a layer of rubber tape making each turn overlap the one ahead of it about half way as in Figure 18-A.

After this is in place, a layer of friction tape is wound on, starting back an inch or two on the regular insulation as shown in Figure 18-B. To make a good job, the tape is wound tightly and to prevent waste, the roll of tape is usually rolled around the wire as in Figure 19. By this method, only the tape used is unrolled, therefore none is wasted and that left on the roll is kept in good shape.

As friction tape is waterproof, it usually completes the splice but, in some cases, it is given a coat of shellac or insulating varnish for added protection.

WIRE ENDS

Another point we had better explain at this time, is the handling of wire ends which fasten to some sort of a terminal on an electrical unit. In many cases, the terminal consists of a screw, threaded into a piece of metal having a lug raised on each side like that of Figure 20-A.

To make a proper connection here, the wire is stripped for about two inches and given a single turn to the right. This turn, or loop, Figure 20-B, is slipped under the head and pulled tight against the body of the screw. As the screw is tightened, by turning it to the right, and the loop in the wire is made in the same direction, the action tightens the connection. If the loop is made to the left, tightening the screw will force it out from under the head making a very shaky connection at the best.

Another plan is to first make the loop and then give the end two or three turns around the wire as shown at Figure 20-C.

This is not necessary, except in special cases, and then both the loop and turns should be soldered the same as a regular tap or splice.

However, when a connection of this kind is to be made with stranded wire, it is a mighty good plan to twist the stripped end until all the small wires are tightly in place and then tin them. The stranded wire can then be handled as easily as a solid wire without any danger of a loose strand sticking out and causing a short or other trouble.

IMPORTANCE OF WIRE

In giving you these explanations on the handling of wire, you may think that we have gone into unnecessary detail but, as all the common forms of electricity are carried by wires, their importance cannot be over emphasized.

One poorly soldered joint or one improperly insulated piece of wire can easily prevent the operation of a complete Radio or other Electronic unit. Thinking along these lines, even the most uninteresting details assume major importance and we want you to study them accordingly.

We are now ready to go back to the Electric Circuit and therefore, for the next Lesson, will take up the subject of batteries which are a common, yet comparatively simple source of Electrical energy.

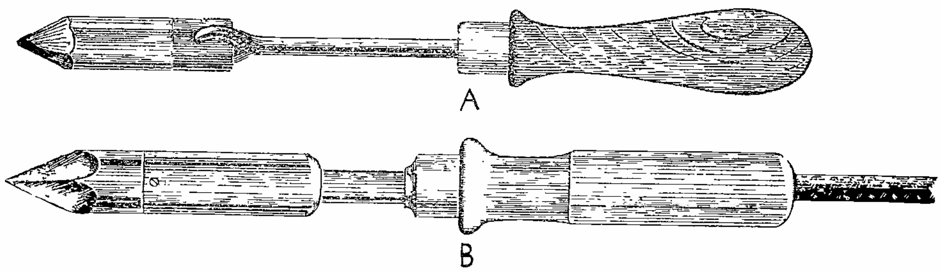


FIGURE 1

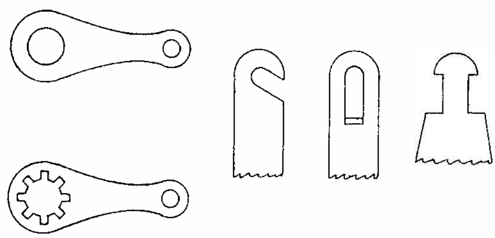


FIGURE 2

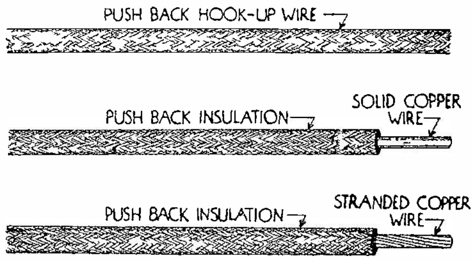


FIGURE 3

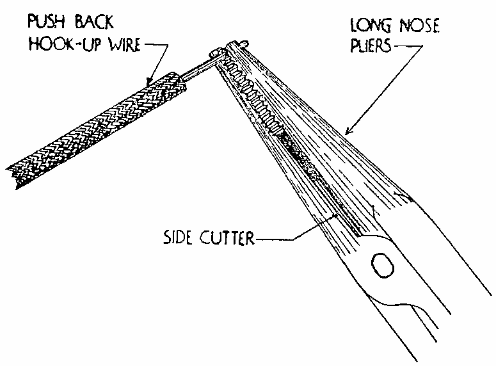


FIGURE 4

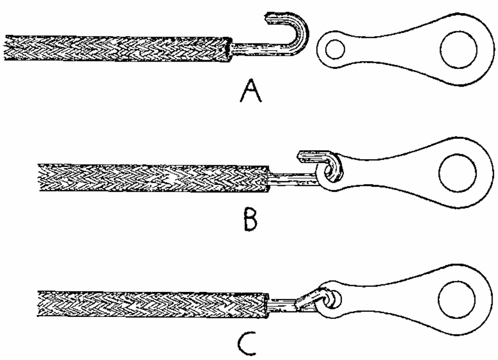


FIGURE 5

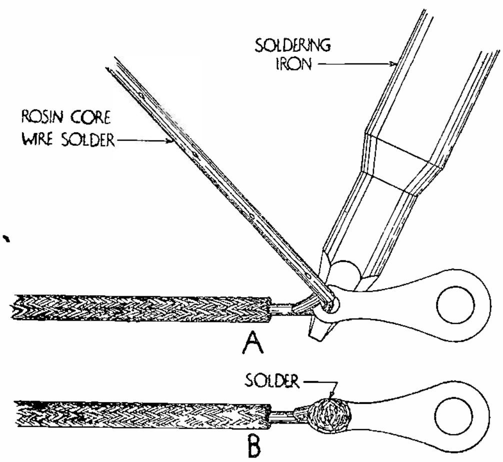


FIGURE 6

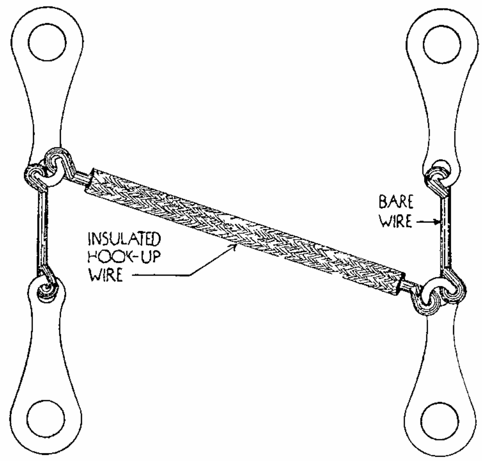


FIGURE 7

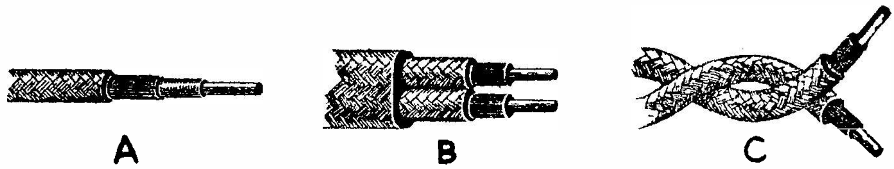


FIGURE 8

FIGURE 9

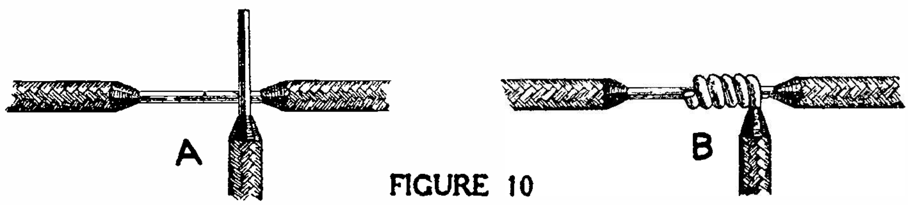


FIGURE 10

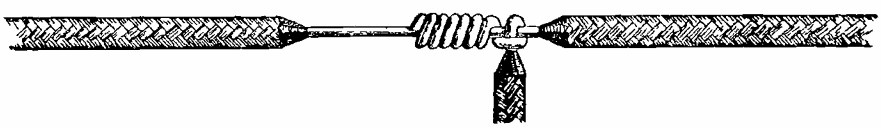


FIGURE 11

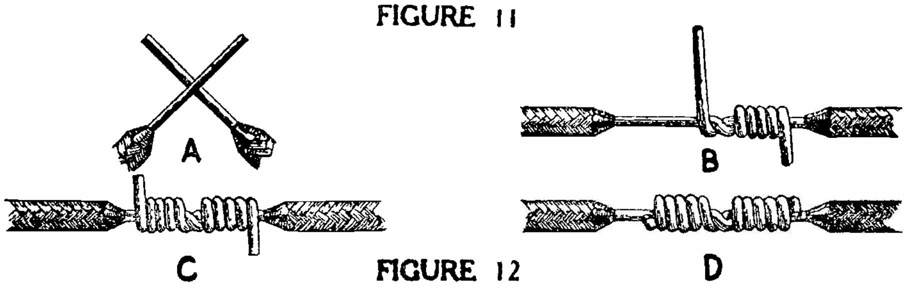


FIGURE 12

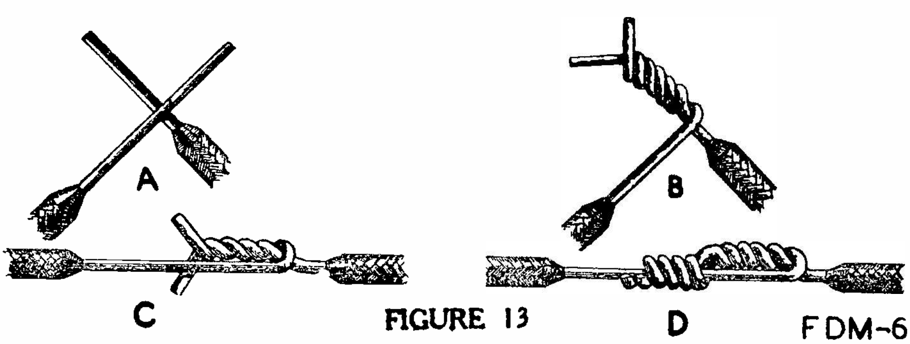


FIGURE 13

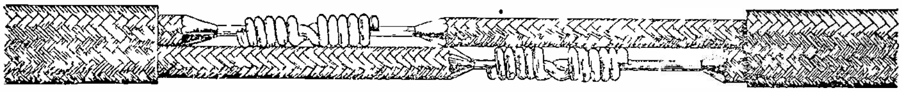


FIGURE 14

FIGURE 15

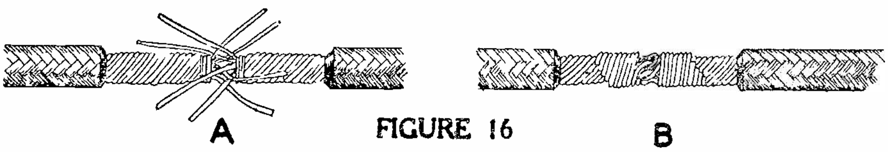


FIGURE 16

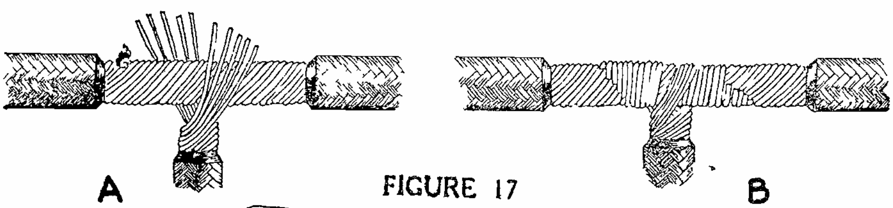


FIGURE 17

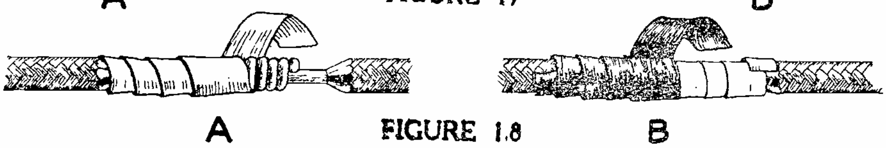


FIGURE 18

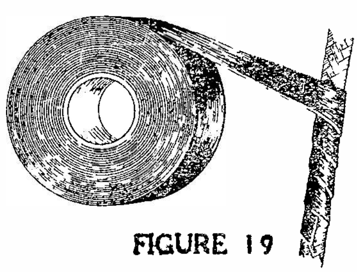


FIGURE 19

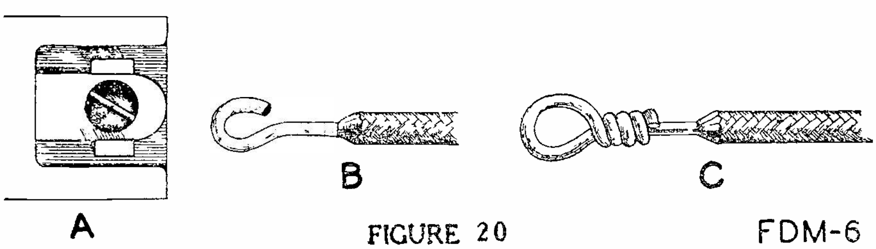


FIGURE 20

DE FOREST'S
TRAINING, Inc.

LESSON FDM - 7
CELLS AND BATTERIES

* * Founded 1931 by * *

H. A. DeVRY

A PIONEER AND LEADER OF VISUAL EDUCATION

RADIO FUNDAMENTALS

LESSON 7

CELLS AND BATTERIES

Primary Cell Principles ---------------------------------- Page 1
Methods of Producing Electrical Energy ------------- Page 1
Generating Electricity by Chemical Action ---------- Page 2
How to Make a Simple Cell ---------------------------- Page 2
Voltage Produced --------------------------------------- Page 3
Names of Parts of Cells -------------------------------- Page 4
Polarization -- Page 4
Depolarizers -- Page 4
Open Circuit Cells --------------------------------------- Page 4
Closed Circuit Cells ------------------------------------- Page 4
Local Action -- Page 5
Amalgamation -- Page 5
Internal Resistance ------------------------------------- Page 5
Testing Cells -- Page 6
Cells and Batteries -------------------------------------- Page 6
Common Primary Cells ---------------------------------- Page 6
The Le Clanche Cell -------------------------------------- Page 7
The Sampson Cell --- Page 7
Dry Cells -- Page 7
Air Cell Battery -- Page 9
Primary and Secondary Cells --------------------------- Page 9
Action in a Lead-Acid Cell ----------------------------- Page 10
Action on Discharge ------------------------------------ Page 11
Action on Charge --------------------------------------- Page 11
Capacity -- Page 11
Ampere-Hours --- Page 12
Voltage of a Cell -- Page 12
Formed Plates --- Page 12
Pasted Plates --- Page 13
Separators -- Page 13
Groups --- Page 14
Elements --- Page 14
Storage Batteries -------------------------------------- Page 14
Electrolyte -- Page 15
Hydrometer -- Page 15
Temperature -- Page 16
Edison Batteries -------------------------------------- Page 17
Action in the Edison Cell ----------------------------- Page 17

o o o o

There is but one straight road to success and that is merit. The man who is successful is the one who is useful. Capacity never lacks opportunity. It cannot remain undiscovered, because it is sought by too many anxious to use it.

— Bourke Cockran

PRIMARY CELL PRINCIPLES

In all of our explanations of Electricity, so far we have assumed a source of Electro Motive Force but have given no details in regard to it. Electricity is so common that the general public does not give it much thought. They plug Floor Lamps, Vacuum Cleaners and Radios in their wall sockets, put new cells in their flashlights or new batteries in their portable Radios much the same as coal in their stoves or gasoline in their automobiles.

However, by this time, you know there must be a source of Electromotive Force or Voltage in order to cause an electrical current. For this Lesson therefore, we are going to explain one of the three common methods of producing or generating Electrical energy.

METHODS OF PRODUCING ELECTRICAL ENERGY

First: - Mechanically, which includes all kinds and types of generators. We can say that any device which changes mechanical motion, or energy, into electricity, is a generator.

Second: - Chemically, which includes all kinds and types of cells and batteries.

Third: - Thermally, which includes all devices that produce electricity by heat, or a difference of temperature.

One fact that we want to emphasize at the start, is that we know of nothing which actually makes electricity. The electricity we are telling you about is always in motion, and naturally there must be something to start it and keep it going.

The three methods which we mentioned are just different ways of putting the electricity in motion. Think of it this way. If you were to put a large water wheel on the shore of a lake and let the lower paddles dip in the water, nothing much would happen. If the lake was rough, the waves would rock the wheel back and forth, but that is all. It would not make any difference how the wheel was placed, one quarter, one half or all of it under the water, it would not revolve no matter how big the lake was.

However, if you put the same wheel on the bank of a swift river and let the lower paddles dip in the water, the wheel will run because the water is in motion. The same thing is true of electricity. It is all around us but, unless we put it in motion, it is not of much practical benefit.

Should someone ask you where a battery or generator gets all the electricity it puts out, just tell them that it does not make any of it, but merely puts it in motion. The action is somewhat like that of the pump on a well because the pump does not "make" any water, but simply raises it, or puts it in motion.

GENERATING ELECTRICITY BY CHEMICAL ACTION

It has been found that whenever two different metals are placed in any liquid, except water, that will conduct electricity, an electrical pressure is produced. This we call an Electro Motive Force, or E.M.F. For all practical work, two dissimilar metals are immersed in some chemical solution that combines actively with, or attacks one of the metals because, with this combination, a much greater E.M.F. is produced.

To explain the action, we can tell you first that, whenever there is chemical action, there is also electrical activity. When the solution attacks one of the metals, new compounds are formed and the parts being separated are charged with opposite kinds of electricity. The negative charges collect on one metal while the positive charges collect on the other and thus the chemical action produces an Electromotive Force.

HOW TO MAKE A SIMPLE CELL

In Figure 1, we have shown a very simple arrangement that you can easily make. Take an ordinary drinking glass and fill it about two thirds with weak sulphuric acid. The kind that the automobile storage battery repair men call "1300" will be all right. Then get a strip of copper and a strip of zinc, each about one inch wide and long enough to reach almost to the bottom of the glass after the tops are bent over as shown. Scrape the strips until they are clean and shiny and then put them in the glass. You can put them in any place but you must not let them touch each other.

Now get a short piece of copper wire and touch both strips of metal with it. With both the wire and strips clean and making good contact, you have made an electrical connection and formed a circuit. Holding the wire in place, you will see bubbles gather on the copper and float up through the acid. When you remove the wire, the action almost stops.

By replacing the copper wire with a meter, as in Figure 2, you can see, by watching the meter, that when you make a connection between the strips, there is electrical current through the meter. From our former explanations, you know that in order to have a current of electricity, there must be a pressure or voltage therefore, if this arrangement causes current, it must produce an E.M.F.

What really happens while the cell is working requires a very long explanation and a knowledge of chemical action but, in a general way, you can think of it like this. Sulphuric acid is made up of 2 parts of hydrogen, one part of sulphur and four parts of oxygen which, mixed with water, is the liquid or electrolyte. When the action takes place, the acid attacks the zinc, absorbs one part of it and lets go of the hydrogen.

Thus, the acid is reduced to a new compound, the sulphur and oxygen, with a negative electrical charge, which combines with the zinc to form zinc sulphate. The hydrogen, with a positive charge, gathers on the copper in the form of bubbles. In this way, the electrical charges are transferred to the metals and the copper becomes positive while the zinc becomes negative.

By this action, one part of the acid and one part of the zinc have been lost, as far as our use is concerned, but the change has produced an E.M.F. Remember, the parts we mention are very small, so small that you can not even see them with a microscope, and are called atoms. To continue to produce the electrical pressure, the cell will gradually use up the zinc and the acid, and the length of time they last will depend on how fast the electricity is used. An arrangement of this kind is called a Primary Cell.

Now isn't this about the same thing that happens when you build a fire? The coal or wood is burned but, in burning, it gives off heat.

VOLTAGE PRODUCED

From what we have said, you know that this cell produces an E.M.F., which means that there is a difference of pressure or potential. You will also remember that, according to Benjamin Franklin, the direction of current is from the higher to the lower level or potential. Therefore, in the complete circuit of Figure 2, the path of the current will be from the copper, through the meter to the zinc and from the zinc, through the acid in the cell, to the copper.

This makes the direction of current, outside the cell from plus to minus but, inside the cell, from minus to plus. Just think back for a minute to the simple water circuit of the earlier Lesson on "Current Electricity". Isn't the action of the cell exactly the same as that of the water pump? There, the pump raised the level, or pressure, of the water and the direction of the water, inside the pump, was from a low to a higher level. In comparison, the cell is really nothing but an electrical pump, raising the electricity from a low to a higher potential.

NAMES OF PARTS OF CELLS

The liquid, or solution of a cell is called the "Electrolyte". The metals are called the "Electrodes" and the copper is the Positive Pole, very often called the Plus and marked with a small cross "+". The zinc is the Negative Pole or the minus and is marked with a "-". Thinking of a cell as an Electric generator, the positive pole or terminal may be called the Anode and the negative or minus the Cathode.

POLARIZATION

As long as the simple cell is in operation, a quantity of bubbles gather on the copper. These bubbles are hydrogen which is a very poor conductor of electricity. The more bubbles on the copper, the less chance the current has of getting through, so that the longer the cell works, the less current it can deliver. This action, called Polarization, takes place in all primary cells and even when the cell is used for but short periods, such as ringing a door bell, it causes a reduction of current and unsatisfactory operation.

DEPOLARIZERS

All sorts of ideas have been tried to overcome and reduce polarization, such as brushing off the bubbles mechanically, but the most common and practical method is to place around or near the anode, some substance that will readily unite with and absorb the hydrogen. This substance will have to be a good conductor of electricity and a chemical of this kind is called a "Depolarizer".

OPEN CIRCUIT CELLS

The action of the different depolarizers takes place at different speeds and, if the hydrogen bubbles are not absorbed as fast as they form, the cell will not deliver proper current for any great length of time.

It can, however, be used for a short time and then allowed to rest. While at rest, the depolarizer absorbs the hydrogen and, in a few minutes, the cell will again deliver its proper current. This type is called an "Open Circuit" cell as it must be used in circuits where current is not needed all the time. Here again we can mention an ordinary door bell circuit as a very common and good example.

CLOSED CIRCUIT CELLS

When the action of the depolarizer is fast enough to absorb the hydrogen as rapidly as it gathers on the anode, the cell

will deliver its proper current continuously. A cell of this type can be connected in a circuit which requires current all the time and is therefore kept closed. Used on closed circuits, we call this type a "Closed Circuit" cell.

LOCAL ACTION

As it is practically impossible to obtain ordinary metals which are absolutely pure, zinc like that used in the simple cell, may have small pieces of other metals in it. When it is placed in the acid, the same action takes place, between it and these small pieces of other metals, that we want to take place between it and the copper anode. The currents, set up by this action, never get outside of the cell and can never be of any use as they simply run around between the zinc and the other metal particles to produce what is known as "Local Action".

AMALGAMATION

Local action wastes the zinc, whether the cell is in use or not, and thus shortens its life. By coating the zinc with mercury, we can greatly reduce and almost eliminate the local action. When a piece of clean zinc is rubbed with mercury, the two combine and the mercury not only covers the particles of other metals but makes a very smooth clean surface of pure zinc. The smooth surface also helps as it causes the zinc to hold a very thin coating of hydrogen which practically stops all action unless the cell is in use. This process of coating the zinc is called "Amalgamation".

INTERNAL RESISTANCE

From what we said in former Lessons, you know that everything offers some resistance to the passage of an electrical current. Even while a cell is producing an E.M.F., the current it supplies will have to pass through the cell in order to complete its circuit. In this complete circuit, it is the resistance of the cathode, the anode and the electrolyte, which we call "Internal Resistance". The amount of this resistance will vary greatly, according to different conditions in the cell, but you can readily understand that it will be an advantage to keep the internal resistance as low as possible. This by the way, is the reason for the depolarizer.

For example, when an open circuit cell is used steadily, the polarization increases its internal resistance and, as the cell is part of the circuit, the resistance of the circuit will be increased accordingly. You can easily see that, if the voltage remains the same and the resistance increases, the current will be reduced.

You also know that it requires voltage, or pressure, to force current through a resistance therefore, as the internal resistance of a cell increases, the voltage required to force current through this resistance is lost for use in the circuit outside the cell. A voltmeter, connected across the outside of the cell, will show a drop when the cell becomes polarized and its internal resistance increases.

TESTING CELLS

This action can be tested quite easily by means of a voltmeter, an ammeter and a dry cell, which is similar to the simple cell we have been explaining. The voltmeter is connected across the dry cell, to form a circuit like that of Figure 2, and its reading indicates the open circuit voltage of the cell.

The ammeter is then connected across the cell also. The ammeter reading is quite high at first but soon starts to drop, the voltmeter reading falling also. The reduced readings show the cell is polarized and the voltmeter indicates the closed circuit voltage.

After this reading has been taken, the meters are disconnected and the cell is allowed to rest for a while. If the cell is in good shape, the depolarizer will do its work and, in a few minutes, a test with the voltmeter will show the open circuit voltage is again at the same value as when the test was started.

CELLS AND BATTERIES

You may hear some people talk about dry cells and as many more speak of dry batteries. It does not make a great deal of difference which word is used because we know what is meant but electrically, there is a big difference between a cell and a battery.

The simple outfit that we described in the first part of this Lesson is a cell. Should we take two or more of these cells and connect them together, then we would have a battery.

You can go into a store and buy four dry cells but, if you take them home and connect them together, you have one dry battery. A cell is a unit for the production of electricity by chemical means. When two or more cells are connected so as to work together, the combination is called a battery.

COMMON PRIMARY CELLS

There have been hundreds of different combinations of chemicals and metals used to produce electricity but most of them have been discarded and forgotten for one reason or another

While there are still a great number of cells used for laboratory and experimental work and in places where no other electrical power is available, about the only type of primary cell you will have to work with is the dry cell.

THE LE CLANCHE CELL

To trace the development of the dry cell, first we will explain the Le Clanche cell of Figure 3, one of the most common "Wet Cells" which gives good results for open circuit work. The negative electrode is made of zinc, usually in the form of a pencil, with the lower half square. The positive carbon electrode is sealed in a porous cup which is filled with Manganese Dioxide or Peroxide for the depolarizer.

For the standard size cell, the electrolyte is made by dissolving about 4 ounces of white powdered Sal Ammoniac in water. If mixed in the glass jar, it should be filled about one third with water.

After the Sal Ammoniac is all dissolved, the carbon and zinc are put in place and the cell is ready to operate. As the cell operates, the zinc wastes away quite rapidly but, on account of the open construction, any of the parts are easily replaced.

This cell is a good example of a slow acting depolarizer because, when used steadily, the voltage very soon drops. After standing idle for a while, the depolarizer does its work and the voltage comes back to its original value.

THE SAMPSON CELL

The Sampson Cell of Figure 4 is really a form of Le Clanche but has some features which make it very popular. It uses the same metals, electrolyte and depolarizer as the Le Clanche and requires the same treatment.

In this cell, the carbon is made hollow and filled with the depolarizer which consists of manganese peroxide and granulated carbon. By this arrangement, the carbon acts as a porous cup thereby cutting down the number of parts. The zinc is made in the form of a cylinder and surrounds the carbon thus exposing a very large surface to the action of the electrolyte.

DRY CELLS

Like the Sampson cell of Figure 4, dry cells are a form of Le Clanche cell and in Figure 5, we have removed the pasteboard cover and then cut a dry cell through the center so as to expose the various parts.

Starting at the outside, you will find the entire cell is built like a cup of zinc which acts as a cathode as well as the container. Inside the zinc is a layer of blotting paper that is soaked in an electrolyte of sal ammoniac. Inside the blotting paper, the cell is filled with a mixture of coke, carbon and manganese peroxide, in the center of which is the carbon anode. To prevent evaporation, the top is sealed, first with a layer of sand and then about a half inch of tar or asphaltum.

The name "Dry" is apt to be misleading because, while it is dry on the outside, a cell of this type must be moist on the inside in order to operate. In fact, not only the blotting paper, but the mixture between it and the carbon is generally soaked with electrolyte before the cell is sealed.

While there are many different compounds used in the various makes of dry cells, most manufacturers add some zinc chloride to the electrolyte to prevent the rapid wasting away of the zinc while the cell is not in use. This is a very important feature because it naturally takes some time, after the cell is made, to deliver it to the final buyer who places it in use. The time between the making and using of the cell is spoken of as its Shelf Life.

Mixed with the depolarizer there is usually a certain amount of carbon, graphite or coke which also aids the action. Don't think that all dry cells are alike because, by using different compounds, a manufacturer can build a cell with a high current output and a short life or make one with a lower output but a much longer life. You can see therefore that a cell, built for some special kind of work, will give much better results when used for its particular service.

The depolarizer of the dry cell, shown as Manganese Peroxide, is similar to the Manganese Dioxide of the Le Clanche cell, and the terms are often considered as having the same meaning. However, to be more nearly correct, each molecule of the "Dioxide" consists of one atom of Manganese and two atoms of oxygen, while the molecules of "Peroxide" may consist of one or more atoms of Manganese and two or more atoms of oxygen. Thus, the depolarizer of a dry cell may be Manganese Dioxide or some other Manganese Compound with a higher state of oxidation.

Dry cells are made in a number of standard sizes but, regardless of size, each new cell develops an open circuit electrical pressure of approximately $1\frac{1}{2}$ volts. After a shelf life of a year, a good cell will drop only about one tenth of a volt. However, the internal resistance of a cell does increase with age and therefore, the older the cell, the less current it will deliver.

AIR CELL BATTERY

Another form of battery, which has proven quite popular in the rural communities for supplying filament voltage for battery operated Radio Receivers, is known as the "Air Cell Battery". It consists of two "Air Cells", assembled in a hard rubber container, and permanently connected in series.

Like the dry cell just explained, the electrodes are carbon and zinc. The electrolyte however, is a solution of sodium hydroxide and common drinking water. In this battery, the oxygen, used as a depolarizer, is absorbed directly from the surrounding atmosphere instead of being supplied in the form of manganese peroxide as in the case of the dry cell.

At the time of manufacture, the electrolyte-forming chemicals are placed in the battery in solid form. Then, to prevent them losing some of their strength before being placed in service, by possible contact with moist air, the battery is sealed. While in this condition, no change can take place in the chemicals and thus the battery may be placed in service any time after manufacture and the purchaser will be certain that he is buying a "fresh" unit.

To place the battery in service, all that need be done is to remove the covers from the electrodes, so they can obtain the oxygen from the surrounding air, punch out the seals in the bottom of the filler holes and fill the compartments with water.

There is one very important precaution concerning this battery because it has a very definite overload value beyond which it is unsafe to go. This overload point is determined by the maximum rate at which the carbon electrodes can absorb oxygen from the air.

To prevent excessive current, a battery of this type should be tested only with a voltmeter. However, when making voltage tests, be sure the batter is delivering its normal load current or else you will obtain the open circuit voltage which will not give you the proper indication of its condition. A new "Air Cell Battery" should test 2.5 volts and, when this drops below 2 volts, it should be replaced.

PRIMARY AND SECONDARY CELLS

In our explanation of Primary Cells, we told how electricity is produced by chemical action and you will remember the cells are made up with two electrodes, or plates, and a solution called the electrolyte

When an electrical circuit is completed between the electrodes, outside the cell, a chemical action destroys some of the parts but produces an E.M.F. which supplies the circuit with current.

A secondary, or storage cell, is similar in many ways but, after producing an E.M.F., until no further action takes place, the parts can be brought back to their original form by forcing current through the Cell in a reverse direction.

ACTION IN A LEAD-ACID CELL

All of our modern storage batteries really began back about 1850 when a man, by the name of Plante, first made up a cell, something like the primary cells, with two electrodes and an electrolyte. His electrodes, or plates, were made of lead and the electrolyte was weak, or diluted sulphuric acid.

There is not much chemical action between lead and sulphuric acid but the electrolyte will form a thin coating of lead sulphate on the lead plates. Plante connected his cell in an electrical circuit and, after sending current through it, found that this thin coating of lead sulphate, on the plate connected to the positive side of the circuit, had changed to lead peroxide. On the other plate, the lead sulphate had changed to pure lead of a spongy form.

When in this condition, the cell could be disconnected from the circuit and, like a primary cell, produced an E.M.F. of its own. While it was connected so as to furnish current for a circuit, the lead peroxide and spongy lead changed back to lead sulphate, leaving both plates about the same as when the cell was first assembled.

The cell could then be connected back in the circuit that sent current through it and the lead sulphate, on the plate connected to the positive, again changed to lead peroxide while that on the other plate again changed to spongy lead.

While current was being sent through the cell, it was said to be Charging, and when it was delivering current, it was said to be Discharging. Each time this cell of Plante's was charged and discharged, more lead peroxide and spongy lead formed on the original plates.

Then he found that as more of these materials formed on the plates, the cell would deliver current for a longer time. These compounds are called the "Active Materials", because the chemical action takes place in them and the amount of electricity a cell can produce is called its "Capacity".

ACTION ON DISCHARGE

To follow the entire action, we will assume a charged storage cell is connected to supply current in a circuit. The active materials in this charged cell are Lead Peroxide, on the positive plate, Spongy Lead on the negative plate and a mixture of Sulphuric acid and water for the electrolyte.

As the cell supplies current to the external circuit, chemical changes take place at both plates. The lead peroxide of the positive plate and the spongy lead of the negative plate combine with the sulphuric acid of the electrolyte and are converted into lead sulphate.

This action breaks down the sulphuric acid of the electrolyte and it is converted into water. These changes take place gradually, as long as the cell is supplying current, and when all of the active material has been converted, there is no further action. The cell can no longer produce an E.M.F. and we say it is "Discharged".

ACTION ON CHARGE

The discharged cell can now be placed in a circuit which causes current to pass through it in the opposite direction to that which the cell supplied while discharging. Passing through the cell in the opposite direction, the current causes the chemical actions to reverse.

At the positive plate, the lead sulphate is converted back to lead peroxide, the lead sulphate on the negative plate is converted back to spongy lead and some of the water in the electrolyte is converted into sulphuric acid.

While these changes are taking place, we say the cell is "Charging" and, when all of the available active material has been converted, the cell is "Charged".

On most storage cells, the positive terminal is marked with a "+" and the negative with a "-" but, if there is no marking, remember the positive is dark brown in color while the negative is grey.

CAPACITY

As we mentioned before, the amount of electricity, or current, that a cell can produce is called its capacity. From the chemical actions just explained, you can see that the greater the amount of active material, the more energy the cell will be able to produce.

For practical work, the capacity is measured by the amount of current, in amperes, multiplied by the time it is produced, in hours. This makes the unit for measuring capacity, the Ampere-Hour.

AMPERE-HOURS

However, this is not quite as simple as it sounds because a cell that will deliver 10 amperes for ten hours, will not necessarily deliver 100 amperes for 1 hour. In general, the higher the current, or rate of discharge, the smaller the capacity will be. For example, a standard 100 Ampere-Hour auto battery will supply 5 amperes for 20 hours and 125 amperes for but 20 minutes.

The amount of energy, or current, that a cell can deliver will depend on the number of plates, the amount of active material on the plates, the strength of the acid in the electrolyte and the ease with which the active materials and electrolyte can come in contact with each other.

VOLTAGE OF A CELL

Regardless of the size of a cell, or the number of plates in it, the voltage produced is always the same. As the cell is being charged, the voltage across it will rise to about $2\frac{1}{2}$ volts but, three or four minutes after the charging current is stopped, it drops to 2.1 volts.

As the cell discharges, and delivers current, the voltage drops quickly to 2 volts and holds there until the discharge is almost complete, when it drops very fast.

FORMED PLATES

When we were telling you about Plante's cell we mentioned that each time the plates were charged and discharged, more active material was formed on them. As the amount of active material increased, the capacity of the cell also increased and, in order to get the plates in the proper condition, they had to be charged and discharged many times.

This charging and discharging, to produce the proper amount of active material, is called forming the plates and, by the original method, requires a long time and a large amount of current. You can see here however, as the chemical action takes place on the surface of the lead that comes in contact with the electrolyte, the larger the surface, the faster the plate will be formed.

No matter how the lead is shaped or made, all plates that have to be formed in this way are called Plante, and are made as

positives. The plante negatives are made from the positives, simply by connecting them in the cell as negatives and then charging. The active material is thus changed from lead peroxide to spongy lead.

PASTED PLATES

As the long and expensive forming process with Plante plates, simply changes the lead of the positive to lead peroxide, a man by the name of Faure suggested that the plates be made up of a framework of lead, having the open spaces filled with active material. Plates of this type are called "Pasted" and the framework, called the "Grid", is made so as to form a series of shelves. The active material, prepared outside, is pasted in the shelves.

With the exception of the grid, the pasted plates are all active material and, in comparison to the plante type, are very quickly and cheaply formed. Like the Plante however, they have to be placed in weak sulphuric acid and formed by sending current through them.

Some makers use the same paste for both the positive and negative plates, while others use different mixtures for the active material of each. This type simply gives the plate the proper amount of active material without going through the long forming process.

SEPARATORS

In addition to the plates in the cell, there must be something to keep them from touching. You know that the action must take place between the electrolyte and the active material of the plates but, as lead is a good electrical conductor, if the positive and negative plates should touch, there would be a direct circuit between them. This would act the same as a short between the plates outside the cell and thus prevent current in the circuit to which the cell is connected.

The parts, or insulators used for this purpose, are called "Separators" because they separate the plates. They are made in many different shapes and of many materials. Some types are nothing but a thin sheet of hard rubber that is punched full of holes. When placed between the plates, the rubber keeps them from touching, and the holes allow the acid to have a free path.

Other types are made of glass or hard rubber rods which, when placed between the plates, hold them apart without interfering with the action of the electrolyte.

Perhaps the most common type of separator is made of a thin wood sheet with grooves cut on one side. It is treated chemically to open up the pores and also to remove any substances that might harm the plates.

The wood acts as a separator and holds the plates apart but, being full of pores or very small holes, allows the electrolyte to pass freely through it and have the proper action. Just now, remember that the grooves side of the wood separator is placed toward the positive plate.

GROUPS

Like nearly everything else that we have explained, in order to obtain the proper amount of energy from a cell, it is necessary to use more than two plates. This is done by fastening a number of the same kind of plates to a connecting strap which also carries a lug or post to act as the cell terminal. Right here, we want to mention that you must never use ordinary solder around a storage battery. All of the joints and connections are made by "Burning", which means that the lead parts to be joined are melted until they run together and form one solid piece.

A group of plates consists of a number of positives or negatives, burned to a connector strap and forming one solid piece. For the different sizes of cells, there are different sizes and numbers of plates in the groups.

ELEMENTS

Each complete cell consists of a group of positive plates and a group of negative plates, saw-toothed together. There is usually one more negative than positive, so that both of the end, or outside plates, are negatives. This arrangement places each positive between two negatives. A separator is placed between each of the plates and, if of the wood type, the grooved side is turned toward the positive plate.

This complete assembly of groups and separators is called an Element and, after it is placed in its jar, or container, the electrolyte is added to form a complete cell.

STORAGE BATTERIES

Like the dry cell battery, when a number of storage cells are connected so as to work together, the combination is called a "Storage Cell Battery" or more commonly, a "Storage Battery". For Figure 6 we show the type used in present day automobiles, made up of three storage cells connected in series to produce a battery of 6.3 volts.

One end of the case has been cut away to show the arrangement of the parts in a cell. Starting from the left of the opening, you will find first a negative plate, then a separator, next a positive plate, then another separator, another negative plate and so on.

In the upper right corner of the opening, you will see a part of the strap to which the positive plates are attached. On the other side of the cell, a similar strap, which terminates as the "-" terminal post, is attached to the negative plates.

ELECTROLYTE

The electrolyte used for this type of battery is made up of sulphuric acid and distilled water. In our first explanation of the action in a cell, we told you that when the cell was charged, the electrolyte was acid, and when discharged, it was water.

In practical work however, we never reach that condition and no matter in what state of charge the cell may be, there is always both acid and water in the electrolyte. As the cell charges, the chemical action takes place and the amount of acid increases, which gives us a very handy way of testing.

As you perhaps know, the same amount, or volume, of different liquids have different weights. For example, five gallons of sulphuric acid weighs more than five gallons of water while five gallons of gasoline weighs less. We call this the "Specific Gravity" of the liquid, which means its ratio of weight as compared to an equal amount of water. As water is perhaps the most common liquid, we say it has a specific gravity of 1 and figure all the other liquids from it. Pure sulphuric acid weighs about twice as much as water or 1.835 to be exact. As we mix the two for the electrolyte, the specific gravity will be somewhere between 1 and 1.835.

To make use of this fact, we build a little float, called a hydrometer, which is weighted at the lower end with shot and has a scale in the upper part of the tube. Being made of glass, we can put the scale inside and read it from the outside. The more acid there is in the electrolyte, the heavier or denser it will be and, if we drop the hydrometer in, it will sink only as far as the density of the liquid will let it.

HYDROMETER

By properly marking the scale, all we have to do is to place the hydrometer in the electrolyte and read on the scale how

far it sinks. The point on the scale that comes level with the surface of the liquid shows the specific gravity.

Unless special space is provided, it would not be very handy to drop the hydrometer into the electrolyte of the ordinary cell, therefore we place it in a larger glass tube that has a rubber bulb at the top and a tube at the bottom, as shown in Figure 7.

This assembly is called a hydrometer Syringe, or just Hydrometer for short, and is used by placing the tube into the electrolyte. The bulb is squeezed and then let go to draw the electrolyte up into the large tube and, as soon as the hydrometer floats, a reading can be taken.

The scale we show reads from 1300 to 1100 and is the one used for most Lead-Acid Storage batteries. The number 1300 means a specific gravity of 1.3 and the 1100 means 1.1 but, as it is much easier to say eleven fifty or twelve hundred than one and fifteen hundredths, or one and two tenths, the decimal point is left out.

The range of this scale, 1.1 to 1.3 is much less than the 1 to 1.835 that we mentioned before, but it covers the ordinary working range of the cell. If the acid gets so strong that its gravity is over 1.3, it will injure the plates and separators. If it gets so weak that it is below 1.1, the chemical action is so slow that the cell is not of much use.

TEMPERATURE

Like everything else, when the electrolyte is heated it expands and thus its density, or specific gravity decreases. A temperature of 70 degrees Fahrenheit is taken as the standard and it has been found that the specific gravity changes about .001 for each three degrees. In order to obtain an accurate specific gravity reading, it is necessary to add .00033 for each degree above 70 and subtract .00033 for each degree below 70.

While this variation may appear to be extremely small, the readings on the ordinary Hydrometer are 1000 times the specific gravity they represent therefore the error becomes 1 point for each 3 degrees or 1/3 point per degree.

For example, suppose you tested a battery on a morning when the temperature was 10 degrees above zero and obtained a hydrometer reading of 1200. As 10 degrees is 60 below the standard of 70 degrees and the variation is 1/3 point per degree, 1/3 of 60 is 20 and subtracting this value from 1200, the corrected reading is 1180.

EDISON BATTERIES

All of the cells that we have been talking about are of the "Lead-acid" type because the plates are made of lead, the active materials of lead compounds and the electrolyte is acid. There is however, another type of cell, called the "Edison", which contains neither lead nor acid and is used in many commercial applications.

In this cell, the active materials are Nickel Peroxide for the positive plate, finely divided Iron for the negative and the electrolyte is a solution of 21% Potassium Hydrate and water.

In order to improve the action, layers of flake Nickel are added to the positive, some Mercury is added to the Iron of the negative and a little Lithium Hydrate is mixed in with the electrolyte.

ACTION IN THE EDISON CELL

Like the Lead type of cell, the plates are assembled in groups but, instead of being burned to a connector strap, they are placed on a steel pin which also carries the terminal. Spacers are placed on this pin, between the plates, and a nut at each end holds the entire group together.

As before, there are separators between the plates when the groups are assembled into elements. The electrolyte is not acid therefore the jars, or containers for the elements, are made of nickel plated sheet steel. The sides are corrugated in order to make the walls stiff and also to help keep the cell cool.

When delivering current, an Edison cell produces an average of 1.2 volts which is lower than the other type but it is not injured by discharging to zero voltage, by standing idle, by overcharging, as long as the temperature does not rise above 115° F., by low temperature nor by freezing. Like the lead-acid type of cell, distilled water must be added to the electrolyte of an Edison cell but, as the density has only a slight change during charge and discharge, the specific gravity of the electrolyte does not indicate the amount of charge. Instead, the gravity falls steadily as the cell is in service and, when it reaches a value of 1.16, the electrolyte should be renewed.

Edison cells are tested by measuring their voltage which reaches a maximum of 1.8 to 1.9 volts while on charge and when two readings, taken at least 15 minutes apart, show no voltage change, the cell is considered as fully charged.

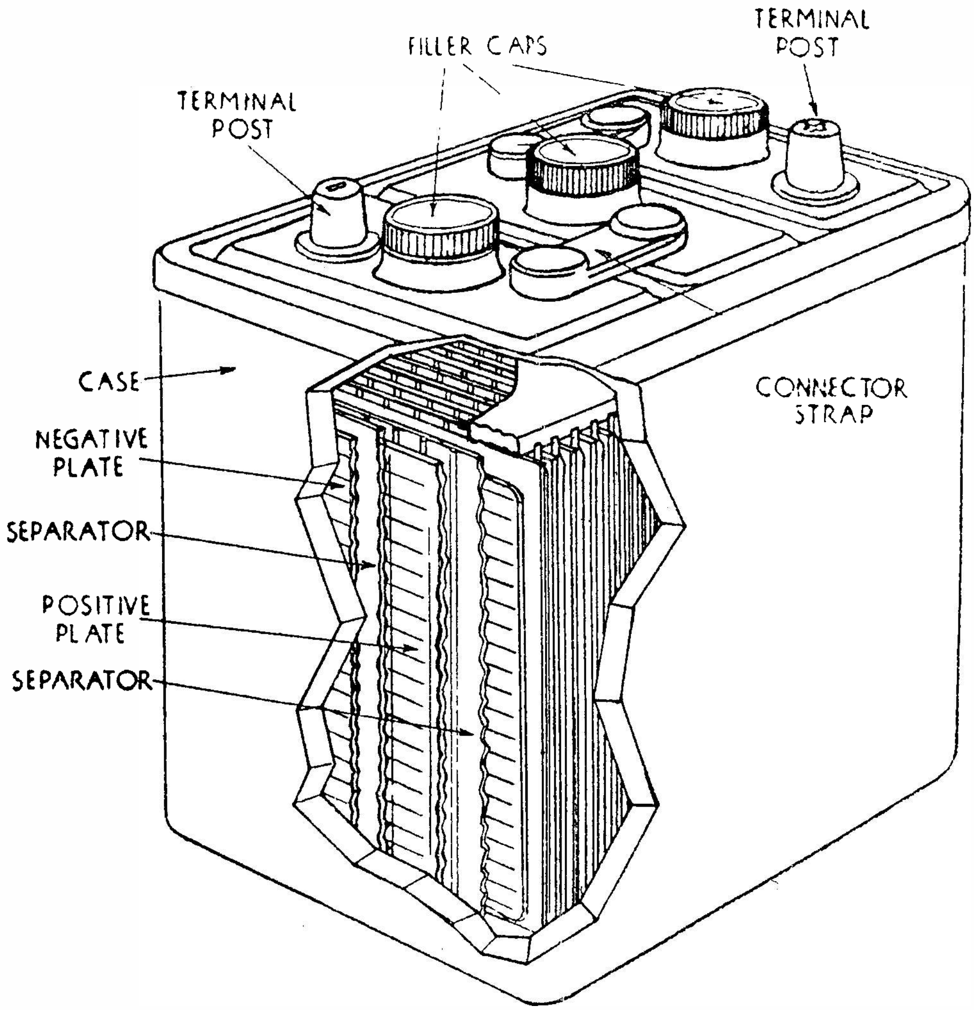


FIGURE 6

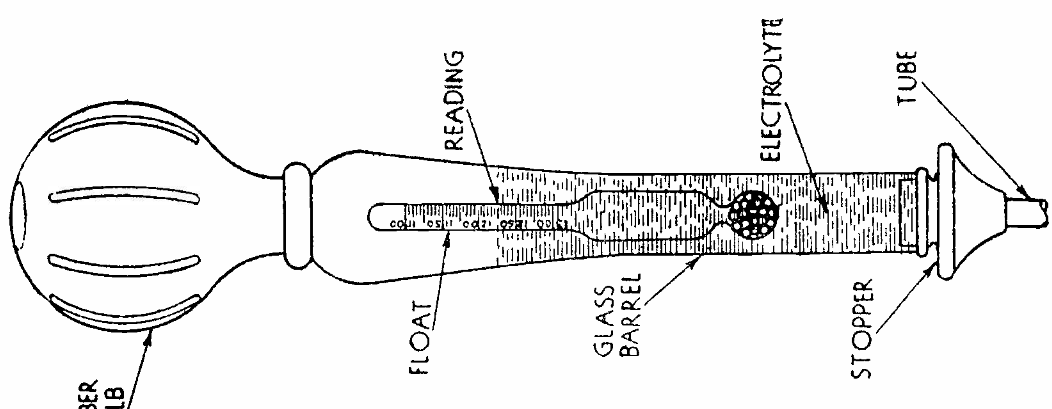


FIGURE 7

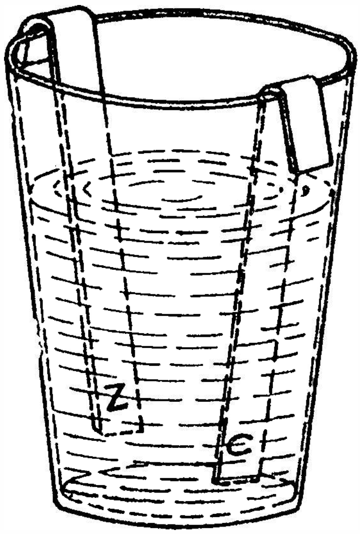


FIGURE 1

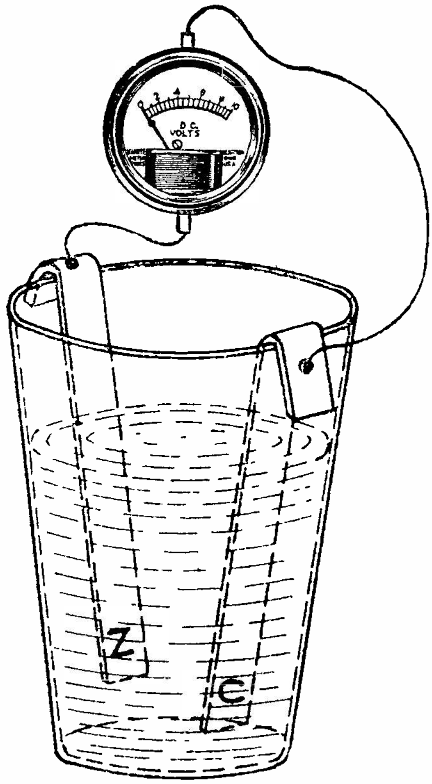


FIGURE 2

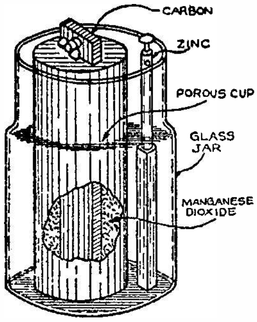


FIGURE 3

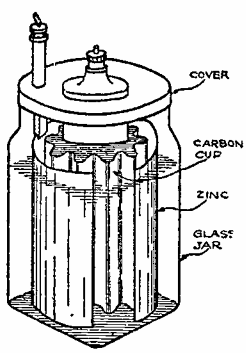


FIGURE 4

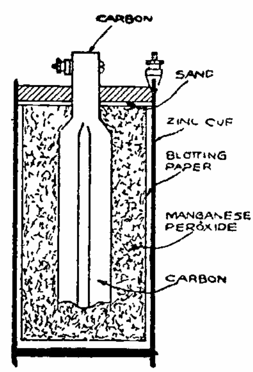


FIGURE 5

DE FOREST'S
TRAINING, Inc.

LESSON FDM - 8
BATTERY CONNECTIONS

* * Founded 1931 by * *

RADIO FUNDAMENTALS

LESSON 8

BATTERY CONNECTIONS

Action of a Water Pump ——— Page 1
Connecting Water Pumps in Series ——— Page 1
Connecting Dry Cells in Series ——— Page 2
Connecting Water Pumps in Parallel ——— Page 4
Connecting Dry Cells in Parallel ——— Page 4
Parallel Series Connection ——— Page 5
A, B and C Batteries ——— Page 6
Battery Voltages ——— Page 7
B vs. C Batteries ——— Page 8
Testing A, B and C Batteries ——— Page 10

* * * * *

No matter whether you are twenty, thirty, forty or sixty; no matter whether you have succeeded or failed, or just muddled along, life begins each morning. Each morning is the open door to a new world, new vision, new aims and new tryihgs.

If yesterday was a dismal failure, then turn those failings into successes today. Josh Billings once said,

"It ain't no disgrace to make a mistake. The disgrace comes in making the same mistake twice".

BATTERY CONNECTIONS

As we explained in our last Lesson, the purpose of the various types of cells is to develop an Electro Motive Force or Electrical Pressure. This pressure will, in turn, force a current of Electricity through a circuit to which the cells are connected and thus the cells are a source of Electrical energy.

Individual cells develop the comparatively low electrical pressure of but one or two volts and therefore, to obtain higher voltage, it is common practice to combine several cells which, working together, form a battery.

There are a number of different plans, or methods, by which the cells can be combined and, to simplify the various actions, we will follow the plan of explanation used for the simple electrical circuit and make comparisons to similar water circuits.

ACTION OF A WATER PUMP

Nearly everyone has had some experience with water pumps of one type or another and knows they have the ability to draw or force water from a lower to a higher level. Due to the pull of the Earth's gravity, water will try to flow from a higher to a lower level and thus produce a force or "push" which can be thought of as pressure.

Any individual pump is able to lift, or raise, water for some definite height and thus has the ability to produce a definite value of water pressure. Also, depending on its size or design, it has the ability to handle a certain amount or current of water. This particular feature is known as the "Capacity" of the pump and is usually measured in gallons per minute or per hour.

The specifications of hand operated pumps usually include only the "lift" in feet because the capacity depends upon the speed at which the handle is operated. However, for power driven pumps, it is customary to state the operating pressure in pounds and the capacity in gallons per minute.

For the following explanations therefore, we will consider a power driven water pump which has the ability to produce a water pressure of so many pounds and a capacity to deliver a current of so many gallons per minute.

CONNECTING WATER PUMPS IN SERIES

To simplify the explanation and give some definite values, we will assume a water pump which can develop a pressure of 1.5 pounds with a capacity of 20 gallons per minute.

Although stated as so many pounds, pressure usually means "pounds per square inch" and, in the case of a tank of water, is caused by the weight of the overlying liquid pushing outward. Thus, the amount of pressure depends on the dept or height of the water.

The ratio between water pressure, in pounds per square inch, and the height of "head" has been found to be .433. Thus, as the head of water, in feet, is equal to the pressure divided by .433, the pump which develops a pressure of 1.5 pounds can raise the water to a height of 1.5 divided by .433 or 3.46 feet. In round numbers, we can consider this as 3.5 feet.

Suppose now, we have four of these pumps to use on a job that requires the water to be lifted 14 feet. As each pump can raise the water but 3.5 feet, it would be necessary to install them on the plan of Figure 1.

Here, pump No. 1 would lift the water from the intake and force it up $3\frac{1}{2}$ feet to pump No. 2. With exactly the same action, pump No. 2 would force the water up $3\frac{1}{2}$ feet to pump No. 3 which is two times $3\frac{1}{2}$ or 7 feet above the intake.

In the same way, pumps 3 and 4 would each raise the water another $3\frac{1}{2}$ feet until it reached the outlet, 14 feet above the intake. Checking back, we multiply the head of 14 feet by .433 and find the pressure is 6 pounds.

Thus, by connecting the water pumps in cascade, or in series, as shown in Figure 1, the total pressure is equal to the sum of the pressures developed by the separate pumps. In the same way, the total height or head of the water is equal to the sum of the heads of the separate pumps.

One other important point here is the total capacity compared to the capacities of the separate pumps. Looking at Figure 1 again, you can see that the 20 gallons per minute, taken from the intake by pump No. 1, will be elevated to pump No. 2. This same current of water will be elevated by pumps 3 and 4 so that the current at the outlet will be exactly the same as that at the intake.

Therefore, this battery of pumps, connected in series, will develop a total pressure, equal to the sum of the pressures of the separate pumps but its capacity, in gallons per minute, will be equal to that of one pump.

CONNECTING DRY CELLS IN SERIES

Somewhat similar conditions exist in a battery of dry cells and, for Figure 2, we have drawn an arrangement which can be

compared to Figure 1. Here, each dry cell develops an Electrical Pressure of 1.5 volts and the large No. 6 size, used for door bells, can deliver a current of 20 amperes.

The terminal from the carbon electrode, brought out to the center, is positive while the outer terminal, connected to the zinc, is negative. To complete the electrical circuit, wires are connected from the carbon of one cell, to the zinc of the next and thus we say they are connected in series.

This arrangement leaves the zinc terminal of cell No. 1 and the carbon terminal of cell No. 4 for connections to the circuit. Thinking of the water current through the pump battery of Figure 1, you can see that, in the dry cell battery of Figure 2, there is but one path for the electrical current and all four cells are in this path.

From our explanation of the dry cell, you know the carbon is positive and has a potential 1.5 volts higher than the zinc. To check the electrical pressure we can assume the negative of cell No. 1 is at zero potential and thus the carbon will be 1.5 volts higher.

Because of the connecting wire between them, the zinc of cell No. 2 is at the same potential as the carbon of cell No. 1, 1.5 volts higher than the zinc of cell No. 1. However, as conditions in cell No. 2 are the same as those in cell No. 1, the carbon of cell No. 2 has a potential $1\frac{1}{2}$ volts higher than its zinc.

The zinc of cell No. 2 is already at a potential 1.5 volts above cell 1 zinc therefore cell 2 carbon is another 1.5 volts higher or 3 volts above the zinc of cell 1. In the same way, the carbon of cell 3 is 4.5 volts higher than the zinc of cell 1 while the carbon of cell 4 is 6 volts higher.

Thus, by connecting four dry cells in series, we have a battery which develops a total electrical pressure, or voltage, equal to the sum of the voltage of the separate cells.

As far as the circuit is concerned, conditions are somewhat like those explained for Figure 1 because, with but one path, the current output of the battery will be the same as that of any one of the cells.

To sum up these various actions, when cells are connected in series, the resulting battery develops a voltage equal to the sum of the cell voltages but with a current capacity equal to that of one cell.

CONNECTING WATER PUMPS IN PARALLEL

Going back to the water pumps again, suppose we still have those of Figure 1 but this time have a job which requires the water to be lifted 3.5 feet but with a capacity of 80 gallons per minute. As each pump will raise the water to the required height, one of the conditions can be met with a single pump but, to obtain the increased capacity, the four pumps are connected as shown in Figure 3.

Here, you can imagine the outlet pipe is 3.5 feet above the intake and each of the four pumps is connected in between. With all the intakes connected together and all the outlets attached to the same pipe, the total head or pressure, developed by this battery, will be the same as that of one pump.

This is known as a "Parallel" or "Multiple" method of connection because, as far as the intake and outlet pipes are concerned, all of the pumps are in the same relative position.

As far as the capacity of the battery is concerned, conditions are different. Pump No. 1 can draw its 20 gallons per minute from the intake pipe and deliver it directly to the outlet pipe. In the same way, pump No. 2 can draw its 20 gallons per minute from the intake and deliver it to the outlet.

With both pumps working, this means there will be 20 gallons per minute from each for a total of 40 gallons per minute. In the same way, with pumps 3 and 4 in operation, each delivering its 20 gallons per minute, the total current in the outlet pipe will be 4 x 20 or 80 gallons per minute. Of course, this same current will be drawn from the intake.

As we explained for Figure 1, each pump can produce a pressure of 1.5 pounds or a head of 3.5 feet with a current of 20 gallons per minute. Connected in parallel, as in Figure 3, a battery of four of these pumps will produce a pressure of 1.5 pounds with a current of 80 gallons per minute.

Summing up the operation, when connected in parallel, the pressure developed by the battery of pumps is equal to that of one pump but the total current is equal to the sum of the currents of the separate pumps.

CONNECTING DRY CELLS IN PARALLEL

The same general action can be obtained electrically by connecting dry cells in parallel or multiple, as shown in Figure 4. Here you will see that all of the carbon terminals are connected to each other and to the battery "Pos" while all the zinc terminals are connected together and to the battery "Neg".

This arrangement provides separate electrical paths, one for each cell, between the battery "Neg" and "Pos". With but one cell in each path, the total battery pressure, or voltage, will be equal to that of one cell.

Like the water pumps of Figure 3, each cell in the battery of Figure 4 can supply its current independently of the other cells and thus the total battery current will be equal to the sum of the cell currents.

As a brief summary, remember, for a series connected battery like that of Figure 2, the battery voltage is equal to the sum of the cell voltages while the battery current is equal to the cell current. For a parallel or multiple connected battery, like that of Figure 4, the battery voltage is equal to the voltage of one cell while the battery current is equal to the sum of the cell currents.

The arrangements of Figure 2 and 4 were made to bring out the action but, in practice, the cells will usually be placed and connected as shown in Figures 5 and 6. As an exercise in the important subject of circuit tracing, we want you first to compare the connections of Figures 2 and 5. Although the cells are numbered differently, you will find, in both cases, that the cells are connected in series.

Following the same plan, you will find that electrically, the batteries of Figure 4 and 6 are alike.

PARALLEL SERIES CONNECTION

With two main methods of connecting cells, it follows naturally that, in some cases, a combination of both will be of benefit. Experiments have shown that the useful life of a cell is reduced when the amount of current it delivers is increased. Thus, if the cell current were reduced to one half, the life of that cell would be more than doubled.

Because of this action, it is often economical to combine the series and parallel methods of connection in a single battery on the plan of Figure 7. Here you will find that cells 1, 2, 3 and 4 are connected in series the same as those of Figures 2 and 5. These connections are duplicated for cells 5, 6, 7 and 8 so that, in effect, we have two batteries each of 4 series connected cells.

Thinking of each of these batteries as a single cell, the parallel plan of Figures 4 and 6 is employed by connecting the carbons of cells 1 and 5, also connecting the zincs of cells 4 and 8. The complete battery will have a voltage, equal to the sum of four cell voltages but, because of the

parallel connection of the two groups, each cell will have to deliver but one half of the total battery current.

At first glance, it may seem that we have simply used twice as many cells to cut the current of each in half and therefore made no saving. However, as previously mentioned, reducing the current to one half more than doubles the life of a cell and, used for the same purpose, the battery of Figures 7 would last more than twice as long as those of Figures 2 or 5.

In explaining the actions of series and parallel connected cells, we used the value of 20 amperes per cell as the maximum available value of current. In practice, dry cells are used only on circuits which require much lower current values but the distribution follows the same plan.

For example, if the battery of Figure 5 was connected to a 6 volt circuit which allowed a current of 1 ampere, each cell of the battery would carry a current of 1 ampere. Connected to the same circuit, the battery of Figure 7 would supply a total current of 1 ampere which would divide equally between the parallel paths of the battery and thus each cell would carry a current of ½ ampere.

To supply 1 ampere at 1½ volts in the battery of Figure 6 with four parallel paths, each cell would carry but ¼ ampere.

"A" - "B" AND "C" BATTERIES

In the explanations of the later Lessons, we will tell you that, in many cases, the ordinary radio tubes require three sources of electrical energy to provide the proper operating conditions. For convenience, these are known as "A", "B" and "C" and when batteries are employed, as in most portable equipment, they are known as A, B, and C batteries.

Without going into great detail at this time, the A battery must furnish a comparatively large current at low voltage, the B battery must deliver a comparatively small current at high voltage while the C battery must provide intermediate values of voltage with little or no current.

Because of these conditions, A batteries are composed of comparatively large cells connected as shown in Figures 2, 4 or 7. The general plan is to connect enough cells in series to provide the required voltage and then, connect two or more like groups in parallel to provide economical current.

To meet their requirements of higher voltage and lower current, B batteries are made up with dry cells of a smaller

size. Sufficient cells are connected in series to provide the required voltages. Figure 8-C shows the cell arrangement in the common type of "B" battery with 30 cells, connected in series, to develop a total of 45 volts. For convenience, a mid-connection is made to provide 22½ volts.

While similar to B batteries, C batteries are commonly made with a lower number of smaller size cells. Figures 8A and 8B show two common types of C batteries, each of which has one or more additional terminals so that different voltage values are available.

Figure 8A, with three dry cells in series, forms a common type of 4½ volt C battery. The central terminal makes it possible to use one or two of the cells in case a lower voltage is needed. The "C" battery of Figure 8-B consists of 15 cells connected in series but here, a number of additional terminals are provided so that various values of voltage may be obtained.

For the common types, the 30 cell battery of Figure 8-C has the highest voltage and, when still higher voltage values are needed, these batteries are connected in series like the cells of Figure 2. This plan is illustrated in Figure 9 where we show four of the batteries of Figure 8-C connected to provide a total of 180 volts.

Connected in series, the cell voltages are added and thus, by making use of the battery terminals as shown below the batteries of Figure 9, various lower values of voltage are readily obtained. Batteries like those of Figures 8-A and 8-B can also be connected in series to provide higher voltage values.

BATTERY VOLTAGES

Looking at Figure 8-A again, you will find the lower terminal is marked "+" or positive, the center terminal "-3" and the upper terminal "4½". This can be checked by remembering that each dry cell develops about 1½ volts. Thus, starting at the lower "+" terminal there is an electrical path through two of the cells to the "-3" terminal. As the cells are connected in series, this value checks with our former explanation.

Following the same plan, and starting from the "+" terminal again, you will find an electrical path through all three of the series connected cells, up to the "-4½" volt terminal.

Exactly the same plan is followed for the battery of Figure 8-B which has a total of 15 series connected cells. For the practice it will give you, start at the "+" terminal and

trace the path to each of the other terminals. If you do this properly, you will find that the marked voltage value of each terminal is equal to 1.5 times the number of cells in the path.

For the battery of Figure 8-C, again the same plan is followed but here the "Neg" terminal is the starting point and, after tracing through 15 cells, you reach the "+ $22\frac{1}{2}$" volt terminal. Following through the remaining cells, you reach the "+ 45" volt terminal.

"B" vs. "C" BATTERIES

There are several points, regarding the markings of the battery terminals, which require explanation. First, voltage is a difference of electrical pressure or potential and therefore a single terminal cannot be given a value of voltage unless a second, or reference point is known.

For the battery of Figure 8-A, the upper terminal is marked "$-4\frac{1}{2}$" but the lower one is marked "+ " and thus we know that the upper terminal is $4\frac{1}{2}$ volts negative in respect to the lower "+ " or positive terminal. In the same way, the center terminal is marked "-3" which means it is 3 volts negative in respect to the lower "+ " terminal.

The same is true for the battery of Figure 8-B where the "+ " terminal is the common reference point and the markings of the other terminals indicate they are so many volts negative in respect to this "+ ".

For the B battery of Figure 8-C, conditions are reversed because here, the "Neg" is the reference point and the other terminals are the marked number of volts they are positive in respect to it. In the later Lessons we will tell you why this is done but now, we want to explain the markings themselves.

For a common example of a similar situation, we have drawn the steps of Figure 10. Starting at the 1st floor, you could walk up six steps to reach the 2nd floor but, starting from the second floor, you would have to walk down six steps to reach the 1st floor. In either case, you would start counting the steps from your starting point.

Suppose you were standing on the step marked "4-2" in Figure 10 and wanted to tell someone exactly where you were. You could say you were "four steps up from the 1st floor" or "two steps down from the 2nd floor" but, in either case, would state a starting or reference point.

Notice particularly that the reference point makes a difference in the number of the steps. The first step "UP" is the fifth step "DOWN", the second step "UP" is the fourth step "DOWN" and so on. With the exception of the middle step, which is 3 up or 3 down, each of the steps has a different "UP" and "DOWN" number.

To make a comparison to electrical conditions, for Figure 11 we have drawn a battery of six dry cells in series and, by means of extra wires, have made left and right hand connections to each of the cell terminals. Electrically, each horizontal connection is at the same potential as the cell terminals to which it is connected.

Checking the markings of the left hand or "B" battery terminals, we start with the lower "Neg" as the reference point. Then, tracing up through one cell we reach the "+1.5" volt terminal. Starting at the "Neg" again and tracing up through two cells, we reach the "+3" terminal.

This is equivalent to going upstairs in Figure 10 but here, each cell is a step and in respect to the "Neg" reference point, provides an increase of 1-1/2 volts until we reach the top or "+9" terminal. Notice particularly, there is one cell connected between each adjacent pair of terminals and, considering the negative reference point as "0", there is a difference of 1-1/2 volts between each pair of adjacent voltage values.

For the "C" battery connections, shown in the right hand column, we start at the upper right with the "Pos" terminal as the reference point. Compared to Figure 10, this time we will come downstairs and thus each marked voltage value is negative in respect to the positive reference point.

Tracing the electrical path from the upper positive terminal down through one cell we reach the "-1.5" volt terminal. Starting at the "Pos" again and tracing down through two cells, we reach the "-3" volt terminal. The same plan can be followed for each of the terminals and, in every case, the marked voltage of the terminal is equal to 1-1/2 times the number of cells between it and the reference point.

Here again, there is one cell connected between each adjacent pair of terminals and, considering the positive reference point as "0", there is a difference of 1-1/2 volts between each pair of adjacent voltage values.

Looking at Figure 11 again, you will find the "+6" B battery terminal is connected directly to the "-3" C battery terminal and therefore both of them must have the same electrical potential. However, both markings are correct because the B

battery terminal is 6 volts positive in respect to the "Neg" reference point while the C battery terminal is 3 volts negative, in respect to the positive reference point.

Regardless of the marked values, you will find the difference of electrical pressure, or the voltage, is the same for any pair of terminals. For example, suppose we look at the "+6" and "+1.5" terminals of the B battery. The difference here is 4.5 volts, which checks with our former explanations because there are three cells in between.

Going over to the C battery terminals, we find the "-3" is equivalent to the "+6" of the B battery while the "-7.5" is equivalent to the "+1.5". However, the difference between "-7.5" and "-3" is 4.5 volts the same as for the corresponding terminals of the B battery.

TESTING A, B AND C BATTERIES

In our explanation of the chemical action in a dry cell, we told you that, while in operation, Hydrogen will gather on the carbon and cause a reduction of the available voltage. With this in mind, you can readily see that, to make an accurate test of a cell or battery, it should be properly connected in its circuit and delivering its normal current when the test is made.

For Radio and other Electronic work, it is customary to make these tests with a meter which indicates the voltage. As you will learn later, it requires electrical current to operate the meter and, as this will be lost for any other purpose, do not keep the meter connected across the cell or battery any longer than is absolutely necessary to obtain a reading.

While conditions vary a great deal, as a general rule, a dry cell or battery should be replaced when its tested voltage is 20% below that for which it is marked. For example, the battery of Figure 8-C is marked "Neg" and "+45". 20% of 45 is 9 and therefore, if a meter reads but 36 volts, when connected across these terminals, the battery should be replaced.

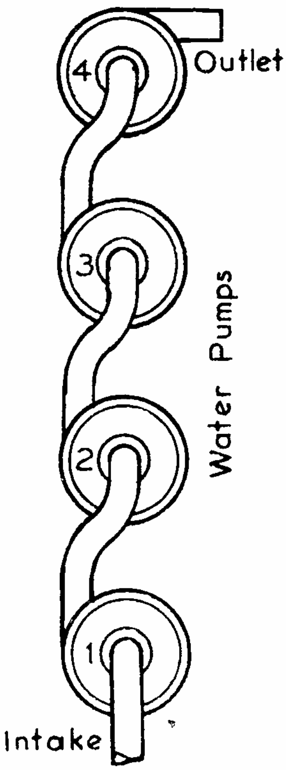


FIGURE 1

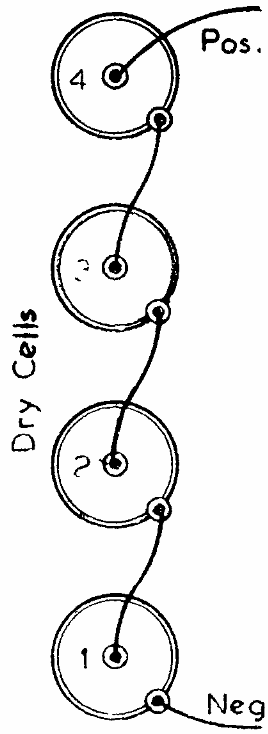
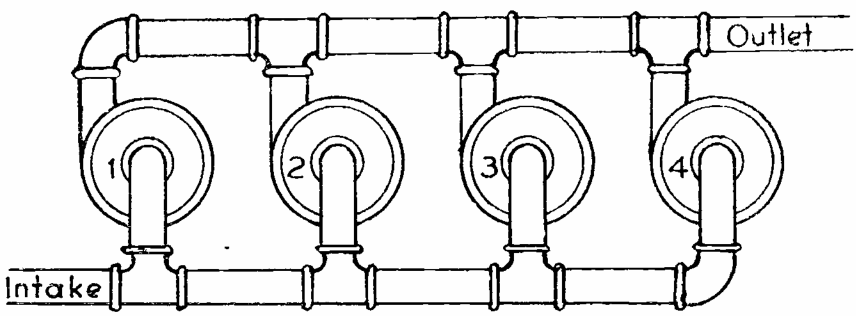
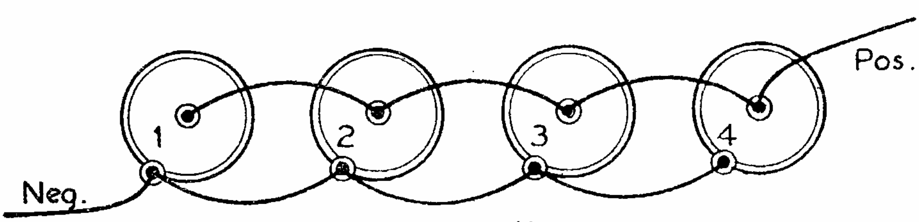


FIGURE 2



Water Pumps

FIGURE 3



Dry Cells

FIGURE 4

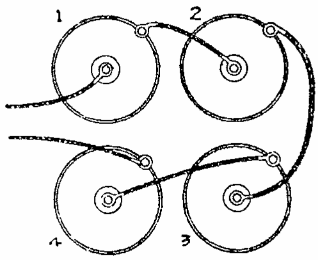


FIGURE 5

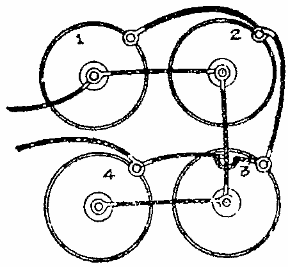


FIGURE 6

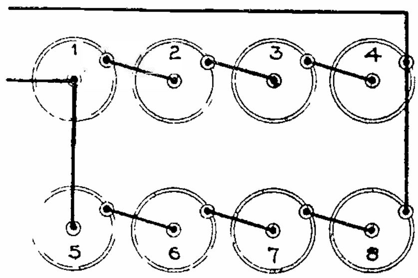
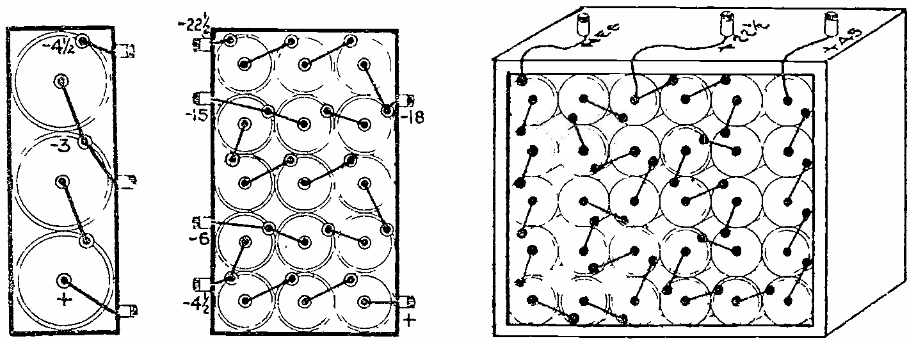


FIGURE 7



A B FIGURE 8 C

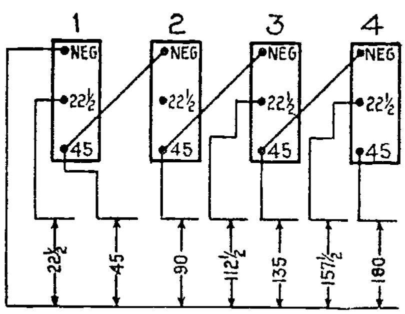


FIGURE 9

FDM-8

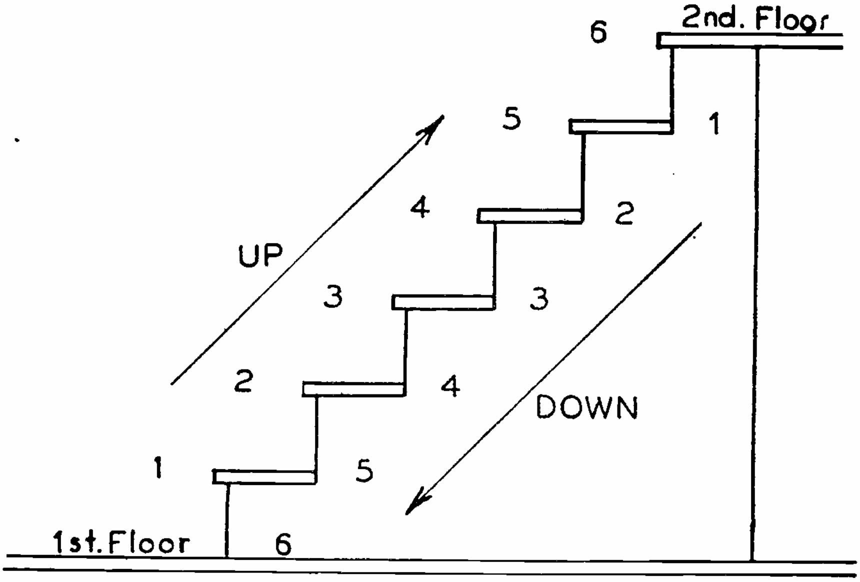


FIGURE 10

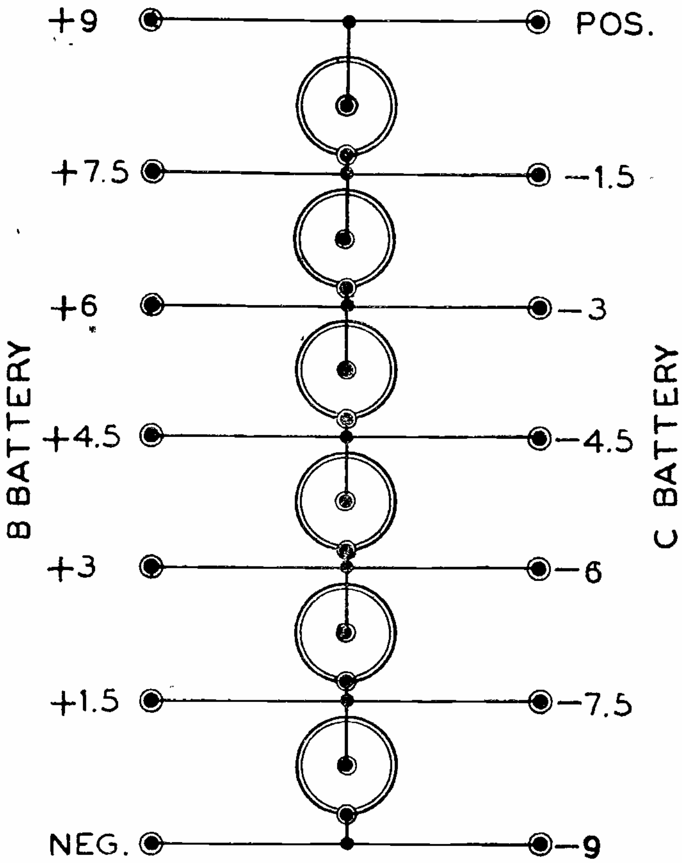


FIGURE 11

DE FOREST'S
TRAINING, Inc.

LESSON FDM - 9
MAGNETS AND MAGNETISM

Founded 1931 by

RADIO FUNDAMENTALS

LESSON 9

MAGNETS AND MAGNETISM

Natural Magnets -------------------- Page 1
Magnetic Substances ---------------- Page 1
Artificial Magnets ----------------- Page 2
Magnet Poles ----------------------- Page 2
Magnetic Lines of Force ------------ Page 3
Magnetic Fields -------------------- Page 3
Magnetic Flux ---------------------- Page 4
Measuring Magnetic Flux ------------ Page 4
The Maxwell ------------------------ Page 5
The Gauss -------------------------- Page 5
Repulsion of Magnet Poles ---------- Page 5
Attraction of Magnet Poles --------- Page 6
One Law of Magnetic Force ---------- Page 6
Making Magnetic Fields ------------- Page 6
Location of Magnet Poles ----------- Page 7
Another Law of Magnetic Force ------ Page 7
Induced Magnetism ------------------ Page 8
Theory of Magnetism ---------------- Page 8
Retentivity ------------------------ Page 8
Permeability ----------------------- Page 9
Forms of Magnets ------------------- Page 9
Magnetic Screens ------------------- Page 10
Distortion ------------------------- Page 10
Making Permanent Magnets ----------- Page 10
Ageing Magnets --------------------- Page 10
Testing Magnets -------------------- Page 11

* * * * *

When someone doing a piece of work says, "Let it go, that's good enough," it is generally a pretty good sign that it is not good enough. If it were, no one would need convincing.

-- Dr. Frank Crane

In an earlier Lesson on the "Forms of Electricity", we mentioned the subject of Magnetism and told you of a few early experiments which showed a close relationship between Electricity and Magnetism.

As you will learn in the later Lessons, this relationship is of extreme importance and therefore, before going ahead with an explanation of Electricity, we will spend this Lesson on the subject of Magnetism.

To help you appreciate its importance, we can tell you that in electronic equipment, none of the many transformers, chokes or most types of speakers could operate without magnetism in some form. Therefore, we want you to learn the general principles now, in order to save time later on.

NATURAL MAGNETS

Briefly reviewing the explanations of the earlier Lesson, the ancient Greeks knew of a certain kind of stone, called "Lodestone", which had the strange power of attracting pieces of iron. They also discovered that when a piece of iron had been rubbed on one of these stones, it then had the same power of attracting other pieces of iron.

The name "Lodestone" came from the fact that when one of these stones was hung on a string, so that it could turn easily, it would always point in a North and South direction. This was perhaps their most important power and the stones were in common use for "leading" in places where directions were not known, hence the name "Leadstone" or "Lodestone".

Today, this same idea is still in very common use but we call our modern lodestone a Magnetic Compass. Every ship on the ocean today uses a compass of some sort to show the proper directions when out of sight of land. Hunters and Fishermen generally take a compass along when they go into the woods or other strange country where there are but few roads or houses.

MAGNETIC SUBSTANCES

Like electricity, the exact nature of magnetism is not known but, a very careful and thorough study of magnets and their actions shows that all materials are affected to some extent when brought close to a strong magnet. Trying all of the known substances, we find that while iron and steel are affected very strongly, cobalt and nickel to some extent, the effect on all of the rest is very small. In fact, the difference is so marked that iron and steel are called "Magnetic Substances" or "Ferromagnetic", the prefix "ferro" being taken from the Latin word "ferrum" which means iron.

The magnetic effect on iron is so much greater than that on cobalt and nickel that, by itself, iron is the only element of commercial importance. However, certain alloys of iron, cobalt and nickel have come into quite common use because of their improved magnetic qualities.

ARTIFICIAL MAGNETS

When a piece of steel is rubbed on a magnet or lodestone, it becomes a magnet itself and, by the proper treatment which we will explain later, can be made to keep its magnetism almost indefinitely. That is why, when properly magnetized and treated, a piece of steel is called a permanent magnet.

While almost any kind of steel can be made into a permanent magnet, some of the alloys mentioned above can be magnetized more strongly than ordinary steel. Thus, you will find that most permanent magnets used in Electronic equipment are made of Chromium, Tungsten or Cobalt steel.

In much the same way, when a piece of iron is rubbed on a lodestone, or permanent magnet, it becomes magnetized as strongly as a piece of steel but, whenthe lodestone or magnet is removed, the iron loses practically all of its magnetism. Therefore we consider iron, especially soft iron, as a "Temporary Magnet".

As you will soon learn, there are many uses for both permanent and temporary magnets but for this Lesson, we are interested mainly in the magnetism itself and will give our explanations accordingly.

MAGNET POLES

To begin, we will take a small bar of magnetized steel and, by tying a string around it in the middle so that it will balance as in Figure 1, hang it up and let it turn around easily. No matter which way we point it, when we let it go, it turns and swings back and forth, but always stops when pointing approximately north and south. We can explain this action by saying that the earth itself is a huge magnet which is attracting our little steel bar.

The end of the steel bar magnet that points toward the North is called the "North Seeking Pole" and the end that points toward the South, is called the "South Seeking Pole". Whenever you see a permanent magnet with the ends marked "N" and "S", remember that the "N" is the north seeking pole and the other, or the "S", is the south seeking pole. It is the general custom to speak of them simply as north and south poles. This is the action which gave the natural magnets their name of "Leadstone" or "Lodestone".

MAGNETIC LINES OF FORCE

At some time in your life, you may have played with a little toy horse-shoe magnet, as shown in Figure 2, and perhaps you were surprised at some of the things it would do. Did you ever notice that a real small piece of iron would actually jump a quarter of an inch or more to reach the magnet? The fact that the iron jumps up to the magnet shows very clearly that its action extends out and around it.

Here then, we have a form of energy which, in some ways, can be compared with Electricity. For electrical circuits, the source of energy produces an Electromotive Force and, in comparison, the magnet provides a Magnetomotive Force.

The magnetomotive force produces an action in the space around the magnet, known as the Magnetic Field which, for convenience, is considered as being made up of "Magnetic Lines of Force". Thus, the magnetomotive force, abbreviated "M.M.F.", sets up a field of magnetic lines of force in somewhat the same way that an electromotive force causes a current of electricity in a circuit.

You know that an electric circuit consists of a definite endless path made up of conductors but the magnetic field extends into the space around the magnet regardless of the materials in this space.

MAGNETIC FIELDS

One simple, yet effective method of making a magnetic field visible is to place a piece of ordinary window glass over a bar magnet and then sprinkle iron filings on the glass. Under these conditions, the filings will arrange themselves in the lines to produce a general pattern like that shown in Figure 3.

You will notice that these appear to be lines, from the North to the South pole of the magnet, and we think of them as the lines of force. It is assumed that these lines come out of the "N" pole and enter at the "S" pole so that each one, if fully drawn, will form a complete loop from "N" to "S" outside the magnet and from "S" to "N" inside the magnet.

In thinking of the action of these lines, just imagine that they are very small rubber bands, stretched quite tight. Under this condition, the rubber band will try and shorten itself and that is exactly what the magnetic lines try to do. They also crowd each other somewhat and try to push sidewise. The entire space around the magnet, in which the lines of force have appreciable strength, is known as the "Magnetic Field"

MAGNETIC FLUX

In addition to providing a convenient means of explaining the action of a magnetic field, the lines of force are also used as a means of measurement. In electronic work, we are seldom concerned with individual magnetic lines and usually consider all the lines of a magnetic field as a single group, known as the "Magnetic Flux".

As a general definition, we can state; the total number of magnetic lines, passing through any given area, is known as the"Magnetic Flux".

MEASURING MAGNETIC FLUX

In order to measure the strength of Magnetic Flux or compare the strength of one magnetic field with another, it is necessary that we have some units of measure. Like most of our other units, such as the inch for length or the pound for weight, the following units of magnetic measurement are arbitrary values which have been adopted and are in general use.

By themselves, these units may be of little practical value in your electronic work but a knowledge of their names and value will be of great benefit in helping you to understand the explanations of the later Lessons.

Starting with a Unit magnetic pole, it can be defined as one which will repel an equal and like pole with a force of one dyne at a distance of one centimeter. Should some of these terms be new to you, a dyne is the force which, acting upon a mass of one gram during one second, gives the mass a velocity of one centimeter per second.

The centimeter is a unit of length of the metric system and is equal to .3937 inch while a gram is the weight of a cubic centimeter of water. Thus, we have defined the unit magnetic pole in terms of weight, time and distance, things with which we are familiar.

We can now tell you that a unit magnetic field is one which acts upon a unit magnetic pole with a force of one dyne. This unit field has but one line of force with an area of one square centimeter.

In practical work, all magnetic flux has a comparatively large number of lines and the magnetic fields are of all shapes and sizes. Therefore, we usually describe them as having so many lines of force per square inch which means the number of lines that will pass through each square inch of any material which is placed squarely across the magnetic field.

THE MAXWELL

In some text books and technical articles you may find the term "Maxwell" used in connection with magnetic fields. However, it is simply the name of a unit of measure and one Maxwell is equal to one line of force.

Thus, instead of describing a magnetic field as having so many lines of force per square inch, we can state it has so many Maxwells per square inch.

As the metric system of measure is employed quite extensively in technical work, the size of a magnetic field may be measured in square centimeters and thus the magnetic flux will be stated as so many Maxwells per square centimeter.

THE GAUSS

Because a magnetic flux of any given number of lines of force may be spread over a comparatively large magnetic field or compressed into a relatively small field, it is necessary to know both the number of lines and the size of the area through which they pass. Thus, the number of lines passing through a given area is known as the "Density" of the field.

To combine the number of lines and the area into a single unit of measure, one Maxwell per square centimeter is sometimes called a "Gauss". Thus, when a magnetic field has a density of 10,000 gausses, it means a magnetic field with 10,000 lines of force, or 10,000 Maxwells per square centimeter.

Like electrical energy, magnetic energy can not be seen and therefore it is necessary to base all measurements on the effects which are produced. Therefore, before going ahead, we want to explain some magnetic actions which can be seen.

REPULSION OF MAGNET POLES

Figure 1 shows the magnet, mentioned earlier in the Lesson, tied up with a string and left free to turn, marked with an "N" on the end that points North and an "S" on the end pointing South. Now, to find out just how two magnets act toward each other, we take a second magnet marked the same way.

To begin, we take the second magnet in our hand with the "N" end out, as in Figure 4, and bring it slowly up to the "N" pole of the magnet hanging on the string. We find that as the two "N" poles get close to each other, the magnet hanging on the string turns away from the magnet in our hand. It looks just as though the magnet in our hand was actually

touching and pushing the magnet on the string. We can easily see however, that the magnets do not touch and therefore decide that it is the magnetic force which does the pushing.

ATTRACTION OF MAGNET POLES

We now turn the magnet in our hand so that the "S" pole is out, as in Figure 5, and again bring it slowly toward the magnet on the string. Now we see that the "N" pole of the hanging magnet turns toward the "S" pole in our hand and will, when we get close enough, swing over until the magnets touch.

ONE LAW OF MAGNETIC FORCE

Should we move the "S" pole of our magnet toward the "S" pole of the magnet on the string, it would turn away exactly as it did when the "N" poles were brought close together.

These simple tests prove one of the most important laws of magnetism which is -- Like poles of a magnet repel each other and unlike poles attract each other.

MAKING MAGNETIC FIELDS

This same action can be shown by following the plan explained for Figure 3. This time two magnets are used and placed in line with their "N" poles about one inch apart. A piece of glass is then placed over the magnets and iron filings are sprinkled on the glass.

By gently tapping the glass, the filings will arrange themselves in lines which curve away from the end of each magnet as shown in our simplified sketch of Figure 6. It is customary to sketch magnetic fields on this plan because it is much simpler than the drawing of Figure 3, yet does supply the desired information as far as the direction of the magnetic lines is concerned.

By turning one of the magnets around, as in Figure 7, and bringing an "N" and "S" pole together, we find that when the filings are again sprinkled on the glass, they arrange themselves in almost straight lines right across the gap between the "N" and "S" poles.

We want you to think of these magnetic lines as always forming a complete circuit, just like an electrical circuit, except that they will pass through every known substance and travel from the "N" pole, out around to the "S" pole and then back through the magnet to the "N" pole again. With this in mind you can see, in Figure 6, that the magnetic lines of

each magnet turn around toward their own "S" pole and have nothing to do with those of the other magnet. In fact, it looks as if they were trying to crowd each other out of the way. In Figure 7, however, the lines go straight across from the "N" pole of one magnet to the "S" pole of the other and the magnetic circuit is completed through both of the magnets.

LOCATION OF MAGNET POLES

Going back to Figure 3 for a minute, you will notice that the lines of magnetism form complete loops all of which come very close together at a point near each end. These points are the real poles of the magnet. Now, the pull of the magnet on a piece of iron will change with the number of magnetic lines passing through it. As the lines are the closest at the poles, it stands to reason that the closer we move a piece of iron to the pole, the more magnetic lines there will be passing through it and therefore the stronger the pull will be.

ANOTHER LAW OF MAGNETIC FORCE

Looking at Figure 3 again, you will notice that as the lines leave the poles, they spread out in all directions and, should you move a piece of iron further away from the pole, there would be fewer lines passing through it and the pull on it would be less. This reduction in pull changes quite rapidly and Figure 8 shows you the reason. Here we have taken all of the magnetic lines coming out of the center of the end of a magnet and find that when we are one inch away, they all pass through a piece of iron one inch square.

Moving the iron away another inch, that is putting it two inches away from the magnet, we see that it would take a piece two inches square in order to have all of the lines pass through it. Now, as it takes four one inch squares of iron to make a piece two inches square, if the first one inch square of iron were held two inches away from the magnet, only one quarter of the magnetic lines would pass through it. If there were but one quarter of the magnetic lines through the iron, there would be but one quarter of the magnetic pull.

Notice here that twice the distance gives but 1/4 the pull, and, in the same way, three times the distance would give but 1/9 the pull, four times the distance 1/16 the pull and so on.

This change follows a very definite rule. For example: From the figures above, 2 times the distance gave us 1/4 the pull. Now 2 times 2 equals 4, and if we turn 4 over we get 1/4. In

the same way, 3 times 3 equals 9, which turned over is 1/9. Whenever we multiply a number by itself, we say that the number is squared. As the distance gets smaller, the pull gets stronger, at a rate equal to the square of the distance, therefore we say that the pull varies opposite to, or inversely as, the square of the distance.

As a general rule we can state -- "The field of a magnet at any point, varies inversely as the square of the distance from the pole to that point".

INDUCED MAGNETISM

Another thing we find is that when a piece of iron, such as a tack, is hung on the end of a magnet, it also becomes magnetized and will attract and hold a second tack. This one in turn becomes magnetized and will attract and hold a third tack. If the magnet is strong enough, we can build quite a string of tacks but, no matter how carefully we take the magnet away from the first tack, as soon as it is removed the tacks all fall apart. This is because the tacks, being made of iron, are but temporary magnets and will not retain the magnetism. Whenever a piece of iron or steel is made to act as a magnet, by being held in contact with a magnet, we call the action "Induced Magnetism".

THEORY OF MAGNETISM

As we said at the beginning of this Lesson, no one knows the exact nature of magnetism but all of its actions can be explained by what is called the Molecular Theory. This theory explains that all metals are made up of very small particles, called molecules, each of which is in itself an extremely small magnet. In iron and steel, the molecules are much stronger magnets than in any of the other metals.

As shown by Figure 9, in the ordinary piece of iron or steel, these molecules are not arranged in any particular order and the magnetic fields are all neutralized.

RETENTIVITY

Whenever the iron or steel is put in a strong magnetic field, as unlike poles attract each other, the molecules all turn in one direction, like Figure 10, the magnetic fields of all of them combine and make the entire piece of metal into one large magnet.

It all depends on the kind of metal, as to how easily the molecules can be turned. In soft iron they turn quite easily but, as soon as the magnet that attracts them is taken away,

they turn back again to their original position just about as easily. This of course accounts for the fact that soft iron will not keep its induced magnetism and is called a "Temporary Magnet".

In the case of steel however, it is much harder to turn the molecules all in the same direction and therefore requires a stronger magnet. Once they are all turned the same way, they stay in that position after the magnet that attracted them has been removed, and the steel retains its magnetism.

This is the reason why all permanent magnets must be made of steel. This action is called "Retentivity". We will mention here also, from the explanation just given, you can see that every time a permanent magnet is jarred or hammered, the molecules would have a tendency to turn back to their original position and thus weaken the strength of the magnet. Heating the magnet would also have a similar weakening effect.

PERMEABILITY

Because the molecules of soft iron will turn quite easily, under the influence of a magnetizing force, the magnetic flux will be comparatively strong. As this action varies for different materials, the ratio of the magnetic flux density produced to the magnetizing force is known as the "Permeability" of a substance.

In general, you can think of permeability as the ease with which a magnetic flux may be developed in a material. As we will explain later, the opposition which a material offers to the passage of magnetic flux is known as its reluctance.

FORMS OF MAGNETS

So far, all of the magnets we have mentioned have been of a horse-shoe or straight bar type but a solid ring of iron or steel can also be strongly magnetized. Of course, as the ring is solid, very few magnetic lines come outside and there are no poles. However, if we cut out a section of the ring at any point, we find a very strong magnetic field in the break with an "N" pole at one side and an "S" pole at the other.

As far as anyone knows, magnetic lines will pass through any material. In making up the magnetic fields with iron filings in the earlier part of this Lesson, we put the magnet under a piece of glass and sprinkled the filings on top. Those materials used as electrical insulators have no more effect toward insulating magnetism than the air itself.

In this connection however, remember that the air and all materials except iron, steel and a few alloys, offer a high resistance to the lines of magnetic force.

MAGNETIC SCREENS

Should we want to prevent magnetism from passing through any object, such as a watch for example, the only thing we can do is to put a piece of iron around it. Iron, being a magnetic substance, carries the magnetic lines so much easier than air or other materials that, instead of passing through the watch, they will pass around it through the iron. We call this a Magnetic Screen.

Looking at Figure 11, you can see what happens and will notice that the space inside the iron shield has no magnetic lines passing through it.

DISTORTION

Instead of the shield of Figure 11, in Figure 12 we have placed a piece of soft iron in the field of a permanent magnet. The magnetic lines are pulled around so that a great many of them pass through the iron. With all these lines through it, the iron becomes a magnet and has poles of its own. As unlike poles attract, it is easy to understand how the poles of the piece of iron attract the opposite poles of the permanent magnet and thus pull the magnetic field out of its natural shape.

This action is called "Distortion", and whenever a magnetic field is pulled out of shape by the presence of iron, or another magnet, we say that the field is distorted.

MAKING PERMANENT MAGNETS

As we have already mentioned, a permanent magnet can be made by rubbing a piece of steel on another magnet, but this method does not make a magnet strong enough for practical use. In all commercial work, permanent magnets are made by placing a piece of steel in a very strong magnetic field which is produced by electricity, an action which will be explained in the following Lesson.

AGEING MAGNETS

In order to keep the greatest amount of magnetism, for the longest time, the steel of the magnet is hardened and then aged. One method of ageing the steel is to heat treat it for a long period after it is hardened. Then, after it is magnetized as strongly as possible, it is given another heat

treatment. This second heating, or ageing, weakens the magnetism to some extent, but what is left is almost permanent.

TESTING MAGNETS

A very simple method of testing the strength of a permanent magnet is to place a bar of iron across its poles and then, by using a spring type of weighing scale, see how many pounds pull is required to remove the piece of iron.

There are also testing meters which are placed across the poles of the magnet to be tested and their action is very similar to the method explained above except the flux of the magnet pulls a pointer across a marked scale.

Permanent magnets are used in a great variety of electrical apparatus as you will learn as you study your Lessons. They are made in many different shapes but the most common are the straight bar and the "U" or horse-shoe.

While all magnetic speakers and headphones have permanent magnets, nearly all the other units operate by magnetism and in many respects, it is as important as electricity.

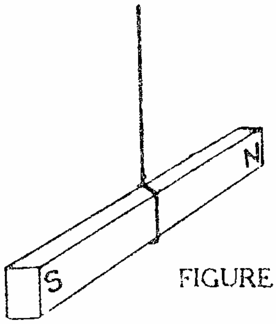
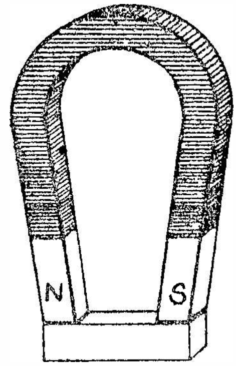


FIGURE 1



TOY MAGNET
FIGURE 2

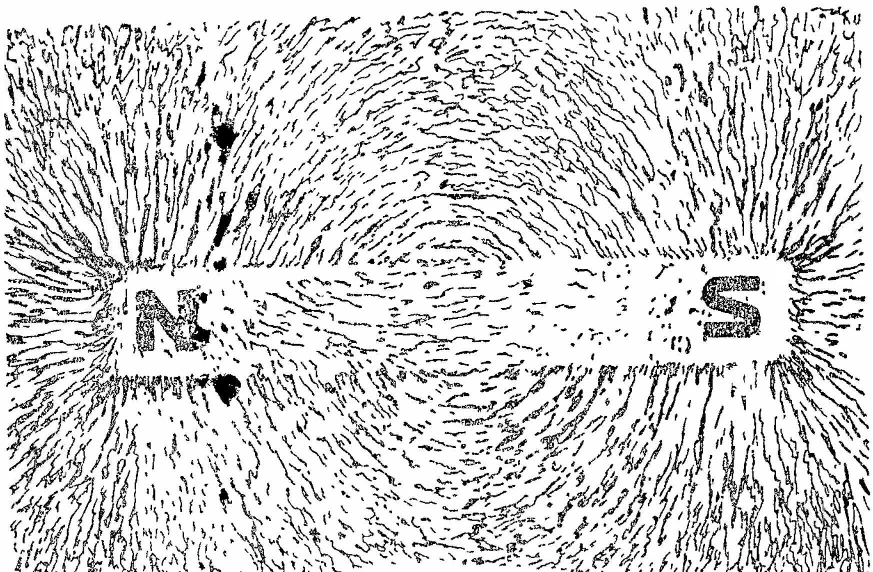


FIGURE 3

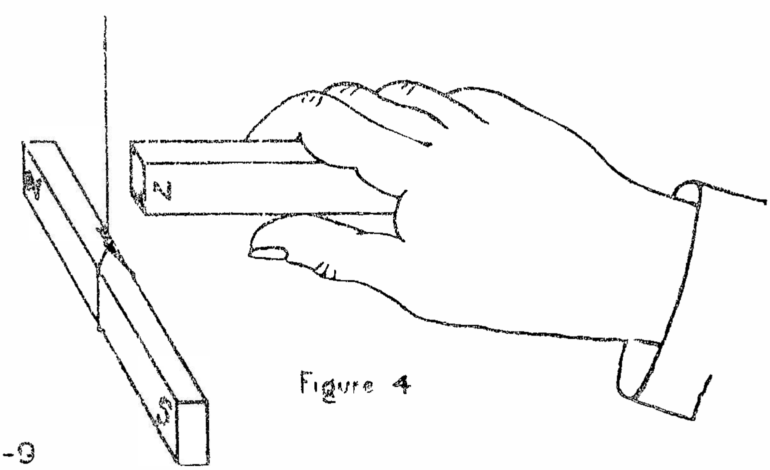


Figure 4

FDM-9

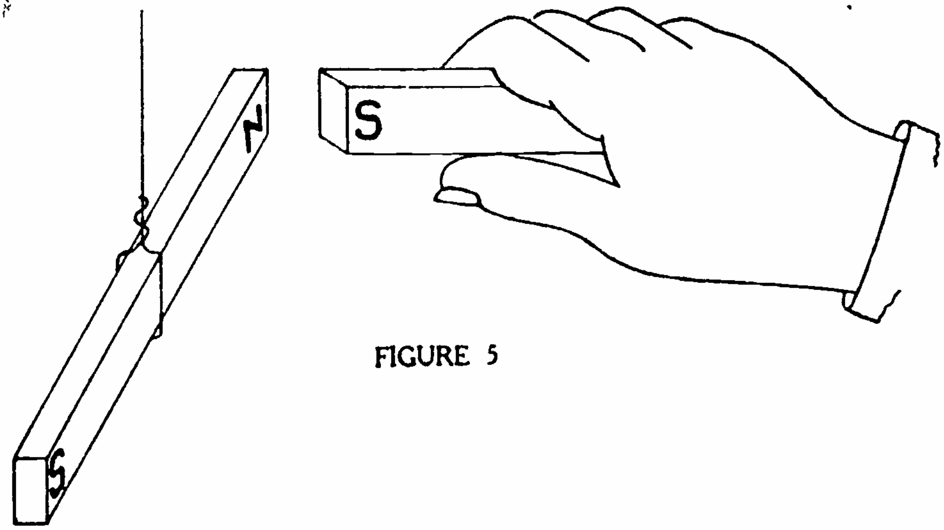


FIGURE 5

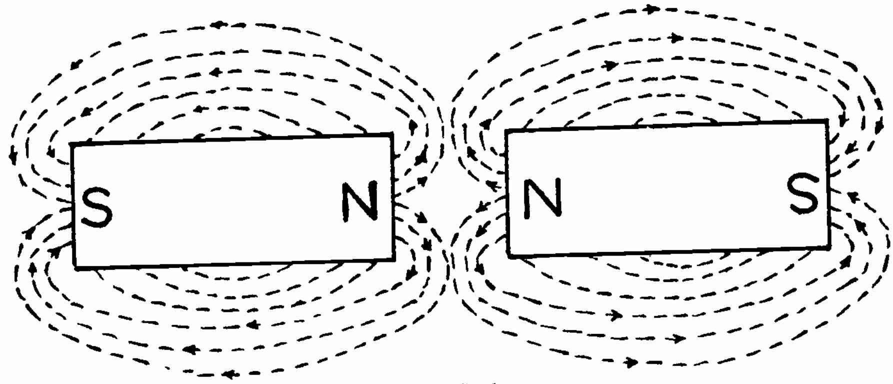
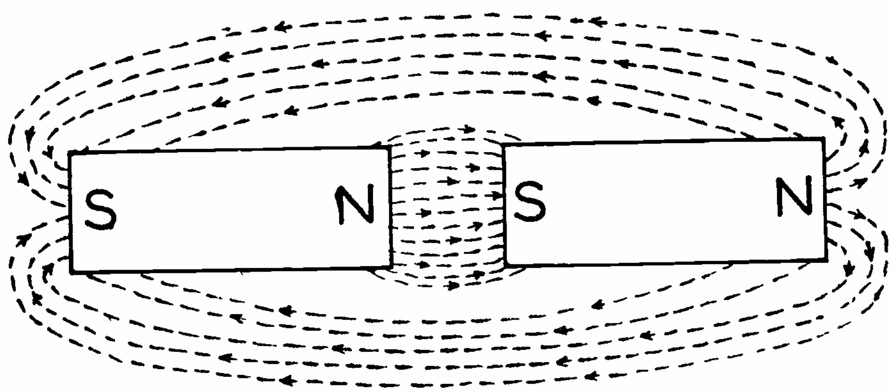


FIGURE 6



FDM-9

FIGURE 7

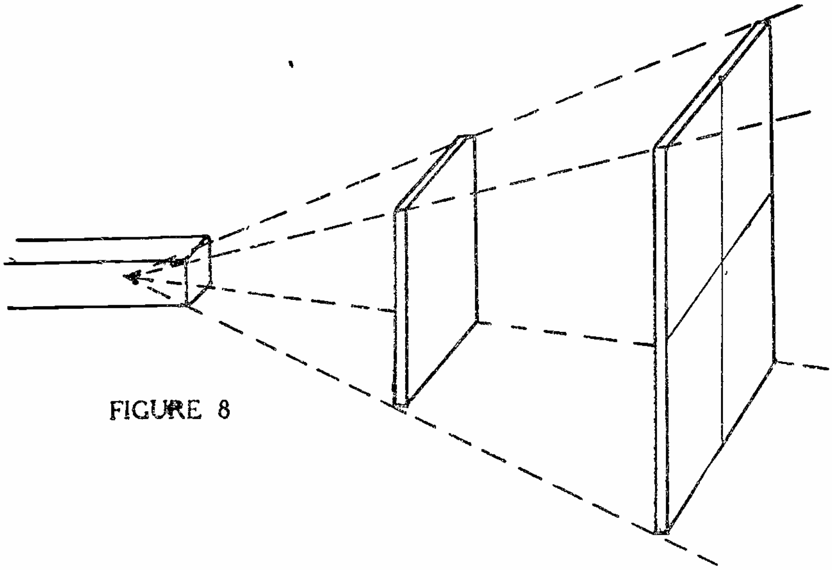
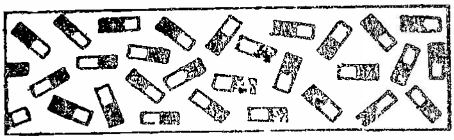


FIGURE 8



FIGUP [illegible] 9

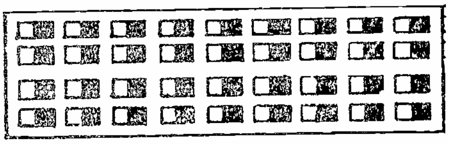
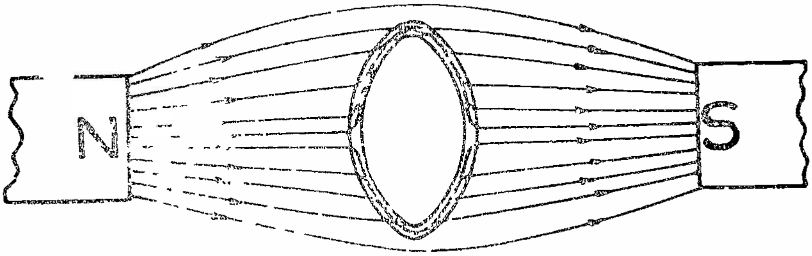


FIGURE 10



[illegible]URE 11

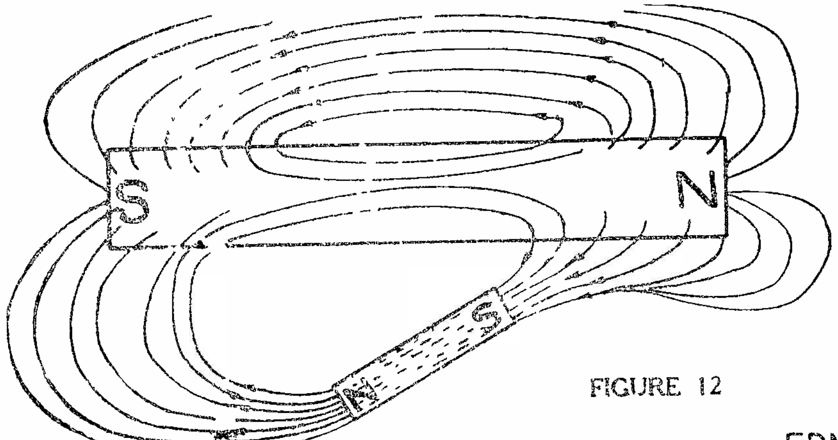


FIGURE 12

DE FOREST'S
TRAINING, Inc.

LESSON FDM - 10
ELECTRO-MAGNETS

• • Founded 1931 by • •

RADIO FUNDAMENTALS

LESSON FDM-10

ELECTRO-MAGNETS

Magnetic Field Around a Wire - - - - - - - - - - - - Page 1
Action of the Compass in a Magnetic Field - - - - Page 1
Direction of Magnetic Field - - - - - - - - - - - - Page 2
Thumb Rule - Page 2
Magnetic Field Around a Loop - - - - - - - - - - - - Page 3
Magnetic Field Around a Coil - - - - - - - - - - - - Page 3
Right Hand Rule - - - - - - - - - - - - - - - - - - - Page 4
Solenoids - Page 4
Ampere Turns - Page 4
Action of an Iron Core - - - - - - - - - - - - - - - Page 5
Magnetic Circuits - - - - - - - - - - - - - - - - - - Page 6
Laws of Magnetic Circuits - - - - - - - - - - - - - - Page 6
Forms of Electro-Magnets - - - - - - - - - - - - - - Page 7
Uses of Electro-Magnets - - - - - - - - - - - - - - - Page 7

# # # # # #

"A person should never be ashamed of possessing but little knowledge. But a person should be ashamed if he fails to add to his knowledge whenever he can and especially so when he fails to make use of it for himself and his fellow man."

— Arthur Brisbane

ELECTRO-MAGNETS

You may wonder why we changed from Electricity to Magnetism for the preceding Lesson, but we want to explain, as soon as we can, enough of the important principles so that, in our later Lessons, we can go ahead more rapidly. For this Lesson, we will continue with Magnetism because, in all ordinary circuits, wherever there is a current of electricity, there is also a magnetic field.

MAGNETIC FIELD AROUND A WIRE

In order to find out as much as we can about the relationship between an electrical current and a magnetic field, in Figure 1, we have pushed a piece of wire through a square of card-board and made up an electrical circuit which includes the wire. The connections have been made so that as soon as the circuit is completed, there will be an electrical current down through the wire.

We now place a magnetic compass on the cardboard and move it all around the wire. It no longer points North, but keeps changing its position, as we move it around in a circle. When we remember that the moving part of the compass is a permanent magnet and has an "N" and "S" pole, the very fact that it changes position as we move around the wire, proves that there is some magnetic action set up by the current in the wire.

As soon as the circuit is opened and there is no current in the wire, the compass points North no matter how close we place it or in what position we put it around the wire. However, the instant the circuit is closed, the current in the wire immediately sets up the magnetic action and pulls the compass needle around. It is thus very easy to see it is the current and not the wire that sets up the magnetic action.

ACTION OF THE COMPASS IN A MAGNETIC FIELD

Thinking back for a minute to the laws of magnets, we know that if the magnetized needle of the compass is placed in a magnetic field, its "N" pole will try and turn away from the other "N" pole, while its "S" pole will try and turn towards the other "N" pole. The same effect will take place at the "S" pole, but in the opposite direction which gives a double action, a pull on one end and a push on the other. This double action will make the compass needle turn until it is lined up with the magnetic lines of the flux in which it is placed.

Now, looking at Figure 1 again, when we moved the compass around the wire, the needle pointed out a circle, therefore, the magnetic field around the wire must be circular in shape. Raising or lowering the cardboard on the wire has no effect on the compass action and it still points around in a circle as we move it around the wire.

We want you to think of this magnetic field around a straight wire just as though you had a lot of cardboard disks on a string, as shown in Figure 2. Of course, the magnetic field is not in flat disks like the cardboard but is exactly the same all along the wire. However, magnetism is always in motion and travels at the same speed as electricity, so that we will have to think of this magnetic field as spinning around the wire.

It is just the same as though the cardboard disks of Figure 2, were spinning around on the string. In Figure 1 then, there is a magnetic field whirling around and around the wire.

DIRECTION OF MAGNETIC FIELD

To continue our investigation of this action, we change the connections of the circuit of Figure 1, so that the direction of current is reversed and it passes up through the wire. Putting the compass on the cardboard now, we find that it still points in a circle, when moved around the wire, but points in the opposite direction.

Checking these changes, we find that when the direction of current is down through the wire in the cardboard, the compass needle points around in a clockwise direction. When the circuit connections are changed, so that the direction of current is up through the wire, the compass needle turns around and points in an anti-clockwise direction.

THUMB RULE

These actions prove that there is a fixed relationship between the direction of electrical current and the direction of the magnetic field it produces. Looking farther, we find that these directions are in the same relation to each other as the thumb and fingers of our right hand.

To make use of this fact, we can take hold of the wire, as in Figure 3, with our thumb pointing in the direction of the electrical current and our fingers will go around the wire in the same direction as the magnetic flux. This is the "Thumb Rule" but, when you use it, remember that it is always a good plan to play safe and instead of actually taking hold of the

wire, just place your hand in the proper position along side of it.

You will find this simple rule very useful because, if you know the direction of current, you can find the direction of the magnetic field, or should you know the direction of the magnetic field, you can find the direction of the electrical current.

There is not much to the thumb rule, is there? It looks so easy that you may be wondering what good it will do. Well, just take our word for it, until you find out for yourself, that all of the rules we are going to explain are just as easy as this one, once you understand them.

It is knowing a few easy rules like this that makes Radio and other Electronic work much easier but, if you don't know them, you can never advance very far in this field.

MAGNETIC FIELD AROUND A LOOP

Going ahead with our experiments, next we take the wire of Figure 1 out of the cardboard and bend it in a loop like Figure 4. Using the thumb rule here, we find that when the current is in the direction shown by the arrows, our fingers will point toward the inside of the loop no matter on which part we place our hand. With all the magnetic lines going one and the same direction inside the loop, and the opposite direction outside, as a whole, the magnetic field must be very much like that set up by a permanent magnet.

MAGNETIC FIELD AROUND A COIL

Following this idea a little further, we bend the wire into several loops, or a coil, like Figure 5. Connecting this wire in an electrical circuit which causes current in the direction of the large arrows, we again take a magnetic compass and move it around both inside and outside of the coil.

By watching the action of the compass we find that the magnetic lines, instead of whirling separately around each coil of the wire, all seem to join and form one magnetic field whose direction is as shown by the light broken lines. You will notice this flux is exactly the same as that set up by a permanent magnet and in this case, the "N" pole is at the upper end where the compass shows the magnetic lines coming out.

As long as there is current in this coil, it acts exactly like a permanent magnet. It has "N" and "S" poles and, if free to turn, will point north and south. The big difference between this coil and a permanent magnet is that the instant

there is no current in it, there is no magnetic field around it, and the more current there is in the wire, the stronger the flux will be.

RIGHT HAND RULE

Like the straight wire of Figure 1, there is a definite relation between the direction of electrical current and direction of magnetic flux. In this case, we again use our right hand, as in Figure 6, with the fingers pointing around the coil in the direction of the current and our thumb will then point toward the "N" pole.

This is called the "Right Hand Rule" and can be used whenever the wire is coiled and the direction of current and coils is the same through the entire length.

Before reading further, we want you to make a careful comparison of the "Thumb Rule" of Figure 3 with the "Right Hand Rule" of Figure 6. The thumb rule is applied to a straight wire, the thumb pointing in the direction of current while the fingers point in the direction of the magnetic field or flux.

Conditions are reversed in the Right Hand Rule because the fingers point in the direction of current while the thumb points out the direction of the magnetic field or flux. Also, the right hand rule applies to coils only and the direction of current is that in the turns of the coil.

For example, in Figure 6 the current enters at the top of the coil and the right hand rule shows the N pole at the top. However, if the turns of the coil were wound to the right instead of to the left as shown, the direction of current would be reversed and the right hand rule would show the "N" pole at the bottom.

SOLENOIDS

In common practice, a coil like that of Figure 6 is called a Solenoid which, as long as there is current in it, has all the magnetic qulaities of a permanent magnet. As we found in the single loop of wire, there must be an electrical current in the coil before a magnetic field is set up. Here again, an increase of current increases the strength of the magnetic flux and, in the same way, when the current is reduced, the magnetic flux is weakened.

AMPERE TURNS

Should we increase the number of loops, or turns, of the solenoid, and keep the current the same, the strength of the magnetic field would also increase. You can easily under-

stand the reason for this when you remember that each loop of the solenoid sets up its own magnetic field, which unites with those of the other loops. The more loops there are in the solenoid, the more magnetic fields there will be to unite, therefore the main magnetic field will be stronger.

To compare the magnetic strength of different solenoids, and obtain a unit for measuring them, we usually multiply the number of turns of wire by the number of amperes in the wire and call the answer "Ampere-Turns".

For example: A solenoid with ten turns and a current of ten amperes will have one hundred ampere-turns. Another solenoid with 50 turns and a current of 2 amperes will also have 100 ampere-turns.

While the ampere-turn, abbreviated "NI", is the common unit of measure for Magnetomotive Force, (M.M.F.), a more technical unit is called the "Gilbert". One gilbert is the amount of Magnetomotive Force which will force one line of flux through one centimeter of air.

In comparison, one ampere-turn (NI) is equal to 1.257 Gilberts but to convert a number of gilberts to the corresponding value in ampere-turns we use the equation -

$$\text{Gilberts} = 1.257\ NI$$

This apparent contradiction can be readily explained by comparing it to common linear measure which states,

$$1\ \text{Foot} = 12\ \text{inches}$$

but if you want to convert some number of feet into the corresponding number of inches, you use the general equation,

$$\text{Inches} = 12 \times \text{Feet}$$

ACTION OF AN IRON CORE

From our Lesson on Magnets, you know that iron and steel will carry magnetic lines of force much better than air or other materials therefore, to increase the magnetic flux of a coil like that of Figure 6, we place a piece of iron inside it. This is called the Core and, as iron carries the lines several hundred times easier than air, there will be many more magnetic lines of force in the iron core than the air inside the coil could possibly carry. The complete assembly of a solenoid, with an iron core inside it, is called an Electro-Magnet.

MAGNETIC CIRCUITS

We want you to think of the different paths for magnetic lines of force in much the same way as we explained the electrical circuit. In the electrical circuit there is a pressure, or emf, that forces a current of electricity through a path that has resistance.

For a magnetic circuit, we use exactly the same idea but do not have to build a special path because the magnetic lines will travel through anything. Their path, however, will always be from the "N" to the "S" pole outside the magnet.

Instead of an emf, for the magnetic circuit we have a Magnetomotive Force, mmf, which forces a Flux around a circuit that offers Reluctance.

Now don't let the word "reluctance" bother you because it is only that property of a magnetic circuit which opposes or tends to stop the passage of magnetic lines of force. In electric circuits, nearly all substances have different resistance properties, some offering little and others offering great opposition to the electric current. In magnetic circuits, nearly all substances, except magnetic metals, have practically the same Reluctance. Iron has relatively low reluctance while air and other non-magnetic materials have about the same and a relatively high reluctance.

Comparing the Magnetic Circuit with an Electrical Circuit, we have mmf instead of emf, Flux instead of Current and Reluctance instead of Resistance.

LAWS OF MAGNETIC CIRCUITS

As a law for the magnetic circuit we can state: "The Flux of a magnetic circuit is equal to the mmf divided by the Reluctance".

Although a piece of iron will carry magnetic lines several hundred times better than air, there is a limit to its ability. You might think of it as a blotter. When a blotter is new, it soaks up ink very readily and quickly but, after it has been used for a while and is pretty well ink soaked, it is very hard to make it soak up any more.

The action of an iron core is very much the same. When there are but few magnetic lines through it, an increase of mmf will cause a similar increase in the number of lines. When there are a great many lines through it, a great increase of mmf is required to cause a small increase in the number of lines.

A piece of magnetic material is said to be saturated when an increase of M.M.F. does not cause a corresponding increase of Magnetic Flux. Of course, it is still possible to increase the magnetic flux but the M.M.F. required is so great, compared to the increase, that it is seldom done in practical work.

FORMS OF ELECTRO-MAGNETS

Electro-Magnets are used in many different ways, each of which we will explain fully in our later Lessons therefore, at this time, we will just mention some of the more common ones.

Every electric motor and generator requires a very strong magnetic field to cause its action. With the exception of some small machines and special types, all have electro-magnets. Practically all headphones and most Loud Speakers have electro-magnets and, by a change of electrical current in the magnet winding, the strength of the magnet varies to make the diaphragm vibrate so as to reproduce the voice or music being broadcast.

Telegraph instruments use electro-magnets to attract a movable arm which causes the clicking noises by which messages are received.

Very large electro-magnets are mounted on cranes and hoists and used to lift large pieces of iron or steel. These magnets are so strong that they can hold several tons of metal and are used extensively in foundries, machine shops and steel mills for loading and unloading cars or moving metal to various parts of the shop.

We could go on and give you many more uses of electro-magnets but, for this Lesson, all we want you to remember are these few simple facts.

Whenever a current of electricity is sent through a coil of wire, like Figures 5 or 6, the coil sets up a magnetic field and has all the properties of a permanent magnet.

The strength of the magnetic field varies with the number of turns and the amount of current but, with no current, there is no magnetism.

An iron core placed inside the coil greatly increases the strength of the magnetic field.

USES OF ELECTRO-MAGNETS

In a general way, whenever it is desired to produce mechanical motion by electricity, you will find some form of electro-

magnet in use. In almost every case, the part to be moved is made of magnetic material and placed quite close to the magnet. This has to be done because, as we have already told you, the pull of a magnet varies inversely as the square of the distance.

As you advance in your studies, we will give detailed explanations of many Electronic and Radio components which employ electro-magnets but, at this time, we can explain the general plan of operation by means of an ordinary type of door bell.

For Figure 7-A, we have drawn a unit of this type and have removed the cover to show the main parts which are named in Figure 7-B. Starting at the top, you will see the "gong" or bell proper while directly below is the "armature" which has a small ball or "hammer" attached to its upper end.

The coil of wire for the electro-magnet is wound on a cylindrical iron core which is riveted to the center of a "U" shaped iron frame. The lower end of the armature extends across the open end of the "U" of the frame, being held in position by the spring, riveted to both the armature and the frame.

The upper end of the spring is bent away from the armature and carries a contact which is in line with another contact mounted rigidly on the main base, but electrically insulated from it. The spring tension is in a direction to pull the armature away from the frame and to hold the contacts together as in Figure 7-A.

Electrically, there is a circuit from the right hand binding post, up through the turns of the coil and over to the stationary contact. As the spring holds the contacts together, the circuit is through them, down through the spring to the left hand binding post.

To simplify our drawing, we show but a few turns of wire in the coil. Actually, the coil may have several hundred turns and fill the entire spool as indicated by the light lines above and below the coil of Figure 7. The larger number of turns provides a greater number of ampere-turns at lower values of current and thus provides more satisfactory circuit conditions.

To provide operation, the binding posts of the bell are connected in an electrical circuit and, when this circuit is closed, usually by means of a push button switch, there is current in it. Following the circuit of the bell through the turns of the coil, this current will set up a magnetic field or flux across the open end of the U shaped frame.

Located in this space, the iron armature will be attracted and pulled toward the frame as soon as the magnetic pull is strong enough to overcome the tension of the spring. When this happens, the armature moves from the position of Figure 7-A to that of Figure 7-B.

The movement of the armature does two things. First, the ball on its upper ends strikes the gong and causes the bell to ring. Second, the contact on the upper end of the spring no longer touches the stationary contact. Mechanically, the gong has been struck while electrically, due to the operation of the contacts, the circuit has been opened.

As soon as the circuit is opened, it no longer carries current, the magnetism dies out and the spring pulls the armature back to the position of Figure 7-A. The instant the contacts touch, the circuit is complete, it carries current again and the entire action is repeated.

The movement of the armature is quite fast, therefore, as long as the circuit push button switch is held closed, the armature vibrates rapidly, the hammer on its upper end striking the gong each time the magnet pulls it over.

While the door bell is a very simple example, you can see how the electrical current in the turns of the coil is converted to magnetic energy which attracts the armature and causes mechanical motion. This motion is used to "ring" the bell and also, because of the location and electrical connections of the contacts, to cause the armature to vibrate as long as the circuit push button switch is closed.

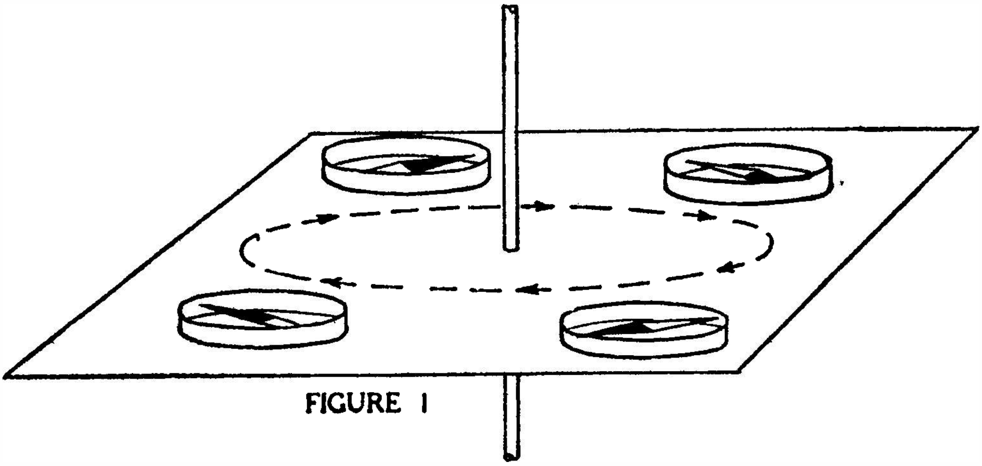


FIGURE 1

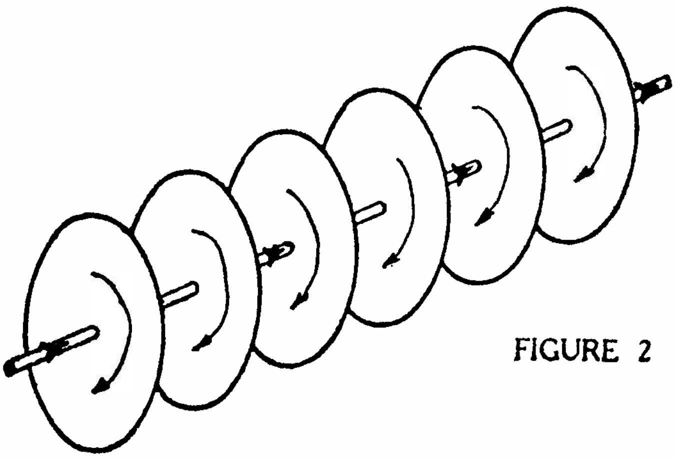


FIGURE 2

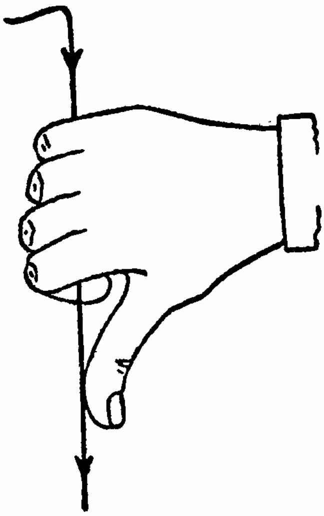


FIGURE 3

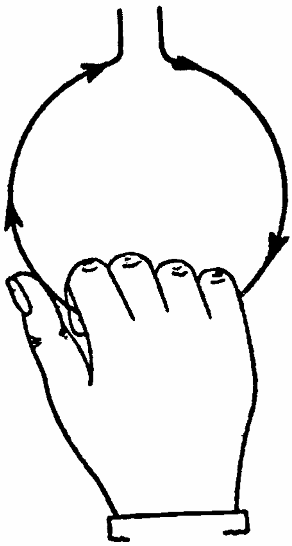


FIGURE 4

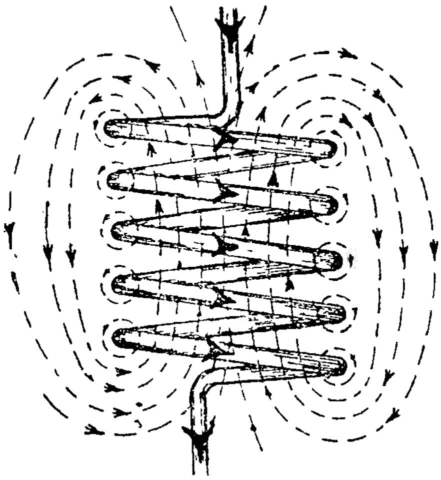


FIGURE 5

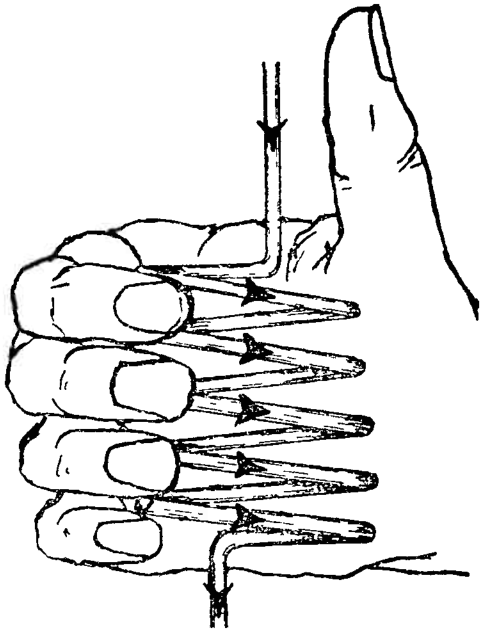


FIGURE 6

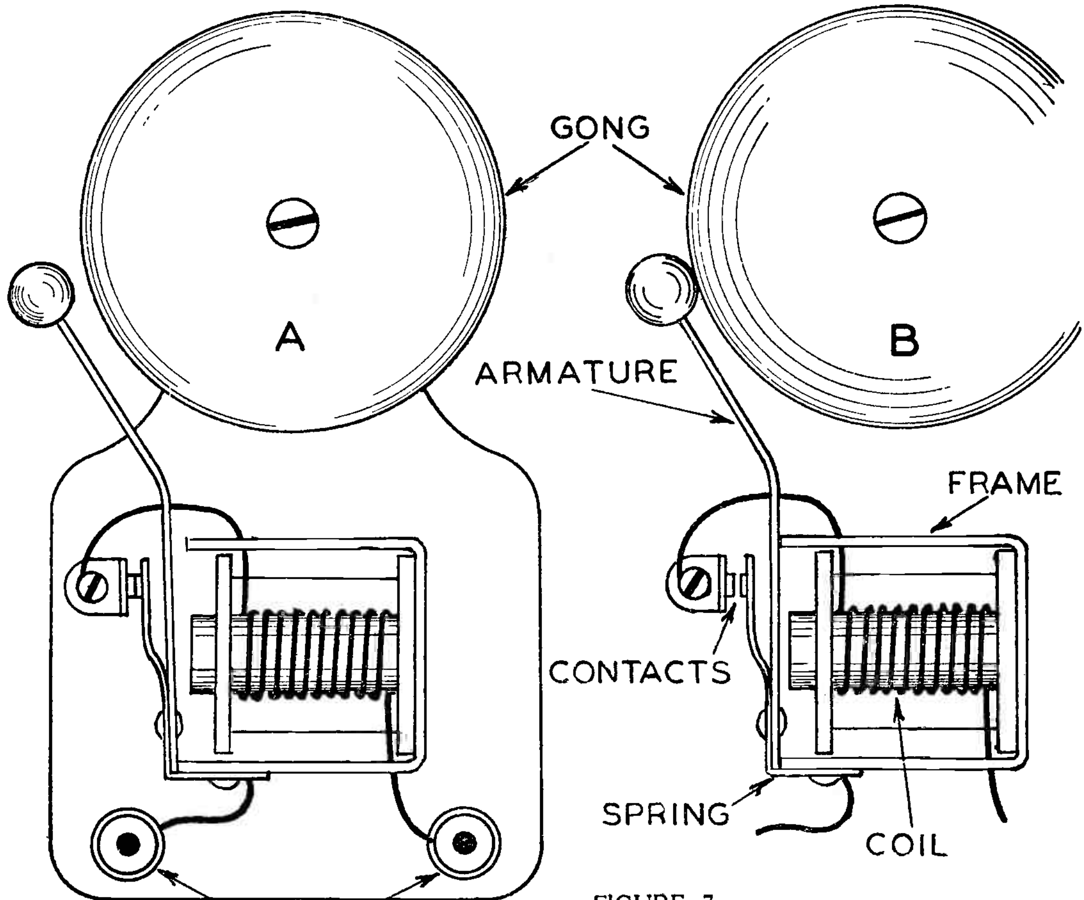


FIGURE 7

DE FOREST'S
TRAINING, Inc.

LESSON FDM - 11

VOLTMETERS - AMMETERS

Founded 1931 by

RADIO FUNDAMENTALS

LESSON 11

VOLTMETERS - AMMETERS

Measuring Electricity -------------- Page 1
Direct and Alternating Current ----- Page 1
Measuring the Magnetic Effect ------ Page 2
Meters for Both D.C. and A.C. ------ Page 5
D'Arsonval Meters ------------------ Page 5
Dead Beat Action ------------------- Page 6
Hot Wire Meters -------------------- Page 6
Voltmeters ------------------------- Page 7
Ammeters --------------------------- Page 9
Ammeter Shunts --------------------- Page 9
Combination Meters ----------------- Page 10
Volt - Ammeter --------------------- Page 11
Testing and Calibrating Meters ----- Page 11

* * * * *

"Persons of the highest intelligence never cease to learn and any person, whatever may be his station in life, who devotes a share of his time to self betterment through home study courses, will never regret the time thus spent."

-- C. Haile, Pres., M-K-T R.R.

In the earlier Lessons, we told you that no one really knows just what electricity is yet it is used in so many different ways, and is bought and sold, that we must have some way of measuring it.

You may think that it is going to be a pretty hard job to measure something when we don't even know what it is, but we take the easy way out and measure the effects of electricity, instead of the electricity itself.

MEASURING ELECTRICITY

From your Lesson on Electro-magnets, you know that a current of electricity sets up a magnetic field, or we can say, produces a magnetic effect.

From your Lesson on Cells and Batteries, you know that when certain substances or chemicals are brought together, that electricity is produced, therefore there is a relationship between electricity and chemical action.

The ordinary electric flat iron, or electric toaster, is a very common example to show you that electricity can produce a heating effect.

There is a fourth effect of electricity, called "Electro-static", which we will just mention here as we are going to take it up later on in our work.

Electricity then, under the proper conditions, produces four different effects, Magnetic, Chemical, Heating and Electro-static. When we measure the amount or value of these effects, for all practical purposes we have the same information as though we measured the electricity itself.

DIRECT AND ALTERNATING CURRENT

In common use today, there are two kinds of electrical current or power called Direct and Alternating. So far, all of our work has been with direct current and we will continue with it for quite a few advance Lessons. We have mentioned alternating current in former Lessons therefore, when explaining the different kinds of measuring instruments, we will tell you whether they are for direct current, d-c, alternating current, a-c, or both.

For this Lesson we can think of d-c as an electrical current that always travels in the same direction. Take a primary cell for example. The current, in the circuit in which it is connected, will always be from the anode to the cathode outside the cell and from the cathode to the anode inside the

cell. It is always in the same direction, therefore the name Direct.

On the other hand, A.C. keeps changing its direction, going first one way around the circuit, then reversing and going around the other direction. As the current keeps changing, or alternating its direction, we call it alternating current and in our later Lessons we have many things to tell you about why we use it and the effects it produces.

MEASURING THE MAGNETIC EFFECT

As the magnetic effect of electricity is perhaps the most common, and so many of the ordinary measuring instruments operate by it, we will explain this action first.

Going back to the Lesson on Electro-Magnets, we found the presence of a magnetic field, around a wire carrying current, by placing a magnetic compass near the wire. There are two things we want to remind you of here. First, the compass needle lined up with the magnetic lines of force. Second, the more current there was in the wire the stronger the magnetic field and the further the compass needle would swing.

For Figure 1 of this Lesson, we are using just about the same layout but have placed the wire over the compass in such a position that with no current in the wire, it lies in the same direction as the compass points. By using the thumb rule here, you will find that, regardless of the direction of current in the wire, the magnetic lines set up will cut square across the compass needle at right angles to it.

Suppose we connect this wire in a circuit and send current through it. The magnetic lines that it sets up will cut across the compass needle and make it turn as it tries to line itself with them. The more current in the wire, the stronger the magnetic field and, the strong the magnetic field, the further the compass needle will turn.

You can see now that the distance the compass needle turns from its natural position will depend on the amount of current in the wire because the current causes a magnetic effect which in turn affects the compass.

To make a measuring instrument, or rather a meter, out of this arrangement, we would first arrange the circuit so that there would be just exactly one ampere of current in it. Then after the compass needle had turned, we would mark a figure 1 at the place it stopped. Next, we would rearrange the circuit so that there would be exactly 2 amperes in it and then put a figure 2 at the point where the compass needle stopped.

We could keep this up, increasing the current in the circuit and marking the points where the needle stopped each time until it was pointing square across the wire. We would have to stop here because the magnetism is not able to move the needle further.

Now we could take this outfit and connect it in any circuit and, by watching at which figure the compass needle stopped, we would know the number of amperes in the wire. We have the simplest kind of a meter and it would be an Ammeter because we marked it to show the number of amperes in the wire. You can also see that, for every day practical work, this would not be very good because if the compass was moved closer to, or further away from the wire, the reading would vary.

To overcome this trouble, in Figure 2 we have mounted the compass on a stand which also holds a coil of wire. Think of this coil as a solenoid and, by using the Right Hand Rule, you can see that the magnetic lines here will have exactly the same effect on the compass needle as they did in the arrangement of Figure 1.

By mounting the compass and coil on the same stand, they will always be held the same distance apart and eliminate the trouble just mentioned. The ends of the wire in the coil are fastened to terminals and the complete assembly is called a "Tangent Galvanometer" or an "Ammeter".

Instruments of this kind, while very simple, are too delicate for everyday use because they must be level to allow proper action in the compass and must also be turned so that, before there is current in the coil, the compass needle lines up with it.

In Figure 3 we have the same idea but have worked it out in a different way. We again have the coil, or solenoid, the ends of which are connected to terminals on the outside of the meter. Instead of the magnetic compass, we have a small piece of soft iron which hangs in the end of the solenoid but at "A" is supported on a shaft which is free to turn.

With current in the coil, the magnetic field will attract the piece of iron and pull it further inside the solenoid. The larger the current, the stronger the magnetic field and the further the iron will be pulled up into the center of the solenoid.

We next add a pointer, fastening it to the same shaft as the piece of soft iron and, as the iron moves, the pointer moves with it. A scale is placed behind the end of the pointer and marked in the same way that we explained for the magnetic compass of Figure 1.

You can see that this arrangement works just about the same as the compass and coil of Figure 2, but is much more practical as the weight of the piece of iron will steady the action of the pointer and bring it back to the 0 on the scale when there is no current in the solenoid. Also, the parts will be always in the same position in regard to each other and the readings will be the same no matter in which direction the coil is placed.

In Figure 4, we have another type of instrument that also operates by the magnetic effect of electricity. It works on the principle that a piece of iron, or other magnetic substance, when placed in a magnetic field will move, or try to move, into the position in which it can carry the greatest number of magnetic lines.

Here again we have a solenoid, the ends of which are connected through terminals to the outside circuit. Inside the coil, but to one side of the center, we mount a shaft and fasten on it a small piece of soft iron, called a "Vane". As in Figure 3, a pointer is also fastened to the same shaft.

In this type of instrument, a fine coiled spring, much like the hair spring in a watch, is fastened to the shaft also and its tension is set so that, with no current in the coil, it will pull the vane and shaft to the position where the pointer stands at the "0" on the scale.

When there is current in the solenoid, a magnetic field is set up which is strongest, or has the greatest number of lines, at the center. The vane, being at one side or off center, will try and move to a position where it can carry more lines. As it moves, it pulls the pointer with it and also winds up the coil spring.

Here again, the distance the vane moves depends on the strength of the magnetic field which, in turn, depends on the amount of current in the solenoid. Therefore, the distance that the pointer moves will depend on the amount of current in the meter.

There are a great many different designs and combinations of Figures 3 and 4 on the market, especially in the smaller and less expensive meters. Some of them use a permanent magnet in addition to the solenoid and the movement of the vane is controlled by the pull of the two magnetic fields. In this type, a reversal of current in the solenoid makes the vane move in the opposite direction. This is a very useful feature in many cases such as an automobile dash meter that has to read "Charge" and "Discharge".

METERS FOR BOTH D.C. AND A.C.

All instruments of this kind, except those using permanent magnets, which includes those shown in Figures 1 and 2, can be used for either direct or alternating current. When used for direct current, they must not be placed near any pieces of iron or strong magnetic fields.

D'ARSONVAL METERS

One of the most common, and perhaps the most reliable type of meter for direct current measurement is the D'Arsonval, the main parts of which are shown in Figure 5-A. Here we have a U shaped permanent magnet, on the lower ends of which are shaped "Pole Pieces" of soft iron. These are put on to reduce the reluctance of the magnetic circuit and make the magnetic field more uniform in strength.

Inside the pole pieces, and quite close to them, is a round piece of iron. You will notice that inner ends of the pole pieces are curved to fit the round piece of iron to provide a very good magnetic circuit between the N and S poles. This makes the magnetic path all iron or steel, except the small air gap between the pole pieces and the round center piece of soft iron.

The coil for the current is wound on an aluminum frame that is large enough to fit over the center piece of iron but small enough to pass between the pole pieces. The frame is mounted on jewel bearings so that it can turn freely and easily.

With current in this coil, it will set up a magnetic field of its own, whose N pole will be attracted by the S pole of the permanent magnet. As the strength of the magnetic field of the permanent magnet is always the same, while the strength of the magnetic field set up by the coil varies with the current in it, you can see that the pull on the coil will have to vary with the current.

The shaft of the moving coil is usually mounted as at Figure 5-B with a coiled spring on each end and a pointer on one end. The tension of the springs is set so as to bring the pointer to the "O" on the scale when there is no current in the moving coil. Most of these meters have a little screw head on the outside of the case marked "Set Zero" which, when turned, changes the tension of the spring so that the pointer will stop exactly over the "O" on the scale.

As the permanent magnet partly controls the movement of the coil and pointer, current in the coil in one direction will

make it turn in one direction. Reversing the current in the coil reverses the magnetic field which it sets up but the field of the permanent magnet does not change, therefore the coil will move in the other, or opposite direction.

You will find meters of this type with the "O" of the scale at one end, in the center, or part way between depending on the service required.

DEAD BEAT ACTION

Another feature we must mention here is what is called the "Dead-Beat" action. You remember that the coil of this type of meter was wound on a frame of aluminum which is an electrical conductor. The frame is placed between the pole pieces and the center round iron, where there is the strong magnetic field of the permanent magnet. As the meter operates and the coil moves, in the aluminum frame we have a conductor cutting a magnetic field. As you will soon learn, whenever a conductor cuts through, or is cut by, a magnetic field, a voltage is induced in it and here, the frame forms a circuit which allows current. This current will try and stop the motion producing it and thus act as a brake on the action of the coil and pointer. This action prevents a lot of swinging back and forth when a reading is taken and makes the pointer come to a stop almost immediately. It helps us to get an accurate reading quickly.

HOT WIRE METERS

As a very good example of the way we measure electricity by its heating effect, we have drawn a simplified form of a hot wire meter in Figure 6. In explaining this action, all we want you to remember is that when an object is heated, it expands.

Looking at Figure 6 closely now, we have a piece of wire from "A" to "B" which, at each end, connects to a terminal on the outside of the meter. In other words, this wire is going to be a part of the circuit in which the meter is connected. At "B", we have an adjusting screw by means of which the wire "A-B" is kept stretched tight.

A second wire, which is also stretched quite tight, is fastened between "F" and "C". Tightening up on the adjusting screw at "B" will keep both of these wires tight.

On this second wire at "G", we fasten a thread or cord, run it down and once around a small pulley at "D", and then on down and fasten the end to the spring "E". this spring is strong enough to take up all the slack there may be in the

cord and wires. The pulley at "D" is mounted on a shaft that carries the pointer and, of course, is made so that it can turn easily.

Now, with the meter connected in a circuit and current in the meter from terminals "A" to "B", the wire will be heated and expand. As it expands, it gets longer and allows some slack in the wire "F-C". The spring "E" pulls up this slack through the cord which, you will remember, is run around the pulley "D". As the spring "E" pulls up the slack and moves the cord, the pulley "D" will turn and the pointer will move across the scale.

The idea behind this arrangement is that the wire will heat in proportion to the amount of current in it. The distance it expands will be in proportion to the amount it is heated. The distance the pointer moves will be in proportion to the amount of expansion. Leaving out the steps in between, the distance the pointer moves will be in proportion to the current in the wire "A-B".

These hot wire meters work equally well for both a-c and d-c, but the markings on the scale have to be made very carefully. This is because it takes a small amount of current to heat the wire to any noticeable extent therefore, at the lower end of the scale, the divisions are quite small although not shown in detail on our scale.

All of these meter actions that we have been explaining can be used for either Ammeters or Voltmeters depending on the way they are connected both inside the meter and in the circuit. The difference between an Ammeter and a Voltmeter is not very great as you will learn in the next few paragraphs.

VOLTMETERS

As a very good and common example, we are going to take a meter, built as shown in Figure 5 and connect it up in a circuit to use as a voltmeter. There are several things to think about here. In the first place, we know that voltage means the difference in electrical pressure between two points such as the terminals of a battery. To measure this difference in pressure, or voltage, we will have to connect the meter terminals across the two points.

However, this meter acts by the magnetic effect of a current of electricity therefore, we will have to allow current in the meter coil. Just to simplify the explanation, we will suppose that the meter of Figure 7 requires one ampere of current in its moving coil to set up a magnetic field strong enough to move the pointer all the way across the scale.

As we told you in the Lesson on "Current Electricity", electrical pressure is measured in Volts and current is measured in Amperes. Now here, we want to measure the pressure, or voltage, but need current to operate the meter and, as this current will be lost for other uses, we want to keep it as low as possible. To obtain this result, we place extra resistance in the circuit and connect it as shown, so that a voltage across the terminals will have to force current through both the moving coil and the resistance.

Suppose we want to make the meter read up to 100 volts. Remember that one ampere of current in the moving coil moves the pointer clear across the scale therefore, the total resistance of the meter circuit will have to be increased sufficiently to allow but one ampere of current in the circuit when a pressure of 100 volts is connected across the terminals. In other words, 100 volts across the terminals causes sufficient current to pull the pointer all the way across the scale and we can put the figures "100" at the point on the scale where the hand stops.

Next, we can connect 50 volts across the terminals and put the figures "50" at the point on the scale where the hand now stops. As 50 volts is $\frac{1}{2}$ of 100 volts, the 50 volts will cause a current of but $\frac{1}{2}$ ampere and pull the pointer only half way across the scale.

By changing the voltage across the terminals and properly marking the scale each time, we can locate all the figures we need and the meter is ready for use.

The main point to remember here is that a voltmeter really operates because of current in it, but the scale is marked to read, not the actual amount of current, but the voltage necessary to force that amount through the moving coil and the resistance.

All standard voltmeters have a comparatively high resistance and the current required to operate them is so small a fraction of an ampere that ordinarily we do not think of it. This high resistance in the meter also makes it safe to connect it right across a battery or other source of electrical pressure.

Many Radio and other electronic circuits have small currents in them with values of only a few thousandths of an ampere. To measure these small quantities we take one thousandth (.001) of an ampere as a unit and call it a "milliampere" often spelled "Mil-Ampere" or abbreviated "MA".

In the meter we have just explained, a pressure of 100 volts across its terminals caused a current of 1 ampere or 1000 milliamperes in the meter circuit. We marked the scale 100

To show the voltage across the meter, but we could mark this same point 1000 to show the MA. in the circuit.

With 50 volts, there would be .5 ampere or 500 MA., and so on, all the way along the volt scale therefore, knowing the ration, we could either make a second scale, or else multiply the voltage reading by 10.

We mention this fact merely to show you how certain types of Test Meters can be used for Milliameters as well as Voltmeters, but usually, other changes are made.

AMMETERS

As an ammeter is not very much different from the voltmeter just explained, we are going to use the meter of Figure 7, and make it into an ammeter. As its name tells you, an ammeter is for measuring amperes, or current, and it will have to be connected in series with the circuit in which it is used so that all the current in the circuit will pass through it. This also means, that in order to allow the proper current in the circuit, the resistance of the ammeter will have to be very low.

By removing the resistance coil of the meter in Figure 7, and connecting the ends of the moving coil to the terminals, we could then connect it in a circuit as an ammeter.

As before, a current of 1 ampere would pull the pointer all the way across the scale. If we did not want the meter to read over 1 ampere, it is all right the way it is, but we will have to mark the scale "Amperes" and put a figure 1 at the end. 1/2 ampere would move the hand half way across the scale and so on as explained for Figure 7.

You can see that the action here is exactly the same as before except that the meter is now connected in series with the circuit and the reading on the scale shows the actual number of amperes in the moving coil.

AMMETER SHUNTS

Should we want this particular meter to read up to 100 amperes, we could not put a resistance in series as in the case of the voltmeter, but instead, install a "shunt" as shown in Figure 8. In this case, a shunt is nothing but a very low resistance path for the current and notice, it is connected in parallel to, or across, the moving coil of the meter.

Without going into details at this time, just remember that in any circuit, with the voltage remaining the same, the

higher the resistance the lower the current, while the lower the resistance the higher the current. In Figure 8, there are two paths for current between the meter terminals. One through the shunt and one through the moving coil.

Now, with the meter connected properly, we want the hand to move all the way across the scale only when we have a current of 100 amperes in the circuit. We already know that 1 ampere in the moving coil pulls the hand all the way over therefore, we need 1 ampere in the coil and the other 99 in the shunt.

To have 99 amperes in the shunt and but one ampere in the moving coil, the shunt must have but 1/99 the resistance of the moving coil. Then, with a current of 100 amperes between the terminals, there will be 99 amperes in the shunt and one ampere in the moving coil. This will move the pointer all the way across the scale and again we can put the figures 100 at the point where it stops.

Should there be but 50 amperes between the terminals, it would divide as before, giving us 99/2 or $49\frac{1}{2}$ amperes in the shunt, and $\frac{1}{2}$ ampere in the moving coil. This $\frac{1}{2}$ ampere, as explained before, would pull the pointer half way across the scale, but we would mark the point where it stopped 50, because that is the total amount of current in the circuit.

By this method, we can accurately measure very large currents, but still keep the moving parts of the meter small and therefore sensitive.

COMBINATION METERS

By using several resistances, connected in series, but bringing each one out to a separate terminal as in Figure 9-A, we can make a voltmeter that will read several different values on the same scale. Each scale of values has its own figures and the jumps are usually made in steps of 10 in order to make the reading easier.

By making a connection on the "Plus" and "3" terminals, of the meter in Figure 9-A, 3 volts will pull the hand over to the end of the scale, marked 3. By making connections on the "Plus" and "30" terminals however, the moving coil is in series with a resistance of such a value in Ohms that it takes 30 volts to pull the hand over to the end of the scale. The same thing is true of the "300" terminal, because when we connect on it and the "+" terminals, both resistances are in series with the moving coil and their added value in ohms requires 300 volts to pull the hand over to the end of the scale.

By using several shunts, of different resistances, we can also make an ammeter read on several different scales as shown in Figure 9-B. By tracing out the circuits you will notice that as you change connections from the "Plus" and "3" terminals to the "Plus" and "30", or the "Plus" and "300", that you really take the shunts out of the main circuit and put them in series with the moving coil. In this way, the resistances of the moving coil and shunts remain of proper ratio to cause the desired division of current through them.

VOLT - AMMETER

There are quite a few meters that have but one scale, yet will read either volts or amperes depending on which terminals are used in connecting them up. There are usually three outside terminals as shown in Figure 10 and there may be a switch, as at Figure 10-A, by means of which the moving coil can be connected either in series with the resistance for voltage readings, or in parallel to the shunt for current readings.

At Figure 10-B, we have just about the same connections, except that there is no switch. This leaves the shunt connected across the meter coil at all times and while it affords good protection for the moving coil, the meter is less sensitive.

TESTING AND CALIBRATING METERS

By far, the easiest and simplest way to test or calibrate a meter is to compare it with a similar meter that is known to be correct. The connections between the different kinds of meters will be a little different and, in Figure 11, we show how 2 voltmeters are connected at A and two ammeters at B. You will notice the main difference is that the voltmeters are connected in parallel and the ammeters in series.

In both cases, we will suppose that the square meter is all right and we want to check the round one with it. In order to take readings at different points on the scale, at A we have a very high resistance connected right across the source of E.M.F. Then, by changing the position of the movable contact shown by the arrow, we can vary the voltage across the meters and thus change their readings.

At B however, we have both meters and the resistance all in series. By changing the position of the movable contact shown by the arrow, the resistance of the circuit is changed and thus the current is varied.

In addition to the usual examination questions, you will find a "Work Diagram" attached to this Lesson. As your first assignment in actually drawing circuit diagrams, you are to show,

by means of lines, where wires would have to be connected to allow the voltmeter to read the battery voltage and allow the ammeter to read the lamp current.

Briefly reviewing the Lesson explanations, you will remember that a voltmeter is connected in parallel to, or across the terminals between which the voltage is to be measured. In contrast, the ammeter must be connected in series with a circuit so that it will carry all of the current to be measured.

Looking at the diagram, you will notice the battery terminals are marked "+" and "-" to indicate polarity while one terminal of each meter is marked "+". Although the meters do not develop a voltage, their "+" terminal must be connected to the battery "+" terminal in order that the meter hand will move in the proper direction across its scale.

The complete diagram will have two circuits or paths, one containing the battery and voltmeter, the other containing the battery, ammeter and lamp. To complete the diagram, you need only draw lines between the various terminals to indicate these paths.

When the diagram is completed, send it in with your examination and we will return it with a properly completed diagram.

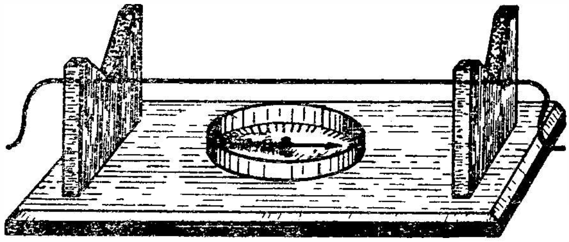


FIGURE 1

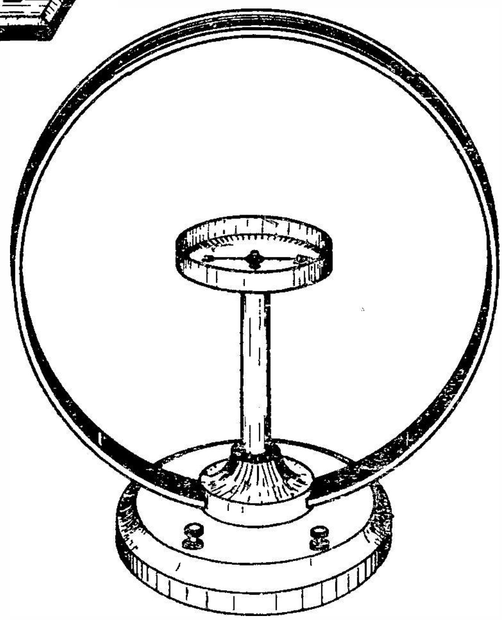


FIGURE 2

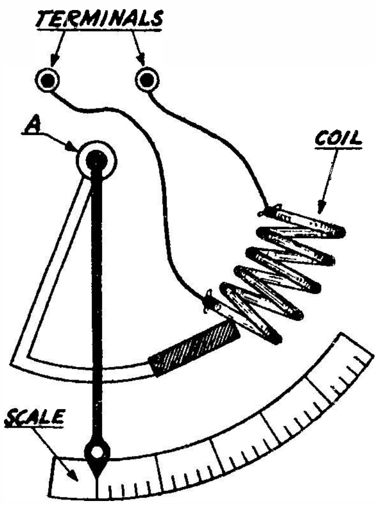


FIGURE 3

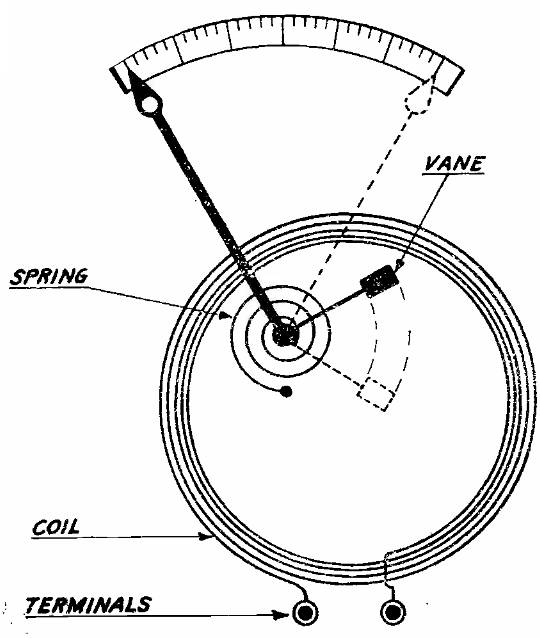


FIGURE 4

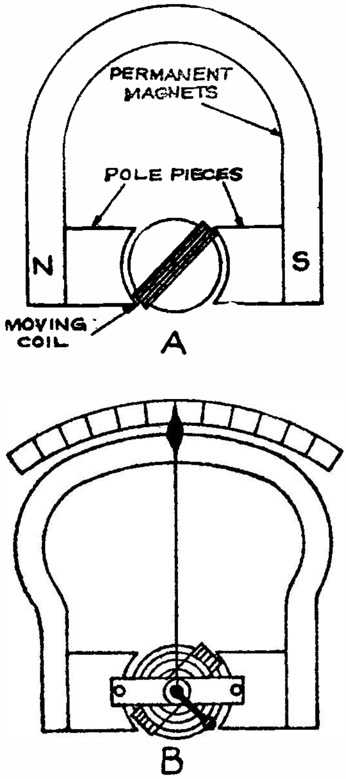


FIGURE-5

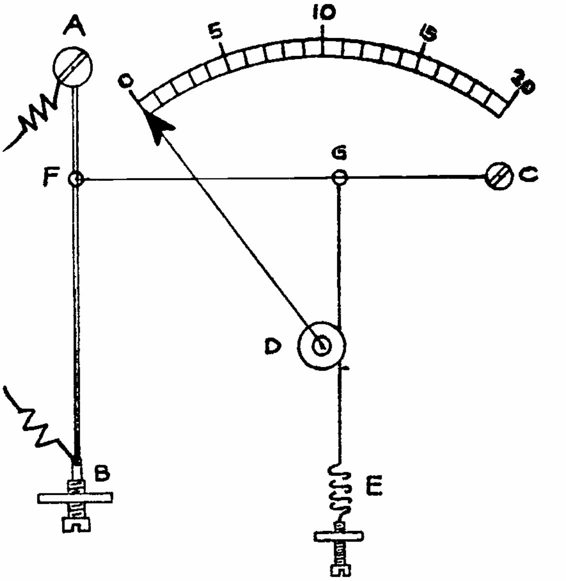


FIGURE-6

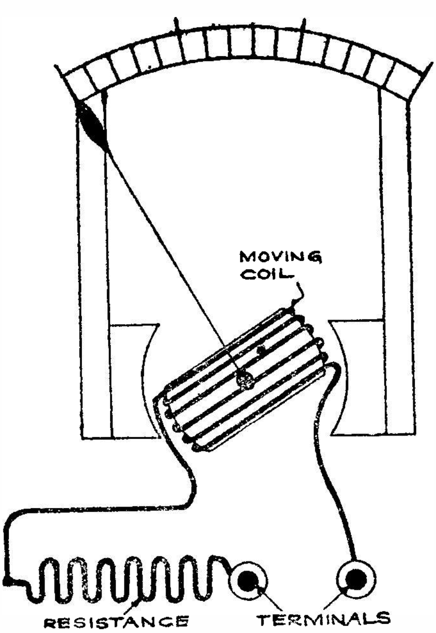


FIGURE-7

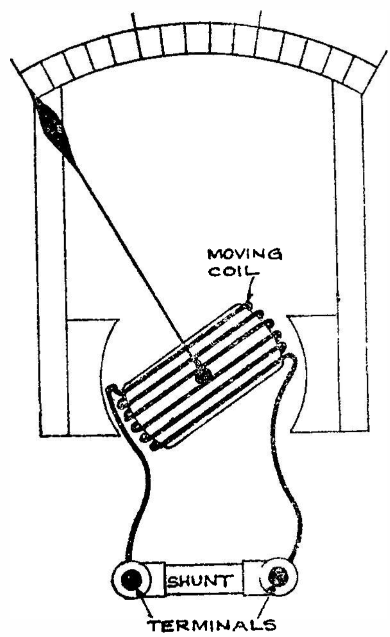


FIGURE-8

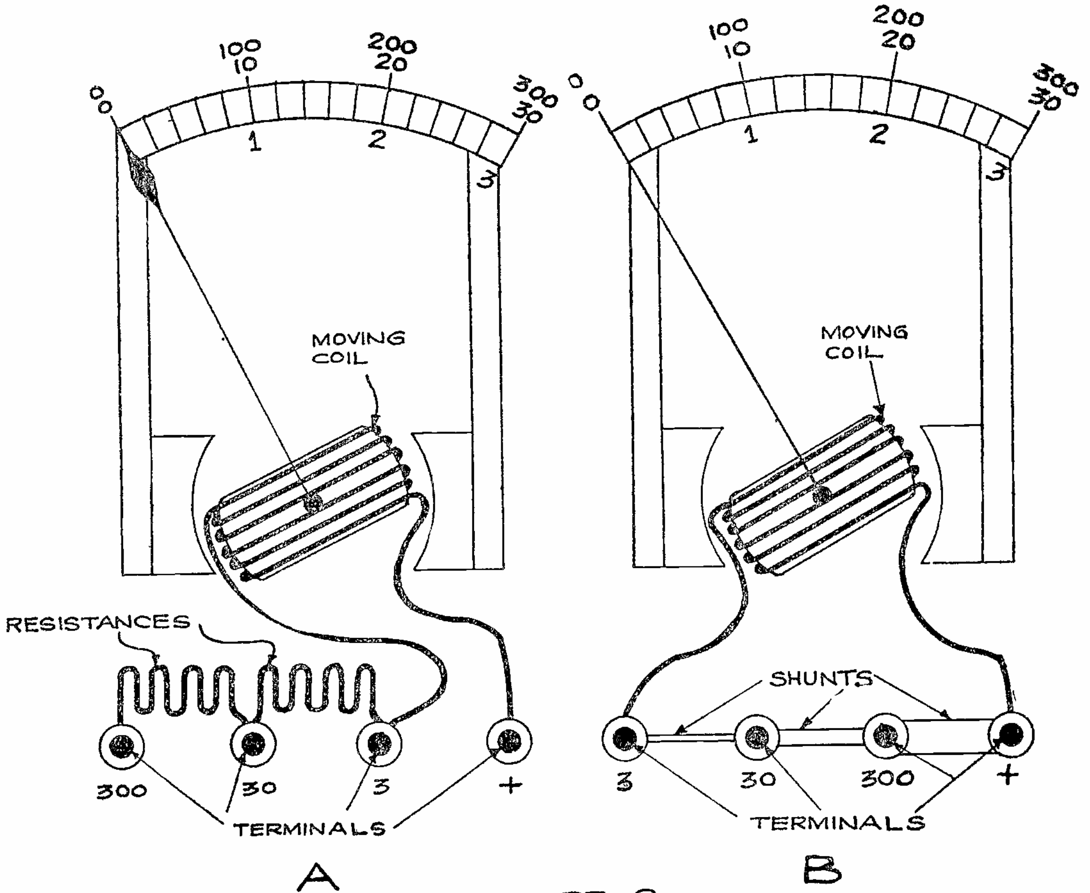


FIGURE-9

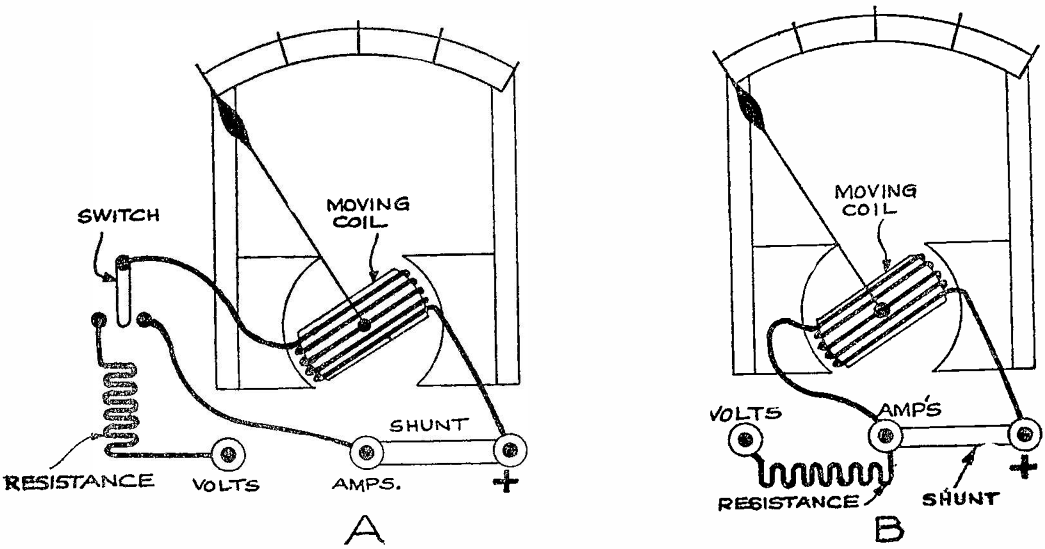
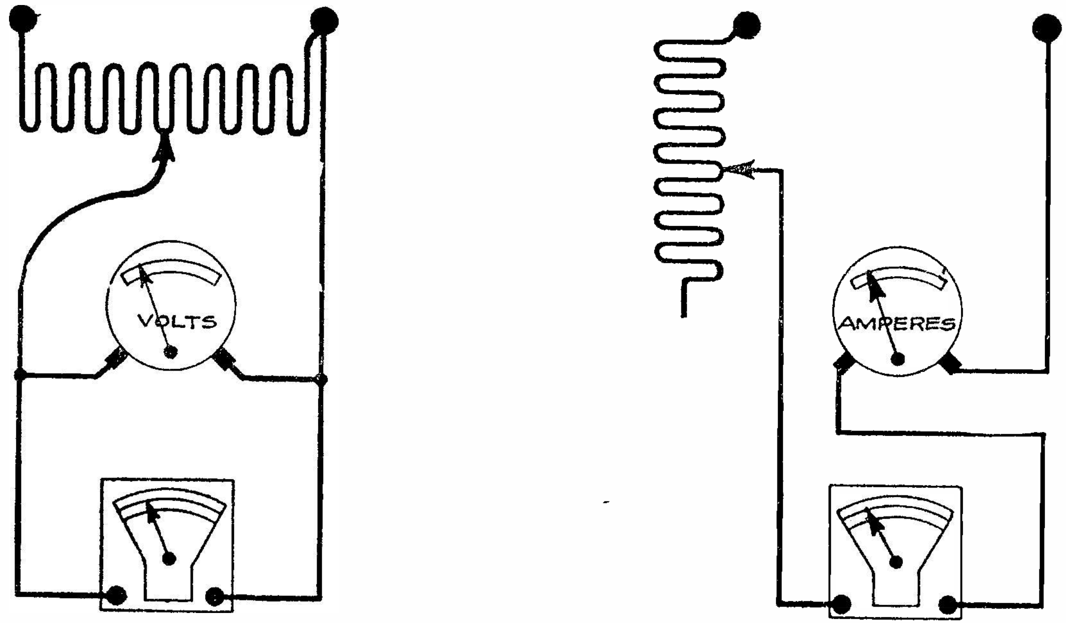


FIGURE 10



A B

FIGURE — 11

DE FOREST'S
TRAINING, Inc.

LESSON FDM - 12

OHM'S LAW

Founded 1931 by

RADIO FUNDAMENTALS

LESSON 12

OHM'S LAW

Units of Measure ---------- ---- Page 1
How Long is an Inch ------------- Page 1
What Pressure Means ------------- Page 2
Voltage ------------------------ Page 3
Electro-Motive Force ------------ Page 3
Potential ---------------------- Page 3
The Ampere --------------------- Page 3
The Coulomb -------------------- Page 4
The Ohm ------------------------ Page 4
International Ohm --------------- Page 5
International Ampere ------------ Page 5
International Volt -------------- Page 5
Ohm's Law ---------------------- Page 5
Forms of Ohm's Law -------------- Page 8
Remembering Ohm's Law ----------- Page 9
Using Ohm's Law ----------------- Page 9
Importance of Ohm's Law --------- Page 11
Practical Uses of Ohm's Law ------ Page 11

* * * * *

Many people are "marking time" in their chosen trade or profession because they haven't had the preparation to take them farther. Somebody better qualified is always ahead of them. If they but knew it, they could soon become superior in their work through home-study.

-- Webster H. Pearce

UNITS OF MEASURE

In the explanations of the preceding Lessons, the descriptions of the various actions have included quite a number of electrical units and now, we want to give you important details in regard to the relationship between some of them. As many of us are inclined to take most things for granted, it may be of benefit to begin by mentioning a few facts which are well known but seldom given much thought.

Our present civilization makes it necessary for nearly all of us to live what might be called a "Measured" life. Our time is measured in minutes, hours, days and weeks. The value of our work, as well as the things we buy and sell, is measured in dollars and cents but, to determine their value, most ordinary food and merchandise must be measured in other ways.

For solids, such as butter, sugar, and coal, 16 ounces equal one pound and 2000 pounds equal one ton but, for liquids, such as water, milk or gasoline, 16 ounces equal 1 pint, 2 pints equal 1 quart and 4 quarts equal 1 gallon. However, if you buy something like potatoes, onions or apples, 8 quarts equal one peck and 4 pecks equal 1 bushel.

There are other common measures such as 12 inches equal 1 foot, 3 feet equal 1 yard, 16-1/2 feet equal 1 rod and 1760 yards or 320 rods equal 1 mile yet, because all of these units of measure are well known, they are accepted without question. But, how would you explain that, although 16 ounces equal one pound and 16 ounces equal 1 pint, a pound is seldom equal to a pint? Also, with 4 quarts equal to 1 gallon and 8 quarts equal to one peck, why is it incorrect to assume that one peck is equal to two gallons?

HOW LONG IS AN INCH?

Thinking of separate units, suppose someone should ask, "How long is an inch?" You might say "One-twelfth of a foot" but that would not answer the question properly. You would have to explain that the United States Bureau of Standards has a bar of steel which, when at the proper temperature, has a length of exactly one yard. This is the "standard" with which all our rulers should coincide and one inch is equal to 1/36 of the length of this standard yard.

In much the same way, standards have been adopted for all common units of measure such as pounds, gallons, bushels, and so on. The actual or absolute value of each unit is not of great practical importance as long as it is accepted and used by everyone. You may not know exactly how much gasoline there is in a gallon but, touring this country in

an automobile, you know the gallon of gasoline you buy in Maine is exactly the same in quantity as the gallon of gasoline you buy in California. However, should you go to Canada, you would buy your gasoline in British gallons, each equal to 1-1/5 of our gallons.

Reviewing an earlier Lesson on Current Electricity, we made a comparison of water and electrical circuits and found three important quantities or factors. For the water circuit, there was "Pressure", measured in pounds, "Current" measured in gallons per minute and "Resistance" to the current or flow of water.

For the electrical circuit, there was "Pressure" measured in Volts, "Current" measured in Amperes and "Resistance" measured in Ohms.

For the water circuit, the units of measure were pounds, gallons and minutes, all of which are familiar and common. For the electrical circuit, the units of measure were volts, amperes and ohms which may be new to you but are easier to understand and use than some of the common units mentioned earlier in this Lesson.

The actual or absolute values of the electrical units of measure havo been arbitrarily chosen and accepted and are therefore used as standards.

WHAT PRESSURE MEANS

To compare these electrical units with those in more common use, let us start by asking what is actually meant when someone says his automobile tire is pumped up to 30 pounds pressure. Certainly he does not mean the tire weighs 30 pounds more than it did before the air was pumped in because he does not weigh the tire to measure the pressure.

As pressure means "push", a pressure of 30 pounds means that air has been forced into the tire until it is pushing outward, 30 pounds to the square inch, harder than the air on the outside is pushing inward. Thus, we can say that a pressure of 30 pounds means a difference of 30 pounds between the pressure of the air inside and the air on the outside of the tire. Because the air on the outside of the tire is the air which we breathe and as its pressure does not vary a great deal, we are apt to forget that air pressure, steam pressure and water pressure really mean the difference of pressure between the inside and outside of the container which holds them.

VOLTAGE

For electricity, a difference of pressure is known commonly as voltage because the unit of measure is the "volt". The ordinary house lighting circuits operate at 110 volts, power circuits at 220 volts and many electric street cars at 500 volts. The filaments or heaters of Radio tubes are designed for various values and, depending on the type, operate at values from 1.4 volts for battery type Radio Receivers up to 117 volts for some AC-DC types of apparatus. In every case, the number of volts indicates the difference of electrical pressure between the connections to the source of the power.

ELECTRO-MOTIVE FORCE

Quite often, voltage is called "Electro-Motive-Force" which you can think of as Electricity Moving Force, because, without pressure, there can be no current. In our future Lessons, instead of writing these three words out, we will use the abbreviation E.M.F.

POTENTIAL

Another word used in this same connection is "potential". You know that in order to make water flow from one place to another there must be a difference in level. This difference in level can be thought of as a difference in Potential. Water at any level has some potential, but the higher the level, the higher the potential. The flow of water, or current, will be from a higher to a lower level. This could be stated by saying that the water flows from a high to a low potential. Notice however, there must always be a difference in potential before there will be any current.

To cause an electrical current there must be a difference in electrical potential and for the explanations of these early Lessons, we will consider the direction of an electrical current as being from the high to the low potential. A 110 volt circuit has a difference of potential of 110 volts across it. The side of the circuit that has the higher potential is called the plus or positive. The side with the lower potential is known as the minus or negative.

THE AMPERE

The next electrical unit is the Ampere, which measures current, and remember, the water current indicates motion. We can put five gallons of water into a can but, unless there is a leak, there will be no current because the water will be stationary and there will be no motion.

However, when we turn on a faucet, and water runs out, then there is a current. In order to measure this current it is necessary to know the amount of water that runs out in a certain time. For example, if we hold a one gallon can under the faucet and find that it takes just one minute to fill it, then the current is one gallon per minute. Don't form the habit of saying a "Flow of current", because you can not have a current without a flow.

The electricity we are talking about, in these first few Lessons is always in motion. You cannot take a quart or gallon of it, put it in a bottle and examine it the way you can the water. However, the electrical current is measured just like the current of water. As the electricity is always in motion, it surely would be a lot of trouble to say so much electricity per minute, or so much per second, every time we talked about a current therefore, both the amount and the time are combined in the Ampere. The Ampere is the unit of measure for electrical current.

THE COULOMB

At this time it might be well to mention that there is an electrical unit of quantity, the Coulomb, which is similar to the gallon for water. When one coulomb of electricity flows in one second, the current equals one Ampere.

THE OHM

The third electrical unit is the Ohm, which measures Resistance. Resistance is that quality of both water and electrical circuits that tries to stop or retard the current. You can readily see that it would be easier to cause current in a smooth pipe than in a rough one. Resistance is not any part of the current, but is a part or quality of the circuit that the current is in. There is no unit for measuring the resistance of water pipes therefore, we can not make any direct comparisons to explain the Ohm.

In order to use electricity, we must always have a circuit and, no matter what we make it out of, or how we build it, it will always have some resistance. Then, in order to have a current in the circuit, there will have to be the voltage or pressure that is forcing it through and the resistance the circuit offers in trying to prevent it.

The higher the Voltage, the more Current it can force through any given circuit but, with the Voltage remaining the same, the higher the Resistance, the smaller the Current. Therefore, we can state that the Current will vary with the Voltage but opposite to, or inversely as, the Resistance.

The resistance however, is a part or quality of the circuit and does not vary the same as the voltage or current. In other words, all circuits have a definite amount of resistance, the exact value of which will depend on the units connected in the circuit and, under ordinary operating conditions, this resistance will not vary. To change its resistance, the units of a circuit must be changed.

Before going further with the details of the relationship, we want to give you an idea of the separate units of measure known generally as "International".

INTERNATIONAL OHM

The International Ohm is defined as the resistance offered, at the temperature of melting ice, to an unvarying electric current by a column of mercury 14.452 grams in mass, of uniform cross section area and 106.3 centimeters in length.

You can think of this as being similar to the standard yard mentioned earlier in this Lesson because the specificiations are given in terms of other systems of measure such as weight, area and length.

INTERNATIONAL AMPERE

The International Ampere is defined as the current which, when passed through a solution of silver nitrate in water will deposit silver at the rate of 0.00118 gram per second. These definitions are given in terms of metric units and, for comparison, 1 centimeter equals .3937 inch or 1 inch equals 2.54 centimeters while 1 gram equals .03527 ounce and 1 ounce equals 28.3495 grams.

INTERNATIONAL VOLT

The third unit, the International Volt, is the electrical pressure which, when applied steadily to a conductor whose resistance is one International Ohm, will produce a current of one International Ampere. This definition is most important because it contains the relationship between the three primary units of Resistance, Current and Voltage.

OHM'S LAW

For practical work, this relationship is more important than the absolute value of the units considered separately and is known generally as "Ohm's Law". Notice carefully, the definition states that when a circuit, with a resistance of one ohm, has a current of one ampere, there is an electrical pressure of one volt across it.

Because but one of each type of unit is included, Ohm's Law is frequently worded to read, "When a pressure of one volt forces a current of one ampere through a circuit, that circuit has a resistance of one ohm".

Rereading Ohm's Law and checking back on our former explanations, if one volt can force a current of one ampere through a circuit with a resistance of one ohm, then two volts could force two amperes through this same circuit.

Thinking along similar lines, if the resistance of the circuit was doubled, then the original one volt pressure could cause a current of but $\frac{1}{2}$ ampere. Thus, the actual amount of current in a circuit will depend upon the relative values of the voltage which is trying to cause it and the resistance, which is trying to prevent it.

From this standpoint, Ohm's Law can be reworded to read:- "The current in an electrical circuit is equal to the voltage across the entire circuit divided by the Resistance of the entire circuit.

To save both time and space, the value of voltage, or Electro-Motive Force is often represented by the letter "E", the value or "Intensity" of the current by the letter "I", and the value of the resistance by the letter "R". Remember here "E" represents the number of Volts, "I" the number of Amperes and "R" the number of Ohms.

With this in mind, we can not only simplify Ohm's Law, but write it in three different ways.

(a) Current equals Voltage divided by Resistance.

(b) Amperes equals Volts divided by Ohms.

(c) $I = \frac{E}{R}$

This is a general law which applies to all values of Voltage and Resistance and, regardless of what the actual numerical values may be, their relationship to each other remains the same. That is why we can use the form at "C" which requires a minimum of writing.

To show you how this works out, we can go back to the conditions of the examples mentioned above. For the first, we assumed a pressure of two volts and a resistance of one ohm and said there would be a current of two amperes.

To use form "C" for this particular circuit, the voltage, represented by the letter "E" has a value of "2" while the

resistance, represented by the letter "R" has a value of "1". Knowing these numerical values, we can substitute them for the corresponding letters:-

$$I = \frac{E}{R}$$

$$I = \frac{2}{1}$$

$$I = 2 \text{ amperes}$$

For the second example, we assumed a pressure of one volt and a resistance of 2 ohms so that, for this circuit, E is equal to "1" and R is equal to "2". Substituting these numbers for the corresponding letters we have:-

$$I = \frac{E}{R}$$

$$I = \frac{1}{2} \text{ ampere}$$

Although the solution of these examples may seem extremely simple, we want you to study them carefully because the same general plan is used for most Radio and Electronic calculations.

The expression,

$$I = \frac{E}{R}$$

represents the relationship between current, voltage and resistance in all circuits and is known as a "Formula" or an "Equation". The equality sign, "=", in the center, indicates that everything to its left, known as the first member, has the same value as everything in the second member to its right.

Thus, the above expression is read as "I" equals "E" divided by " R". Or using the values which the letters represent, it is read as, "The current in a circuit is equal to the voltage applied to the circuit divided by the resistance of the circuit."

The equation or formula is therefore nothing but a simple and practical method of stating Ohm's Law. Simple, because single letters are used to represent the values of current, voltage and resistance. Practical, because by substituting actual values in place of the letters which represent them, desired values can be calculated by simple arithmetic.

For example, the common 60 Watt electric lamp bulb is made to operate at 120 Volts and has a resistance of 240 Ohms. To find the amount of current it will allow, the formula can be used. Here, the voltage "E" has a value of 120 and the resistance "R" a value of 240. Writing these numbers in place of the letters, the formula becomes,

$$I = \frac{120}{240}$$

Looking at this fraction, you will see that 240 is exactly twice 120 and therefore it can be reduced to 1/2. Thus, by using the formula we have been able to find the value of current in the lamp bulb. As "I" represents the value of the current in amperes, the solution of this problem would be written as

$$I = \frac{1}{2} \text{ ampere}$$

This example illustrates the fact that, with three values in the formula, two of them must be known in order to find the third.

FORMS OF OHM'S LAW

Thinking of the relationship between Resistance, Current and Voltage, as well as the action of the resistance in a circuit, Ohm's Law can be worded to read:

2. (a) The resistance of a circuit is equal to the voltage across the circuit divided by the current in it.

   Or, using the names of the units,

   (b) Ohms equal Volts divided by Amperes,

   and using the letters, to represent these units,

   (c) $R = \frac{E}{I}$

Following the same plan, the relationship between Voltage, Current and Resistance can be expressed by

3. (a) The voltage across a circuit is equal to the current times the resistance.

   (b) Volts equal Amperes times Ohms.

   (c) $E = I \times R$

but, for this circuit, as E has a value of 6 volts and I a value of 2 amperes, we can substitute the numbers for the corresponding letters and write

$$R = \frac{6}{2}$$

which indicates that 6 is to be divided by 2 and, using simple arithmetic, 6 divided by 2 is equal to 3. Therefore, for this circuit,

$$R = 3 \text{ (ohms)}$$

Following the same plan, if we know the voltage and resistance but want to find the current, we would use the form of Ohm's Law which states.

$$I = \frac{E}{R}$$

Keeping the values of the example above, E equals 6 volts and R equals 3 ohms therefore, substituting the numbers for the letters,

$$I = \frac{6}{3}$$

$$I = 2 \text{ (amperes)}$$

Going further, if we know the current "I" is 2 amperes and the resistance "R" is 3 ohms, to find the voltage "E", we would use the form of Ohm's Law which states,

$$E = IR$$

Substituting the numbers for the corresponding letters,

$$E = 2 \times 3$$

$$E = 6 \text{ (Volts)}$$

All problems with Ohm's Law are worked out on exactly the same plan by replacing the letters E, I or R with numbers which represent the values of some particular circuit. One important point to remember in this connection is, when using a number which represents the value of the resistance of an entire circuit, it is necessary to use numbers which represent the voltage across or the current in the entire circuit.

Should the problem call for the resistance of some part of a circuit, then it is necessary to use numbers which represent

the voltage across or current in that same part of the circuit only.

IMPORTANCE OF OHM'S LAW

Perhaps you are wondering about the practical benefits of a knowledge of Ohm's Law but, as you advance in your studies, you will find it is the basis for practically all circuit calculations as well as a great many tests.

For example, most Radio circuits include a number of resistances with color coding to indicate their value in ohms. By measuring the voltage across it and applying Ohm's Law, the current in a resistance can be calculated. Some models of AC-DC Radios require a reduced line voltage for the operation of the tube heaters. Knowing the value of current and the necessary reduction of voltage, Ohm's Law is used to calculate the required value of resistance.

These are but two of an almost unlimited number of applications and, as nearly all circuit conditions are based on Ohm's Law, its importance will become more evident as you progress with your studies.

PRACTICAL USES OF OHM'S LAW

As you will learn soon, most Radio circuits are designed to provide definite values of voltage or allow definite values of current to permit the proper operation of the various components. As Ohm's Law states the relationship between Voltage, Current and Resistance and, when two values are known, makes it possible to calculate the third, its use is a necessity for practical work. All three forms of the Law are equally important, and the following examples will illustrate their use.

How many volts will be required to force a current of 2 amperes through a circuit having a resistance of 50 ohms? Here we know the current and resistance, but want to find the voltage. We also know that voltage equals current times resistance, therefore in this case, replacing the words with the numbers we can say that the voltage must equal 2 times 50 which is 100.

How many ohms resistance will be necessary to allow but 5 amperes in a circuit which has 500 volts across it? This time we know the voltage and current, but want to find the resistance. Resistance equals voltage divided by Current, so that for this circuit, the resistance equals 500 divided by 5 which is 100 ohms.

How much current will there be in a circuit with 20 ohms resistance and a pressure of 10 volts? We are given the resistance and voltage but want to find the current. Current equals voltage divided by resistance, so that for this circuit, the current is equal to 10 divided by 20 which is .5 ampere.

Do not leave this Lesson until you are satisfied you understand the relationship between Volts, Ohms and Amperes, as expressed by Ohm's Law because, in the following Lesson, we are going to use it for our explanations of the common types of electrical circuits.

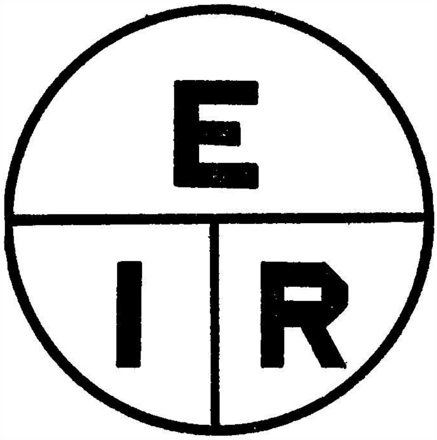


FIGURE 1

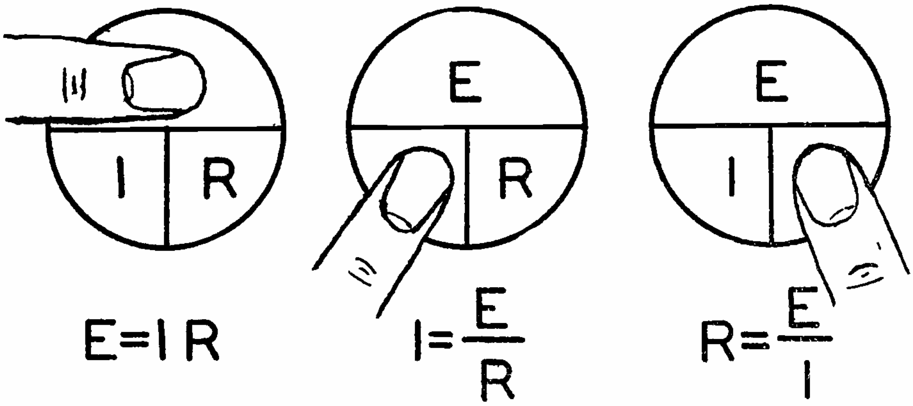
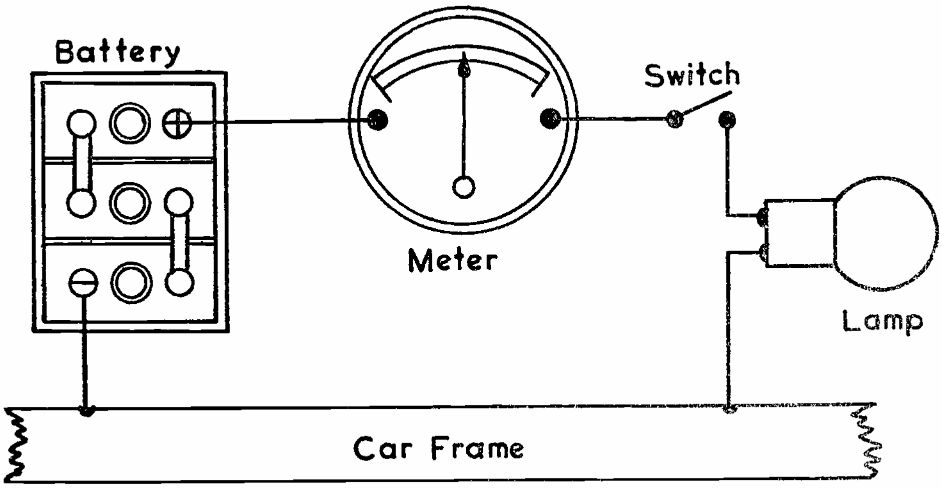


FIGURE 2



FDM-12

FIGURE 3

DE FOREST'S
TRAINING, Inc.

LESSON FDM - 13
SERIES AND PARALLEL CIRCUITS

Founded 1931 by

RADIO FUNDAMENTALS

LESSON 13

SERIES AND PARALLEL CIRCUITS

The Series Circuit ----------------------------------Page 1
Connecting Water Pipes in Series ------------------Page 1
Water Pressure in a Series Circuit ----------------Page 1
Water Current in a Series Circuit -----------------Page 2
Resistance in Pipe --------------------------------Page 2
Connecting Electrical Devices in Series -----------Page 3
Current in a Series Circuit -----------------------Page 3
Voltage in a Series Circuit -----------------------Page 4
Resistance in a Series Circuit --------------------Page 5
Common Series Circuits ----------------------------Page 6
The Dropping Resistor -----------------------------Page 7
Parallel Circuits ---------------------------------Page 8
Connecting Water Pipes in Parallel ----------------Page 8
Current in a Parallel Water Circuit ---------------Page 9
Resistance of a Parallel Water Circuit ------------Page 9
Parallel Electrical Circuits ----------------------Page 10
Current in the Branches of a Parallel Circuit -----Page 12
Current in a Parallel Circuit ---------------------Page 12
Resistance of a Parallel Circuit ------------------Page 12
Conductance of a Parallel Circuit -----------------Page 13
Branches with Equal Resistance --------------------Page 15
Parallel Series Circuit ---------------------------Page 15
Series Parallel Circuits --------------------------Page 16

* * * * *

Reading is to the mind what exercise is to the body. As by the one, health is preserved, strengthened and invigorated: by the other, virtue (which is the health of the mind) is kept alive, cherished and confirmed.

---- Addison

THE SERIES CIRCUIT

From the Lessons already studied, you know now that, in order to use electrical energy, we must have a circuit first of all. In this circuit there will be some source of electric pressure, units for changing the electricity into useful form, switches to control the current and wire to connect the various parts.

Suppose you had three or four Radio tubes, the heaters of which were to be operated from one voltage supply. There are many different ways you could connect them up but we are going to divide all of the methods of connection into three general classes called, Series, Parallel or combinations of both known as "Series Parallel" and "Parallel Series". The Parallel connection is often called "Multiple" but, to make our explanation as simple as possible, we are going to use only the name Parallel.

You may have seen or heard of some very complicated electrical circuits but, in every one of them, all of the units were connected in series, parallel or a combination of both.

In this Lesson, we are going to explain the action in an electrical circuit in which the units are connected by these methods and, here again, the conditions in a water circuit will help to build the ideas clearly in your mind.

CONNECTING WATER PIPES IN SERIES

In Figure 1, we show a hot water system, installed in a three story house, with the supply pipe coming into the basement and a feeder running up to the first floor where the heater is placed. Inside the heater there is a coil of pipe through which the water passes, while being heated. From the heater the water goes up to the third floor where it is used in the bath room.

We will imagine there has been trouble in getting the hot water up to the bath room and, to find out just what is wrong, we have to put pressure gauges at various places along the pipe.

WATER PRESSURE IN A SERIES CIRCUIT

The first gauge, G-1, right on the supply pipe where it enters the building, shows a pressure of 20 lbs. The gauge, G-2, on the feed pipe near the basement ceiling, shows but 18 lbs. G-3, at the intake end of the heater, reads 14 lbs., while G-4, at the heater outlet, reads but 9 lbs. The faucet on the top floor is turned on while we are taking these readings and, although a small stream of water runs out, the gauge G-5 reads 0.

We know that it takes pressure to force the water up in the building and it also takes pressure to force water through a pipe. These gauges show us just what happens. We find that G-2, at the basement ceiling reads 2 lbs. less than G-1, which means that it takes 2 lbs. pressure to force the water through the supply pipe and up into the feed pipe. Gauge G-3, at the heater, reads 4 lbs. less than G-2 to show us that it takes 4 lbs. pressure to force the water up to the heater. As G-1 reads 20 lbs., and G-3 shows 14 lbs., we can say that 6 lbs. pressure is lost between the supply and the heater.

As the pipe inside the heater is rather small, with many turns and bends in it, we are not surprised to see that G-4 reads 5 lbs. less than G-3. By the time the faucet and G-5 are reached, the pressure is all gone but the water, forced up to the faucet, runs out slowly.

WATER CURRENT IN A SERIES CIRCUIT

As far as the current is concerned, you can easily understand that no more water can come into the piping at the supply, than runs out at the faucet therefore, the current of water must be the same through all of the pipe.

RESISTANCE IN PIPE

We call this a series arrangement because there is but one path for the current of water. All of the pipe offers some resistance to the current and, having but one path, the resistance of the entire circuit must be equal to the sum of the resistances of all the different pieces of pipe used.

The action that we have just explained will take place all along the supply pipe even though it is perfectly level. For example, in Figure 2, the supply tank is 50 feet above the feed and the pipes numbered 1, 2, 3, 4 and 5 supply water to different houses. With no other place to go, the water will naturally come up in all of the pipes to the same height as it is in the tank but, when the outlet is opened, it makes a big difference.

As it is much easier for the water to flow out of the outlet than to go up into the numbered pipes, we find the level of the water in pipe 1, is a little lower than the level in the tank. In pipe 2, it is still lower and the further we move away from the tank, the lower the water level in the feed pipes. A feed pipe, placed right at a distant outlet, would have but little if any water in it.

Figure 2 is just another way of showing you that it takes pressure to force a current of water through a pipe and the loss of pressure here, as we move further away from the supply

tank, is just about the same as the loss of pressure shown in Figure 1. The idea we want you to remember about these two water circuits is that it requires pressure to force a current of water through a pipe and while the current is the same all the way through, the pressure is used up, or lost, all the way along the circuit.

To check back on these actions we can say that,

1. The pressure lost in a series circuit is equal to the sum of the pressures lost in all the parts of the circuit.

2. The current in a series circuit is the same in all parts of the circuit.

3. The resistance of a series circuit is equal to the sum of the resistances of all the parts of the circuit.

CONNECTING ELECTRICAL DEVICES IN SERIES

An electrical series circuit is very similar to the water circuit of Figure 1 and, keeping it in mind, we want you to look at Figure 3. Here our circuit consists of a source of voltage "A", an ammeter to measure the current, a switch and four Radio tube heaters. To simplify our explanation we will assume each heater requires 1 ampere at $1\frac{1}{2}$ volts for proper operation and will think of the arrangement as the heater circuit of a four tube Radio unit such as a small Receiver.

A voltmeter is necessary to measure the electrical pressure across different parts of the circuit and we want to remind you of the two important things to remember about meter connections. The ammeter, used to measure currents, is connected in series with the circuit so that all the current must pass through it. The voltmeter, used to measure electrical pressure, which is the difference of pressure between two points, is connected across, or in parallel to, the points we want to test.

CURRENT IN A SERIES CIRCUIT

Assuming that the voltage of the supply is of the proper value, we close the switch and, as all the heaters "glow" we feel reasonably sure the circuit is complete and operating properly. As shown in Figure 4, we notice also that the pointer of the ammeter has moved from its zero position and indicates a current of 1 ampere.

The path of the current is from positive to negative or from a high level to a low level which would be from the supply " +", through the switch, tubes and ammeter back to the supply

"-", completing the circuit. As there is but one path for the current, this is a series circuit and the current is the same in all parts. In other words, if we have a current of 1 ampere at the meter, we also have a current of 1 ampere in each one of the tube heaters and thus they are operating at their correct value.

Think of this exactly as we explained for the water circuit of Figure 1. The amount of water running out of the faucet was the same as that entering the supply pipe and here, the amount of current leaving the "+" terminal of the voltage supply is exactly the same as that returning at the "-" terminal.

As a rule for the current in an electrical series circuit, we can state: At any instant, the electrical current in a series circuit is the same in all parts of the circuit.

VOLTAGE IN A SERIES CIRCUIT

Now that we have found the value of current in the circuit of Figure 4, our next step is to find out what happens to the voltage. As voltage is electrical pressure, we need some sort of instrument for measuring it and, as previously explained, will employ a voltmeter. To check the voltage across the entire circuit, we connect the voltmeter across the terminals of the voltage supply as shown. Doing so, we find it reads 6 and thus we know the supply has a difference in pressure, between the "+" and "-" terminals, of 6 volts.

Under these conditions, we can say that there is a loss of pressure, or voltage drop, of 6 volts across the circuit. Think of this exactly the same as the loss of pressure in the water circuit of Figure 1 because here too, we want to find out just where and how much pressure is lost. To do this we connect voltmeters, which can be thought of as electrical pressure gauges, across different points of the circuit as shown in Figure 5.

When the switch is closed and the heaters are carrying their rated current, as indicated by the ammeter, we find the voltmeter across T-1 reads 1.5. This, of course, tells us that there is a difference in pressure of 1.5 volts across T-1 or, as we explained in the water circuit, it has taken a pressure of 1.5 volts to force the current through the filament of T-1. Electrically, we say there is a "voltage drop" of 1.5 volts across this tube.

Now, checking the voltmeter connected across the heater of T-2, we again find a reading of 1.5 volts, which shows us that tube T-2 also has a 1.5 volt drop across it. The same reading occurs across T-3 and also across tube T-4. For a

final test, we see there is a drop of 6 volts across all four tubes and a drop of 1.5 volts across each of them. In other words, the voltmeters show us just where the pressure is lost in forcing current through the circuit.

Following rule 1, for the water circuit, we can add these pressure drops like this.

Voltage drop across tube T-1 -	1.5
Voltage drop across tube T-2 -	1.5
Voltage drop across tube T-3 -	1.5
Voltage drop across tube T-4 -	1.5
Total Voltage drop across circuit	6.0

As the voltage across the supply measured 6 volts and we find the sum of the voltage drops around the circuit is also 6 volts, we can state the following rule for an electrical series circuit. The sum of the voltage drops around a series circuit is equal to the impressed voltage.

RESISTANCE IN A SERIES CIRCUIT

The three things that interest us in this circuit are Current, Voltage and Resistance. The ammeter shows us the Current is 1 ampere and, as there is but one path, the current is the same in all parts of the circuit.

The voltmeter, connected across the voltage supply "A" tells us that there is a difference of pressure of 6 volts between the "+" and "-" terminals. The other voltmeters across T-1, T-2, T-3 and T-4 show a loss, or voltage drop of 1.5 volts across each tube. By adding the voltage drops across the tubes, we find the total is equal to the supply voltage.

Knowing what happens to the voltage and current, our next step is to find out about the resistance in a series circuit. From your study of an earlier Lesson on Ohm's Law, you will remember that when two values, such as voltage and current, are known, the third, which in this case is resistance, can be found.

In our explanation of the voltage distribution of this circuit, we first found the total voltage drop across the circuit and will follow the same plan for the resistance. Checking back, we found the voltage across "A" was 6 volts and the current in the circuit was 1 ampere. In the explanations of an earlier Lesson, voltage was represented by the letter "E" and current by the letter "I" therefore, for this circuit we can write $E = 6$ and $I = 1$.

By Ohm's Law, resistance is equal to the voltage divided by the current or $R = E \div I$. Substituting the above values,

R = E ÷ I = 6 ÷ 1 = 6 ohms. This tells us that, in Figures 3, 4 or 5, with a pressure of 6 volts and a current of 1 ampere, the circuit must have a total resistance of 6 ohms.

Suppose now that we want to find the resistance of each tube heater. By using Ohm's Law, this is quite easily accomplished but, as we are working with only a part of the circuit, we must use only the voltage and current values of that part. When checking the voltage, we found a drop of 1.5 volts across each of the tube heaters and the ammeter showed a current of 1 ampere. As this is a series circuit, we will also have a current of 1 ampere in each heater.

Applying Ohm's Law, for tube T-1, with E = 1.5 and I = 1 ampere, we find that R = E ÷ I = 1.5 ÷ 1 = 1.5 ohms. Therefore, we can say that to force a current of 1 ampere through the heater of tube T-1 with a resistance of 1.5 ohms, requires a pressure, or voltage drop, of 1.5 volts. As the voltage drop and current for each of the heaters of tubes T-2, T-3 and T-4 are the same as that of T-1, each must have a resistance of 1.5 ohms.

In this circuit, we have four tubes in series, each with a resistance of 1.5 ohms. Adding these separate resistances, we obtain a value of 1.5 + 1.5 + 1.5 + 1.5 or 6 ohms, which checks with the value of total resistance as found by using Ohm's Law for the complete circuit. Therefore, as another rule for an electrical series circuit, we can state, "The total resistance of a series circuit is equal to the sum of the resistances of the parts connected in series".

These three facts, or laws, apply to all electrical series circuits and we want you to go over each one until you fully understand them all.

COMMON SERIES CIRCUITS

A very common but good example of a series circuit is one type of Christmas tree lights arranged to plug into the ordinary 110 volt home lighting circuit. Usually there are seven 15-18 volt lamps connected in series which explains why, when one lamp burns out all the rest go out. With but one path for the current, the burned out lamp breaks the circuit and prevents current in the others. Notice also, seven 15-18 volt lamps in series will have a total voltage drop of 7 x (15-18) which is 105 to 126 volts.

In Radio and Electronic equipment of the AC-DC type, it is common practice to connect the heaters of the tubes in series. Although the tubes may operate at different values of voltage, all are designed for the same value of current and therefore will operate properly in series.

As you advance in your studies, you will find many other applications of series circuits therefore, be sure you understand fully the relationships between Current, Voltage and Resistance as stated in the rules given earlier in this Lesson.

THE DROPPING RESISTOR

For example, a six tube AC-DC Radio Receiver may have four tube heaters designed to operate at 6.3 volts and two designed to operate at 25 volts, all of which require a current of .3 ampere. The uniform current value makes it possible to operate them in series and, when connected this way, the total drop across them will be 6.3 + 6.3 + 6.3 + 6.3 + 25 + 25 which is equal to 75.2 volts.

To connect this circuit across the ordinary house lighting supply which, for design purposes, is assumed to provide 117 volts, we find there is a difference of 117 - 75.2 or 41.8 volts. To reduce the supply to the required value of voltage, we apply Ohm's Law to find the amount of resistance it will be necessary to add to the circuit.

We know the current is to be .3 ampere and there is an excess of 41.8 volts. Substituting these values in Ohm's Law we have:

$$R = \frac{E}{I} = \frac{41.8}{.3} = 139\frac{1}{3} \text{ ohms.}$$

By connecting a resistance of this value in series with the tube heaters, the circuit will operate properly when plugged into the common 117 volt lighting circuit. As this addition has been made to reduce the line voltage to the value required for the tube heaters, the added unit is commonly known as a "Dropping Resistor".

The calculation shows a value of $139\frac{1}{3}$ ohms is required for this example but, as ordinary commercial resistors are made with a tolerance of 10%, a 150 ohm unit would be satisfactory. In practice, this resistance may be a piece of wire wrapped around the two regular wires of the attachment cord or may be built to plug into a socket like a tube in which case it is known as a "Ballast".

Before leaving the subject of series circuits, we want to repeat the four important points that you should remember.

1. At any instant, the current in a series circuit is the same in all parts of the circuit.

2. The total resistance of a series circuit is equal to the sum of the resistances connected in series.

3. The sum of the voltage drops, across the parts of a series circuit, is equal to the voltage across the entire circuit.

4. The voltage drop, across any part of a series circuit, is proportional to the resistance of that part.

PARALLEL CIRCUITS

In the circuit of Figure 3, we had a voltage supply which developed a difference of pressure of 6 volts between its "+" and "-" terminals. With four tube heaters in series, the supply voltage was four times the value required for any one heater and, in case any part of the circuit was opened, or broken, none of the heaters would operate.

For Figure 6, we have the same four tubes connected to the supply "A" which develops but 1.5 volts. As each heater requires 1.5 volts and the supply develops 1.5 volts, each heater is connected directly across the supply. To simplify the circuit as far as possible, instead of running separate wires from the supply to each tube, we have used one wire to carry current for all of them.

Taking each of the tubes separately, there is a simple series circuit from the supply, through the heater and back to the supply again. In a circuit like this, we say the tubes are in Parallel, or Multiple, because each one is connected separately across the voltage supply.

In the usual run of Radio work, you will find parallel circuits are more common than series circuits because they allow each tube, or other unit, to be operated separately from any of the others and require much less wire than if we had a separate voltage supply for each. In much the same way, you will see but two or three wires going into the ordinary house or store building but, by connecting the lamps and other units in parallel, like the tubes in Figure 6, we can turn each one on or off without affecting any of the others.

CONNECTING WATER PIPES IN PARALLEL

To explain a parallel circuit, we will repeat the plan used for a series circuit and, to show the actions more clearly, will again make up a water circuit as in Figure 7. Here we have a supply pipe with four branches, each of which is controlled by a valve and, to be able to see how much pressure there is in the supply, a gauge has been installed.

With all of the valves closed, you can see that the pressure in all four of the branch pipes will be the same as that in the supply pipe. That is the first thing we want you to

remember about a parallel circuit. The pressure on each of the branches is the same as the pressure on the main supply pipe.

CURRENT IN A PARALLEL WATER CIRCUIT

Suppose now that we obtain a 1 gallon measure, put it under branch pipe No. 1, and open the valve just wide enough to fill the measure with water in exactly one minute. Then we know that the current of water in pipe 1 is one gallon per minute. Remember, this water has to come through the supply pipe.

Without changing the No. 1 valve, we place a 2 gallon measure, under pipe No. 2 and open valve No. 2 until the water runs out just fast enough to fill the 2 gallon measure in exactly one minute. The current of water in pipe 2 then will be 2 gallons per minute or twice as great as that in pipe 1.

Leaving both valves 1 and 2 in these positions, there will be a current of 1 gallon a minute from pipe 1, and a current of 2 gallons per minute from pipe 2 making a total current of 3 gallons per minute from both pipes. Remember here also that all of the water has to come through the supply pipe.

We now open valve 3 until there is a current of 4 gallons a minute through pipe 3, and open valve No. 4 until there is a current of 5 gallons per minute through pipe 4. Adding these currents, with all of the valves open, there will be a total current of 12 gallons per minute, all of which has to come through the supply pipe.

This brings us to the second point for you to remember; the current in the main supply of a parallel circuit is equal to the sum of the currents in the branches.

RESISTANCE OF A PARALLEL WATER CIRCUIT

Before explaining the resistance of this circuit, we want you to think back and remember the relation between current, pressure and resistance is such that, if the pressure increases the current will also increase. If the resistance is increased, the pressure remaining the same, the current will reduce. In the same way, when the resistance is reduced with the pressure remaining the same, the current will increase.

Now, with this fresh in your mind, let us look at Figure 8 where we have the same pipe arrangement as in Figure 7 but are going to let the water run into a large tank. We have closed all of the valves except No. 1, and find that the current of water through pipe 1 can be changed by opening and closing the valve. We mention this merely to bring out the

fact that the more the valve is closed, the harder it is for the water to get through and thus the current is reduced.

This can also be explained by saying that as the valve is closed, the resistance is increased and, as the valve is opened, the resistance is reduced. Even with the valve wide open, we find the current of water is but 5 gallons per minute because of the resistance of the pipe itself. While doing all this, we notice that the reading on the pressure gauge remains the same.

Here is the idea we want to emphasize. With valve 1 wide open, and all the others closed, there is a current of 5 gallons per minute through pipe 1 and also through the main supply. Should we now open valve 2, no matter how much or how little water runs through pipe 2, there will be an increase of current in the supply pipe. The pressure has remained the same but opening valve 2 has increased the current in the supply, therefore the resistance must have been reduced. Of course, the resistance of pipe 1 has not changed but the resistance of pipe 2 has and therefore, taking all four pipes as one circuit, opening valve 2 has decreased the total resistance.

Opening valve 2 further, or opening valves 3 and 4 will allow still more water to run through the supply pipe and will still further reduce the resistance of the pipe circuit. With any one of the valves open, there will be some certain resistance to the current of water but, opening any other valve will reduce the resistance of the pipe circuit taken as a whole.

The rule for you to remember about this action is: The resistance of an entire parallel circuit is always less than the branch having the lowest resistance.

PARALLEL ELECTRICAL CIRCUITS

In many ways, a parallel electrical circuit is very similar to the water circuit we have just been talking about and, if you keep the water circuit in mind, you should not have any trouble with the electrical one.

In figure 9, we have three tube heaters connected very nearly like the pipes of Figure 8. The pressure gauge has been omitted because we know a 3 cell storage battery, as shown and indicated by the letter "E", develops approximately 6 volts. The water valves are replaced by switches and the tube heaters carry the electrical current. Therefore, to complete the circuit, the other terminals of the heaters are connected together and a wire is brought back to the negative terminal of the battery through an ammeter. Each of these tubes has a heater, or filament, which is designed to operate at 2.5 volts.

Checking over the circuit, you will find that tube T-1 requires a current of .5 ampere and when "SW1" is closed, there will be a circuit from the battery "+", through resistance "R", over to the right, down through the switch and tube heater back along the lower wire and through the ammeter to the battery "-".

So far, we have nothing but a simple, series circuit and, to simplify the explanation, we will assume resistance "R" is of such value that it produces a 3.5 volt drop, allowing 2.5 volts across the tube.

The center tube, marked T2, has a heater which requires 1 ampere, at 2.5 volts and, to follow its circuit, we open "SW1" and close "SW2". The circuit now is from battery "+" through resistance "R" over to the right down through "SW2" and "T2", along the lower wire and back, through the ammeter to battery "-". Although there is a current of 1 ampere in this circuit, again we will assume "R" has a resistance of such value as to cause a drop of 3.5 volts and allow 2.5 volts across the tube.

The left hand tube "T3", requires a current of 2 amperes, at 2.5 volts and, with switches "SW1" and "SW2" open and "SW3" closed, there is a simple series circuit from battery "+" through "R", "SW3", T3 and ammeter back to battery "-". Here again, we will assume resistance "R" provides the proper voltage drop to allow 2.5 volts across the tube.

Checking back, you will find that the battery, the resistance "R" and the ammeter are a part of all three of the current paths, or circuits, we have just traced and, with all of the switches closed, there will be current in the heaters of all three tubes. Under this condition, by starting at the right end of resistance "R", you can trace a path through any of the heaters back to the ammeter.

Thus, as each heater with its switch is connected across the resistance "R", the battery and the ammeter, in exactly the same way, they are in "Parallel". For that reason, Figure 9 is a parallel circuit and each tube heater with its switch, is a branch of the complete circuit.

Forgetting the small resistance of the connecting wires, as all three heaters, or branch circuits, are connected across the supply in the same way, there must be the same voltage across each of them.

Like the water circuit of Figure 8, the pressure, or voltage across each branch of the circuit is the same as that across the entire circuit. Therefore, the rule for the voltage

across the branches of a parallel circuit can be stated: The voltage across each of the branches of a parallel circuit is the same as the voltage across the entire circuit.

CURRENT IN THE BRANCHES OF A PARALLEL CIRCUIT

As we have already mentioned, tube T1 draws .5 ampere and, closing its switch only, the meter would show this value. Using Ohm's Law for this branch, we have resistance equals 2.5 volts divided by .5 amperes which is 5 ohms.

Tube T2 draws 1 ampere at 2.5 volts and closing its switch, with the other two open, the meter would read this value. Using Ohm's Law for this branch, the resistance equals 2.5 volts divided by 1 ampere which is 2.5 ohms.

The same conditions hold for tube T3 and with 2.0 amperes at 2.5 volts, the resistance of this branch is 1.25 ohms.

CURRENT IN A PARALLEL CIRCUIT

Closing switch "SW1", the ammeter reads .5 amperes but when switch "SW2" is closed also, the meter reading goes up to 1.5 amperes. That is to be expected because the current through both heaters has to pass through the meter to return to the supply.

Then, when switch "SW3" is closed also, the meter reading goes up to 3.5 amperes. Following the upper current values on Figure 9, there are 3.5 amperes in the resistance, "R", 2.0 amperes go down through the T3 heater, 1 ampere goes through the T2 heater and .5 ampere goes through the T1 heater. As shown by the current values on the lower wire, these various currents use the same return wire to the meter making it read 3.5 amperes.

As this same action holds for all parallel circuits, we want you to remember the general rule for the total current in a parallel circuit which states: The total current in a parallel circuit is equal to the sum of the currents in the branches.

RESISTANCE OF A PARALLEL CIRCUIT

By using Ohm's Law, we have already found the resistance of each of the branches of this circuit and now will find the resistance of them all. The ammeter shows a current of 3.5 amperes and there is 2.5 volts across the tube heaters therefore the resistance equals 2.5 volts divided by 3.5 amperes which is 5/7 or .714 ohm.

We just found the resistance of T1 was 5 ohms, of T2, 2.5 ohms and T3, 1.25 ohms but, connected in parallel, Ohm's Law shows their total resistance to be but .714 ohm.

This looks as if Ohm's Law was all wrong but you will remember for the water circuit, the more outlets we opened the less the resistance of the entire circuit. The same is true here and we can repeat the rule which states: The resistance of an entire parallel circuit is always less than that of the branch having the lowest resistance.

Ohm's Law holds true but we must be careful to use it properly. For example, to find the resistance of the entire circuit, we must know the voltage and current of the entire circuit. To find the resistance of any branch, we must use the voltage and current of that branch only.

Perhaps you are wondering about the dropping resistance R, but that is easy to figure out. We said its value was such that it caused a drop of 3.5 volts. Now we know it carries 3.5 amperes and, using Ohm's Law, have 3.5 volts divided by 3.5 amperes which is 1 ohm.

However, there is but one path for the current between the battery plus and the three tube heaters therefore the resistance "R" is in series with all of them and, like any series circuit, the resistances are added giving us .714 plus 1.0 or approximately 1.714 ohms. To check this up we need only divide the 6 volts of the battery by the 3.5 amperes in the meter to find the total resistance of the circuit is approximately 1.714 ohms.

What interests us most, at this time, is the resistances of the separate tube heaters and their total resistance when connected in parallel. While there are various methods and formulas for finding the total resistance of parallel circuits when the resistances of the branches are known, we are going to explain the conductance method.

CONDUCTANCE OF A PARALLEL CIRCUIT

By Ohm's Law, we found the resistance of the heater of the T1 tube was 5 ohms, which really means it opposes the current to the extent of 5 ohms but its ability to conduct, or carry the current, is exactly opposite to its resistance.

Read that last sentence again because it is important. All conductors have a certain amount of resistance and, the lower their resistance, the greater their ability to conduct or carry current. This ability to carry current is called "conductance"

Sometimes it is more convenient to figure conductance instead of resistance and therefore we say the heater of the T1 tube, with a resistance of 5 ohms, has a conductance of 1/5 mho. Notice here, we turned the 5 over to 1/5 and spelled "ohm" backwards, making it "mho". Whenever a number is turned over like this it is called a "reciprocal" therefore ½ is the reciprocal of 2, ¼ is the reciprocal of 4 and so on.

You already know the total current of a parallel circuit is equal to the sum of the currents in the branches of the circuit and therefore the ability to carry current, or the conductance of a parallel circuit, must be equal to the sum of the conductances of the branches.

Going back to Figure 9, the T1 tube branch, with a resistance of 5 ohms has a conductance of 1/5 mho, the T2 branch with a resistance of 2.5 ohms has a conductance of 1/2.5 or 2/5 mho and the T3 branch, with a resistance of 1.25 or 5/4 ohms has a conductance of 4/5 mho. The total conductance will be the sum of these three and, as the fractions already have "5" as a common denominator, we simply add them. Thus 1/5 mho + 2/5 mho+ 4/5 mho equals a total of 7/5 mhos.

As conductance is the reciprocal of resistance and the total conductance is 7/5 mhos, the total resistance must be 5/7 ohm. Dividing 5 by 7. to reduce the fraction, gives a result of .714 ohm, which checks with our former application of Ohm's Law for 2.5 volts at 3.5 amperes.

Here is another method by which you can arrive at the same values. Instead of the supply and resistance of Figure 9, suppose the tubes were connected across a supply which developed an electrical pressure of exactly one volt.

Then, by Ohm's Law, the T1 tube, with a resistance of 5 ohms would have a current of 1/5 ampere, the T2 tube heater, with a resistance of 2.5 ohms would have a current of 1/2.5 ampere and the T3 tube, with a resistance of 1.25 ohms would have a current of 1/1.25 or 4/5 ampere.

The total current in the circuit would be 1/5 plus 2/5 plus 4/5 which, as we explained before, is equal to 7/5 amperes. These values are exactly the same as those given for the conductances above. Therefore, you can think of the conductance of a circuit, or branch, in mhos as numerically as equal to the current the circuit or branch will carry at a pressure of 1 volt.

The rule for the conductance of a parallel circuit can be stated: The conductance of a parallel circuit is equal to the sum of the conductances of its branches.

BRANCHES WITH EQUAL RESISTANCE

Perhaps the most common tube heater circuit is made up with several tubes of the same type connected in parallel. In that case, the total resistance of the circuit is equal to the resistance of one heater divided by the number of tubes.

For example, suppose in Figure 9 all three tubes were like T2 with a heater resistance of 2.5 ohms. Then, the total resistance of the circuit would be 2.5 divided by 3 which is .833 ohm.

Let's see if that is correct. By Ohm's Law, at 2.5 volts, there will be 1 ampere in each heater and with three tubes the total current will be 3 amperes. Then the total resistance will be 2.5 volts divided by 3 amperes which is .833 ohm as above.

A common maintenance job is to replace or install a "Dropping" or "Current Limiting" resistor in the position of "R", Figure 9, and the explanation just given will often be of great help.

PARALLEL SERIES CIRCUIT

Unfortunately, all circuits are not built on the simple plans of Figures 3 and 6 but contain various arrangements of series and parallel connections. To give you an idea of how this is done, suppose we are required to operate three different types of tubes using a 6 volt battery as a supply. Although the common 3 cell storage battery develops 6.3 volts, for simplicity it is customary to consider it as 6 volts. Therefore, we will assume this value in our explanations of Figures 10 and 11. For the circuit of Figure 10, the heater of one tube requires .25 ampere at 5 volts, another requires 1 ampere at 2.5 volts and the third requires .25 ampere at 2 volts.

Thinking first of a series connection, we see the required currents are not the same and no combination of heater voltages will add up to an even value of 6. Therefore, we decide to use the parallel connection of Figure 6 but also make use of an additional resistance as explained for Figure 9.

Following this plan, we arrive at the arrangement of Figure 10 with branch "AB" that contains the 5 volt, .25 ampere tube, "T1", in series with R1. Branch "CD" contains the 2.5 volt, 1 ampere tube, "T2", in series with R2 while branch "EF" contains the 2 volt, .25 ampere tube, in series with R3.

Our job is to find what values of resistance are necessary for R1, R2 and R3 in order that the tube heaters will operate under the required conditions of voltage. As a whole, the circuit may appear complicated but, by taking each branch separately, we have nothing but a simple series circuit.

Starting with branch AB, we know the supply develops 6 volts and the heater requires a drop of 5 volts. From our previous explanation of a series circuit, we know there must be a drop of 1 volt across R1 which, connected in series with T1, will also carry a current of .25 ampere.

Thus, we know R1 requires 1 volt drop and carries a current of .25 ampere. Substituting these values into Ohm's Law, we divide the voltage by the current and find a resistance of 4 ohms is necessary.

Following another method, we know the tube heater has a resistance of 5 volts divided by .25 ampere or 20 ohms and, to allow .25 ampere at 6 volts, the branch "AB" must have a total resistance of 6 volts divided by .25 ampere or 24 ohms. R1 must therefore make up the difference and be equal to 24 - 20 or 4 ohms.

Following the same plan for branch "CD", R2 must cause a voltage drop of 6 - 2.5 or 3.5 volts while carrying a current of 1 ampere. Substituting in Ohm's Law, its resistance must be equal to 3.5 volts divided by 1 ampere or 3.5 ohms.

The value of resistance R3 can be calculated on the same general plan and, if you care to figure it out, you will find it requires 16 ohms.

Analyzing the entire circuit, you will find it consists of three parallel branches, each of which consists of a tube heater in series with a resistance. Thus there are three series circuits connected in parallel, an arrangement sometimes known as "Parallel Series".

SERIES PARALLEL CIRCUITS

In contrast to the arrangement of Figure 10, you will find some circuits in which various units are connected in parallel and the parallel groups connected in series to each other to make up a "Series Parallel" arrangement.

The variations of circuit arrangements are almost unlimited and, for example, in a circuit like that of Figure 10, it is quite common practice to use one large unit instead of three separate resistors. As shown in Figure 11, by making connections at the proper points, the correct operating conditions can be obtained.

We will assume the tubes of Figure 11 are the same as those of Figure 10, T1 requiring .25 ampere at 5 volts, T2, 1.00 ampere at 2.5 volts and T3, .25 ampere at 2 volts. The battery remains the same also but, tracing the paths of current, you will find a difference. Here, the current for all three tubes

must pass through section R1 from battery "+" to junction "A". At this point, the current for T1 passes on through T1 to junction "B" and back to the battery "-", completing its circuit. From junction "A", the current for T2 and T3 will pass through section R2 to junction "C" and here, the current for T2 will pass on through junction "D" and back to battery "-". From junction "C" the current for T3 will pass through section R3, junction "E" and the tube, to junction "F" and back to battery "-".

In the tracing of current paths, it may help you to think of the wires as water pipes and the battery or other supply as a water pump. You can then imagine that the water leaves the pump at the "+" or positive terminal, flowing through the various pipes at rates of so many gallons per minute. To make the comparison complete, you can consider that all of the water must be returned to the pump in order to be recirculated through the system of pipes.

Checking back on this action and using the current values given above, R1 will carry .25 + 1.00 + .25 for a total of 1.5 amperes. Neglecting the other parts of the circuit for a moment, R1 is in series with T1 across a 6 volt supply. Following the rules for series circuits, with a required 5 volt drop across T1 there must be a drop of 6 - 5 or 1 volt across R1. Thus, to produce a drop of 1 volt with a current of 1.5 ampere, R1 must have a resistance of 1 volt divided by 1.5 ampere, or 2/3 ohm which can be written .67 ohm.

Thus we have 5 volts across junctions A-B and require 2.5 volts across C-D which means there must be a drop of 5 - 2.5 or 2.5 volts across R2. As already explained, R2 carries the current for T2 and T3 which, from values given, is equal to 1 + .25 or 1.25 amperes. Substituting in Ohm's Law, the required resistance for R2 is equal to 2.5 volts divided by 1.25 amperes which is 2 ohms.

Following the same plan, with 2.5 volts across C-D and a required 2 volts across E-F, there must be a drop of 2.5 - 2 or .5 volt across R3. However, R3 carries only the .25 ampere of current for T3 and again substituting in Ohm's Law, we find its value should be .5 volt divided by .25 ampere or 2 ohms.

We want you to pay particular attention to the paths of current or what is often called the "Distribution" of current because that is extremely important in the analysis of all except simple series circuits. As circuit action forms the basis for most Radio and Electronic work, for our next Lesson, we will give you further details of similar circuits which are in common use.

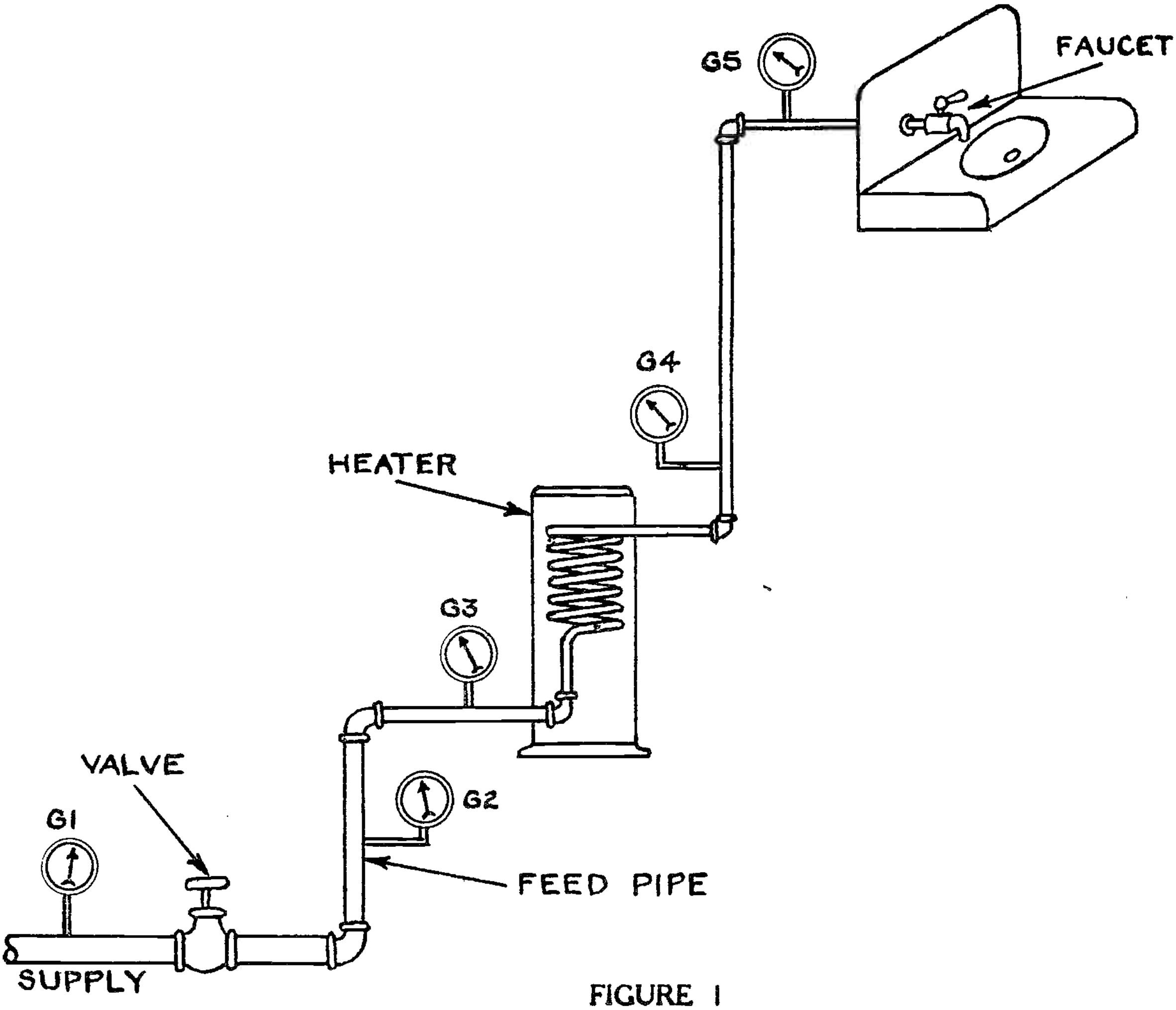


FIGURE 1

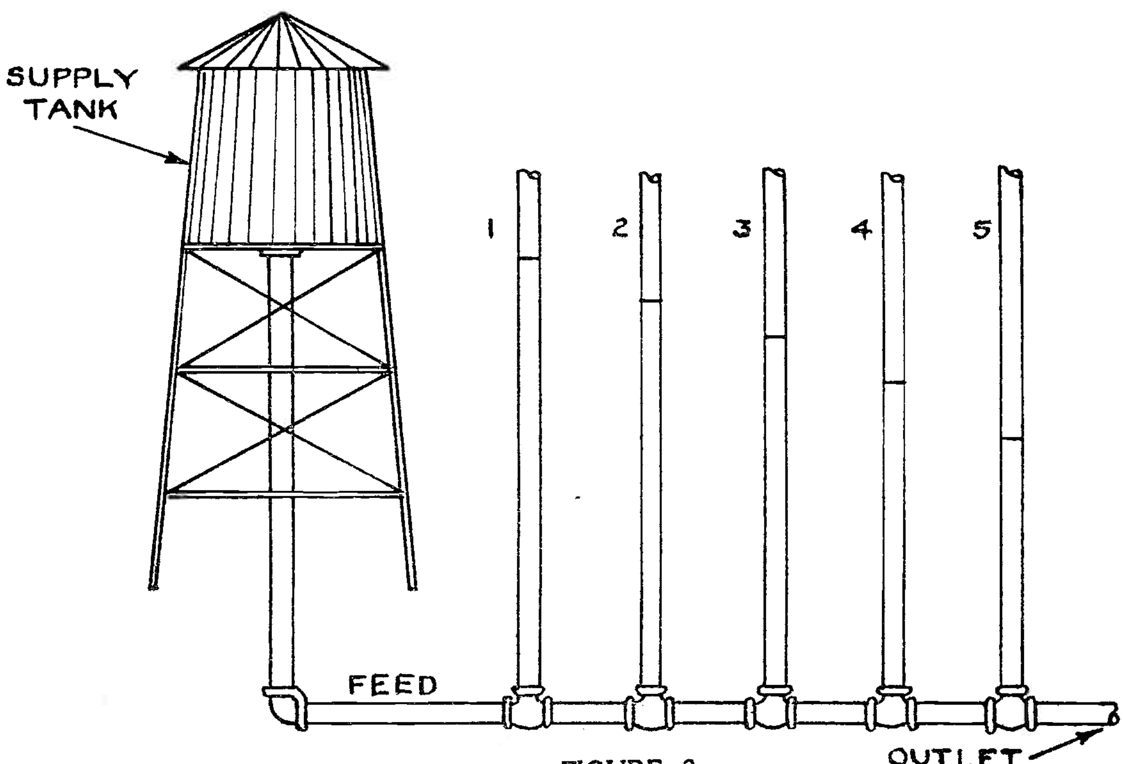


FIGURE 2

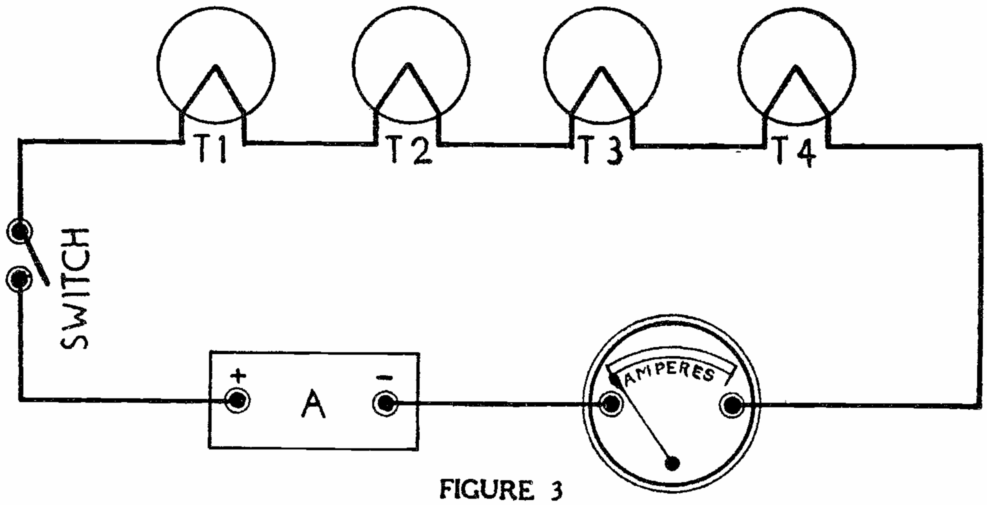


FIGURE 3

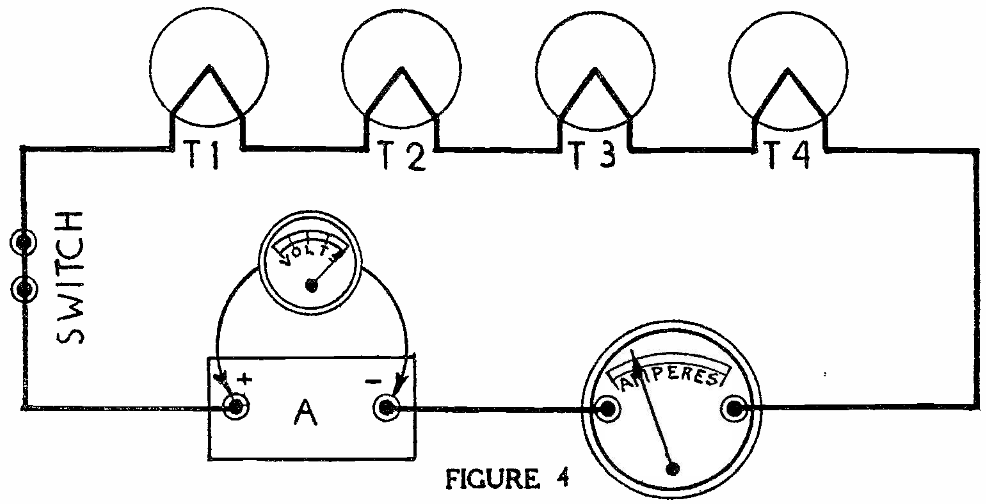


FIGURE 4

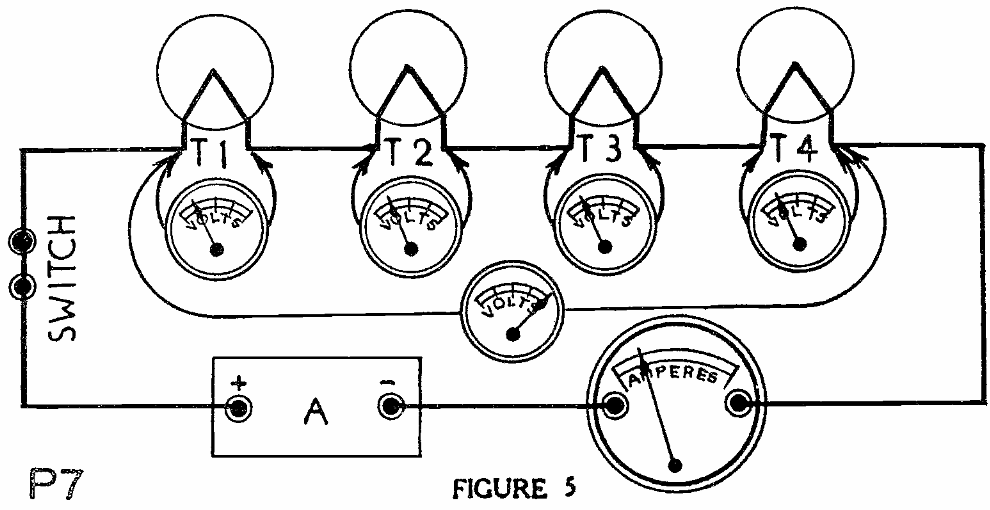


FIGURE 5

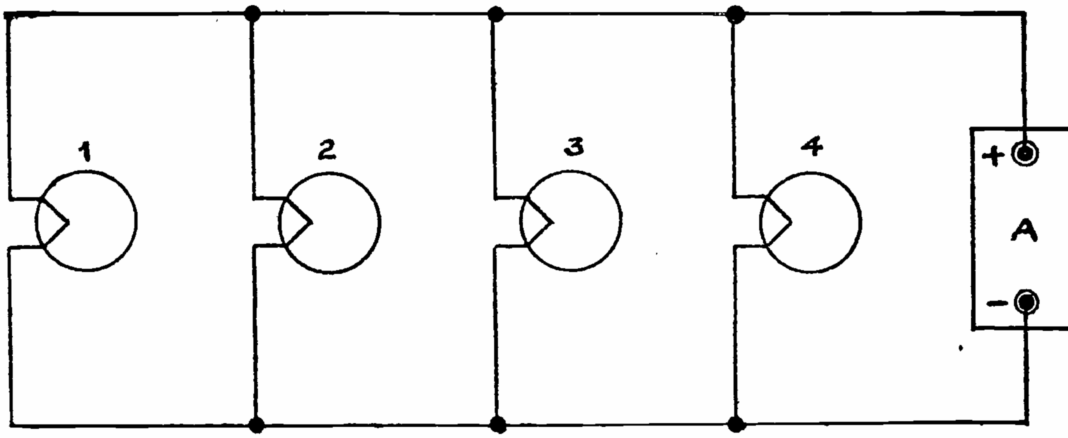


FIGURE 6

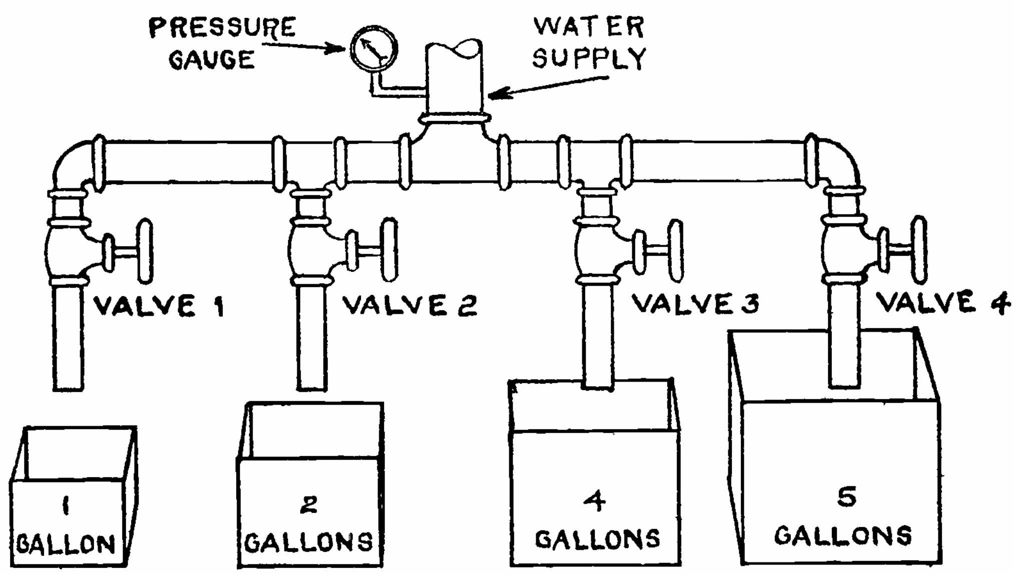


FIGURE 7

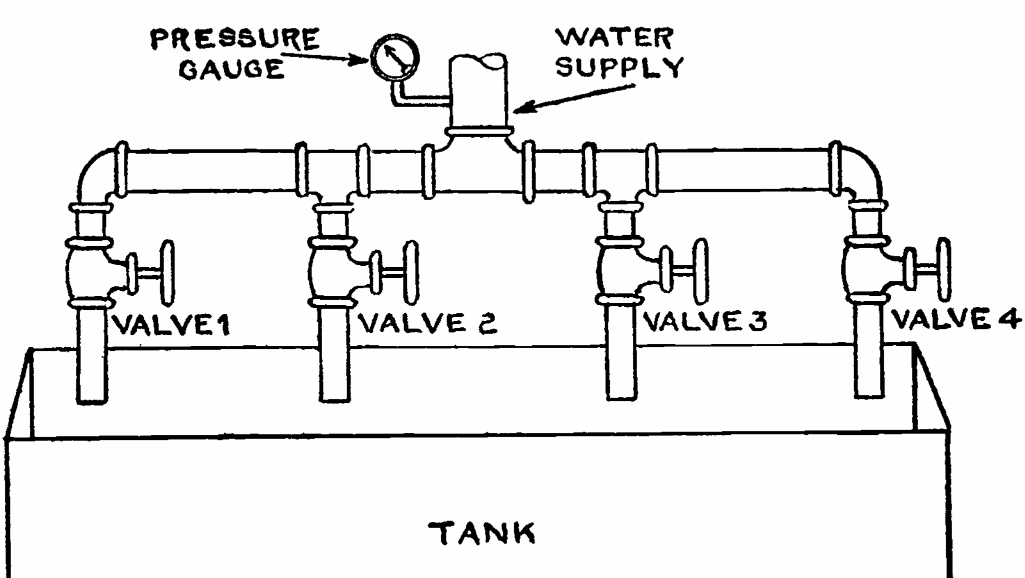


FIGURE 8

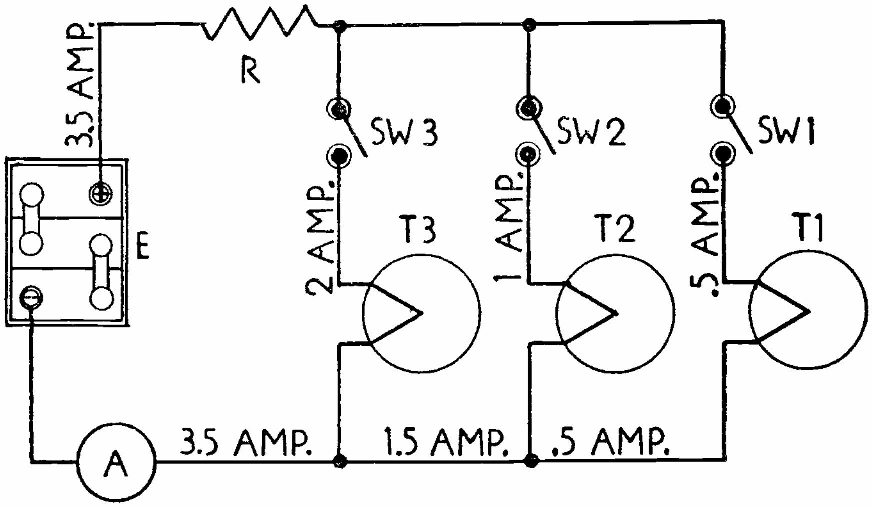


FIGURE 9

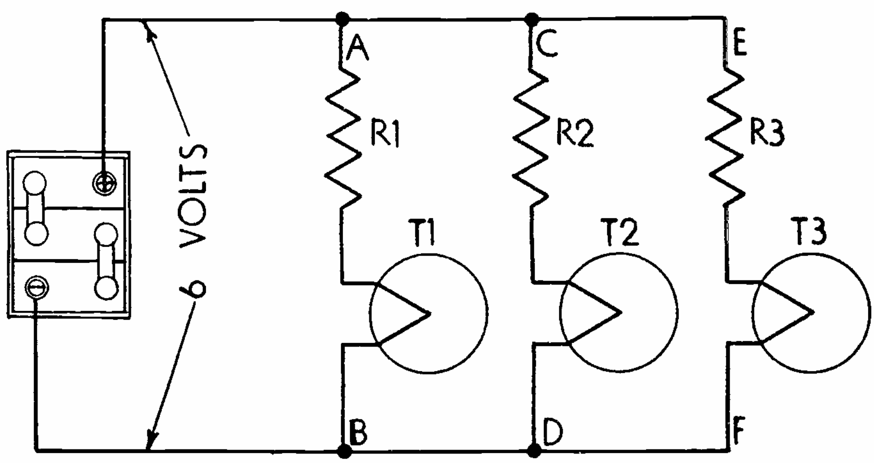


FIGURE 10

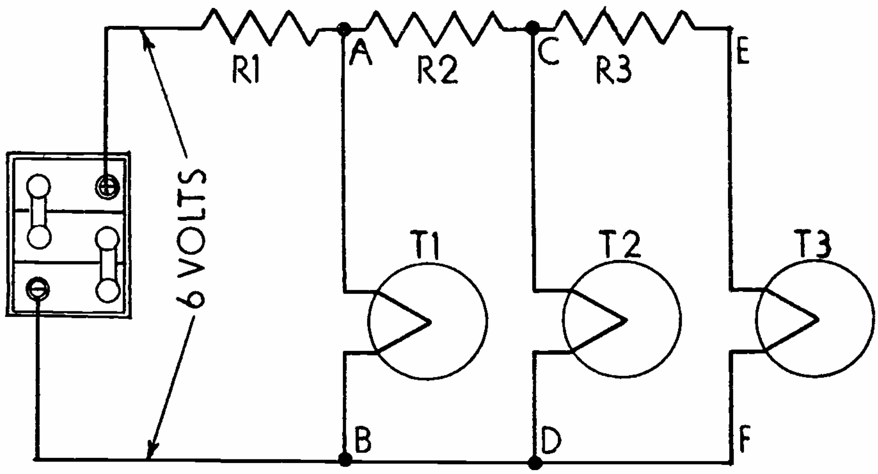


FIGURE 11

DE FOREST'S
TRAINING, Inc.

LESSON FDM - 14
KIRCHHOFF'S LAWS

• • Founded 1931 by • •

RADIO FUNDAMENTALS

LESSON 14

KIRCHHOFF'S LAWS

Series Circuits ------------------------------ Page 1
Voltage Drop ------------------------------ Page 3
Parallel Circuits ------------------------------ Page 5
Combination Circuits ------------------------------ Page 6
Voltage and Current Relations ------------------ Page 7
Resistances for Voltage Drops ------------------ Page 8
Kirchhoff's Laws ------------------------------ Page 12
Voltage Dividers ------------------------------ Page 13
Bias Voltage ------------------------------ Page 18

* * * * *

On some street cars there is the sign, "Pay as you enter". It would be a good thing if that sign were pasted over every career in life. For you get only what you pay for, and pay for in advance.

In any calling of life, the money, or study, or pains, or whatever it is, must first be paid before the rewards come.

--- Dr. Frank Crane

In the former Lessons, we have given you a general explanation of Electrical Circuits, the main principles of their operation and the general methods of connection. Perhaps you do not fully appreciate the importance of this subject but let us remind you that, no matter what the purpose or type of any electronic unit, it must be a part of some circuit.

The earlier explanations included also the general laws or principles which apply to Series and Parallel Circuits and emphasized the importance of Ohm's Law. For this Lesson therefore, we are going to present additional details to show how these laws and principles are applied for the solution of practical circuit problems.

Let us repeat, all Radio and other Electronic units consist mainly of a group or arrangement of electrical circuits, any one of which may be classed as Series, Parallel or a combination of both. In order to do intelligent work in design, installation, operation or repair, you must be able to trace circuits and know how to calculate the resistance, current or voltage drop of each circuit or any of its parts.

This may sound like a large order but, in the following explanations, you will find that it requires only the application of the various laws, rules and principles of the former Lessons. Therefore, to eliminate the necessity of a separate review, some of the explanations, rules and illustrations given here, have been taken from the former Lessons.

SERIES CIRCUITS

Starting with Figure 1 of this Lesson, we have a simple series circuit, made up of the filaments of 5 tubes and a resistance, connected across an ordinary 110 Volt House Lighting circuit. As we will explain in the later Lessons, this circuit is commonly used in the "Universal" or "AC-DC" types of Radios, Amplifiers and similar units.

The tubes are of the "6 Volt" types having filaments designed to operate at 6.3 volts with a current of .3 ampere. These values bring up the first problem because the circuit has a 110 volt supply yet there must not be more than 6.3 volts across the filament of each tube. As the current is the same in all parts of a series circuit, the entire arrangement of Figure 1 must have sufficient resistance to allow a current of but .3 ampere at 110 volts.

By Ohm's Law, we know that resistance equals voltage divided by current and thus, for the entire circuit, the resistance must be equal to 110 volts divided by .3 ampere or 366.66 ohms which, to simplify the calculations, we will consider as 367 ohms.

Following the same plan for the filament of each tube, its resistance is equal to 6.3 volts divided by .3 ampere which is 21 ohms.

As you already know, the total resistance of a series circuit is equal to the sum of the resistances connected in series and thus, in Figure 1, the total resistance of the five 21 ohm filaments will be equal to 5 x 21 or 105 ohms. Our former calculations show the circuit requires a total of 367 ohms and, as the tubes have but 105 ohms, the resistance R must have a value of 367 - 105 or 262 ohms.

From our earlier explanations, you know that the wires, by which the units are connected, will have resistance but this value is so small, compared to that of the other parts, that for most practical work, it is disregarded.

Checking back on the work we have done, all of the units of Figure 1 are connected in series and therefore, the total resistance of the circuit is equal to the sum of the separate resistances.

Adding them up, we have

Tube 1	-	21 ohms
Tube 2	-	21 ohms
Tube 3	-	21 ohms
Tube 4	-	21 ohms
Tube 5	-	21 ohms
Resistance "R"		262 ohms
Total		367 ohms

Figuring backward by Ohm's Law, for the entire circuit, the Current is equal to Voltage divided by Resistance and here we have 110 volts divided by 367 ohms which equals .3 ampere, the value which is required. To be more mathematically accurate, 110 divided by 367 equals .2997 but, as we dropped the decimal from the calculated value of "R", we follow the same plan here and consider .2997 as .3 ampere.

As many commercial resistors are made within but 10% of their rated value and as the voltage of the common types of supply may vary by a similar amount, it is seldom necessary to use decimals in work of this kind because it is customary to purchase resistors in values of even, tens, hundreds, thousands and so on. As 10% of 262 = 26.2, then 262 + 26.2 = 288.2 and 262 - 26.2 = 235.8, a 275 ohm or even a 300 ohm resistor might be installed in the circuit of Figure 1.

This difference between the commercial and calculated values of a resistance may seem somewhat contradictory but you will find it works out very well in practice. In this case, the

higher value of resistance would provide protection against high supply voltages. Therefore, unless special instructions are given, you need carry out your calculations only until they contain three numbers, regardless of the position of the decimal point.

Applying this rule to the former example we have,

$$\text{Total } R = \frac{E}{I} = \frac{110}{.3} = 366 \text{ ohms}$$

$$\text{Tube } R = \frac{E}{I} = \frac{6.3}{.3} = 21.0 \text{ ohms}$$

$$I = \frac{E}{R} = \frac{110}{367} = .299 \text{ amps.}$$

For simplicity, we have not always followed this rule in our explanations but will allow full credit for all examination problems worked by this plan.

VOLTAGE DROP

One action which often causes confusion is that which is known as "Voltage Drop" and therefore we want to use the simple circuit of Figure 1 to show how it works out.

To begin, we show a 110 volt supply which means there is a difference in electrical pressure of 110 volts across its two terminals. Thinking of one terminal as positive, or having the higher potential, there will be a drop of 110 volts between it and the negative terminal or wire. As far as the circuit is concerned, this drop is due to the voltage which is lost in forcing current through the resistance of the various parts.

To find out exactly what happens, you must remember that the current is the same in all parts of a series circuit and one form of Ohm's Law states that Voltage equals Current times Resistance. The values of the different resistances have already been listed and, to find the loss or "Voltage Drop" across each of them, we need only multiply by the value of current in amperes.

Following this plan, we find

Across T_1	– 21 ohms x .3 amp. =	6.3 volts
Across T_2	– 21 ohms x .3 amp. =	6.3 volts
Across T_3	– 21 ohms x .3 amp. =	6.3 volts
Across T_4	– 21 ohms x .3 amp. =	6.3 volts
Across T_5	– 21 ohms x .3 amp. =	6.3 volts
Across R	– 262 ohms x .3 amp. =	78.6 volts
	Total	=110.1 volts

Notice here, with the exception of .1 volt, due to the $\frac{1}{3}$ ohm we added to the total resistance, the sum of the voltage drops across the parts connected in series, is equal to the voltage across the circuit. By making use of this fact, we can more easily calculate the required value of "R" for Figure 1.

For example, five 6.3 volt filaments in series will have a total drop of 5 x 6.3 or 31.5 volts across them while there is a drop of 110 volts across the supply. As the drop across the circuit must equal the supply voltage, we subtract 31.5 from 110 and find the drop across "R" must be 78.5 volts. As the circuit carries .3 ampere, by Ohm's Law, R will have a value of 78.5 divided by .3 which is 261.67 or 262 ohms.

Before going further, we want to mention another point which often causes confusion. As far as the separate units of Figure 1 are concerned, the order in which they are connected will not make any difference. The resistance "R" could be connected between T_1 and the supply, or between any two of the tubes without making any change in the values of voltage drop which have been given.

As we will explain later, the arrangement of the parts will vary the voltage between them and the supply wires but, the voltage drop across each will remain the same, regardless of the order in which they are connected.

In general, Voltage Drop means the difference in voltage between the ends, or across the terminals, of a unit connected in a circuit. As shown by Ohm's Law, this difference of Voltage is equal to the current, in amperes, times the resistance in ohms. Notice here, as far as Ohm's Law is concerned, there is no difference between the Voltage Drop across a resistance which is carrying current and the voltage which is developed by a battery or other source.

For all series circuits, keep these four points in mind.

1. The total resistance of a series circuit is equal to the sum of the resistances, connected in series.

2. At any instant, the current in a series circuit is the same in all parts of the circuit.

3. The sum of the voltage drops, across the parts of a series circuit, is equal to the voltage across the entire circuit.

4. The voltage drop, across any part of a series circuit, is proportional to the resistance of that part.

This last point may seem a little difficult to follow but, going back to the circuit of Figure 1, we found each tube filament had a resistance of 21 ohms while "R" had a resistance of 262 ohms. Dividing 262 by 21, we find R has 12.47 times the resistance of the filament.

Under these conditions, according to point 4 above, the voltage drop across R should be 12.47 times that across the filament. Multiplying the 6.3 volt drop across the filament by 12.47 we have 78.56 volts which practically checks with our former calculation. By using exact values, the results will be exactly equal.

PARALLEL CIRCUITS

For Figure 2, we have taken the tubes of Figure 1 and arranged them so that the filaments can be operated properly by using an ordinary 6 volt automobile storage battery as a source of supply.

Checking over the connections here, you will find there is a complete circuit from battery "+" through each of the filaments back to battery "-". In other words, the filaments are now connected in parallel across the battery.

As we explained in an earlier Lesson, the common type of storage cell produces a pressure of 2.1 volts and, with three of these cells in series, we have a battery which produces 3 x 2.1 or 6.3 volts. While this is commonly known as a 6 volt battery it actually produces 6.3 volts and therefore, when connected as shown in Figure 2, each filament will operate under the same conditions as in Figure 1.

Repeating the general rule of a former Lesson, you know that, connected in parallel, the voltage across each filament will be the same as that across the circuit.

As far as the current is concerned, that which passes through any one filament returns to the battery without passing through any other filament. To operate them all at the same time therefore, the battery must supply .3 ampere to each, for a total of 5 x .2 or 1.5 ampere. This merely brings out the general rule of an earlier Lesson that the total current in a parallel circuit is equal to the sum of the currents in the branches.

To find the total resistance of the circuit of Figure 2, we simply divide the voltage by the total current which gives 6.3 divided by 1.5 or 4.2 ohms. For each tube filament, which in this case is a branch of the parallel circuit, we have 6.3 volts and .3 ampere therefore, as explained for Figure 1, the resistance must be 21 ohms.

In a former Lesson, we told you that when a parallel circuit had branches of equal resistance, its total resistance was equal to the resistance of one branch divided by the number of branches. Applying this rule to Figure 2, we have five, 21 ohm branches and 21 divided by 5 equals 4.2 ohms as found above.

Taking only the tube filaments of Figure 1, you will remember that, connected in series, they require a total of 31.5 volts at .3 ampere. Connected in parallel, as in Figure 2, these same filaments require 6.3 volts at a total current of 1.5 amperes. As we will explain in a later Lesson, electrical power is equal to amperes times volts and, for Figure 1, we have 31.5 volts times .3 ampere for a product of 9.45. For Figure 2, we have 6.3 volts times 1.5 amperes which again gives a product of 9.45.

We mention this fact merely to bring out another important point. By making use of Series and Parallel connections, we can operate properly at the most convenient values of total voltage and current but, regardless of the connections, the amount of power remains the same.

For Parallel Circuits, we want you to keep these points in mind.

1. The voltage across the branches of a parallel circuit is the same as the voltage across the entire circuit.

2. The total current in a parallel circuit is equal to the sum of the currents in the branches.

3. With branches of equal resistance, the total resistance of a parallel circuit is equal to the resistance of one branch divided by the number of branches.

COMBINATION CIRCUITS

To provide proper operating conditions in the simplest arrangement, series and parallel connections are often combined in one circuit. To illustrate the method, for Figure 3 we have a circuit made up of the battery, T_1 and T_2 of Figure 2 while the other tubes, T_3, T_4 and T_5 are a type with a filament which requires .06 ampere at 2.1 volts.

To simplify the circuit, we connect these three 2.1 volt filaments in series to each other and then connect them, as a unit, in parallel to the 6.3 volt filaments. From our explanations of Figure 1, you know that three 2.1 volt filaments in series require a total drop of 6.3 volts and, from our explanation of Figure 2, you know that, connected as a branch of a 6.3 volt parallel circuit, they will be operating under the required conditions.

To allow a current of .06 ampere at 2.1 volts, the filaments of T_3, T_4 and T_5 each have a resistance of 2.1 volts divided by .06 ampere, which is 35 ohms and, connected in series, their total resistance will be 3 x 35 or 105 ohms.

Thus branch "EF", of the parallel circuit of Figure 3, has a resistance of 105 ohms and, at 6.3 volts, will allow a current of 6.3 divided by 105 or .06 ampere. Branch "CD", consisting of the filament of one 6.3 volt tube, with a resistance of 21 ohms, carries a current of .3 ampere as explained for Figure 2. Because it contains a similar unit, branch "AB" of Figure 3 also carries a current of .3 ampere.

The total current of the circuit will thus be equal to .3 + .3 + .06 which is .66 ampere and, by Ohm's Law, the total resistance will be equal to 6.3 volts divided by .66 ampere or 9.54 ohms.

Should you find the low total resistance of a parallel circuit rather confusing, a review of the former Lesson on this subject will be of help. However, the later Lessons of the training will give you additional details.

VOLTAGE AND CURRENT RELATIONS

To carry these ideas a little further, suppose we are required to operate three different types of tubes using a 6 volt battery as a supply. As we have already explained, the common 3 cell storage battery develops 6.3 volts but, for simplicity, it is often considered as 6 volts. Therefore, we will assume this value in our explanations of Figures 4 and 5.

Although the circuits of Figures 4 and 5 appeared in an earlier Lesson, we feel they are of sufficient importance to warrant a review but now, will assume the following specifications for the filaments or heaters of the tubes.

T_1 - 5 volts at .5 amp.
T_2 - 2 volts at .24 amp.
T_3 - 1.4 volts at .1 amp.

Checking these values, we find,

For R_1:-

$$E_1 = 6 - 5 = 1 \text{ volt}$$
$$I_1 = .5 \text{ amp.}$$
$$R_1 = \frac{E}{I} = \frac{1}{.5} = 2 \text{ ohms}$$

For R_2:-

$$E_2 = 6 - 2 = 4 \text{ volts}$$
$$I_2 = .24 \text{ amp.}$$
$$R_2 = \frac{E}{I} = \frac{4}{.24} = 16\tfrac{2}{3} \text{ ohms}$$

For R_3:-

$$E_3 = 6 - 1.4 = 4.6 \text{ volts}$$
$$I_3 = .1 \text{ amp.}$$
$$R_3 = \frac{E}{I} = \frac{4.6}{.1} = 46 \text{ ohms}$$

RESISTANCES FOR VOLTAGE DROPS

Using the tubes and battery of Figure 4, proper operating conditions can be obtained with the arrangement of Figure 5 which is sometimes preferred because but one resistor can be installed, with connections or taps to provide the three sections shown as R_1, R_2 and R_3. However, it is necessary to calculate the required value of resistance for each section.

To calculate resistance by Ohm's Law, it is necessary to know the current and voltage values therefore we will analyze the circuit on this basis.

Starting with the current values, we know the tube specifications are as follows:

T_1	-	.5 ampere
T_2	-	.24 ampere
T_3	-	.1 ampere
Total	-	.84 ampere

Analyzing the circuit of Figure 5, we see there are three current paths which can be traced as follows:

Path 1, Battery +, R_1, T_1, Battery -
Path 2, Battery +, R_1, R_2, T_2, Battery -
Path 3, Battery +, R_1, R_2, R_3, T_3, Battery -

Checking here, we find R_1 is in all three paths and therefore must carry the current of all three tubes. R_2 is in the paths of T_2 and T_3 and therefore must carry the current for these two tubes while R_3 is in the path of T_3 only. From the values given, the currents for each section of the resistance are:

R_1 - .5 + .24 + .1 = .84 amp.
R_2 - .24 + .1 = .34 amp.
R_3 - .1 = .1 amp.

Notice here, the current in R_1 is equal to the sum of the currents in T_1 and R_2, while the current in R_2 is equal to the sum of the currents in T_2 and R_3. Thus, if .84 amperes enters R_1 from the battery positive, .84 ampere leaves R_1 at junction A. Keep this fact in mind because it is important and holds true for all circuits.

Thinking now of voltage, we know that every current path across the source must have a total voltage drop equal to the supply voltage. As the battery develops 6 volts, in terms of voltage drop, the paths can be simplified by letting E_1 represent the voltage drop across R_1, E_2 the voltage drop across R_2 and E_3 the drop across R_3. Making these changes we can write,

$$E_1 + T_1 = 6 \text{ volts}$$
$$E_1 + E_2 + T_2 = 6 \text{ volts}$$
$$E_1 + E_2 + E_3 + T_3 = 6 \text{ volts}$$

According to the specifications of the tubes, T_1 requires 5 volts, T_2 requires 2 volts and T_3 requires 1.4 volts therefore we can write,

$$E_1 + 5 \text{ volts} = 6 \text{ volts}$$
$$E_1 + E_2 + 2 \text{ volts} = 6 \text{ volts}$$
$$E_1 + E_2 + E_3 + 1.4 \text{ volts} = 6 \text{ volts}$$

Completing the calculations for path number 1,

$$E_1 + 5 \text{ volts} = 6 \text{ volts}$$
$$E_1 = 6 - 5 \text{ volts}$$
$$E_1 = 1 \text{ volt}$$

For the second path we can substitute 1 volt for E_1 and find,

$$E_1 + E_2 + 2 \text{ volts} = 6 \text{ volts}$$
$$1 \text{ volt} + E_2 + 2 \text{ volts} = 6 \text{ volts}$$
$$E_2 = 6 - 2 - 1 \text{ volts}$$
$$E_2 = 3 \text{ volts}$$

Following the same plan for the third path,

$$E_1 + E_2 + E_3 + 1.4 \text{ volts} = 6 \text{ volts}$$
$$1 \text{ volt} + 3 \text{ volts} + E_3 + 1.4 \text{ volts} = 6 \text{ volts}$$
$$E_3 + 5.4 \text{ volts} = 6 \text{ volts}$$
$$E_3 = 6 - 5.4 \text{ volts}$$
$$E_3 = .6 \text{ volt}$$

With these values of voltage drops, the total for any of the three paths is equal to the supply of 6 volts and thus the operating conditions are correct.

Checking back, we find our calculations have provided current and voltage values for each section of the resistance therefore, by substituting in Ohm's Law, their values in ohms can be found.

For R_1:-

$$I_1 = .84 \text{ amp.}$$
$$E_1 = 1 \text{ volt}$$
$$\therefore R_1 = \frac{E_1}{I_1} = \frac{1}{.84} = 1.19 \text{ ohms}$$

For R_2:-

$$I_2 = .34 \text{ amp.}$$
$$E_2 = 3 \text{ volts}$$
$$R_2 = \frac{E_2}{I_2} = \frac{3}{.34} = 8.82 \text{ ohms}$$

For R_3:-

$$I_3 = .1 \text{ amp.}$$
$$E_3 = .6 \text{ volt}$$
$$R_3 = \frac{E_3}{I_3} = \frac{.6}{.1} = 6 \text{ ohms}$$

As the voltage and current values of the tube heaters are known, their resistances can be found by Ohm's Law.

For T_1:- $R = \frac{E}{I} = \frac{5}{.5} = 10 \text{ ohms}$

T_2:- $R = \frac{E}{I} = \frac{2}{.24} = 8.33 \text{ ohms}$

T_3:- $R = \frac{E}{I} = \frac{1.4}{.1} = 14 \text{ ohms}$

Tabulating the resistance values of all the units in the circuit, we have

R_1	=	1.19 ohms
R_2	=	8.82 ohms
R_3	=	6. ohms
T_1	=	10. ohms
T_2	=	8.33 ohms
T_3	=	14. ohms
Total	=	48.34 ohms

However, the supply develops 6 volts to cause a total current of .84 ampere and, substituting these values in Ohm's Law,

$$R = \frac{E}{I} = \frac{6}{.84} = 7.14 \text{ ohms}$$

Our problem now is to apply the rules for series and parallel circuits to prove that, when connected on the plan of Figure 5, the units with a total resistance of 48.34 ohms are equivalent to a single resistance of 7.14 ohms. To begin, we want you to keep these two general rules in mind.

1. When separate resistances are connected in series, their total resistance is equal to the sum of the separate resistances.

2. When separate resistances are connected in parallel, their total conductance is equal to the sum of the separate conductances. Rememberhere, conductance is the reciprocal of resistance.

Starting at the end of Figure 5, farthest from the supply, we find R_3 and T_3 are in series across C-F. Using the values given above, we have 6 ohms of R_3 in series with the 14 ohms of T_3 for a total of 20 ohms, or a conductance of 1/20 mho.

As point F connects directly to point D, you will see that T_2 is in parallel to the series combination of R_3 and T_3. Following the plan of the Lesson on Parallel Circuits and considering T_2 to have a resistance of 8.33 ohms or a conductance of 1/8.33 mho, adding the conductances,

$$\frac{1}{R} = \frac{1}{8.33} + \frac{1}{20}$$

and reducing to a common denominator

$$\frac{1}{R} = \frac{1 \times 20}{8.33 \times 20} + \frac{1 \times 8.33}{20 \times 8.33} = \frac{20 + 8.33}{20 \times 8.33}$$

$$\frac{1}{R} = \frac{28.33}{166.6} = .17$$

Thus, the total conductance of these two parallel branches is .17 mho and its reciprocal, the resistance, is equal to 1 divided by .17 which is 5.88 ohms. In problem form,

$$\frac{1}{R} = \frac{.17}{1}, \frac{R}{1} = \frac{1}{.17} = 5.88$$

As this particular problem is quite common, it is customary to work it out with letters, instead of numbers and thus derive a formula which will apply to all cases. For example, if we let R_1 represent one resistance and R_2 the second resistance, connected in parallel to the first, following the steps of the problem above,

$$\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2}$$

and reducing to a common denominator

$$\frac{1}{R} = \frac{1 \times R_2}{R_1 \times R_2} + \frac{1 \times R_1}{R_1 \times R_2} = \frac{R_2 + R_1}{R_1 \times R_2}$$

Inverting to find the value of Resistance,

$$R = \frac{R_1 \times R_2}{R_1 + R_2}$$

which states, the total resistance of two parallel connected resistances is equal to their product divided by their sum. Substituting the former problem values in this formula,

$$R = \frac{20 \times 8.33}{20 + 8.33} = \frac{166.6}{28.33} = 5.88 \text{ ohms}$$

Going back to Figure 5, we see this combination of T_2, R_3 and T_3 is in series with R_2 and, from the laws of series circuits, the values must be added to give

$$5.88 + 8.82 = 14.70 \text{ ohms}$$

as the total resistance beyond points A-D. However, as point D connects directly to point B, the heater of tube T_1 forms a parallel path across AD.

To find the equivalent resistance of this combination, we will think of the 14.7 ohms as R_1 and the 10 ohms of T_1 as R_2 and substituting in the general formula,

$$R = \frac{R_1 \times R_2}{R_1 + R_2} = \frac{14.7 \times 10}{14.7 + 10} = \frac{147}{24.7} = 5.95 \text{ ohms}$$

However, as this combination is in series with R_1 of Figure 5, we add its resistance of 1.19 ohms for a total of

$$5.95 + 1.19 = 7.14 \text{ ohms}$$

which checks with the value found by substituting the values of total voltage and current in Ohm's Law.

This plan can be applied to all ordinary circuits because it is merely an application of the laws of series and parallel connections. Starting at the branch farthest from the supply and working back, series resistances are added and equivalent values found for parallel resistances until the entire combination is reduced to a single equivalent value.

KIRCHHOFF'S LAWS

Reviewing our explanations of Figure 5, we traced the various current paths and checked the division or "distribution" of

current at the various junctions. Then, to check voltage drops, we retraced the current paths to make sure the total voltage drop was equal to the supply voltage. These same general conditions apply for all circuits and are known usually as Kirchhoff's Laws.

Kirchhoff's First Law states: The sum of all the currents approaching any junction, in a network of electrical conductors, is equal to the sum of all currents leaving it. This is the law we followed in checking the values of current in sections R1, R2 and R3 of the resistance of Figure 5.

Kirchhoff's Second Law refers to the Electromotive Forces, or what we commonly think of as voltages, and states: The sum of all the electromotive forces, around any closed current path, is equal to the sum of Voltage Drops around the same path.

For this Lesson at least, you may find it easier to think of this Law as simply stating that the sum of the voltage drops, around any closed current path, is equal to the voltage across the path.

We have already shown you that this is true for all the current paths of Figure 5 and, as the later Lessons explain, you will find it holds good for all circuits and parts of circuits.

VOLTAGE DIVIDERS

While no longer in general use for filament circuits, the arrangement of Figure 5 is in common use for the plate circuits of Radio tubes, the resistances being known as a "Voltage Divider". For Figure 6 therefore, we have made a few changes in the layout of Figure 5 and shown the plate circuits, instead of the filament circuits, for four tubes.

As you will learn later, plate currents of the ordinary tubes are usually but a small fraction of an ampere and are therefore measured by the smaller unit, milliampere, which is equal to one, one thousandth of an ampere. Also, the plate voltages are comparatively high and therefore, for Figure 6, we indicate a supply of 180 volts.

Calculations on circuits of this kind are made on exactly the same plan as explained for Figure 5 but you must remember that, for Ohm's Law, the units are "Volts, Amperes and Ohms".

Therefore, when the value of current is stated in milliamperes, abbreviated "M.A.", it must be converted into amperes before substituting in Ohm's Law.

This conversion is not at all difficult because of the ratio of 1000 to 1 between the units. To change milliamperes into amperes you divide by 1000 which moves the decimal point three places to the left, as follows.

250 M.A. = .250 ampere
20 M.A. = .02 ampere
5 M.A. = .005 ampere

Working the other way, to convert amperes into M.A., you multiply by 1000 which moves the decimal point three places to the right.

2. amperes = 2000 M.A.
.5 ampere = 500 M.A.
.03 ampere = 30 M.A.
.002 ampere = 2 M.A.

For example, suppose you want to find the resistance necessary to allow a current of 25 M.A. when connected across a 200 volt circuit. Changing to amperes

25 M.A. = .025 ampere

and substituting in Ohm's Law,

$$R = \frac{E}{I} = \frac{200}{.025} = 8000 \text{ ohms.}$$

Going back to Figure 6, you will find there are five different current paths and, starting at the supply positive, we can trace them as,

Pos. – A – T_1 – B – D – F – H – Neg.
Pos. – A – R_1 – T_2 – D – F – H – Neg.
Pos. – A – R_1 – R_2 – T_3 – F – H – Neg.
Pos. – A – R_1 – R_2 – R_3 – T_4 – H – Neg.
Pos. – A – R_1 – R_2 – R_3 – R_4 – Neg.

Checking back here, you will find that some parts of the complete circuit are in more than one path but each of the four tubes and resistance R_4 are in one path only. Therefore, if we know the value of current in these five parts, it will be possible to calculate the current in all parts.

To show you how this works out, we will assume the following values of current are present.

T_1 – 20 M.A.
T_2 – 8 M.A.
T_3 – 8 M.A.
T_4 – 2 M.A.
R_4 – 10 M.A.

From a practical standpoint, the currents in the various plate circuits are necessary for the desired operation but the current in R_4 simply completes a path for no apparent purpose. Once again, we will refer you to the later Lessons for a complete explanation of this type of path and, at this time, want you to try and remember only that it is known as a "Bleeder" and carries the "Bleeder Current".

The total current in the circuit will be equal to the sum of these branch currents and, adding the values listed above we find a value of 48 M.A. which, as explained above, is equal to .048 ampere. You can think of this current as leaving the supply at the positive terminal and entering the circuit at junction A.

Applying Kirchhoff's First Law, there will be 48 M.A. approaching junction A from the supply positive and, checking on the current paths and values given, 20 M.A. will leave A and pass through T_1. As the sum of the currents leaving a junction is equal to the total current approaching it, R_1 of Figure 6 must carry 48 - 20 or 28 M.A.

Following the same plan, for junction C there is 28 M.A. approaching and 8 M.A. leaving through T_2 therefore R_2 must carry 28 - 8 or 20 M.A.

For junction E, there will be 20 M.A. approaching with 8 M.A. leaving through T_3 and therefore R_3 will carry 20 - 8 or 12 M.A. For junction G, there will be 12 M.A. approaching with 2 M.A. leaving through T_4 and thus R_4 will carry 12 - 2 or 10 M.A. which checks with the values given. For the complete circuit we can now list these current values.

T_1 - 20 M.A.	R_1 - 28 M.A.
T_2 - 8 M.A.	R_2 - 20 M.A.
T_3 - 8 M.A.	R_3 - 12 M.A.
T_4 - 2 M.A.	R_4 - 10 M.A.

Going further, you can see that the voltage across T_1, or junctions A and B will be equal to that of the supply. To be absolutely accurate, we know the connecting wires have resistance and will cause a voltage drop when carrying current but for work of this kind, these values of resistance and voltage drop are so small, compared to the other parts of the circuit, that we do not consider them.

However, we will assume that, for proper operation, there must be the following voltages.

Across T_1 or A-B, 180 volts
Across T_2 or C-D, 135 volts
Across T_3 or E-F, 90 volts
Across T_4 or G-H, 45 volts

Notice here, points B, D, F, H, the lower end of R_4 and the supply negative are all directly connected and therefore we assume there is no voltage drop between them. Under these conditions R_4 also connects across GH and therefore must have a drop of 45 volts.

Applying Kirchhoff's Second Law, the sum of the voltage drops, around each of the current paths, must equal the supply voltage and thus, for the path through T_1, there will be 180 volts across A-B.

For the path through T_2, which includes R_1, the same conditions hold true and, with but 135 volts across C-D, there must be 180 - 135 or 45 volts across R_1. With 45 volts across R_1 and 135 volts across T_2 or C-D, the total voltage drop for this path will be 135 + 45 or 180 volts which is equal to the supply voltage.

For the path through T_3, which includes R_1 and R_2, from the former assumed values we find 90 volts across T_3 and EF and 45 volts across R_1 for a total of 90 + 45 or 135 volts. For R_2, there must be 180 - 135 or a 45 volt drop. The total for this path will be 45 volts across R_1 plus 45 volts across R_2 plus 90 volts across T_3 or EF which again is 180 volts and equal to that of the supply.

For the path through T_4, which includes R_1, R_2 and R_3 we follow the same plan but can write it out as an equation and thinking only of voltage or voltage drop, by substituting "E" for the corresponding "R",

$$\text{Supply} = E_1 + E_2 + E_2 + T_4$$

As we already know most of these values, we can write them in, in place of the letters, and have

$$180 = 45 + 45 + E_3 + 45$$
$$180 = 45 + 45 + 45 + E_3$$

and adding, we find,

$$180 = 135 + E_3$$

From this equation we can see that E_3 must be equal to the difference between 180 and 135 and thus can write,

$$180 - 135 = E_3$$

and subtracting,

$$45 = E_3$$

Thus we know there must be a drop of 45 volts across R_3 so that the sum of the voltage drops, for the path through T_4, will be equal to the supply of 180 volts. Also, as R_4 is in parallel to T_4, from the laws of parallel circuits we know the voltage across it must be the same as that across T_4, or 45 volts.

From a practical standpoint it is often necessary to calculate the value of resistance which, under the required conditions, will cause the necessary voltage drop. Checking back on our former explanations, we find resistance R_1 carries a current of 28 M.A. and requires a drop of 45 volts.

With this information we simply substitute in Ohm's Law.

$$R_1 = \frac{E}{I} = \frac{45}{.028} = 1607 \text{ ohms}$$

As commercial resistors are usually made within but 10% of their rated value, which is in even tens, hundreds or thousands of ohms, a 1600 ohm unit would be satisfactory under these conditions.

Following the same plan, we find R_2 carries a current of 20 M.A. and requires a drop of 45 volts. Substituting in Ohm's Law,

$$R_2 = \frac{E}{I} = \frac{45}{.02} = 2250 \text{ ohms}$$

In the same way,

$$R_3 = \frac{E}{I} = \frac{45}{.012} = 3750 \text{ ohms}$$

$$R_4 = \frac{E}{I} = \frac{45}{.01} = 4500 \text{ ohms}$$

There are several points we want to mention before going further. First, we assumed certain values of voltages and current in order to make our explanations complete but, the same plan can be used for the required values of any circuit.

Second, as far as Ohm's Law is concerned, the voltage produced by a battery, or other source, is exactly the same as the voltage drop across a resistance which is carrying current.

Third, with known or assumed values of current and voltage, Ohm's Law can be employed to find the values of resistance which will cause the required conditions. While this is the

usual problem in practice, the same general plan can be employed to find current values, when voltages and resistance are known or to find voltage values, when currents and resistances are known.

Fourth, by applying Kirchhoff's Laws to the circuit, two values, known or required, can be determined and substituted in Ohm's Law to find the third.

BIAS VOLTAGE

As you will learn later, the proper operation of the ordinary vacuum tube requires a direct current supply for both the grid and plate circuits. The plate is connected so as to be positive, in respect to the other elements of the tube while the grid is connected so as to be negative, in respect to the other elements of the tube. Also, as explained for Figure 6, the usual plate circuit carries an appreciable amount of current, while the current of the ordinary grid circuit is so small that we do not consider it.

Any questions you may have, in regard to these requirements, will be fully answered in the later Lessons but, at this time, we want to show you how, with but a single supply, the plate can obtain its positive voltage while the grid is given its negative or bias voltage.

For Figure 7, we have redrawn the circuits of Figure 6 but have added resistance R5 and connected the combination across a 220 volt supply. Checking through here, you will find we again have the five current paths of Figure 6, all of which return to junction J and continue to the supply negative through R5 and junction K.

From our former explanations you know that, if R5 is in all paths, the amount of current it carries must be equal to the sum of that in the separate paths. Using the values assumed for Figure 6, here R5 will carry the total current of 48 M.A. of .048 ampere.

Our examination for Figure 6, proved a drop of 180 volts across A-J of Figure 7 and thus, with a 220 volt supply there must be a drop of 220 - 180 or 40 volts across R5. Following the former plan,

$$R5 = \frac{E}{I} = \frac{40}{.048} = 833 \text{ ohms}$$

The point we want to emphasize here is the relationship between current, voltage and resistance. From our former calculations, R4, with a resistance of 4500 ohms and a current

of 10 ma, caused a drop of 45 volts while, for R_5, a resistance of but 833 ohms, and a current of 48 ma, caused a drop of 40 volts. When working on circuits of this kind, do not make the common mistake of considering but two of the factors and ignoring the third.

Going back to the explanations of Figure 6, there will be a 180 volt drop across A-J of Figure 7 because the circuits are identical up to this point. Adding the 40 volt drop across R_5, which is a part of all the current paths, the total drop is 180 + 40 or 220 volts, equal to that of the supply.

As we explained in the earlier Lessons, voltage is really a difference of pressure and, for simplicity, we can think of the supply negative as zero pressure. By this plan, junction A will be + 220 volts in respect to junction K. However, as we found a 45 volt drop across R_1, junction C will be 220 - 45 or +175 volts in respect to K.

Looking at these voltage values in the other way, if A is +220 volts and C is +175 volts, then C must be 220 - 175 or 45 volts negative in respect to A. Remember here, voltage is a difference of pressure between two points and any one point can be positive or negative, by so many volts, only in comparison with some other point.

Repeating the values just given, when point K of Figure 7 is considered as 0, point A is +220 volts and point C is +175 volts. However, should we consider point A as the 0 or reference point, then point C will be -45 volts and point K, -220 volts. Notice here, the voltage, or difference in pressure between any two points remains the same no matter which point is used for reference. Should we consider point C as the zero or reference point, then point A will be +45 volts and point K will be -175 volts.

As we have already told you, point K connects to the supply negative and there is a 40 volt drop across R_5. Therefore, point J is +40 volts in respect to point K. However, point J connects to points H, F, D and B and as far as the tubes are concerned, is really the negative side of their circuits. As the tubes are the useful units in the circuit, it would seem reasonable to select point J as the zero or reference point for all the other voltages and this plan is followed in most practical work.

With "J" as the reference point, "G" will be +45 volts, E will be +90 volts, C will be +135 volts and A will be +180 volts as there is a drop of 45 volts across each of the resistances, R_1, R_2, R_3 and R_4. You will notice also that

these values agree with those worked out for Figure 6 and thus, the tubes of Figure 7 will operate under exactly the same conditions.

With a 40 volt drop across R_5 and "J" as the zero or reference point, point K, which connects to the supply negative, must be listed as -40 volts. Thus, by properly selecting the reference point, a single supply can be used to furnish both positive and negative voltages.

For example, connected to point G, as shown in Figure 7, the plate of tube T_4 is 45 volts positive in respect to point "J" or the filament of the tube. By connecting this plate to point "K", it would be 40 volts negative, in respect to point "J" or the filament.

Perhaps some of these explanations may seem somewhat difficult to follow but we want you to think of them as nothing but an application of the laws for series and parallel circuits. As many of the common circuits are a combination of both series and parallel connections, the use of Kirchhoff's Laws simplifies the various problems which come up.

The various explanations which we have given refer to conditions which will be found in your everyday work and therefore we can not over-emphasize their importance.

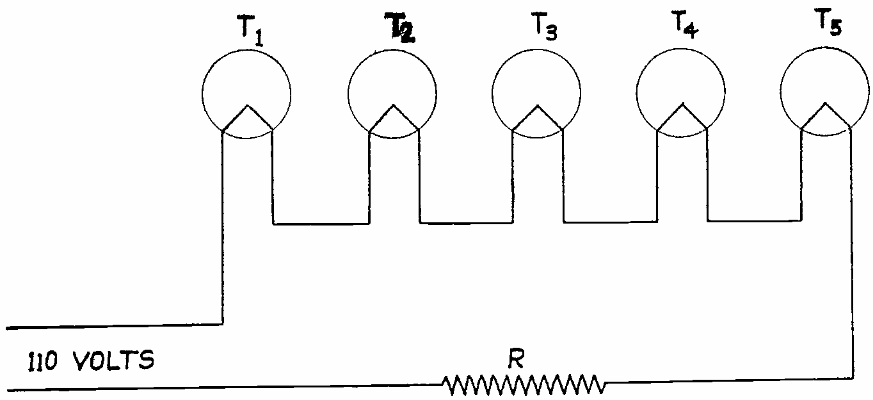


FIGURE 1

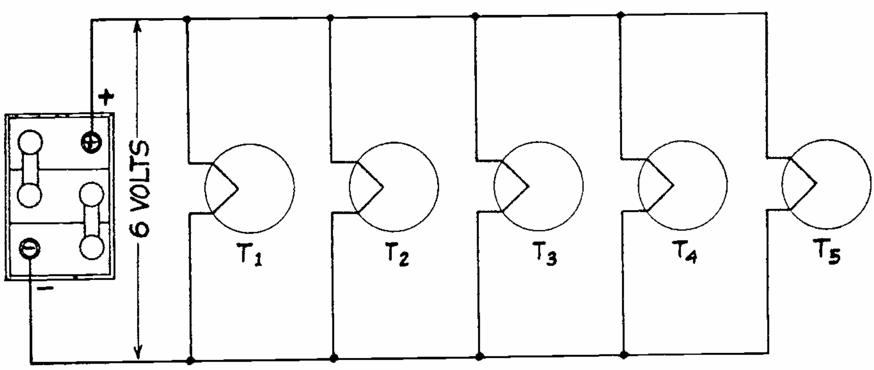


FIGURE 2

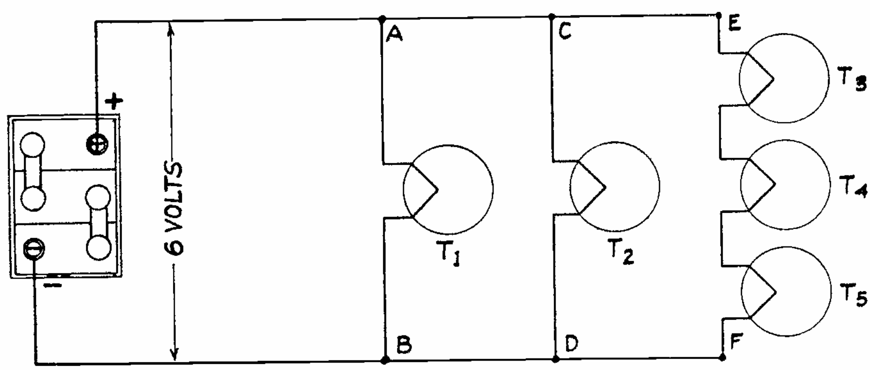


FIGURE 3

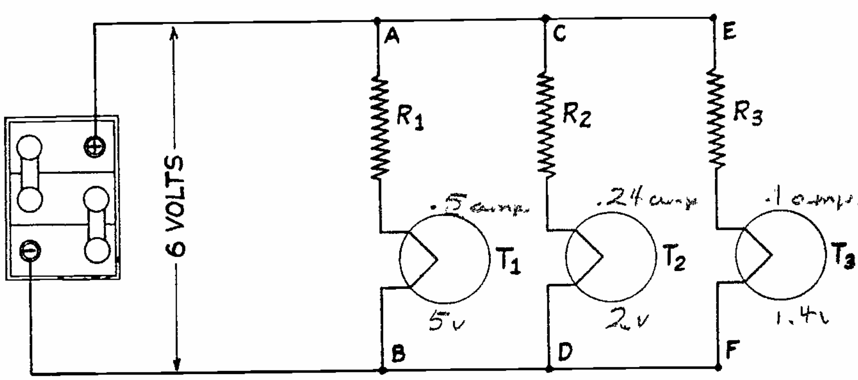


FIGURE 4

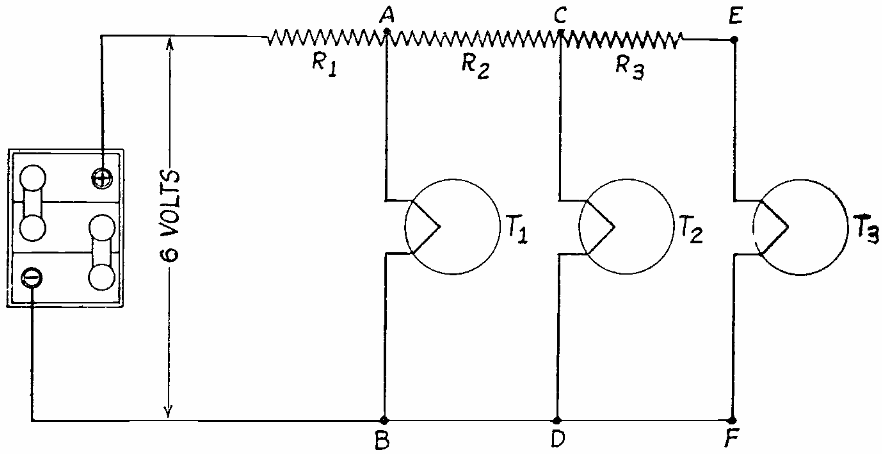


FIGURE 5

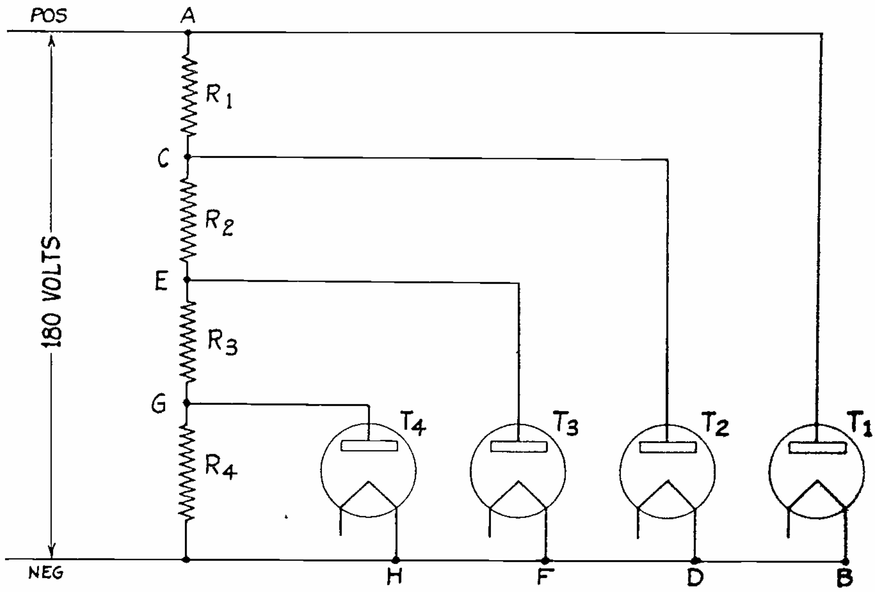


FIGURE 6

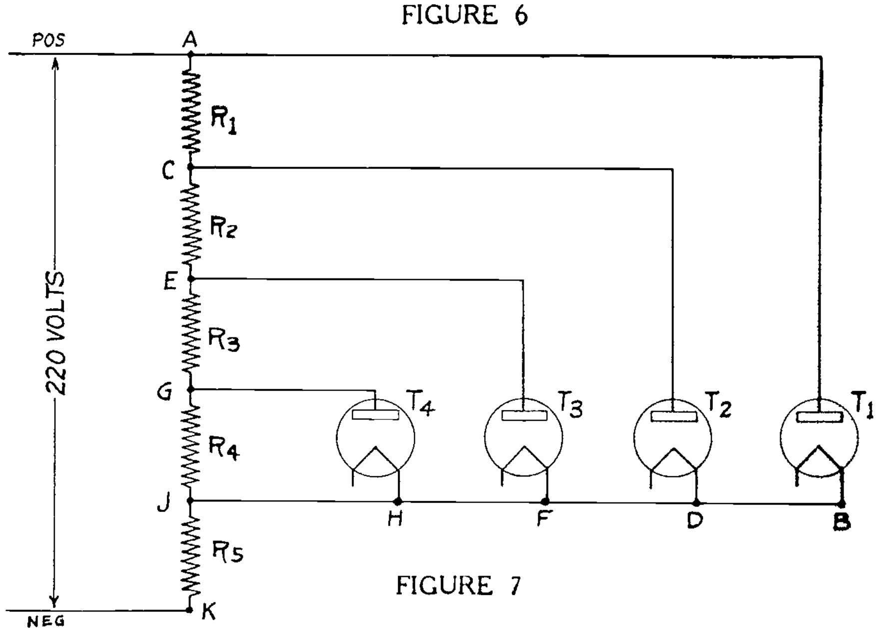


FIGURE 7

DE FOREST'S
TRAINING, Inc.

LESSON FDM - 15
RESISTANCE MEASUREMENT

Founded 1931 by

RADIO FUNDAMENTALS

LESSON 15

RESISTANCE MEASUREMENT

Voltmeter - Ammeter Method - - - - - - - - - - - - - Page 1
Substitution Method - - - - - - - - - - - - - - - - - Page 3
Half Scale Deflection Method - - - - - - - - - - - - Page 3
Voltmeter and Standard Method - - - - - - - - - - - Page 4
Voltmeter Method - - - - - - - - - - - - - - - - - - Page 5
Direct Reading Ohmmeter - - - - - - - - - - - - - - Page 6
Back Up Scale - - - - - - - - - - - - - - - - - - - Page 7
Wheatstone Bridge - - - - - - - - - - - - - - - - - Page 8

# # # # # # #

"Letting well enough alone" is a foolish motto in the life of anyone who wants to get ahead. In the first place, nothing is "well enough", if you can do better. No matter how well you are doing, do better. There is an old Spanish proverb which says, "Enjoy the little you have while the fool is hunting for more". The energetic American ought to turn this proverb upside-down and make it read, "While the fool is enjoying the little he has, I will hunt for more".

— Arthur Brisbane

Among other things, in the former explanations we have given you details in regard to Electrical Circuits, Wires and Wire Tables, Units of Measure, Batteries and Meters. Perhaps you have wondered why we selected such a variety of subjects but, as you will soon learn, all of them are needed to understand the actions which occur in even the simplest Radio Circuits.

To illustrate, for this Lesson we are going to show you how all of the above subjects are needed for the common methods of measuring resistance values. As we have already told you, resistance is an all important quality of electrical circuits and resistance units are used in large numbers for most Radio apparatus.

Because of this condition, you can understand that some means of resistance measurement is necessary. While many different methods have been devised, all of them are based on the relationship of voltage, current and resistance, as expressed by Ohm's Law.

In the following explanations, we are going to take up the most common methods so that, whenever the occasion arises, you will be able to make resistance measurements with whatever type of instruments are available.

VOLTMETER - AMMETER METHOD

For resistance measurement, the most direct application of Ohm's Law is the Voltmeter-Ammeter method as shown by Figure 1. Here, we have an ordinary automobile battery "E", as the source of voltage, a resistor of unknown value, "R_X", a voltmeter and an ammeter.

These units are wired as shown by the double line and you will find one current path from one battery terminal through the ammeter and resistance and back to the other battery terminal. From the earlier Lesson on Meters, you know the ammeter will indicate the value of the current in the circuit.

There is a second current path from one battery terminal, through the voltmeter and back to the other battery terminal. Again, referring to the Lesson on Meters, you know this instrument will indicate the circuit voltage.

Thus, the meters indicate the values of voltage and current and, by making use of Ohm's Law, which states Resistance is equal to Voltage divided by Current, the value of the resistance can be found. For example, if the Voltmeter reads 6 and the ammeter reads 2, the resistance is equal to 6 divided by 2 which is 3 ohms.

In this arrangement, the possibility of error is due to the fact that the voltmeter is connected across both the resistance and the ammeter and therefore, the calculated value of resistance will be that of the resistor plus that of the meter. Fortunately, the resistance of a good ammeter is quite low and therefore, if the value of the resistance is comparatively high, the error will be small. Thus, the arrangement of Figure 1 is useful mainly for the measurement of comparatively high resistance values.

To overcome this type of error, the arrangement of Figure 2 may be employed but, before explaining its action, we want you to study the simplified drawing. The battery is indicated by a series of alternately long and short lines, each pair representing one cell of the battery.

This is what we call a "Symbol", and it is really a form of shorthand as it allows a circuit to be drawn quite rapidly and yet include all the required information. As mentioned above, each pair of lines in the battery symbol represents one cell of a battery and the longer narrow line is the positive while the shorter, thicker line is the negative.

By the same plan, resistance is indicated by a zig-zag line which is also included in Figure 2. Commercially, all circuit diagrams are drawn with symbols and, as one important purpose of this program is to teach you how to read circuit diagrams, we want you to compare Figures 1 and 2 very carefully.

You will find that, with the exception of one voltmeter connection, both circuits are electrically the same. In Figure 1, the voltmeter connects across both the ammeter and resistance while, in Figure 2, the voltmeter connects across the resistance only.

The term "across" is quite common in electrical work and as explained above, simply means all units which form a path between the voltmeter connections. Thus, in Figure 1, the voltmeter is connected across the battery as well as across the ammeter and resistance.

Going ahead to Figure 2, there is one current path from the battery through the ammeter, resistance and back to the battery. There is also a current path from the battery, through the ammeter, voltmeter and back to the battery.

Thus, the ammeter will indicate the total current in both paths but the voltmeter will indicate only the voltage across the resistance. As good voltmeters have a comparatively high resistance and therefore carry but a small current, for lower values of resistance which allow higher values of current,

the voltmeter current will cause but a slight error in the ammeter reading.

As explained for Figure 1, in Figure 2, the resistance will be equal to the voltage, as indicated by the voltmeter, divided by the current, as indicated by the ammeter. To reduce the errors, caused by the meters themselves, the arrangement of Figure 1 is more accurate for measuring high resistance values while that of Figure 2 is more accurate for measuring low resistance values.

SUBSTITUTION METHOD

In the substitution method of resistance measurement a resistor of known value is substituted for one of unknown value and, when the current is the same for both, their resistances are equal.

The circuit arrangement is shown in Figure 3 and here we have used three more symbols. The meter is indicated by a circle with a letter to indicate its type. Here, "A" stands for ammeter. A switch is shown by two dots with a diagonal line drawn from one of them. The fixed resistor has the symbol explained for Figure 2 while a variable resistor is indicated by the same symbol but with a diagonal arrow drawn through it. The variable resistance of Figure 2 is actually a rheostat as explained in the Lesson on resistors.

To operate this circuit, the rheostat "R" is arranged with some sort of a dial which indicates the exact amount of resistance in the circuit and technically we say it is "Calibrated".

With the units connected as shown, both switches are open and switch No. 2, "SW2" is closed first to allow current in the meter and unknown resistance "R_x". The meter reading is noted and "SW2" is opened.

"SW1" is then closed, to allow current in variable resistance "R" which is adjusted until the meter indicates the same value of current as noted for "R_x" when "SW2" was closed.

As the voltage "E" is the same in both cases, with equal current and resistances must also be equal and therefore, the value shown on the dial of the calibrated resistance is also the value of the unknown resistor "R_x". The accuracy of this method depends mainly on the accuracy with which the dial of the variable resistance is calibrated.

HALF SCALE DEFLECTION METHOD

A somewhat similar arrangement is shown in the circuit of Figure 4 except here, there is but one current path through

both resistors. Closing the switch "shorts out" the calibrated resistor because the resistance of the switch is practically as low as that of the connecting wires.

To operate this circuit, the switch is closed and the current, indicated by the meter, is noted. The switch is then opened and the calibrated resistance adjusted until the meter indicates a current exactly one half of its former value.

This condition indicates that the resistance in the circuit has been doubled because, according to Ohm's Law, with the voltage remaining the same, doubling the resistance will reduce the current to one half of its original value.

With but two resistors in the circuit, and the total resistance value doubled, each must have the same value. Therefore, the value of the unknown resistor "R_x" is the same as that shown on the dial of the calibrated resistor "R".

VOLTMETER AND STANDARD METHOD

The circuit of Figure 5 is similar to that of Figure 4 but here the resistance "R", called a standard, is accurate within 1% or less of its rated value. The battery "E" and unknown resistance "R_x" are the same as before.

There are two general methods which may be followed here. First - the voltmeter is connected across the standard resistance, as shown by "V_1" of Figure 5, and its reading in volts, together with the known value of the standard resistance, make it possible to use Ohm's Law to find the current in the circuit. You will remember Ohm's Law states, Current equals Voltage divided by Resistance therefore it is necessary only to divide the voltmeter reading by the "OHMS" value of the standard resistance.

The voltmeter is then connected across the unknown resistance, "R_x" as shown by "V_2" of Figure 5, and Ohm's Law is used again. Now we know the value of current, from the readings already made, and use the form of the Law which states, Resistance equals Volts divided by Amperes. Remember here, the voltage is that value shown by the meter reading "V_2" and the current is the value found from the voltage reading "V_1" and the standard resistor "R".

Second - looking at the circuit of Figure 5, you will see there is but one path for the current, from the battery through "R" and "R_x" back to the battery. Therefore, the current in both resistances must be of the same value because all of the current in one must pass through the other.

According to Ohm's Law, Voltage is equal to Current times Resistance and thus, when the current is the same in two resistances, the voltage across them will vary in proportion to their resistance values.

For example, suppose "R" of Figure 5 has a value of exactly 1000 ohms, "V_1" reads 2 volts and "V_2" reads 4 volts. From the explanation above, we conclude that as the reading of "V_2" is twice the value of that shown by "V_1", "R_x" must have twice the resistance of "R". As we know "R" has a resistance of 1000 ohms, "R_x" must have a resistance of 2000 ohms.

VOLTMETER METHOD

For Figure 6 we show an arrangement similar to that of Figure 5 except that here, the known resistance is the resistance of the voltmeter itself. Most commercial voltmeters are rated at so many "Ohms per Volt", which makes it easy to calculate their total resistance.

To illustrate this procedure, we will assume that "V" of Figure 6 has a sensitivity of "1000 ohms per volt" and its scale reads up to 10 volts. Its total resistance then is equal to 10 times 1000 or 10,000 ohms.

To use this information for resistance measurement, the voltmeter is first connected across the battery to determine the total voltage of the circuit. The unknown resistor "R_x" is then connected as shown and the meter reading taken again.

Using the value of the illustration above, we will imagine the first reading was 6 volts and the second reading 2 volts. Following a plan similar to that explained for Figure 5, if the battery develops 6 volts and the meter reads 2 volts there must be 6 - 2 or 4 volts across the unknown resistance "R_x".

This is twice the voltage indicated by the voltmeter and therefore "R_x" must have twice the resistance of the voltmeter. With the assumed value of 10,000 ohms for the voltmeter, the unknown resistance "R_x" must have a value of 2 x 10000 or 20,000 ohms.

By this time you may have noticed that all of these methods merely enable you to find two values and then, by using Ohm's Law, to calculate the third or desired value. However, for the Substitution and Half Scale methods of Figures 3 and 4, no calculations are necessary, the work having been done when the variable resistance was calibrated.

For the other methods, using ordinary voltmeters and ammeters, the values shown by their readings must be substituted in Ohm's Law and the value of resistance found by calculation.

While we feel it essential that you know how to make these calculations, in many commercial applications, the meters are arranged to read the value of resistance directly in ohms.

DIRECT READING OHMMETER

The circuit of Figure 7 is an application of this idea and the meter is marked "MA" because normally, it measures "Milliamperes". Back in the Lesson on Wire Measurement, we told you a "mil" was a unit of measure equal to one one thousandth of an inch. Here, we are using the same prefix and a "mil-ampere" is a unit of measure equal to one one thousandth of an ampere. To make the pronunciation easier, the other letters are added to make the term, "Milliampere".

Going back to Figure 7, the meter is built so that a current of one milliampere, one one thousandth of an ampere, will move the pointer all the way across the meter scale. Technically, we say a meter of this type requires a current of one milliampere for "Full Scale Deflection".

The circuit includes a battery "E", a variable resistance "R" and an unknown resistance "R_x" but, before any measurements can be made, the variable resistance must be adjusted. To do this, the unknown resistor is taken out of the circuit and the variable resistor is connected from the meter directly back to the battery and then adjusted until the meter indicates full scale deflection.

After this has been done, the unknown resistance is replaced and, as you already know, adding resistance to a circuit will reduce the current, provided no other changes are made. Therefore, as increasing values of resistance are connected in the position of "R_x", Figure 7, the meter will indicate lower current values.

To make a direct reading ohmmeter, the meter scale is marked, not in the value of current actually in the meter but, in the values of added resistance which cause the current to reduce.

For example, with the variable resistance connected back to the Battery direct, there is no "R_x" in the circuit and, when "R" is adjusted for full scale deflection a "0" is placed at that point on the "OHMS" scale of the meter.

Then, suppose a standard resistance of 1000 ohms is connected in the position of "R_x". The current will reduce and the meter hand will drop back but, at the point it stops, the numbers "1000" are placed on the OHMS scale.

By following this plan, with different values of standard resistances, a complete "Ohms" scale can be laid out and then,

When some unknown resistance is connected in the position of "R_x", the meter will indicate its value on the ohm scale.

Commercial meters of this type, found in modern Radio test equipment, will measure resistance values from a few ohms up to several million ohms. However, due to the sensitivity of the meter, this arrangement is not sufficiently accurate for measuring low values of resistance.

BACK UP SCALE

To overcome this difficulty, the arrangement of Figure 8 is now in quite common use because, by simple switching arrangements, it can be combined with the circuit of Figure 7.

Here again, there is a current path from the battery, through the meter and variable resistance back to the battery. As explained for Figure 7, with "R_x" out of the circuit, the variable resistance is adjusted to provide full scale deflection of the meter.

This time, the unknown resistance is connected across the meter and, as it will sort of "side track" some of the current around the meter, we say the unknown resistance is "shunted" across the meter.

The circuit current will divide, part of it passing through the meter and part through the shunt resistance "R_x". The lower the resistance of the shunt, the more current it will carry and thus the meter reading will be lower.

As explained for Figure 7, here again we can connect known values of resistance in the positions of "R_x", Figure 8, and mark the point, where the meter hand comes to rest on the scale, in the proper value of ohms.

In the circuits of Figures 7 and 8, the variable resistance "R" will have a value of several thousand ohms while the meter itself, has a value of 100 ohms or less. Thus, to cause half scale deflection, in Figure 7, "R_x" must be equal to "R" with a value of several thousand ohms while in Figure 8, "R_x" must have a value equal to that of the meter, 100 ohms or less.

In general, both circuits operate on the same plan and from the values given above you can understand why that of Figure 7 is used to measure high resistance values while that of Figure 8 is used to measure low resistance values. Later on in the training, we will show you how one meter can be made to act as a voltmeter and ammeter as well as an ohmmeter.

WHEATSTONE BRIDGE

One of the oldest, and still common Laboratory methods of measuring resistance, as well as other electrical quantities, is the Wheatstone Bridge shown diagrammatically in Figure 9. Checking the component parts, you will find a battery or source of voltage "E", four resistances, "R_A", "R_B", "R_C", and "R_x" together with an instrument, usually a Galvanometer, "G".

Tracing the circuits and neglecting the meter, you will find two current paths across the battery "E". One path through "R_A" and "R_B" in series, with the second path through "R_C" and "R_x" in series but, with the paths in parallel to each other. As the meter is "Bridged" across from one path to the other, the arrangement is known as a "Bridge" circuit and named after its inventor, Sir Charles Wheatstone, an English physicist.

To understand the action, there are two main points to remember. First, the voltage across a resistance is equal to the value of the resistance, in ohms, times the current it is carrying, in amperes. Technically, this is often called the "IR" drop and is taken from that form of Ohm's Law which states, E = IR. Second, with no voltage across a circuit, there will be no current in it.

Unlike many measuring instruments, the values of the Bridge resistances are adjusted until the meter reads zero to indicate a balanced condition or what is often known as the "Null" point. Electrically, this condition is reached when the voltage drop across "R_A", Figure 9, is equal to the voltage drop across "R_C".

As both these resistances connect to one side of the supply "E" and both have the same voltage drop, there will be no voltage drop, or difference of potential across the meter, therefore, it will read zero. To express this equality in the form of an equation, we can write,

$$I_1R_A = I_2R_C$$

Then, as the total voltage across each current path is equal to the supply voltage and, for series circuits, the total drop is equal to the sum of voltage drops across the parts connected in series, when the above equation is true, it follows that,

$$I_1R_B = I_2R_X$$

In a parallel circuit, the current divides inversely as the resistance of the branches and, to find this ratio for Figure 9, we divide one equation by the other to have,

$$\frac{I_1R_A}{I_1R_B} = \frac{I_2R_C}{I_2R_X}$$

but here, the current values cancel out to leave,

$$\frac{R_A}{R_B} = \frac{R_C}{R_X}$$

which shows the relationship between the various resistances and is known as the fundamental equation of the bridge.

In practice, resistances in the positions of "R_A", "R_B" and "R_C" of Figure 9 are of known value and thus, by making use of the fundamental equation, the value of the unknown resistance "R_X" can be found. To simplify the calculations, the terms of the ratio can be transposed to,

$$R_X = R_C \times \frac{R_B}{R_A}$$

which states that the value of the unknown resistance is equal to the value of the resistance in series with it times the ratio of the value of the resistances in the parallel branch. Therefore, resistances in the position of "R_A" and "R_B" are often called the "Ratio Arms" while the resistance in position "R_C" is variable and known as the "Rheostat Arm".

To illustrate, suppose "R_A" has a value of 2 ohms, "R_B" a value of 10 ohms and "R_C" a value of 4 ohms when adjusted so that the meter reads zero.

Substituting these values in the equation,

$$R_X = R_C \times \frac{R_B}{R_A}$$

$$R_X = 4 \times \frac{10}{2}$$

$$R_X = 4 \times 5$$

$$R_X = 20 \text{ ohms}$$

To check up, we will assume "E" has a value of 6 volts and then, for the "I_1" path, "R_A" and "R_B" are in series for a total of 2 + 10 or 12 ohms. Using Ohm's Law,

$$I_1 = \frac{E}{R} = \frac{6}{12} = \frac{1}{2} \text{ ampere}$$

For the "I_2" branch, "R_C" and "R_X" are in series for a total of 4 + 20 or 24 ohms and thus,

$$I_2 = \frac{E}{R} = \frac{6}{24} = \frac{1}{4} \text{ ampere}$$

Knowing the resistance and current values, it is a simple matter to calculate voltage drops by using the relationship

$$E = IR$$

For R_A, $E = 1/2 \times 2 = 1$ volt
For R_C, $E = 1/4 \times 4 = 1$ volt

Therefore, with equal voltage drops across "R_A" and "R_C" there will be zero voltage across the meter and it will read zero.

For R_B, $E = 1/2 \times 10 = 5$ volts
For R_X, $E = 1/4 \times 20 = 5$ volts

Which proves the bridge is in balance and there is a 6 volt drop across each current path.

Notice here, the current in the two paths does not have to be equal and multiplying the value of "R_C" by the ratio of "R_B" to "R_A" gives the value of the unknown resistor "R_X". By changing the ratio of "R_B" to "R_A" an extremely wide range of resistance values can be spanned with an accuracy determined by the accuracy of the known values of resistance.

There are many variations of the circuit of Figure 9, one common form being shown in Figure 10. Compared to Figure 9, resistances "R_A" and "R_B" consist of a straight piece of wire, mounted usually on a good stock and equipped with a sliding contact connected to one terminal of the indicating meter. Because of this construction the arrangement is known as a "Side Wire" Bridge.

Electrically, the circuits of Figures 9 and 10 are alike and, as the resistance of the wire is uniform, the positions of the sliding contact determines the resistance ratio of "R_A" and "R_B". The value of "R_C" is known while "R_X" is the unknown value which is to be measured.

In operation, the circuit is connected as shown and the sliding contact adjusted until the meter reads zero and the bridge is balanced. The ratio of "R_A" to "R_B" is then used as the scale and multiplied by the value of "R_C" as explained for Figure 9.

As shown in Figure 10, the sliding contact is 21/2 main divisions from the left on a scale which reads from 0 to 10. Thus, "R_A"

has a length of $2\frac{1}{2}$ while "R_B" has a length of $10 - 2\frac{1}{2}$ or $7\frac{1}{2}$. Therefore, the ratio:-

$$\frac{R_B}{R_A} + \frac{7\frac{1}{2}}{2\frac{1}{2}} = 3$$

Assuming "R_C" to have a value of 5 ohms, these values can be substituted in the formula given for Figure 9, to find,

$$R_X = R_C \times \frac{R_B}{R_A}$$

$$R_X = 5 \times 3$$

$$R_X = 15 \text{ ohms}$$

Should the bridge balance with the sliding contact at "5" on the scale, the ratio of "R_A" to "R_B" would be 5/5 or 1 and,

$$R_X = 5 \times 1$$

$$R_X = 5 \text{ ohms}$$

However, if a balance was obtained with the sliding contact at $7\frac{1}{2}$ on the scale,

$$R_X = R_C \times \frac{R_B}{R_A}$$

$$R_X = 5 \times \frac{2\frac{1}{2}}{7\frac{1}{2}}$$

$$R_X = 5 \times 1/3 = 1\frac{2}{3} \text{ ohms.}$$

You will find many variations of bridge circuits, some of which are arranged to measure the values of other electrical components but, in any case, the general plan remains the same with readings taken only after the bridge has been balanced.

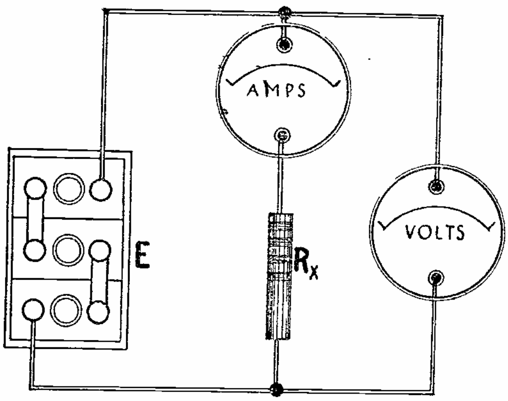


FIGURE 1

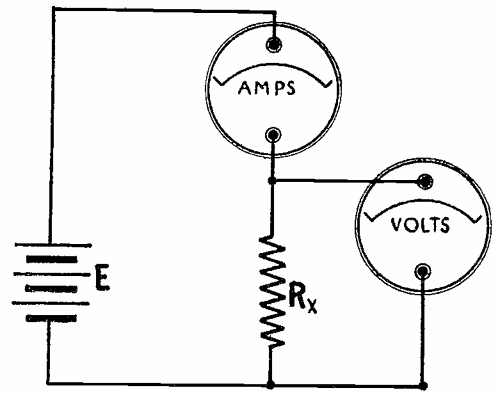


FIGURE 2

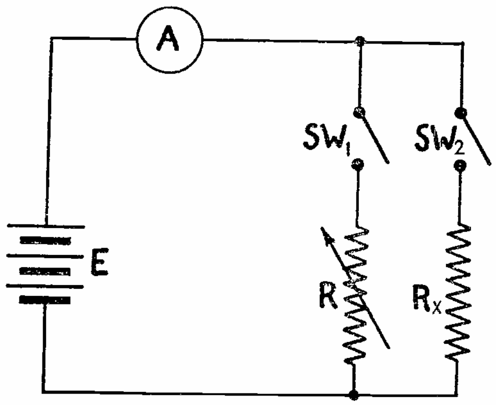


FIGURE 3

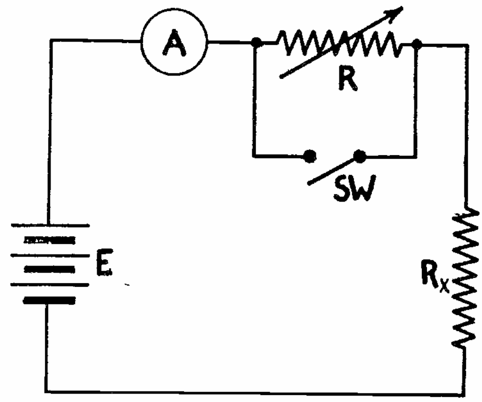


FIGURE 4

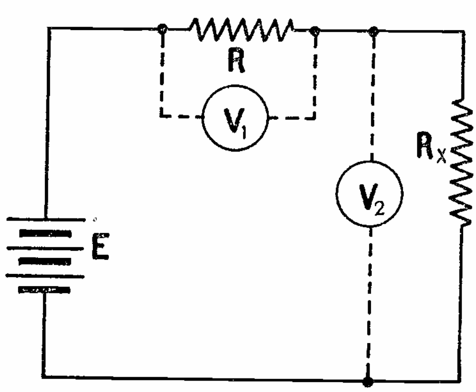


FIGURE 5

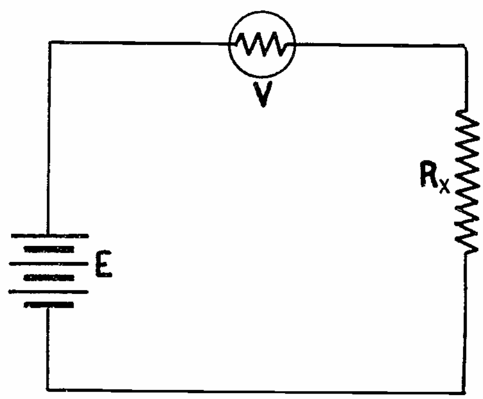


FIGURE 6

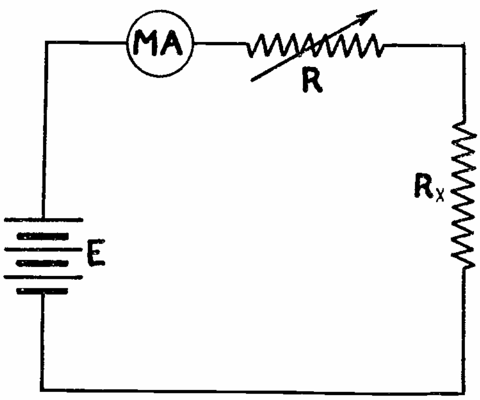


FIGURE 7

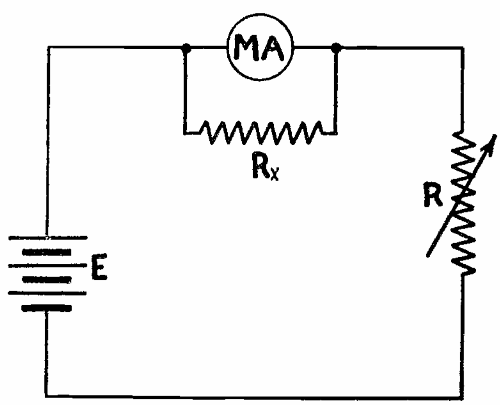


FIGURE 8

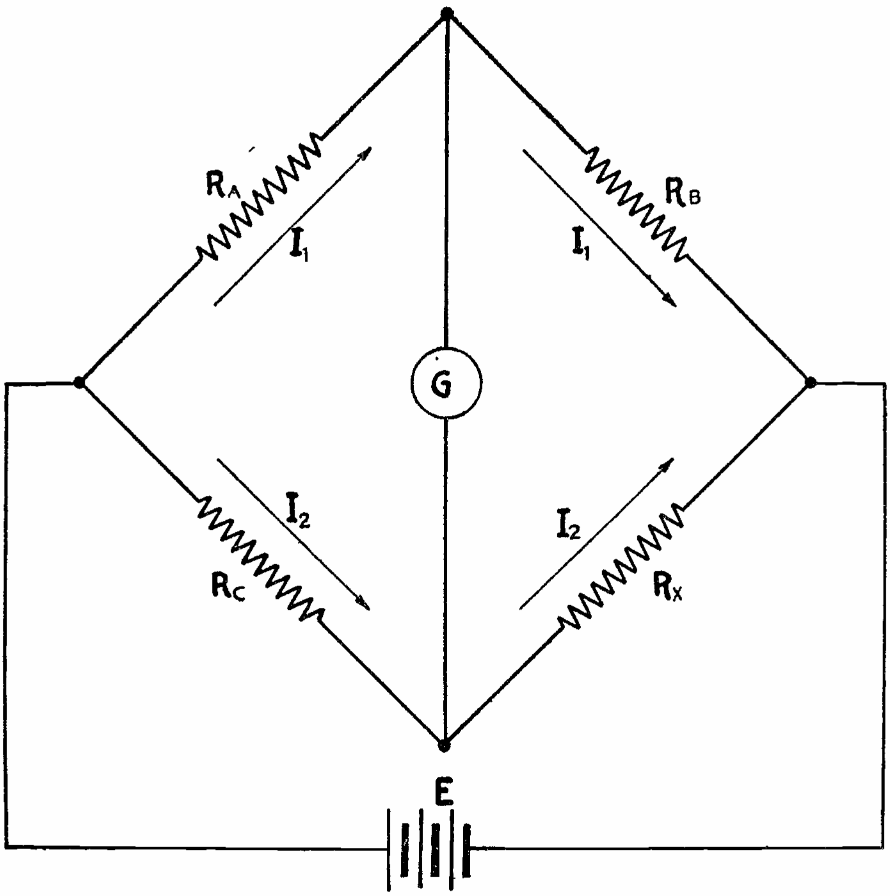


FIGURE 9

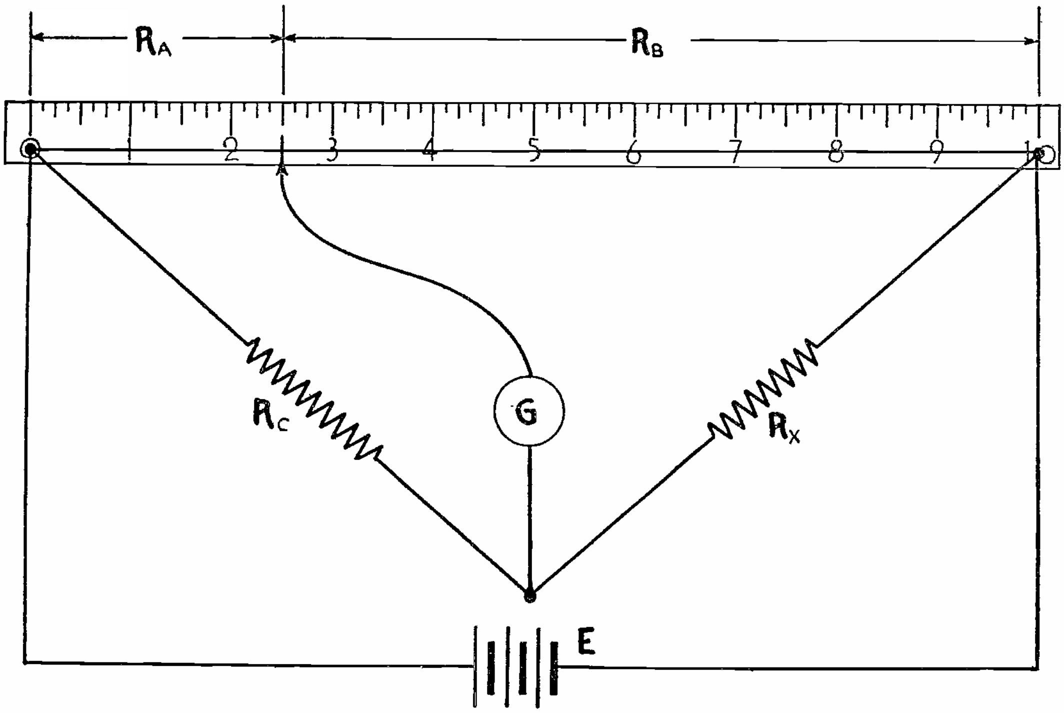


FIGURE 10

DE FOREST'S
TRAINING, Inc.

LESSON FDM - 16
MULTIMETERS

* * Founded 1931 by * *

H. A. DeVRY

A PIONEER AND LEADER OF VISUAL EDUCATION

RADIO FUNDAMENTALS

LESSON 16

MULTIMETERS

Milliammeter ---------------- Page 1
D.C. Voltmeters ------------- Page 5
Ohmmeters ------------------- Page 7
Meter Curves ---------------- Page 9
A.C. Voltmeter -------------- Page 10
Capacity Meter -------------- Page 11
Free Point Testers ---------- Page 12
Complete Analyzer ----------- Page 14

* * * * *

"All the genius I have lies in just this: When I have a subject in hand I study it profoundly. Day and night it is before me. I explore it in all its bearings; my mind becomes filled with it. Then the effort which I make people are pleased to call genius. It is the fruit of labor and thought."

Alexander Hamilton

FDM-16

In former Lessons we have explained the uses of voltmeters and milliameters for circuit testing. Here, we want to show you how, simply by changing the circuit, one meter movement may be employed for several different tests, among which are d-c current, a-c and d-c voltage, Resistance and Capacity.

By looking through any test equipment catalogue, you will notice instruments which incorporate some, or all, of the above features, the different tests being made available by separate terminals, push buttons or other switching arrangements. To make our explanations simple, we will take up each feature separately, using the same movement in all explanations, and then combine them into a complete "Analyzer".

MILLIAMMETER

Practically all of the Direct Current meters, used for testing Radio and other Electronic equipment, employ the D'Arsonval movement which has been previously explained and if you have forgotten the electrical action, a review will be of benefit before going ahead. In Figure 1, we show a diagram of this type of meter with its permanent magnet and moving coil wound on a cylinder placed between the pole pieces. The coil can be wound with any number of turns which, together with the strength of the magnet, will determine the amount of current necessary to pull the pointer all the way across the scale. To make our explanations definite, we will assume that the coil is wound so as to have a d-c resistance of 50 ohms and requires a current of 1 ma for full scale deflection. For this reason, the scale is calibrated, in equal divisions, from 0 to 1.0, and marked "Milliamperes".

Now, suppose the circuits we are testing often have current values up as high as 100 ma, but we do not want to use another meter. From the study of parallel circuits, we remember that the current divides inversely as the resistances of the branches, therefore decide that a resistance, in parallel to the meter movement, will allow higher current readings. Back in the Lesson on meters, we explained this action and called the added resistance, a "SHUNT" but here, to secure a wider range of readings, we use two shunts and designate them as S1 and S2.

At the left of Figure 1, we show the negative terminal connected to one side of the moving coil. At the right, we have the positive terminal which connects to the other side of the moving coil. Connecting the meter in a circuit, with the rotary switch in the 1 ma position, will cause it to read according to the scale markings because all current in the circuit will be carried by the moving coil.

To make the meter indicate 10 M.A., it can carry but 1 M.A. in the moving coil when there is a total current of 10 M.A. in the circuit. Therefore, with the switch in the 10 M.A. position, the shunt, S1, will have to carry 9 M.A. when the moving coil has 1 M.A.

As the shunt is to carry 9 times the current it must have 1/9 the resistance of the moving coil and be connected in parallel to it. We stated the moving coil had a resistance of 50 ohms and therefore the shunt, S1, must have a resistance of one ninth of 50 or 5.55 ohms.

Trace the circuits of Figure 1, with the rotary switch in the 10 M.A. position, and you will find the shunt S1 and the moving coil in parallel between the positive and negative terminals. As the shunt has 1/9 the resistance, it will carry nine times the current of the moving coil or .9 of the total current in the circuit. Therefore, the moving coil will carry but .1 of the total current and, to read the value of total current, the indication on the scale must be multiplied by 10.

In the same way, to read circuit current values up to 100 M.A., the shunt S2 will have to carry 99 M.A., when the moving coil carries 1 M.A. To do this, the shunt must have but 1/99 of the resistance and figuring as before, 1/99 of 50 ohms is approximately .5 ohms.

Then, with the rotary switch in the 100 M.A. position and connecting the positive and negative terminals in series with a circuit, .99 of the total current will pass through shunt S2 and .01 through the moving coil. Because but .01 of the total current is carried by the moving coil, to read the current in the circuit, the indication of the scale must be multiplied by 100.

Of course, the resistance values of each shunt must be accurate or the meter readings will not be correct. Also, by increasing the values in steps of 10, one series of numbers on the scale can be used for all. For example, if the pointer stands at .2, with the selector in the 1 M.A. position, when connections are made to the meter terminals, we read it as .2 M.A.

If the pointer stops at .2, with the rotary switch at the 10 M.A. position, we multiply by 10 and read it as 2 M.A. Likewise, with the pointer at .2, on the 100 M.A. switch setting, we multiply by 100 and read it as 20 M.A.

The arrangement of Figure 1 is commonly referred to as "Parallel Shunts" while in Figure 2, we have an arrangement which is known as a "Ring Shunt". You can easily understand

the reason for this name by considering only the meter and the shunts. They are connected in series with each other and thus form a resistance circle, or ring with the various ranges obtained by tapping in at different points of the ring.

To show you how this works out, we will assume that we want to convert the meter of Figure 1 to have 10 ma, 100 ma, and 200 ma ranges with a ring shunt arrangement. The first step is to determine the total value of shunt resistance at the lowest current. As this is 10 ma and the total shunt is in parallel to the moving coil, we can use the method explained for Figure 1. Here, with 10 ma as the total current, we must have 9 ma in the shunt and 1 ma in the moving coil. Therefore, the total shunt must have 1/9 the meter resistance which, as previously determined, is 5.55 ohms.

Another method of finding the value of a parallel shunt is by using an equation which is sometimes referred to as the "Law of Shunts" and express by,

$$I_m = \frac{R_s I}{R_m + R_s}$$

Where—

I_m = current in the meter, in amperes
I = total current, in amperes
R_s = resistance of the shunt
R_m = resistance of the meter

In our work here however, we know all the values except the resistance of the shunt. Therefore, by methods which will be explained in later Lessons, we rearrange or "transpose" the terms of the equation so that it reads:—

$$R_s = \frac{I_m R_m}{I - I_m}$$

Now, the equation states the value of the shunt resistance, in terms of the total current, meter current and meter resistance. To check the equation, we will use the values of Figure 1 for the 10 ma range. Here, I = 10 ma = .01 ampere, I_m = 1 ma = .001 ampere, and R_m = 50 ohms.

Substituting in the formula,

$$R_s = \frac{.001 \times 50}{.01 - .001} = \frac{.05}{.009} = 5.55 \text{ ohms}$$

which checks with our former method, for the 10 ma scale.

In Figure 2, this gives us the total value of S1 + S2 + S3 and our next step is to find the value of each section or determine where we will tap in the "ring", for the ranges indicated. The easiest way to do this is by using the equation for the Law of Shunts but we must remember that, for taps, we will have part of the total shunt in series with the meter and part in parallel, the ratio of which will depend on the ranges desired. Under these conditions therefore, we will let $R_m + R_s$, of the original equation, equal R_o and substituting,

$$I_m = \frac{R_s I}{R_m + R_s} \quad \frac{R_s I}{R_o}$$

Where -

I_m = meter current in amperes
R_s = parallel section of total shunt
R_o = total resistance of the shunt plus the meter resistance

As we are interested in finding the parallel section of total shunt, we transpose the terms of this equation to make it read

$$R_s = \frac{I_m R_o}{I}$$

For the 200 M.A. range on the meter of Figure 2, I_m = 1 M.A. = .001 amp., R_o = 50 + 5.55 = 55.55 ohms, I = 200 M.A. = .2 ampere.

Substituting,

$$R_s = \frac{.001 \times 55.55}{.2} = \frac{.05555}{.2} = .27775 \text{ ohm}$$

As S1 is the parallel section of the 200 M.A. range, it would have a value of .27775 ohm.

For the 100 M.A. range, we follow exactly the same plan but I = 100 M.A. = .1 ampere.

Substituting,

$$R_s = \frac{.001 \times 55.55}{.1} = .5555$$

Here, R_s is equal to the total resistance of the parallel section which, for the 100 M.A. range, includes S1 and S2, and thus the value of S1 must be subtracted from R_s to obtain

the resistance of S2 which, in this case, would be .5555 - .27775 = .27775. We found the total resistance of the shunt to be 5.55 ohms and S1 + S2 is .5555 ohm, therefore as S3 is in series with the other sections, it must have a value of 5.55 - .5555 or 4.9945 ohms.

The scale of Figure 2 is read in the same way as Figure 1, with the exception of the 200 M.A. range. Here, if the pointer stops at .2, you would have to multiply by 200 and read it as 40 M.A.

Although we have based our explanations on a 1 M.A. movement, with a D.C. resistance of 50 ohms, the methods can be used on any current meter, to extend the range upward. A meter cannot be made to read a lower value than that for which it was designed unless the moving coil is rewound with more turns of wire, a job which usually is more expensive than a new meter of the desired type.

D.C. VOLTMETERS

As we explained in the earlier Lessons, a voltmeter actually operates because of the current in it, although the scale is calibrated in volts. Therefore, we can again make use of a 1 M.A. meter movement but, as voltage is the difference of pressure between two points, we must employ some means of limiting the maximum current to a value of 1 M.A.

Taking the 10 volt range of Figure 3 as an example, there must be enough resistance between the "-" and "10 volts" terminals, to allow only 1 M.A. of current at a pressure of 10 volts. Using the form of Ohm's Law, where $R = E/I$, you will find 10,000 ohms is necessary but, as the meter resistance of 50 ohms is in series with this circuit, R_1 would have a value of 10,000 - 50 = 9,950 ohms.

Assuming then that we have a resistance of 10,000 ohms in the circuit and the minus and 10 volts terminals are connected across a 6 volt battery, the current in the meter will be 6 volts divided by 10,000 ohms, or .0006 ampere.

To find the milliamperes, we multiply the .0006 by 1000 and have .6 for the answer. With this current in the moving coil, the pointer will stop at the .6 position on the scale and this time we multiply the scale reading by 10 volts to find the correct value of 6 volts.

Now notice, in Figure 1 the shunts are connected across, or in parallel to, the moving coil while in Figure 3 the resistances are in series with it. Also, as we used 10,000 ohms resistance to provide a reading of 10 volts, the voltmeter

has a sensitivity of 1000 ohms per volt. You may have seen instruments advertised as having a sensitivity of 20,000 ohms per volt, or more, and this simply means that the basic movement requires a small amount of current to move the pointer all the way across the scale. For example, if the meter of Figure 2 required 50 micro-amps. (.00005 ampere) for full scale deflection then, for the 10 volt scale, it would need a series resistance of 10 divided by .00005 or 200,000 ohms. Thus, in the 10 volt scale, it would be a 200,000 ÷ 10 or a 20,000 ohms per volt meter.

As you will learn later in the training, the highly sensitive meters give more accurate readings in high resistance networks, due to the fact that they require a smaller value of current for their operation. This means that the meter current will cause only a small voltage drop across a series resistance which, in turn, will allow approximately the total voltage drop of the circuit across the meter and thus provide an actual indication of the available voltage.

Getting back to our basic movement of Figure 3, to read higher values of voltage, we need only add resistance to the circuit. To read up to 100 volts and still allow but 1 M.A. in the meter circuit, there will have to be 100,000 ohms resistance between the minus and 100 volts terminals. We already have 10,000 ohms in R1 and the moving coil therefore, by using 90,000 ohms for R2 and connecting it in series with R1, as shown, we have the proper values.

For example, connecting a 45 volt B battery across the minus and 100 volts terminals, the current in the meter circuit would be 45 volts divided by 100,000 ohms or .00045 ampere.

Multiplying this value by 1000, to change to milliamperes, we have .45 M.A. in the moving coil which would move the pointer to the .45 mark on the scale. To read the scale properly this time, we multiply the .45 by 100 volts and have 45 volts. Here again, there are 1000 ohms per volt in the meter circuit.

For higher values, it is only necessary to insert additional resistances like R3 which we show for the 1000 volt scale. To use this, we need a total of 1,000,000 ohms in the circuit, but T2, R1 and the moving coil have a total of 100,000 ohms, therefore R3 must have a value of 900,000 ohms and be connected in series with the others as shown.

Connecting the minus and 1000 volts terminals across a circuit, the scale reading will have to be multiplied by 1000 volts for the correct value. For example, if the pointer moved to .8 on the scale, there would be 800 volts across the terminals.

The multiplication of the readings is apt to be confusing and therefore you will find many multi-purpose testers with several rows of figures along the scale. Whenever you use a meter with more than one scale, always start with the higher values and then move to the lower one if the reading is low. For example, on the "-" and "1000" volt terminals, in Figure 3, a pressure of 10 volts would move the pointer only to the .01 division, making it very hard to obtain an accurate reading. Moving over to the 100 volt terminal, the pointer would move to the .1 division making the reading easier but, seeing the hand did not pass the .1 division, you would be safe in moving the connections to the 10 volt terminal where the pointer would move all the way across the scale.

OHMMETERS

In making tests of various electronic equipment, it is sometimes necessary to measure the D.C. resistance of certain component parts and therefore, in the circuits of Figure 4, we show you how the meter movement of Figure 1 can be employed as an "Ohmmeter".

Because an ohmmeter requires a source of supply, we will use a $4\frac{1}{2}$ volt C battery for our explanations and, applying Ohm's Law as we did for the voltmeter of Figure 3, it will be necessary to have 4500 ohms resistance in the circuit to limit the current to 1 M.A. and move the pointer all the way across the scale.

The total resistance is made up of the resistance in the moving coil and the variable resistor "R". Following the plan of commercial units, the resistor is shown variable to compensate for variations of battery voltage.

Notice, the terminals marked "Unknown Resistance" are in series with the battery, moving coil and variable resistor. Now, if the terminals are shorted, there will be $4\frac{1}{2}$ volts across the circuit with 4500 ohms resistance. This will allow 1 M.A. of current and move the pointer all the way across the scale.

Suppose we connect a resistance of 1000 ohms across the terminals. That means the total resistance of the meter circuit has increased from 4500 to 5500 ohms. With $4\frac{1}{2}$ volts, the current will now be approximately .8 M.A. and the pointer will stand at the .8 position. In calibrating the scale, we would mark 1000 at the .8 position, because there are 1000 ohms across the terminals.

In the same way, resistance of 2000, 3000, 5000 and 10,000 ohms and so on can be connected across the terminals and the

proper figure marked on the scale, at the place the pointer comes to rest, when each respective resistor is in the circuit.

For Figure 5, we show another circuit of an Ohmmeter which is quite commonly referred to as a "Back-Up Ohmmeter". It receives its name from the fact that, when reading resistance values, the pointer moves in the reverse direction as compared to Figure 4. The circuit is very similar to that previously explained and we have the battery, moving coil and variable resistance all connected in series. Thus, to have 1 M.A. of current in the moving coil, with a pressure of 4½ volts, the circuit must have a resistance of 4500 ohms.

The unknown resistance terminals are not in series with but are "shunted" across, or in parallel to, the moving coil. Therefore, with the "Unknown Resistance" terminals open, the meter will have full scale deflection. With the terminals shorted, the pointer will return to the "0" mark of the scale because, as explained earlier in the training, the current in the branches of a parallel circuit varies inversely as the resistance.

Suppose that we connected a resistance of 50 ohms across the "Unknown Resistance" terminals of Figure 5. The moving coil also has a resistance of 50 ohms and with the total current of 1 M.A., there would be .5 M.A. in the resistance and .5 M.A. in the moving coil. Thus, the pointer would stop at the .5 division on the scale which could be marked 50, as the unknown resistance is 50 ohms.

This is an important point to remember because the center marking of any "Back-up Scale" Ohmmeter will give you the internal resistance of the moving coil. Of course, if shunts are internally connected across the moving coil, the center scale marking will be the resultant resistance of the internal combination.

An ohmmeter of this type is calibrated exactly the same as explained for Figure 4. However, due to the fact that the resistance of the moving coil is comparatively low and that it determines the mid-scale value of measurable resistance, the circuit of Figure 5 is generally used only for the measurement of low resistance values. Also, in commercial units, a switch is provided to open the battery circuit when the "Back-up Scale" is not in use.

The circuit of Figure 4 is really more flexible and the resistance ranges can be varied to take care of any practical measurements. The ranges depend on the sensitivity of the movement and also on the value of the supply voltage. Although we have used a battery as a source of D.C. voltage,

any other type may be employed. For example, in a number of commercial units, a high voltage D.C. supply is obtained from an A.C. power outlet, with suitable transformers, rectifiers and filters built in as an integral part of the Ohmmeter.

METER CURVES

In some cases, we may desire to use a meter for certain tests but do not want to mark up the dial, or perhaps the dial is already crowded, therefore we draw a curve by means of which the scale readings can be changed without making any calculations. Although this method can be employed for any readings, we will use it in conjunction with the ohmmeter of Figure 4.

Such a curve is shown in Figure 6 and, to make it, we obtain a piece of "Cross Section" paper, which is nothing but ordinary paper with small uniform squares printed on it. Then, as the meter scale of Figure 4 reads from 0 to 1.0, we lay off a similar scale along the left side of the paper. This can be made any size but, if possible, each square on the paper should represent at least one division of the meter scale.

No matter what size the curve is made, each square must represent an equal amount. For example, in Figure 6, there are four squares between 0 and .2 therefore each square represents .05 and the same is true all the way between 0 and 1.0. Then across the bottom we mark the Ohms scale, again letting each small figure represent an equal amount which happens to be 1000 in Figure 6.

As explained for Figure 4, a resistance of 1000 ohms, placed between the terminals, allowed .8 M.A. in the meter circuit to provide a reading of .8. Using these values for the first point of the curve, we go across the Ohms scale from 0 to 1000, which is the first line, then straight up and put a dot where it crosses the .8 line.

Following the same plan, we connect several known values of resistance across the terminals, read the meter on the M.A. scale and, on the cross section paper, mark the point where the lines, representing each pair of resistance and current values, are found to cross. By using Ohm's Law, as previously explained, 5000 ohms across the terminals plus the 4500 ohms of R and the moving coil of the meter make a total of 9500 ohms which, at $4\frac{1}{2}$ volts, would cause a reading of .47 M.A.; 10,000 ohms across the terminals would cause a reading of .31 M.A. and so on. After a few such points are found on the paper, a curved line is drawn through them and Figure 6 is the result.

Now, suppose we have the meter of Figure 4, and connecting an unknown resistance across the terminals, obtain a reading of

.3. Looking at Figure 6, we start at the lower left corner, go up to the .3 line, half way between .2 and .4. Then we follow this line across to the right until it crosses the curve. From the point they cross, we go straight down, as shown by the dotted line, and find we are about half way between 10,000 and 11,000 line of the ohm scale which means the resistance has a value of approximately 10,500 ohms. By following this plan, any reading on the meter scale can be converted to the corresponding value in ohms.

A.C. VOLTMETER

So far, all of our explanations have assumed a continuous current in one direction only, supplied by a battery or similar source of voltage. Because of its uniform direction, this is known as "Direct" current, usually abbreviated "D.C.".

However, as we will explain later, most commercial circuits carry current which is continually changing in value and periodically reversing in direction. Because it alternates in direction, we call this "Alternating" current, usually abbreviated "A.C." and employ a source which develops an A.C. voltage.

In order to use the basic meter movement for the measurement of A.C. voltages, it is necessary to incorporate another unit to change the A.C. to D.C. This is necessary because the D'Arsonval meter is fundamentally a D.C. instrument and the pointer will not respond, to any great extent, to A.C.

One common method of making this change is to add a copper-oxide rectifier, the symbol of which is shown directly below the meter of Figure 7. The rectifier consists of a sheet of copper on which a coat of cuprous oxide has been formed on one side. Properly made, this combination has relatively low resistance to current from the oxide to the copper and high resistance to current from the copper to the oxide.

For meter purposes, the units are usually made in plates, or discs, varying in size from 3/16 in. sq. up to diameters of 3/4 of an inch. The units are then assembled in any desired series or parallel arrangement by mounting bolts. The surface of the oxide is graphitized and soft metal washers, placed between the units, are for the purpose of improving the contact with the oxide. Terminals are brought out from the assembly for connection to the meter and external circuit.

Copper oxide rectifiers have a number of applications, some of which will be brought out in the later Lessons. For this Lesson however, we are interested only in their application for the conversion of a D.C. instrument so that it can measure A.C. values.

Following the action of Figure 7, if an A.C. voltage is applied to the "-" and "10" terminals, for one direction the current will be through R1, the upper right hand rectifier, the moving coil of the meter and through the lower left hand rectifier to the "-" terminal. For the other direction, the current will be from the "-" terminal, through the upper left hand rectifier, the meter and through the lower right hand rectifier and R1 to the "10" terminal.

Notice, the direction of current through the meter is always the same, although we are making use of both directions of the A.C. voltage, and thus there is direct current in the moving coil. This will cause the pointer to move across the scale and the distance it moves will depend on the amount of current which, in turn, will depend on the impressed voltage.

There are several important differences between D.C. and A.C. which affect the operation of a meter, like that of Figure 7, and which we want to mention at this time. In the ordinary home lighting circuit, the alternating current changes direction 120 times a second and, while in each direction, varies from zero to its highest value and back to zero again.

As a result, in a circuit like that of Figure 7, the meter current will be a series of pulses, instead of a steady value and, because the meter hand can not follow the rapid changes, it will indicate the average value of current which is approximately .9 of the correct value. Also, the resistance of the rectifier, which is in series with the meter, changes with varying values of current. This action is known as the "current density" of copper oxide rectifiers and, because of it, the calibration of rectifier type A.C. instruments is quite complicated.

Various circuit arrangements of meter and rectifier are in common use and usually, the "ohms per volt" sensitivity of the A.C. voltage ranges is less than that of the D.C. voltage ranges. At this point of the training, we can not give you complete details regarding the actual calibration of rectifier type A.C. voltmeters therefore, the explanation has been included to show only the application and is not for constructional purposes.

CAPACITY METER

In addition to resistors, Radio circuits require numerous condensers, the construction and action of which will be explained in a later Lesson. However, at this time, we can show you a method by which the electrical size of a condenser, known as its "capacity", can be measured. Connected in an A.C. circuit, a condenser opposes the current and, as explained for resistance, this opposition is measured in ohms. The

capacity of a condenser is measured usually in "Microfarads", a term which will be explained later but now, you need remember only that the larger the capacity of a condenser, the smaller its opposition in ohms.

Because of this relationship, the meter and rectifier of Figure 7 can be incorporated in the ohmmeter circuit of Figure 4, provided the battery is replaced by an a-c source as shown in Figure 8. As we mentioned earlier in this Lesson, the common a-c house lighting current reverses direction 120 times a second therefore, the complete or entire change, consisting of current in both directions, occurs 60 times a second. As each complete change is known as a cycle, changes at this speed are known as 60 cycle a-c.

As shown in Figure 8, the circuit has a 60 cycle a-c supply at the lower right and the unknown value of capacity is connected across the terminals to place it in series with the variable resistance R1, the rectifier, meter and supply.

By using known values of capacity, the meter can be calibrated, by the plan explained for Figure 4, to read directly in Microfarads. However, as the larger capacities offer less opposition and allow larger currents, the higher values will appear at the right end of the scale like those in the back up scale of Figure 5. If the meter dial is crowded, a capacity curve can be drawn as explained for Figure 6 but with the lower horizontal scale in microfarads instead of ohms.

FREE POINT TESTERS

For Figure 9, we show the schematic diagram of a "Free Point Tester" and, although it is not actually a part of the meter circuits, you will find such a unit incorporated in some models of a complete analyzer. The purpose of a free point tester is to allow complete checks of voltage and current of the tube circuits of a Radio Receiver, without "pulling" the chassis out of its cabinet or console.

Checking through the circuit, the various tube sockets are connected in parallel with their terminals connected through nine circuit breaking switches to the cable, which terminates with an analyzer plug. This plug is arranged with various types of adapters which will accommodate all tube sockets. The "Top-Cap" terminal at the right is for connecting the top-cap of a tube to the "T.C." circuit breaking jack. Also, the fourth socket from the left, is generally made to take care of both large and small 7 pin base tubes.

To make tests, a tube is removed from the Radio and placed in the proper socket of the "Free Point Tester" while the

analyzer plug is placed in the socket from which the tube was removed. Electrically, these changes extend all of the circuits of the tube to the free point tester which has terminals available at the circuit breaking switches numbered from 1 to 8 and "T.C.". These numbers are shown as they appear on top of the sockets and conform to the standard tube marking system which will be explained in a later Lesson on Tube Characteristics.

The action of these switches is quite unique in view of the fact that by their use, it is possible to put a meter in series with, or parallel to, any of the socket terminals. By inspecting the switch symbols, you will notice that they show two, single contact switches in parallel, the contacts normally closed and with spring contacts connected opposite to each other.

Directly above each spring is a pin jack brought out to the front of the panel and when a plug is inserted, it makes contact with the spring, opens that set of contacts but still leaves the circuit complete through the other switch. Therefore, if plugs were placed in either of the two pin jacks of #1 and #2 switches, the voltage across these two socket terminals would be made available for measurement.

However, if two plugs were placed into the pin jacks of any one of the switches, its circuit would be open and any unit, connected across the plugs, would be in series making it possible to measure current. Also, by the use of these switches, it is possible to insert any device in series in the circuit. An application of this would be placing headphones in the proper circuit to determine if some tube of an electronic unit was operating satisfactorily.

To give you a better idea of the actual operation of a free point tester, we will assume that we desire to check the voltage across socket terminals 3 and 8 and the current in the circuit of terminal 3 for some particular tube. The first step is to place the tube in the proper socket of the free point tester and the analyzer plug in the socket from which the tube was removed. The Radio receiver or electronic device under test, is then turned "ON" and we are ready to make our measurements.

The voltage is measured first because, without voltage, there would be no current. Assuming this circuit requires D.C., we will employ the voltmeter of Figure 3 and, to protect the meter, use the 0 to 1000 volt scale. By the use of suitable leads, we connect the "-" terminal to one of the number 8 pin jacks, with the "1000" terminal being connected to one of the number 3 jacks. The meter should now indicate the

voltage but, if the indication is less than 100 volts, the maximum value of the next lower scale, the meter connections should be changed, as previously explained.

Assuming that the voltage is correct, our next step is to measure the current and for this test we will employ the meter of Figure 2, although the meter of Figure 1 could be used just as well. With the power still on, the voltmeter is disconnected by removing the plugs from the pin jacks. Using the highest range of the milliammeter, we plug into both jacks of the #3 switch, connecting the "-" terminal to the right hand jack and the "200" terminal to the left hand jack. This operation serves to place the meter in series with the circuit and the current will be indicated. Should the value be low, the next lower scale of the meter can be used. Should the meter pointer move to the left or "off the scale", the connections to the jacks must be reversed.

From the above explanation, you can see the versatility of the "Free Point Tester" and the time it will save in making voltage and current tests of the various tube circuits. As time is money, this simple unit is worth a great deal.

COMPLETE ANALYZER

Now that we have explained the various units which go to make up an analyzer, in Figure 10, we have the complete assembly.

Provisions are made for a-c and d-c voltages, d-c milliamperes, capacity and resistance with the different ranges made available by the use of terminals shown along the bottom of the diagram. Also, built as a part of the analyzer, is a "Free Point Tester" like that of Figure 9.

As only one meter movement is used, provisions must be made to incorporate the proper circuits for the desired readings and this is accomplished by a 5 point, 4 gang, rotary switch, the symbol of which is shown in the middle of the diagram. The position of the contacts for different tests is indicated by the abbreviations, DCMA (D-C Milliamperes), MFDS (Microfarads), and ACV (A-C Volts), DCV (D-C Volts) and Ohms.

The voltage and current circuits are the same as previously explained and fundamentally, the circuits for the measurement of capacity and resistance are also the same. However, to obtain the desired ranges of capacity and resistance, a combination of series and parallel resistances is employed. Also, the voltage necessary for the low range resistance scales is obtained from a battery while, for the higher ranges, the d-c voltage is obtained from a built in power supply

operating from a regular 110 volt 60 cycle home lighting circuit. The A.C. voltages for capacity measurements are taken directly from taps on the power transformer secondary.

Go over the circuits and explanations of the Lesson very carefully because all test meters and analyzers are built on the same general plan. The main point we want you to remember is that the current in the meter circuit controls the movement of the hand or pointer. By the use of the proper connections, the current will be in proportion to various other values such as voltage, ohms or microfarads and by properly marking the scale, these readings can be taken directly from the meter dial.

At this time, we want to remind you that the values we have given do not apply to any particular model and, while approximate, are used only to explain the action. The construction and exact calibration of test instruments is quite tedious and it is usually more economical to purchase commercial units now on the market.

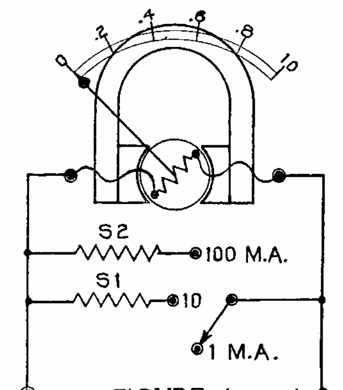


FIGURE 1

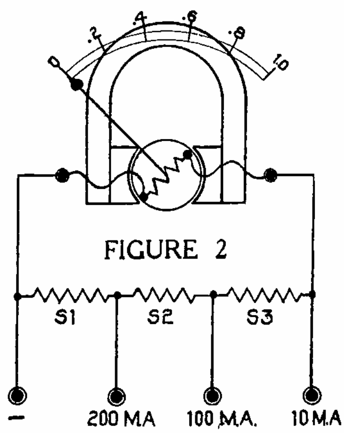


FIGURE 2

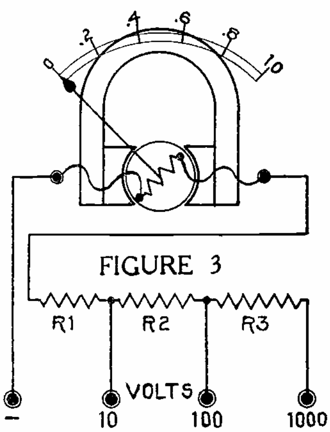


FIGURE 3

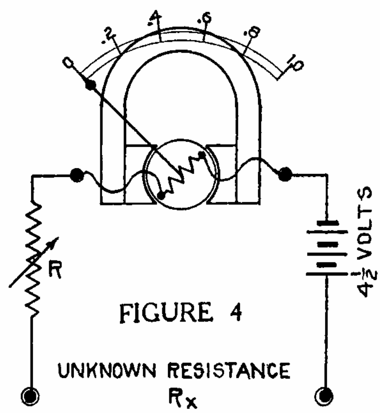


FIGURE 4

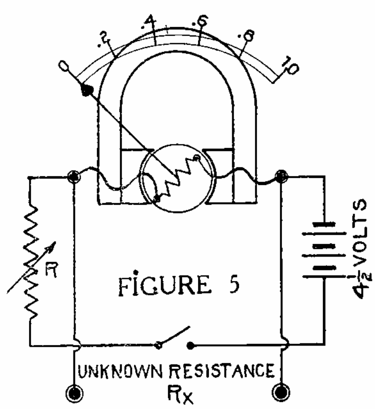


FIGURE 5

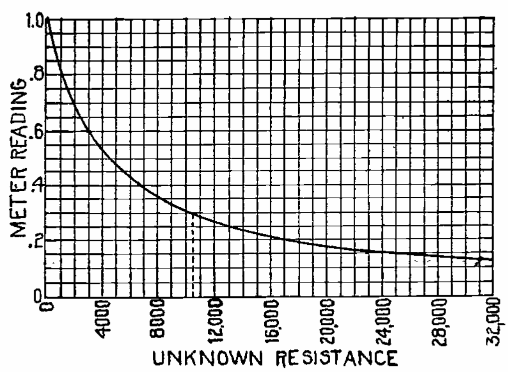


FIGURE 6

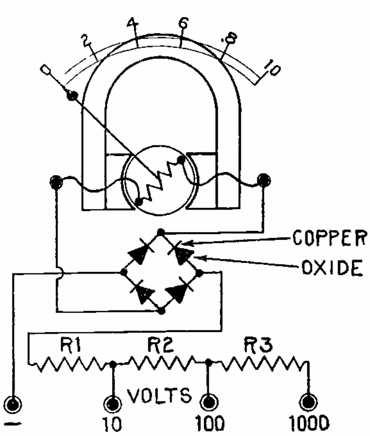


FIGURE 7

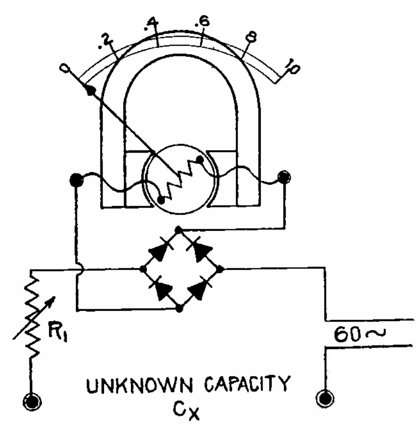


FIGURE 8

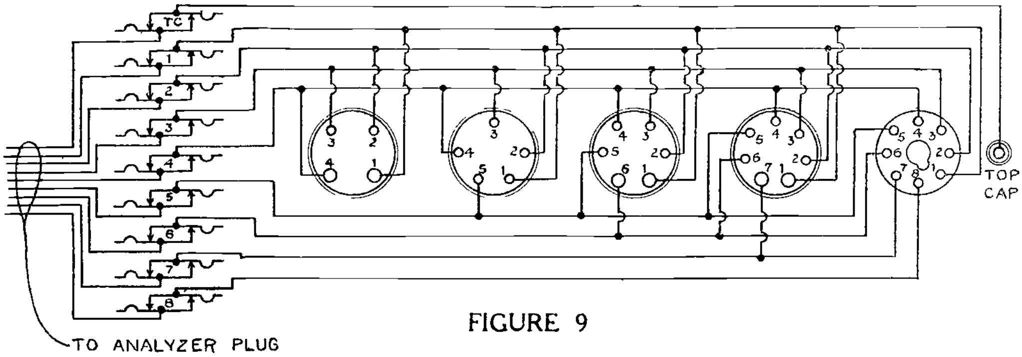


FIGURE 9

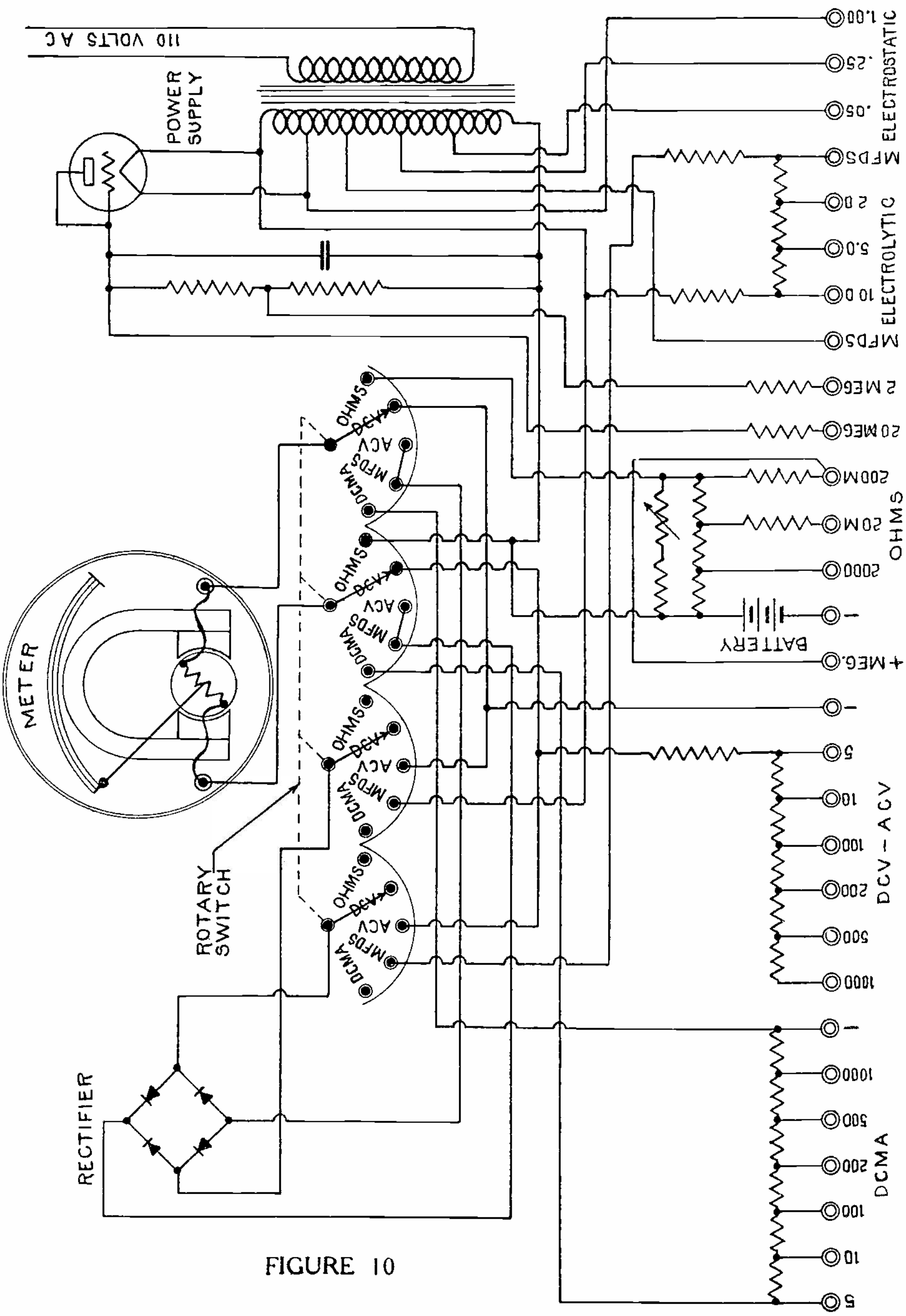


FIGURE 10

DE FOREST'S
TRAINING, Inc.

LESSON FDM - 17
ELECTRICAL POWER

* * Founded 1931 by * *

RADIO FUNDAMENTALS

LESSON 17

ELECTRICAL POWER

Mechanical Force -------------- Page 1
Mechanical Work --------------- Page 1
Energy ------------------------ Page 2
Foot-Pounds ------------------- Page 2
Mechanical Advantage ---------- Page 3
Levers ------------------------ Page 3
Torque ------------------------ Page 4
Mechanical Power -------------- Page 5
Horse Power ------------------- Page 5
The Prony Brake --------------- Page 6
Electrical Power -------------- Page 7
The Watt ---------------------- Page 8
The Kilowatt ------------------ Page 10
Milliwatts and Microwatts ----- Page 11
Watt - Hours ------------------ Page 12
Kilowatt - Hours -------------- Page 12
Horse Power Hours ------------- Page 12
Input and Output -------------- Page 12

* * * * *

In the struggle for advancement in the world, two people oftentimes have the same natural ability and fight along neck-and-neck for a time. The one who pulls ahead on the final home stretch under such conditions is almost always the one who has trained himself to take pains.

-- Dr. Frank Crane

So far, the principal electrical terms, or units, we have taken up are volts, amperes and ohms, and while other units such as "Henrys", "Farads", "Cycles" and so on, will be explained with the actions they measure, for this Lesson we are going to tell you what is meant by "Power".

No doubt, you have read many Radio articles and advertisements about "Power Tubes", "Power Detectors", "Power Amplifier", "Super-Power Stations", "Power this and Power that", and in order that you may fully understand them, you must know exactly what is meant by "Power".

Instead of comparing electricity with water, as in our former Lessons, this time we will go into mechanics for our examples and, in this connection, there are several terms that you must know and keep clearly in mind.

MECHANICAL FORCE

In your everyday conversations, you no doubt use the word "Force" in talking about many different things such as, "He was forced to pay the bill", or in football, "On the fourth down, they were forced to punt" but, in almost every case, Force means about the same as Push.

In mechanical work, Force does means the same as Push. If you put your hand on the edge of your table and push, you are exerting a force on the table. Of course, the weight of the table opposes the force with which you are pushing and, as the weight of the table is measured in pounds, the force is measured in pounds also.

Suppose you push harder. You can see that as soon as the force you apply is greater than the weight by which the table opposes you, the table will move. Mechanically, we say: "The applied force overcame the resistance". You can think of anything able to produce a push or a pull, as some form of Force. For example, when a tea kettle boils, it is the force of the steam that raises the lid.

MECHANICAL WORK

This brings us to the second word, or term, which is "Work". This word certainly is not new to you but we are going to use it in a little different way. Mechanically, whenever a force overcomes the resistance and, for a measurable distance, moves anything that has weight, we say that Work has been done. Work then consists of two separate things, a force measured in pounds, which moves a weight for some distance, measured in feet. To measure the amount of work done, it is necessary to consider both the pounds and the feet, therefore

we multiply them and have a unit of measure called the "Foot-Pound", usually written as ft.-lbs.

As a definition, a foot-pound is equal to the work done in raising a weight of one pound through a vertical distance of one foot.

ENERGY

Another term, or word, that we had better mention here is "Energy". This also is very common because there are many forms and kinds of energy but, in a mechanical way, anything has energy, when it can do work. As a definition, Energy is the ability to do work.

There are, however, two main classes of energy called "Potential" and "Kinetic", names which are not at all hard to remember because "Potential" energy means energy in an object or a body because of its "Position".

For instance, imagine an ordinary brick lying on the roof of a two story building. It doesn't look as though it had much energy but, if you pushed it off the roof and let it fall, it could exert quite a force when it hit the ground. The energy it had was potential and was in it because of its position on the roof.

"Potential"means energy of position or at rest, while "kinetic" means energy in motion. The instant you pushed the brick off the roof and it started to fall, it was in motion and its energy changed from potential to kinetic. Have you ever seen a pile driver or well drilling outfit where a heavy weight is pulled up and then let fall? As long as the weight is held up, its energy is potential but, when it falls, its energy is kinetic.

To get down to actual facts and figures in the use of these terms, for Figure 1 we show a 10 lb. weight lying on a ordinary table. Due to its position, it has a certain amount of potential energy but we are not interested in that right now. Instead, we are going to lift the weight.

As soon as we take hold and start to lift, we apply a force on the weight and, the instant that force is over 10 lbs., the weight moves.

FOOT-POUNDS

If we lift it for one foot, we have a force of ten pounds acting through a distance of one foot, therefore 10 ft. lbs. of mechanical work is done. Lifting it for 2 feet, we have

10 lbs., times 2 feet or 20 ft.-lbs. of work. What we want you to remember is that, regardless of the form of energy, the foot-pounds of mechanical work done is always equal to the distance, in feet, multiplied by the force in pounds.

MECHANICAL ADVANTAGE

There are many common mechanical devices by which mechanical work can be done in the easiest way. For example, suppose that you had 2000 ft-lbs of work to do. Thinking only of the force required, it would be quite a job to lift 2000 lbs. for a distance of 1 foot, and it would be almost as hard to raise 200 lbs. for 10 ft. You could, however, raise 20 lbs. for 100 ft., without much effort and could put 1 lb. in your pocket and carry it on a mountain climb of 2000 ft., without even noticing it. Just look at the table below and you will see that, in every one of the cases mentioned, the work done is the same.

Pounds	times	Feet	equals	Ft.-lbs.
2000	x	1	"	2000
200	x	10	"	2000
20	x	100	"	2000
1	x	2000	"	2000

Whenever we have an arrangement that will let us shift the amounts of weight and distance, or let a smaller force, by acting through a greater distance, move a larger weight, we say there is a mechanical advantage.

LEVERS

Perhaps a lever action is the simplest arrangement which will illustrate what we mean by mechanical advantage. In Figure 2-A, we show a balance or see-saw that extends for three feet each side of the center support and find that a two pound weight, placed at each end, keeps it balanced. We expected this because on each side there is a weight, or force, of 6 ft.-lbs. As there is no motion, no work is done.

In Figure 2-B, we still have the 6 ft. balance but have moved the support so that one end is five feet long while the other is but one foot long. With a 2 lb. weight on the five foot end, we find it takes a 10 lb. weight on the 1 foot end to obtain a balance. On the right we have 10 lbs. acting through a distance of one foot giving 10 ft. lbs. On the left we have 2 lbs. acting through a distance of 5 ft. which also gives 10 ft.-lbs. and thus keeps the support in balance.

Checking these values carefully, you will find it is not the weight alone nor the distance, but the product of the two which determines the number of ft.-lbs.

One of the most common tools, for using the mechanical advantage of a lever, is the ordinary crowbar. If you have never used one, you certainly must have seen many of them being used for moving heavy weights and to illustrate the action, for Figure 3 we have an ordinary 6 foot bar that we are using as a lever. A small block is put under it, one foot from one end which is placed under a heavy box or crate. This leaves the long five foot part sticking up in the air. This is the same arrangement as Figure 2-B therefore, for every pound of force that we push down on the long end at A, Figure 3, there will be five pounds of force pushing up under the box at "B".

Suppose that it takes a force of 300 lbs. to raise the side of the box, then if we push down with a force of slightly more than 60 lbs. at A, the box will move. This checks up with what we said before because, with this crowbar, we have 60 lbs. acting through 5 ft. giving us 300 ft.-lbs., and on the other side of the block, there is 300 lbs. acting through 1 ft. which also gives 300 ft.-lbs.

We want you to notice here also that, in order to raise the box 1 foot, we would have to push down for 5 feet at A. You can see how this works out by looking at the dotted lines of Figure 3. Then also, we can not get more mechanical work out of a lever than we put into it. Pushing on A with a force of 60 lbs. for a distance of 5 feet produces 300 ft.-lbs. of work which, on the other side of the block, raises 300 lbs. for a distance of 1 ft., again producing 300 ft.-lbs. of work. We have not gained anything in the amount of work done but were able to do it with less effort. Because of the mechanical advantage of 5 to 1, we lifted the 300 lbs. with a force of 60 lbs.

TORQUE

Torque is another term that is commonly used and, in some ways, it is more important than mechanical work. We said that work was equal to the force, in pounds, multiplied by the distance, in feet, through which it moves. However, there are many cases where a force is present but does not move for any distance at all.

For example, in Figure 4 we show a clamp, including a 1 foot handle, mounted rigidly on a shaft. Should we pull on the end of the handle, at the point and in the direction of the arrow, we would exert a force on the shaft but, unless the shaft turned, no work would be done. This checks with our former definition because the force did not move anything for a measurable distance. However, if the torque is strong enough to overcome the resistance, the shaft will turn and work will be done.

This action is known as "Torque", which means to twist or try to twist, and to prevent confusion, it is measured in pounds feet, on the same general plan as mechanical work but with this one difference. To measure work, we use the distance that is actually traveled. To measure Torque, we use the length of the arm through which the force acts. It can be written:-

WORK equals Distance (in ft.) times Force (in lbs.)
TORQUE equals Force (in lbs.) times Length (in ft.)

Putting a force of 10 lbs. on the handle of Figure 4, the torque will be Force (10 lbs.) times Length (1 ft.) which equals 10 lbs.-ft. The length of the handle, or arm, is measured from the center of the shaft to the point where the force is applied.

MECHANICAL POWER

The last term we want to explain is Mechanical Power. You may have noticed so far, in both Work and Torque, it does not make any difference in respect to time. With the crowbar, we could lift the weight 1 ft. in a minute or a week and still do the same amount of work but, to do a certain amount of work in some given time requires power. As a general definition, Power is work done in a given time or the rate of doing work.

We usually say that power is equal to work, divided by time. Work is equal to Pounds multiplied by Feet and the time is measured in Minutes. Using these terms, we say that Power equals lbs. times ft., divided by minutes. The unit of measure for mechanical power is Foot-Pounds per Minute but it is too small for ordinary commercial work.

HORSE POWER

The usual unit of measure is the Horse-Power. Now don't think that this has a whole lot to do with the strength of one live horse because we have all seen one horse do things that a 50 horse-power engine could not do. It was, however, originally estimated as the amount of work that a good strong horse could do for a very short time and is equal to 33,000 ft.-lbs. per minute.

Written in the form of equations:

$$\text{Power} = \frac{\text{Work}}{\text{Time}}$$

$$\text{Power} = \frac{\text{Pounds x Feet}}{\text{Minutes}}$$

$$\text{Horse Power} = \frac{\text{Pounds x Feet}}{\text{33,000 x Minutes}}$$

Suppose an elevator has to lift 880 pounds a distance of 150 feet in 2 minutes, and we want to know the horse-power required. By the last equation above we have:

$$\frac{880 \times 150}{33,000 \times 2} = \frac{132,000}{66,000} \text{ equals 2 H.P.}$$

THE PRONY BRAKE

Perhaps you are beginning to wonder how we can find the pounds pull and distance traveled when we obtain power from the pulley of a motor or engine. While there are many ways by which power can be estimated, to find the actual foot-pounds per minute, we use a device called the "Prony Brake".

Prony brakes are built in a great variety of forms but, as the idea of all of them is the same, the one we show in Figure 5 will simplify our explanation. It consists of a band or clamp around the pulley or flywheel. Fastened on the inside of the band are a number of wooden blocks which rest on the face of the pulley. The ends of the band are held together with a clamp which is adjustable to make a form of brake.

A pair of arms are solidly fastened to the outside of the clamp so that they have to turn with it. The ends of the arms are laid on an ordinary platform scale, but must be blocked up so that the point on which they rest is level with the center of the pulley shaft.

Now, as the pulley turns in the direction of the arrow, the clamp and its arms will try and turn with it but the scale will stop them from moving. However, the arms will press down on the scale and we can weigh the force they are exerting.

You can easily see that, the tighter we draw the clamp, the harder the blocks will rub against the pulley and the greater the force on the scale will be. We now have one of the things we want, the force in pounds.

The next thing is to find the distance through which the force acts and you will have to read carefully to follow the idea. As the pulley is turning and the clamp is held still, all the rub is between the pulley face and the wooden blocks, the force of which is measured in pounds on the scale. We figure it like this, every time the pulley makes one complete turn, the work done is the same as though the weight, shown by the scale, was pulled for the distance the end of the arm would travel if it turned with the pulley. Read that last sentence over again and then look at Figure 6.

Here we have the brake of Figure 5 but, by the arrowed circle. show the path point A would travel if the brake turned with the pulley. Although the brake does not move, we have to figure the length of the large circle as the distance.

This is not very hard as we know from arithmetic that the outside, or circumference, of a circle is just 3.1416 times as long as the diameter, which is the greatest distance across the circle. From Figure 6, we see the diameter of the large circle is just twice the length of the arm on the brake therefore the distance, for each revolution, will be 2 times the length of the arm, in ft. times 3.1416.

So far, we have the weight and distance per revolution, which, multiplied together, gives the work per revolution. As power is measured in ft.-lbs. per minute, we will also have to know how many times the pulley turns, or revolves each minute. Taking all these things, the ft.-lbs. per minute will be -- "W" (weight on the scale in lbs.) times 2 times "L" (length of the arm in ft.) times 3.1416 times "R.P.M." (revolutions per minute). Written briefly we have power equals 2 x 3.1416 x L x W x R.P.M.

This gives us the ft.-lbs. per minute and to find the horse power we remember that 1 H.P. is 33,000 ft.-lbs., per minute and divide the above by 33,000. Written as an equation for use with a Prony Brake.

$$\text{Horse Power} = \frac{2 \times 3.1416 \times L \times W \times R.P.M.}{33,000}$$

ELECTRICAL POWER

It is common knowledge that electricity can do work and therefore, by our former explanation, electricity is a form of energy. Also, as electricity can do work in a given time, it produces power.

From the earlier parts of this Lesson, we know that power is measured in foot-pounds per minute therefore, in order to measure electrical power, we will have to work out some similar units of measure.

From the Lesson on Ohm's Law, we know there are really but two things making up the electrical power: The pressure, measured in volts and the current, measured in amperes, but we remember here that 1 ampere is a current of electricity of 1 coulomb per second.

Mechanical power is measured by the force, in pounds, the distance, in feet and the time, in minutes.

Electrical power is measured by the force, E.M.F., in volts, the amount, in coulombs, and the time in seconds but the amount and time are usually taken together as amperes.

THE WATT

To measure electrical power we simply multiply the volts by the amperes and call the result Watts. This is just about the same as mechanical power because the time is included in the amperes. As a unit of measure, 1 volt times 1 ampere equals 1 watt.

You can think of this in the same way as you did of Ohm's Law and rearrange the terms into three forms.

1. Watts equals Volts times Amperes.
2. Volts equals Watts divided by Amperes.
3. Amperes equals Watts divided by Volts.

Using symbols instead of words, usually you will find these statements written,

1. $W = EI$ 2. $E = \frac{W}{I}$ 3. $I = \frac{W}{E}$

In the same way, Ohm's Law is written,

4. $E = IR$ 5. $I = \frac{E}{R}$ 6. $R = \frac{E}{I}$

As it is a well known fact that things equal to the same thing are equal to each other, we can substitute the values of Voltage and Current, as given by Ohm's Law, in the expressions for Power.

Ohm's Law states, $E = IR$, therefore, by substitution,

$$W = EI = (IR)\ I = I \times I \times R$$

7. $W = I^2R$

This form is useful in Radio and other Electronic work because it states the relationship between Power, Current and Resistance. By its use, it is possible to find the corresponding number of Watts when the Current and Resistance are known. Here again, the terms can be rearranged as explained for Ohm's Law, to provide additional formulas.

7. $W = I^2R$ 8. $I = \sqrt{\frac{W}{R}}$ 9. $R = \frac{W}{I^2}$

Going back to the first form which states W = EI we can substitute the value of I from Ohm's Law to find:

$$W = EI = E \times \frac{E}{R} = \frac{E \times E}{R}$$

10. $W = \frac{E^2}{R}$

Here we have the relationship between Power, Voltage and Resistance and, to simplify the solution of problems involving these values, the terms can be rearranged to,

10. $W = \frac{E^2}{R}$ 11. $E = \sqrt{WR}$ 12. $R = \frac{E^2}{W}$

Checking back, you will find these twelve equations, or formulas, provide three forms for each of the four factors and can be grouped as follows:

Power,	$W = EI$	$W = I^2R$	$W = \frac{E^2}{R}$
Voltage,	$E = IR$	$E = \frac{W}{I}$	$E = \sqrt{WR}$
Current,	$I = \frac{E}{R}$	$I = \frac{W}{E}$	$I = \sqrt{\frac{W}{R}}$
Resistance,	$R = \frac{E}{I}$	$R = \frac{E^2}{W}$	$R = \frac{W}{I^2}$

Remember here,

W represents Watts
E represents Volts
I represents Amperes
R represents Ohms

To illustrate the use of these formulas, suppose you want to know the rated maximum current of a 50,000 ohm, 1 watt resistor. Here we know R = 50,000, W = 1 and want to find the value of "I". Looking over the equations we find,

$$I = \sqrt{\frac{W}{R}}$$

and substituting the known value of W and R, we can write

$$I = \sqrt{\frac{1}{50,000}}$$

By arithmetic, 1 divided by 50,000 is equal to .00002 to make the problem

$$I = \sqrt{.00002}$$

The next step requires us to find the square root of .00002 which works out to .00447. Therefore, we can write

$$I = .00447 \text{ ampere}$$

and, using the smaller unit of current measure, the milliampere, the answer is multiplied by 1000 to give us,

$$I = 4.47 \text{ milliamperes}$$

As another common example, suppose you want to find the current of a lamp bulb which is marked 120 volts, 60 watts. This, by the way, is the common method of rating incandescent lamp bulbs. Here we know E = 120, W = 60 and from the equations, see that:

$$I = \frac{W}{E}$$

Substituting the values of the example,

$$I = \frac{60}{120} = 1/2 \text{ ampere.}$$

Knowing the Watts, Volts and Amperes, the Resistance of the lamp can be found by substituting in any of the Resistance formulas. When E = 120, W = 60 and I = 1/2

$$R = \frac{E}{I} = \frac{120}{1/2} = 240 \text{ ohms}$$

$$R = \frac{E^2}{W} = \frac{120^2}{60} = \frac{14400}{60} = 240 \text{ ohms}$$

$$R = \frac{W}{I^2} = \frac{60}{(1/2)^2} = \frac{60}{1/4} = 240 \text{ ohms}$$

We now have four factors, Watts, Volts, Amperes and Ohms and, when any two of them are known, one of the equations is in proper form to find the third. With three of the factors known, there are three equations by which you can find the fourth.

THE KILOWATT

The watt is quite a small unit, therefore, for most commercial uses, we take 1000 watts as a unit and call it a "Kilowatt".

As an equation, 1 kilowatt equals 1000 watts.

$$\text{Kilowatts} = \frac{\text{Watts}}{1000}$$

In this connection, we want to tell you it has been found by experiment that 746 watts are equal to 1 mechanical horse power. This figure makes it easy to change from mechanical to electrical units, or the reverse.

Watts equals Horse Power (H.P.) times 746.
H.P. equals Watts divided by 746.

These same figures, used with kilowatts instead of watts, give us roughly, for everyday use,

1 H.P. equals 3/4 Kilowatt, (K.W.)
1 K.W. equals 1-1/3 H.P.

MILLIWATTS AND MICROWATTS

In some Radio circuits, the amounts of Power are so small that we make use of the prefixes, "milli", meaning "one thousandth" and "micro", meaning "one millionth" to indicate smaller units of measure. To compare these units,

1 Watt = 1000 Milliwatts
1 Watt = 1,000,000 Microwatts
1 Milliwatt = .001 Watt
1 Microwatt = .000001 Watt

As these same prefixes are used to indicate smaller units of measure for volts and amperes and, as watts are the product of volts and amperes, the following relationships must be kept in mind.

Volts x Milliamperes = Milliwatts
Millivolts x Amperes = Milliwatts
Volts x Microamperes = Microwatts
Microvolts x Amperes = Microwatts
Millivolts x Milliamperes = Microwatts

The power in the antenna circuit of a Radio Receiver, the power output of a modern microphone or phonograph pickup is seldom more than a few microwatts. A power value of 6 milliwatts is often considered as the minimum which will produce an audible signal in a headphone while small table model Radios have an output of about 1 watt. Larger console types of Radios develop up to 10 or 12 watts of power while large Public Address systems are rated up to 60 watts and more.

WATT - HOURS

As one watt is equal to one volt times one ampere and one ampere is equal to one coulomb per second, the watt is the unit of electrical power for a period of one second. However, as most electrical power is required for comparatively long periods of time, the watts are multiplied by the number of hours they are used to find what are known as "Watt-Hours". As a formula:-

Watts times Hours equal Watt-Hours

KILOWATT - HOURS

Here again the unit is quite small and, for most commercial work, we use the same idea but replace the watts with Kilowatts. Kilowatt-Hours equal Watts times Hours divided by 1000, or in other words, Kilowatt-Hours equal Kilowatts times Hours. This is perhaps the most common power unit of all and is the unit by which most electrical power is sold.

Suppose your home has ten electric lamps that draw 1 ampere each 110 volts. The electric company charges you 12 cents a Kilowatt-Hour and you want to know how much it will cost to burn them all for 25 hours.

First you use the rule that Watts equal Volts times Amperes and find Watts equal 110 times 1 or 110 per lamp. As there are 10 lamps, the total power is 110 times 10 or 1100 watts. Then, as watt-hours equal watts times hours, you multiply the 1100 by 25 and get 27,500 watt-hours.

As it takes 1000 watt-hours to equal 1 kilowatt-hour, you divide 27,500 by 1000 and get 27 1/2 Kilowatt-hours. It costs 12 cents for each kilowatt-hour, therefore, your bill will be 27 1/2 times 12 cents or $3.30.

HORSE POWER HOURS

Where electrical power is used for running motors we sometimes use the term Horse-Power Hours instead of KiloWatt-Hours but all you have to remember here is that 1 H.P. equals 3/4 K.W. or 1 K.W. equals 1-1/3 H.P.

INPUT AND OUTPUT

An electric motor is a machine that changes electrical energy into mechanical energy and the electrical energy that goes into it is called "Input" and is measured in K.W. The power it delivers, or gives out, is called the "Output" and as it is mechanical, is measured in H. P.

Suppose we had a motor rigged up with a Prony Brake on its pulley and an Ammeter and Voltmeter properly connected in its circuit. We could then easily find both the K.W. input and the H.P. output.

Just for an example, we will say that the voltmeter reads 220 and the ammeter 8 which gives us an input of 220 times 8 or 1760 watts. The prony brake shows exactly 2 H.P., but to compare it with the input, we will change it to watts by multiplying 746 by 2 which gives us 1492 watts.

We now have both the input and output in watts and find that with 1760 watts input, the output is but 1492 watts. The difference, or loss, is the power required to overcome the various forms of friction in the motor. Dividing the output, 1492 watts, by the input, 1760 watts, we find that the output is about 85% of the input and this is called the efficiency of the motor.

As a general rule, Efficiency equals the output divided by the input.

We used the motor as an illustration here because it changes electrical energy into mechanical energy however, the same general principles apply for the different Radio and other Electronic units which change electrical energy from one form to another.

Although we will not explain their action until later, we can tell you now that the power transformers, used in A.C. electronic units, change the voltage of the house lighting circuit.

For example, we will assume the circuit for operating the heaters of the tubes requires 1.5 amperes at 6.3 volts. As far as the transformer is concerned, we consider this as the secondary or output circuit. An A.C. ammeter, connected in series with the primary or input circuit of the transformer, indicates a current of .1 ampere at the 110 volts of the lighting circuit.

Thus the voltage has been reduced from 110 to 6.3 while the current has been increased from .1 to 1.5 amperes. To have a complete picture of the action, we must consider both voltage and current to find the power. For the input, the power is 110 volts times .1 ampere or 11 watts while the output is 6.3 volts times 1.5 amperes or 9.45 watts.

In making these changes, we have lost the difference between 11 and 9.45 or 1.55 watts. The efficiency of the transformer is equal to 9.45 divided by 11 which is .859 or 86% approximately.

For most Radio work, the efficiency of power transformers will be of secondary importance and this explanation has been given because the relationship between input and output is important.

As you advance in your studies, you will find the formulas of this Lesson are the basis for practically all d-c circuit calculations and, with necessary modifications which will be explained later, are used for a-c circuits also. Therefore, we can not over-emphasize their importance and urge you to make every effort to understand them completely before going ahead, as the next Lesson will take up an entirely different principle of electricity.

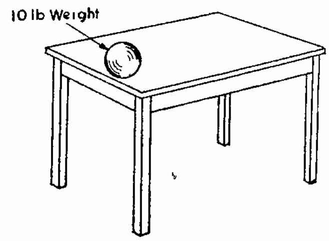


FIGURE 1

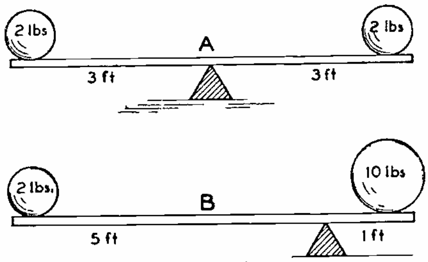


FIGURE 2

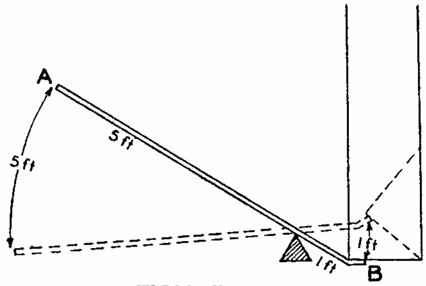


FIGURE 3

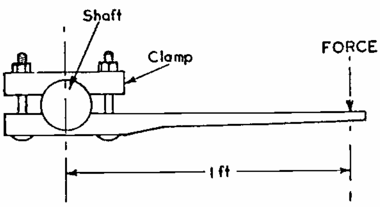


FIGURE 4

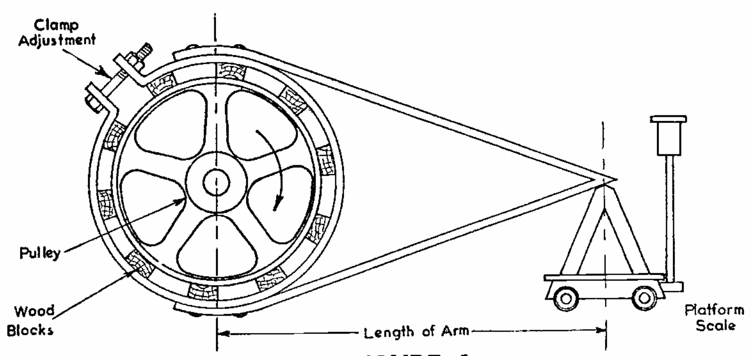
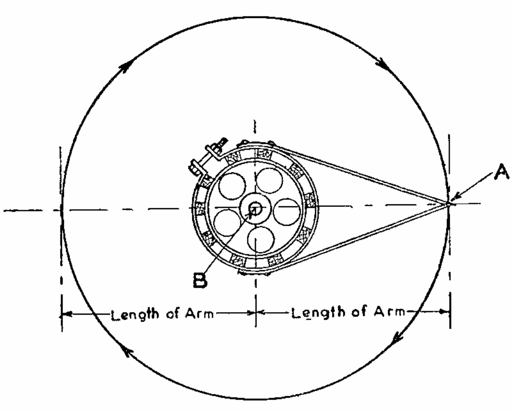


FIGURE 5



FDM-17

FIGURE 6

DE FOREST'S
TRAINING, Inc.

LESSON FDM - 18

MUTUAL - SELF INDUCTION

* * Founded 1931 by * *

RADIO FUNDAMENTALS

LESSON 18

MUTUAL - SELF INDUCTION

Electro-Magnetic Induction ---------- Page 1
Voltage Induced in a Conductor ---------- Page 1
Three Finger Right Hand Rule ---------- Page 3
Factors Controlling the Value of Induced Voltage -- Page 4
Mutual Induction ---------- Page 6
Lenz's Law ---------- Page 7
Power Required to Induce a Voltage ---------- Page 7
Primary and Secondary Coils ---------- Page 8
Action of the Primary on the Secondary ---------- Page 9
Transformer Coils ---------- Page 11
Step-Up and Step-Down Transformers ---------- Page 12
Eddy Currents ---------- Page 12
Self Induction ---------- Page 13
Induction in a Straight Wire ---------- Page 13
Self Induction in a Coil of Wire ---------- Page 14
Inductance ---------- Page 15
The Henry ---------- Page 15
Mutual Inductance ---------- Page 15
Radio Units ---------- Page 15
Circuit Diagram Symbols ---------- Page 17

* * * * * *

If the control of one's self is the greatest of goals, the control of one's thoughts is still greater, for what a man thinketh, so he is.

— Dr. Frank Crane

ELECTRO-MAGNETIC INDUCTION

The explanations of the earlier Lessons have covered the important types and actions of D.C. Circuits, Batteries, Magnetism, Meters and Power, subjects which we will assume you know when making our explanations of this and the following Lessons. Therefore, if some of these subjects are not clear in your mind, a review will be of benefit and speed your future progress.

Going back to the early "Forms of Electricity" Lesso, we told you it was Michael Farady who discovered that when a wire, or any electrical conductor, was moved in a magnetic field so that it cut through or across the magnetic lines of force, an E.M.F. was produced, or more correctly, "Induced" in the wire. While this appears to be a simple discovery, it has changed many of our habits of life because it is the principle which has made possible the low cost and universal use of electricity as a source of light and power.

The movement of the wire represents mechanical energy while the induced E.M.F. represents electrical energy therefore, this discovery provides a method for converting mechanical energy into electrical energy and is the principle by which the common forms of electrical generators operate. Electrically, the action is known as "Electro-Magnetic Induction".

VOLTAGE INDUCED IN A CONDUCTOR

To illustrate the action as simply as possible, for Figure 1 we show the N end of an ordinary permanent bar magnet and have made up a circuit consisting of nothing but a length of wire, each end of which is connected to a very sensitive meter. By taking hold of the wire at "A" and "B", and keeping it close to the end of the magnet, we find that when we pull it up quickly, the hand on the meter jumps a little and then drops back to 0. When we pull it down quickly, past the end of the magnet, the meter hand again jumps from 0, but in the opposite direction to what it did before.

Pulling the wire straight away from the end of the magnet has no effect at all on the meter, nor does pushing it straight toward the magnet make the meter hand move. From this simple little test, we are able to figure out several very important facts. First of all, we know that the meter hand will not move unless there is an E.M.F. across the meter. Then we know the magnetic lines are traveling out from the end of the magnet and, in order to make the meter hand jump, we have to pull the wire so that it cuts through or across the lines. Then we also notice the meter hand moves one way or the other depending on which way we move the wire.

In order to check up on this last action, we must first find out in which direction the E.M.F. must be in order to make the meter hand move to the right or to the left. We know which terminal of a dry cell is positive and know which direction current travels in a circuit both inside and outside of the cell. Therefore, we remove the connecting wires from the meter and touch its terminal "C" to the center or positive terminal of a dry cell. Then we snap the meter terminal "D" across the dry cell zinc and find that the hand jumps toward the right.

Just to make sure, we reverse the connections, that is connect meter terminal "D" to the dry cell carbon and snap "C" across the zinc, and find that the meter hand jumps to the left. This tells us all we want to know about the meter so we reconnect the wire and restore the circuit shown in Figure 1.

Watching the meter closely, we quickly pull the wire up past the end of the magnet and find that the hand jumps to the right. From our test of the meter on the dry cell, this tells us that point "A" on the wire is at a higher potential than point "B". In other words, comparing the wire to the dry cell, "A" is positive and "B" is negative. As the circuit is complete, the E.M.F. induced in the wire will force a current through the circuit and its direction will be from "A" to "C" through the meter to "D", along the wire through "B" and back to "A".

Perhaps you are wondering how we know that there is any current in the circuit but remember, the meter hand will not move unless there is current in the meter coil. You already know that unless there is an E.M.F. across a circuit, there will not be any current in it therefore, the movement of the meter hand, when the wire is moved, proves that there is an E.M.F. induced in the wire.

Next, we move the wire down past the end of the magnet and find that this makes the meter hand jump to the left. By our dry cell test of the meter, this means that terminal "D" is connected to a higher potential and the current in the circuit is now from "B" to terminal "D", through the meter to "C" and back along the wire through "A" to "B".

This gives us something definite to work with because, from the Lesson on magnetism, we know that the magnetic lines are traveling from "N" to "S". We know the direction the wire is moved, and from our test of the meter, we can tell the direction of the induced E.M.F. and current in the circuit.

THREE FINGER RIGHT HAND RULE

These three directions are in exactly the same relationship as the fingers of your right hand will point when you hold them as shown in Figure 2. We know that this is a little hard to see from a picture therefore, the following instructions will enable you to place your fingers properly.

To begin, hold the fingers of your right hand straight out and close together while your thumb, also straight out, is bent back toward your wrist as far as possible. Then, with the palm up, place your hand on this page so that your thumb points to the top and your fingers, still held out straight, point to the left.

Now, bend up all but your fore-finger until they point straight up at the ceiling. As the last two fingers are not used, you can bend them back against the palm of your hand to get them out of the way.

You now have your fingers in the proper position to use the three-finger right hand rule. Hand, palm up on the paper, thumb pointing to top of page, fore-finger pointing to the left, and middle finger pointing up at the ceiling.

To make use of this relationship, your fore-finger points in the direction that the magnetic field travels, that is away from the "N" pole, your thumb points in the direction the wire is moved and your middle finger points in the direction of the induced E.M.F. or in the direction of the current in the circuit.

If your fingers feel cramped, stretch them out, then move back in position and try the rule out on Figure 1. Hold your hand over the figure so that your fore-finger points in the same direction as the arrows coming out of the end of the magnet and then turn your wrist until your thumb is pointing straight up. Now doesn't your middle finger point from "B" to "A" and show you the direction of current to be as we explained when the wire was pulled up?

Here is another way which may make it easier for you to "get the hang" of the three finger rule. Try this one anyway. Hold your right hand with the fingers and thumb straight out as in Figure 3 and then turn your palm against the magnetic lines, which is toward the N pole of the magnet.

With this rule, when the motion is in the direction pointed by your thumb, the current will be in the same direction as your fingers. Remember here, the direction of motion always

refers to the relative movement of the conductor in respect to the flux. For example, if the conductor is stationary and the flux is moved, the direction of motion is opposite to that of the flux.

In either of these rules, you must always know two things in order to find the third. Knowing the direction of the magnetic field and the direction of motion, you can find the direction of the induced E.M.F., or if you know the direction of the induced E.M.F. and the direction of motion, you can find the direction of the magnetic field. As these rules will be useful in your later work, we suggest you learn them now and not wait until later when you need them.

FACTORS CONTROLLING THE VALUE OF INDUCED VOLTAGE

While figure 1 is the simplest possible way of showing the principle of "Electro-Magnetic-Induction", there are two more things that we want to tell you before going further.

First:- An E.M.F. is induced only while the wire is actually cutting the magnetic lines. As long as the wire is stationary, and the magnet is not moved, there will be no action no matter how many magnetic lines are present.

Second:- The faster the wire is moved, the greater the effect. We can explain this by saying that the faster the wire is moved, the more magnetic lines it will cut per second.

To investigate further, for Figure 4 we have taken the wire of Figure 1 and made it up into a coil of several turns, large enough to let the magnet go inside easily. Now we find that when we quickly push the magnet into the coil, it makes the meter hand jump one way, and when we pull it out, the meter hand jumps the other way. Turning the magnet end for end produces exactly the same results but reverses the action, or movement of the meter hand. Turning the coil end for end again produces the same results but also reverses the action of the meter hand.

This tells us that it makes no difference whether the coil or the magnet is moved but shows us that, in order to cause any action, we must move one or the other. We do find however, that the faster we move either the magnet or the coil, the further the meter hand jumps.

By adding more turns to the coil of wire, we find that we can produce a greater action and, by adding a second magnet as in Figure 5, the action is still stronger. After watching all of this, we decide that there are three things, or factors, which control the amount of Induction.

1. The Speed:- or how fast the magnetic lines and the conductor move in respect to each other. The greater the speed, the greater the Induction.

2. The length of the wire that actually cuts through the magnetic field. The longer the wire, the greater the Induction.

3. The strength of the magnetic flux, or the number of magnetic lines. The stronger the flux, the greater the Induction.

There is one other factor that enters into the value of the induced E.M.F. and that is the angle at which the conductor cuts through the magnetic field.

To illustrate this action, for Figure 6 we show the "N" end of a permanent magnet, with the light arrowed lines representing the magnetic flux. Now, if we move the wire at some certain speed up to "A", it will cut through all of the flux. Moving the wire the same distance at the same speed to "B", will make it cut but about three-fourths of the flux. Again, moving at the same speed and the same distance to "C", the wire will not cut through any of the flux.

4. All other factors remaining the same, changing the angle of cutting changes the magnitude of induction.

To sum up then, the factors controlling the value of the Induced E.M.F. are:

1. Speed
2. Length of wire
3. Strength of magnetic field
4. Angle of cutting

Another point we want you to remember is that the action induces an E.M.F. Should the conductor, that cuts the magnetic flux, be a part of a complete or closed electrical circuit, then the induced E.M.F. will cause a current in the circuit. You may read and hear a lot about induced current but technically it means the current caused by an Induced E.M.F.

In Figure 7, we have the same lay-out as in Figure 6 but, to follow the details of the action, show the wire cutting the flux. It may help you to think of the magnetic lines as rubber bands, stretched quite tight and, as the wire is pulled up through them, they bend, stretch and finally break, wrapping themselves around the wire. This is exactly what happens with the magnetic lines and, as the wire is pulled up in Figure 7, there will be magnetic lines whirling around it in the direction shown by the arrows.

Using either of the right hand rules, shown in Figures 2 and 3, you will find that the direction of induction in the wire will be away from you or "In" toward the paper. Now, just to check up, suppose you had this same wire with current in it in the same direction, that is in toward the paper. Then, using the "Thumb Rule", you will find that the magnetic field, set up by the current, would be in the same direction as the one shown, therefore, the relationship between magnetic flux and current remains the same regardless of the source of E.M.F.

Although we started this Lesson by saying that Electro-Magnetic-Induction was the way that electrical energy was produced by mechanical means, in Radio equipment, the same principle is used for changing electrical energy from one form to another and transferring it from one circuit to another.

MUTUAL INDUCTION

At "A", Figure 8, we show the position of two wires, 1 and 2, which, while placed fairly close together, are electrically insulated from each other, and are parts of entirely different or separate circuits. When we close the circuit, of which wire 1 is a part, and cause a current in it, a magnetic field is produced as shown at "B".

Here is the idea. At "A", Figure 8, we had nothing but 2 wires, while at "B", wire 1, with current in it, sets up a magnetic field that extends beyond wire 2. The only way that the magnetic lines in the field around wire 1 can extend beyond wire 2 is by cutting through it. Therefore, again we have magnetic lines cutting a wire or a conductor.

Perhaps you can understand this better by the old example of how a magnetic field builds up. You know that when you drop a stone into a pool of water, little waves start in rings from the point where the stone hits and spread out in all directions. When current is sent through wire 1, the magnetic lines start in rings from the center of the wire and spread out in all directions like the waves in the pool of water.

In Figure 8 then, when current is sent through wire 1, the magnetic lines, or rings, as they spread out, cut through wire 2 and induce an E.M.F. Of course, with any certain amount of current in the wire, the field spreads out to some certain distance and then stays there therefore, the E.M.F. is induced only while the magnetic field is building up, or spreading out, and cutting wire 2.

When the circuit of wire 1 is opened, and the current is shut off or stopped, the magnetic rings collapse and fall back in

toward wire 1 and thus again cut through wire 2, but in the opposite direction to that when they were spreading out, or building up. Again, an emf will be induced but in the opposite direction because the direction of motion has reversed.

We always assume that the rings, or magnetic lines, start at the center of the wire carrying the current therefore, as they build up, they will first cut through wire 1, Figure 8, and when they have built up far enough, will cut through wire 2. When the current is stopped and the magnetic field collapses, the lines will first cut through wire 2, and then cut through wire 1 in order to get back to its center.

The action between the lines and wire 1 is just about the same as the action between the lines and wire 2. It stands to reason that if this action will induce an emf in wire 2, it must also induce an emf in wire 1 although it is carrying the current that produces the magnetic field.

The emf induced in wire 1 is called "Self Induction", because it is the current in the wire itself that really causes the action. The emf induced in wire 2 is caused by "Mutual Induction", because wire 2 is not in the same electrical circuit as wire 1, or the wire carrying the current.

LENZ'S LAW

Regardless of how the emf is induced, the current set up by it will always be in such a direction as to try to prevent the action. Take Figure 4 for example, when the magnet was pushed into the coil, the direction of the current, caused by the induced emf, was such that the magnetic field set up by it had its N pole at the end toward the permanent magnet. As like magnetic poles repel, the action between the two magnetic fields tried to prevent the magnet from being pushed into the coil.

When the magnet was pulled out, the current in the coil reversed, thereby reversing the polarity of the magnetic field. This made the S pole at the end toward the permanent magnet and, as unlike poles attract, the action between the magnetic fields tried to prevent the magnet from being pulled out.

This action is known as Lenz's Law which is usually stated: The direction of the current, caused by the induced emf, is such as to tend to stop the motion producing it.

POWER REQUIRED TO INDUCE A VOLTAGE

The power required to induce an emf may be mechanical and cause either the conductor to move across the magnetic field,

or cause the field to move across the conductor. We can also induce an emf by causing the flux, set up by a wire or an electro-magnet, to vary. As it varies and cuts the wire producing it, we have Self-Induction, but when it cuts a second wire, we have Mutual Induction.

You know that the magnetic flux, set up around a wire or coil of wire, varies with the current in the wire therefore the flux can be varied simply by changing the value of the current.

The main thought we want to leave with you is that the four factors which control the value of an induced emf can all be summed up into one simple sentence by saying: The induced emf is proportional to the rate of cutting. By that we mean the number of magnetic lines cut per second by some certain length of wire. Just check back over them and see if changing any one of the four factors will not change the rate of cutting.

PRIMARY AND SECONDARY COILS

To continue our investigation of these actions, in Figure 9, we show an electro-magnet, consisting of a coil of wire wound on an iron core, connected to 2 dry cells with a switch in the circuit. We also have a second coil, wound on a pasteboard tube large enough to slip easily over the electro-magnet. The ends of this second coil are connected to a very sensitive meter.

We now close the switch in the electro-magnet circuit and then go ahead just the same as we did in Figure 4. Pushing the electro-magnet into the center of the coil of wire makes the meter hand jump in one direction. Pulling the electro-magnet out, makes the meter hand jump in the opposite direction.

This, of course, merely proves that an emf can be induced in a conductor by cutting the magnetic field of an electro-magnet and the action is just the same as with a permanent magnet.

Notice, we have two distinct and separate electrical circuits, one consists of the battery, switch and coil of wire of the electro-magnet while the other circuit is made up of a coil of wire and a meter only.

Both circuits contain coils of wire which are placed so that the magnetic field set up by one of them will cut through the other. The coil of wire connected to the battery is called the Primary because the magnetic field it sets up starts the action. The other coil is called the Secondary because the action in it is caused by the primary.

These names should not bother you because when we say anything is primary, you think of something that comes first, like "Primary Elections", the "Primary Grades" of school and so on. In this case, the electrical energy comes from some outside source, like the battery, and first sets up a magnetic field as it passes through the primary coil.

The next, or second thing that happens is the induction of an E.M.F. in the other coil as it cuts through or is cut by the magnetic field. Therefore, we call this coil the "Secondary".

There are several important reasons why, in many cases, it is easier and better to use an electro-magnet, or primary coil, instead of a permanent magnet. To begin with, by using the proper number of ampere-turns, we can set up a magnetic field of almost any strength we want. Then, by changing the current in the primary coil, we can change the strength of the magnetic flux. Also, by opening the primary circuit we can cause the magnetic field to die out entirely.

ACTION OF THE PRIMARY ON THE SECONDARY

All of this works to our advantage in providing an E.M.F. by induction because we must have the secondary cut the magnetic lines, or else have the magnetic lines cut through the secondary coil. We have told you this several times before, but we can not overemphasize because it is the main idea of all electro-magnetic induction.

To explain more clearly just what happens, for Figure 10 we show a layout that is a little different than Figure 9. We still have the same electrical circuits but have wound both coils on the same iron core. As long as the switch in the primary circuit is open, nothing happens. There is no current in the circuit and therefore no magnetic lines are set up around the primary. With no magnetic lines, there will, of course, be no induction in the secondary.

When the switch is closed, there is current in the primary which, as you already know, builds up a magnetic field. As the field builds up, the magnetic lines move out further from the iron core. Starting in the iron and moving out, as shown by the light lines, they will have to cut through the secondary and thus will induce an E.M.F.

The primary coil has a certain amount of resistance, therefore the voltage of the battery can send but some certain amount of current through it. The magnetic field will build up, or out, to some certain strength depending on the ampere-turns of the primary. Now, for the short time it takes the

magnetic field to build up to its full strength, the lines will cut through the secondary coil. When it reaches its full strength, the lines no longer move out, no longer cut through the secondary and therefore induce no further emf. This is the reason why the meter in the secondary circuit jumps when the switch in the primary circuit is first closed but then drops back to 0 and stays there.

hen the primary switch is opened, the current is stopped and the magnetic field dies out. Now in dying out, the magnetic lines fall back toward the iron core, or collapse, and thus again cut through the secondary, but in the opposite direction to what they did when the switch was closed. That is why the meter in the secondary circuit jumps in the opposite direction as the switch is opened.

In this case, we have induced an emf in the secondary without actually moving either of the coils. By closing and opening the primary circuit, thus building up and breaking down the magnetic field, we can make the magnetic lines cut through the secondary. You can see here that if we keep opening and closing the primary switch fast enough, we can keep an induced emf in the secondary all of the time but, it will be in one direction when the switch is closed and in the other direction when the switch is opened. It will keep changing back and forth and will therefore be alternating.

While there are many different methods of inducing an emf in the secondary, such as moving the primary, moving the secondary, opening and closing the primary circuit or reversing the primary current, in Radio equipment it is usually a varying current in the primary which causes the action.

The main idea we want you to remember is that there must be motion between the magnetic lines and the conductor. A varying current causes a changing magnetic field and a conductor placed in the field will be cut by the magnetic lines as they move away from and toward the conductor carrying the changing current.

We explained the action between two wires earlier in this Lesson and now we want to mention the action between two coils. Suppose, for example, that instead of the meter in Figure 10, we have a spark gap and want to produce a voltage high enough to force current across the gap.

Going back to the laws of Induction, you will find the value of the induced emf is controlled by four factors. 1, the Speed; 2, the Strength of Field; 3, the Angle of Cutting; and 4, the Length of Wire. In order to cause a spark to jump

across an air gap we need a very high voltage and, to produce this high voltage by induction, we will have to greatly increase some or all of the four factors. Let's look them over and see what we can do. No. 1, Speed. We can't do much here because the speed of cutting is controlled by the speed at which the magnetic field builds up or breaks down. When the primary circuit is closed and opened, the change in the magnetic flux will take place as rapidly as possible.

No. 2, Strength of Field. This, of course, depends on the ampere-turns of the primary and the reluctance of the magnetic circuit. We can, by changing the primary, make a change here but as we already have the primary coil made up, we are going to see if there is not some other factor that will give us what we want.

No. 3, Angle of Cutting. As long as the coils are not movable and are wound around the same core, we cannot very well change the angle of cutting.

No. 4, Length of Wire. This looks like a good one. Suppose we make up our secondary with twice as many turns as the primary. Then the same number of magnetic lines, moving at the same speed and cutting at the same angle, but cutting twice as much wire, will produce twice the E.M.F. in the secondary that we have in the primary. Therefore, in general, the more turns we put on the secondary coil, the greater the induced E.M.F. will be.

As it takes about 5000 volts to jump a 3/16 inch gap in the air, to induce this high E.M.F. we make up the secondary coil with thousands of turns of fine wire because, as a general statement, we can say that the induced E.M.F. in the secondary compares to the E.M.F. across the primary the same as the number of turns in the secondary compare to the number of turns in the primary.

Another fact we want you to remember is that mutual induction does not actually produce electrical energy. It can change its form or transfer it from one circuit to another but, figured in Watts, there can never be more power in the secondary than in the primary. In actual practice it will be less because, everytime you change energy from one form to another, there is a loss.

TRANSFORMER COILS

This same idea is used in practically all Alternating Current lighting and power lines where the electrical energy is "Stepped Up" at the power house, carried for long distances and then "Stepped Down" at the place it is to be used.

In Radio equipment, operating on 110 volts a-c lighting circuits, the 110 volts is reduced for some of the tube circuits and raised for others.

This stepping up and stepping down is done by means of transformers which, in their simplest form, look like Figure 11. Here, the core is made up of sheets of soft iron and built in the form of a square. The primary is wound on one side and the secondary on the other. If you bent the core of Figure 10 into a square, you would have the same layout as Figure 11.

In order to operate, the primary of the transformer is connected to some source of alternating current which, as we mentioned before, keeps changing or reversing its direction. This reversal of current in the primary means that the magnetic field it sets up is constantly building up and dying down, first in one direction and then in the other. These changes of the magnetic field mean that the lines are cutting through the secondary and inducing an emf in it.

STEP-UP AND STEP-DOWN TRANSFORMERS

When the secondary of a transformer has more turns than the primary and the induced voltage is greater than that across the primary, we call it a "Step-Up" transformer. When the secondary has fewer turns than the primary and the induced voltage is less than that across the primary, we call it a "Step-Down" transformer. Remember here also, that measured in Watts, we always obtain less out of the secondary than we put into the primary. A transformer changes the values of the Voltage and Current, but cannot produce any electrical energy.

EDDY CURRENTS

You may have been wondering why we mentioned the fact that the core of the transformer of Figure 11 was made up of pieces of soft iron instead of being solid. Going back to the laws of induction, you remember that whenever a conductor cuts a magnetic field, an emf is induced. The core of the primary and secondary will certainly be cut by the magnetic lines about the same as the wire that is wound on it, and being iron, which is a conductor, will have an emf induced in it.

Looking at Figure 11 again, you can see that if an emf were induced at either winding, the core, being square, would furnish a complete and endless path for current caused by the emf. The current in the core would set up a magnetic field of its own and, by Lenz's Law, the magnetic fields set up by current, caused by an induced emf, is always in a direction to oppose the change.

Analyzing the complete action, the core is bound to carry some current which will set up a magnetic field opposing the action we want to produce. Currents set up in a piece of metal in this way are called Eddy Currents.

By making the core of thin pieces of iron, called Laminations, electrically insulated from each other by the dirt, rust or scale on their surfaces, we can greatly reduce the paths, or circuits of the eddy currents without increasing the reluctance of the magnetic circuit. The use of a laminated core will reduce the eddy currents and thus improve the action of the transformer.

To improve the magnetic circuit, you will find most of the iron core transformers, used in Radio equipment, are built on the general plan of Figure 12. This arrangement keeps the windings closer together and minimizes losses.

SELF INDUCTION

So far we have explained how, by Mutual Induction, the primary winding induces an emf in the secondary, but now we are going to forget the secondary for a little while and see what happens in the primary. Reviewing the action explained briefly for wire 1 of Figure 8, we know that the magnetic lines, set up by the primary winding, start at the center of the wire and build up or out, therefore they must cut through the primary. As they induce an emf in the secondary, it stands to reason that they will also induce an emf in the primary itself. This action is called "Self Induction", and to explain it we will first see just what happens in a straight piece of wire.

INDUCTION IN A STRAIGHT WIRE

In Figure 13 at "A", we show the end of a piece of wire which, we are going to imagine, is part of a complete electrical circuit. As there is no current in the circuit, there is no magnetic field around the wire. We now close the circuit and, the instant the current starts in the wire, we have the conditions at Figure 13-B. The magnetic field has just started to build up and the magnetic lines, starting from the center, are as yet all inside of the wire.

At "C" we have the conditions an instant later. The field has built up further, there are more magnetic lines and they extend out around the wire. Each one of these started at the center of the wire and has cut through part or all of the wire to get to its present position. At "D", Figure 13, we have the full magnetic field with still more lines, most of which have cut through the wire.

If the current in the wire is away from you, or "IN" toward the paper, by the thumb rule, the magnetic lines will be going around in a clockwise direction. The E.M.F. induced by this action will try and force a current in a direction opposite to that which caused the field to build up. This we call Counter E.M.F. because it opposes the E.M.F. causing the action.

Like all induction, self-induction occurs only while the magnetic field is changing. At "D", Figure 13, we have the full magnetic field and as there is no further change, there is no further induction and the counter E.M.F. dies out. This complete action takes place very, very rapidly, in a small fraction of a second but, the self-induction prevents the current from instantly jumping to its proper value as indicated by Ohm's Law.

At "E", Figure 13, we still have the same conditions as at "D", but open the circuit. As the Current dies out, the magnetic field collapses as shown at "F", "G", and "H", which, you will notice, is just opposite to the way it built up at "A", "B" and "C". Here again we have self-induction, but as the magnetic lines are now falling in, the direction of the induced E.M.F. will be opposite to what it was while the field was building up. If the self-induction opposed the increase of current before, it has now reversed and will try and help, or maintain it.

To sum up briefly -- Whenever we close a circuit and have current in it, a counter E.M.F. is induced which opposes the current and prevents it from rising instantly to its proper value.

Whenever a circuit is opened and the current dies out, there is an E.M.F. induced in a direction to try and maintain the current. This is just another way of stating Lenz's Law.

SELF INDUCTION IN A COIL OF WIRE

Self induction takes place in a coil of wire in the same way as in a straight wire but is greater because the magnetic field set up around each turn cuts, not only the turn that sets it up, but also the turns close to it. To show the action, for Figure 14 we have drawn a coil of wire, part of which is cut away, with the direction of the current from right to left, or away from you at the top and toward you at the bottom. The magnetic field set up here is exactly like the one we told you about in our Lesson on Electro-Magnets and you can see how the magnetic lines, set up around the first turn, will cut the second turn as well as the first. The induced E.M.F. will therefore be much greater than in the

single wire, just the same as the magnetic field set up by a coil of wire is stronger than that set up by a straight wire. The self induction in a coil of wire will depend on the ampere-turns and the reluctance of the magnetic circuit and, the stronger the magnetic field it sets up, the greater the self-induction will be.

INDUCTANCE

The property of a coil or wire, acting to prevent any change of the current through it, is called its "inductance". From the above explanation, you can see that self-induction is due to the property possessed by a wire or coil because of its physical arrangement, such as number of turns, shape, the material and length of the magnetic path, etc. Thus, a coil of wire possesses the property of inductance whether a current is passing through it or not.

On the other hand, induction is the action by which an electromotive force is produced in a material by magnetic lines of force. Therefore, from these definitions, you can see that inductance is really a property of a circuit while induction is an action.

THE HENRY

Like all other electrical properties, we have a unit of measure for inductance. When the current in a circuit, changing at the rate of one ampere-per second, induces and emf of one volt, we say the circuit has an inductance of one Henry. The Henry is quite a large unit and for many ordinary purposes we use one thousandth of it, called a "Millihenry", or one millionth, called a "Microhenry".

MUTUAL INDUCTANCE

It naturally follows that as we have self-induction and mutual induction, we will have Self Inductance and Mutual Inductance.

As a general definition, we can say: Self Inductance is the ability of a circuit to produce an emf by self induction when the current in it varies.

Mutual Inductance is the ability of one circuit, by a change of current in it, to produce an emf in a closely associated circuit, by mutual induction.

RADIO UNITS

To help you appreciate the importance of Induction and Inductance, we want to mention a few of the many Radio parts

which operate on these principles. Going back to the early Lesson on Radio Systems, we told you that Radio energy was transmitted at high frequencies which means it is A.C. and any currents which it causes, will set up an alternating magnetic flux around the wires which carry them.

Therefore, according to the explanation of this Lesson, Radio signals can be transferred from one circuit to another by means of transformers which are used almost invariably for this purpose. Due to the high frequencies, which cause a high speed of cutting, these transformers do not require an iron core. Instead, the coils are usually wound on a tube of insulating material, on the plan of the larger coil of Figure 9 but may be arranged on the plan of Figure 10.

Single windings of this same general type are used in high frequency circuits to utilize their self induction. As the action tries to prevent any change of current, they are known as "choke" coils.

In much the same way, the lower, or "Audio" frequency signals which we hear, are transferred from one circuit to another by means of transformers. Because the frequencies are lower, these transformers require an iron core and are built on the general plan, shown in simplified form in Figure 12.

The cut away drawing of Figure 16 will give you a better idea of the actual construction because you can see the location of the primary and secondary windings, each of which contains many turns of wire.

To complete the magnetic circuit, as shown in Figure 16, the core laminations are made in two parts. One, as shown in Figure 16, is shaped like the letter "E" while the other is "I" shaped to fit across the open side of the "E". By stacking these laminations alternately through the coil, the finished core has the general appearance of Figure 12.

As explained for the higher frequencies, single windings on an iron core are used as choke coils at both audio and home lighting circuit frequencies. We have already explained the action of power transformers but want to include them in this general class of Radio units.

There are many variations of these general types, most of which will be explained later. As an example, we can mention that some types of high frequency transformers have cores made up of a special form of powdered iron arranged to reduce the eddy currents to a negligible value.

While you may not fully appreciate their importance, this brief mention of a few common Radio units should remind you of the need for a good understanding of Induction and Inductance.

CIRCUIT DIAGRAM SYMBOLS

In the illustrations of the earlier Lessons, we showed the circuit diagram symbols for resistance and batteries and, as circuit diagrams will form an important part of your studies, for Figure 15, we show the symbol for a common type of power transformer. The interlocking circles represent the turns of wire in the coils while the extended lines, at each end of each series of circles, represent the circuit connections. The straight parallel lines in the center represent an iron core. No attempt is made to indicate the number of turns in each winding although the operating voltages may be indicated as shown.

As this is a common type of Power Transformer, the primary operates on the ordinary 110 volt house lighting circuit and this coil is indicated at the left of Figure 15. The symbol shows the winding is tapped for operation at 100, 110 or 120 volts to conform to variations of supply voltage.

At the right of the symbol, three secondary windings are shown each with a middle connection or "center tap". The upper winding develops 6.3 volts, the center winding 500 volts and the lower winding, 5 volts. Thus, by a comparatively simple symbol, we show the circuits and voltages of a transformer with four windings and 13 external connections. As far as circuit connections are concerned, the symbol provides all the necessary information.

Following this same general plan, any choke coil or transformer can be represented by an accurate symbol and, if no iron core is used, the central, parallel lines are omitted.

As you advance in your studies, you will find an increasing need for a knowledge of these symbols therefore, study Figure 15 carefully while the subject of Induction and Inductance is fresh in your mind.

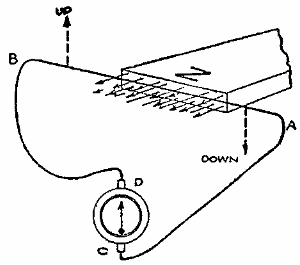


FIGURE 1

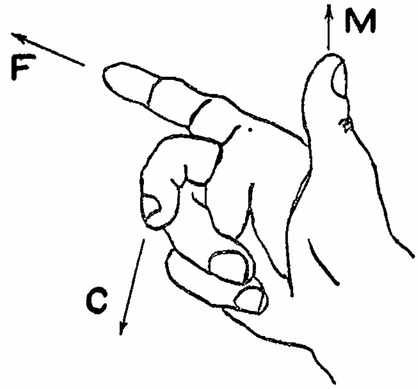


FIGURE 2

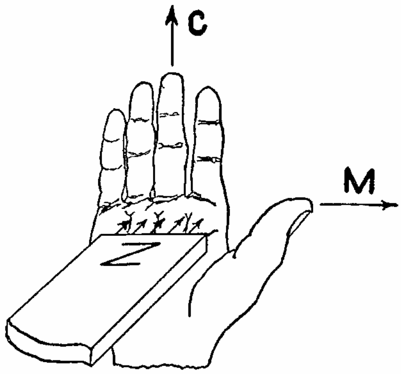


FIGURE 3

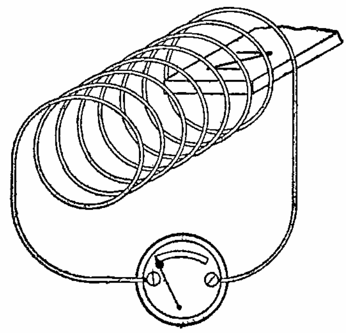


FIGURE 4

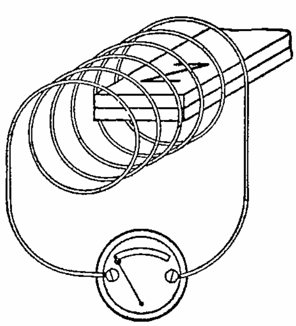


FIGURE 5

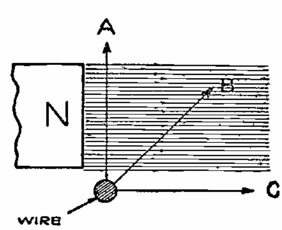


FIGURE 6

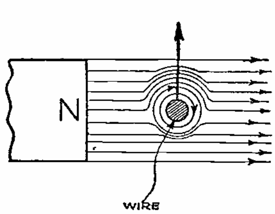


FIGURE 7

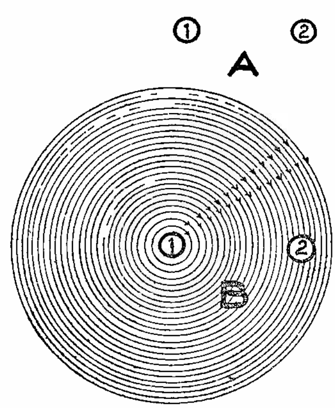


FIGURE 8

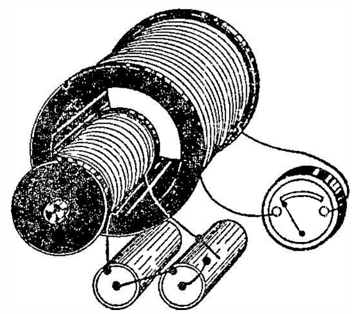


FIGURE 9

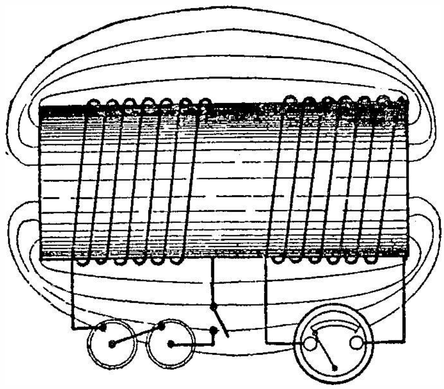


FIGURE 10

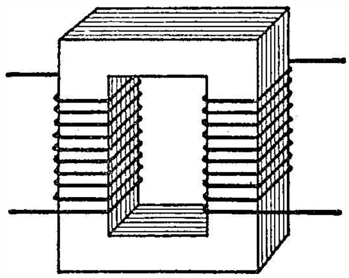


FIGURE 11

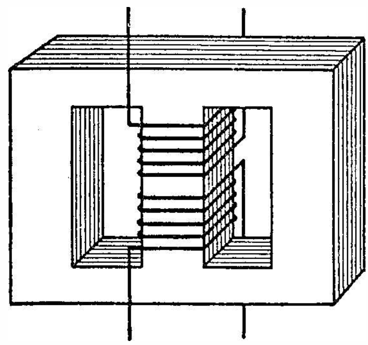


FIGURE 12

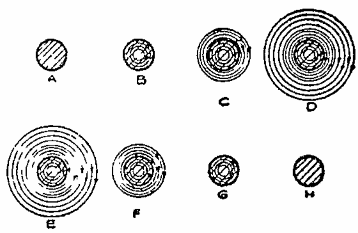


FIGURE 13

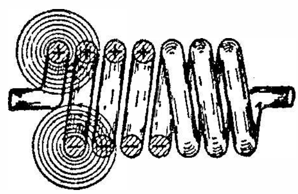


FIGURE 14

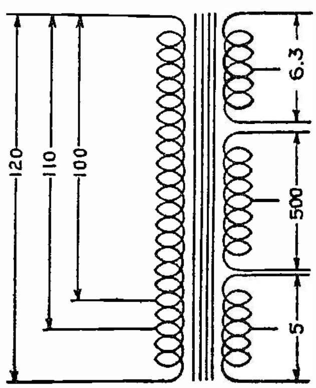


FIGURE 15

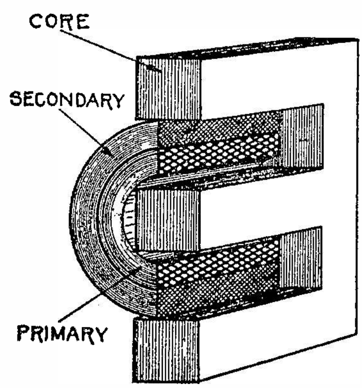


FIGURE 16

DE FOREST'S
TRAINING, Inc.

LESSON FDM - 19
CONDENSERS

Founded 1931 by

RADIO FUNDAMENTALS

LESSON 19

CONDENSERS

Leyden Jars - Page 1
Capacity - Page 3
Dielectrics - - - - - - - - - - - - - - - - - - - Page 4
The Farad - Page 4
Color Code - Page 5
Analogy of Condenser Action - - - - - - - - - - - - Page 6
Plate Condensers - - - - - - - - - - - - - - - - - Page 8
Rolled Condensers - - - - - - - - - - - - - - - - - Page 9
Paper - Mica Condensers - - - - - - - - - - - - - - Page 9
Electrolytic Condensers - - - - - - - - - - - - - - Page 10
Material Used - - - - - - - - - - - - - - - - - - - Page 11
Condenser Capacity - - - - - - - - - - - - - - - - Page 11
Condenser Circuits - - - - - - - - - - - - - - - - Page 12
Condensers in Series - - - - - - - - - - - - - - - Page 13
Condensers in Parallel - - - - - - - - - - - - - - Page 16
Graphs - Page 17
Scales - Page 17
Graph Paper - Page 18
Simple Graph - - - - - - - - - - - - - - - - - - - Page 18
Conversion Graphs - - - - - - - - - - - - - - - - - Page 20
Tuning Curves - - - - - - - - - - - - - - - - - - - Page 22

# # # # # #

Our best friends and our worst enemies are our thoughts. A thought can do us more good than a doctor or a banker or a faithful friend. It can also do us more harm than a brick.

— Dr. Frank Crane

CONDENSERS

In the construction of all electrical circuits there are but three main factors, Resistance, Inductance and Capacity. We have already told you that all materials offer resistance to an electrical current and those with the lower resistances are classed as conductors. Also, we explained the various types of "Resistors" which are in common use.

Then we gave you the details of induction and told you how an E.M.F. is induced when a conductor cuts, or is cut by a magnetic flux. The amount of induction, or rather the ratio of the induced E.M.F., to the current producing it, is known as inductance. Checking back, you will find that every circuit has resistance and inductance.

We merely mentioned the third factor, capacity, but its action is as important as the others therefore we want to explain it now to prepare you for the later Lessons.

LEYDEN JARS

In the early days, electricity was thought to be some sort of a liquid, like water, and many attempts were made to catch or collect it. In one of these attempts, a glass jar was coated with tinfoil, about half way up on both the outside and inside and, as shown in Figure 1, a piece of chain was hung down from the stopper so that it touched the inside tinfoil.

This arrangement was called a Leyden Jar and it was found that, when connected across a source of E.M.F. such as a battery, with the inside tinfoil connected to one terminal and the outside tinfoil to the other, there was no current because the circuit was not complete. Being an insulator, the glass in the sides of the bottle kept the circuit open.

However, after the battery was removed, it was possible to obtain a spark from the jar by holding a piece of metal so that it would complete a circuit from the top of the rod to the outside tinfoil. In other words, a certain amount of electrical energy was actually held, or stored up, somewhere in the jar which was given the name of "Condenser".

To fully understand what happens here, we had better go back for a minute and review some of the laws that were stated in the earlier Lessons. First of all, you learned that an E.M.F. was an electrical pressure always trying to force current from a high to a low potential. Next, we told you that there could be no current unless a complete and endless path was provided. Remember, these two facts still hold true, but we will have to go a little deeper.

Getting back to the Leyden Jar, if we removed the tinfoil and laid it out flat, each piece would be of fairly good size and, when connected to a battery, the circuit would really be as shown in Figure 2.

The instant the switch is closed, the positive or left-hand terminal of the battery, being at a higher potential, will try and force current around in the directions of the arrows. As the two sheets are separated, or rather insulated, from each other, there is no circuit but the upper plate will be at a potential equal to that of the battery positive. Because it is connected to it, the lower sheet will be at a potential equal to that of the battery negative.

Now here is what actually happens. The instant the switch is closed, there is a momentary rush of minute electrical charges to one of the tinfoil sheets and a similar movement away from the other sheet. These exceedingly small charges are known as "Electrons" and it is the methods of their control which make up the entire science of "Electronics".

The later Lessons contain many explanations on the behavior of electrons but at this time, you need remember only that a current of electricity is a flow of electrons. On this basis we can explain the action in Figure 2 by stating that, the instant the switch is closed there is current into one plate and current out of the other. During the comparatively short time this current exists we say the condenser is "Charging" ahd when the current ceases, the condenser is charged.

Assuming the condenser is charged, the battery can be removed from the circuit and the plates, or sheets of tinfoil, will still be at about the same potential difference as that developed by battery. This difference of potential between the two sheets of tinfoil causes an electrical strain and thus we have stored a certain amount of potential energy.

With the battery removed and the wires brought together, as in Figure 3, we complete an electrical path between the upper and lower sheets. The difference of potential, between the two sheets of tinfoil, forces current through the circuit and causes a spark between the ends of the wire. As soon as the two sheets are at the same potential, the strain is relieved, there is no further action and we say the condenser is discharged.

We told you that when the condenser is charged it possesses potential energy. Now, we can add that when it is in the act of discharging and has the ability to do work, it possesses kinetic energy. If you are not clear on the difference between potential and kinetic energy, a review of the earlier Lessons will be of benefit.

While there are many good examples of the charge and discharge action of a condenser, we think that the old "Jack in the Box" toy is as good as any. You may remember these old fashioned toys which looked like an ordinary box but, when you unfastened the cover, a figure of a man, snake or animal jumped out at you.

There was really nothing to it but a coiled spring hidden inside the figure. You put a force on the spring and compressed it, and then held it by closing and fastening the cover. When the catch on the cover was released, the spring expanded and pushed the figure up and out.

In other words, when you forced the cover down and compressed the spring, you put a certain amount of energy into it. The lock on the cover held the energy in the spring and, when the catch on the cover was unfastened, the spring released its stored energy and expanded.

An electrical condenser is very much the same. When you connect it across a battery, or other source of E.M.F., you give it a certain amount of electrical energy. Then, when the battery is removed, it retains this energy until a path or circuit is provided, when it releases the energy and discharges.

CAPACITY

In general, we can say that an electrical condenser consists of electrical conductors insulated from each other. From our explanation of the action in a Leyden Jar, you can see that the amount of energy a condenser can hold, called its Capacity, will depend a whole lot on the exposed area of the conductors.

In order to provide the proper value of capacity, most condensers are made with the conductors in the form of plates or sheets. To show you how it is possible to obtain different values of capacity, in Figure 4 we have placed a third sheet of tinfoil, below the lower one of Figures 2 and 3, and have connected it to the battery positive.

In this case, the action between the lower side of the middle sheet and the upper side of the bottom sheet will be exactly the same as already explained for the two upper ones only. As this arrangement provides twice the active area, twice the amount of energy can be stored and therefore, other things remaining the same, the condenser of Figure 4 will have twice the capacity of that shown in Figures 2 and 3.

DIELECTRICS

The insulation between the plates of a condenser is called the "Dielectric" and can be any electrical insulator. We have already mentioned some discoveries made by Michael Faraday and he also found the capacity of a condenser depends not only on the area of the plates but on the dielectric as well. The material the dielectric is made of and the distance between the plates both have an effect on the capacity.

This difference in the various insulators, when used as a dielectric, is called "Specific Inductive Capacity" or "Dielectric Constant". Both of these terms are in common use but mean about the same thing. Like everything else we have a starting point and, in this case, we consider the specific inductive capacity of air as 1.

With this as a starting point, the more common dielectrics have the following approximate values:

Air	1
Bakelite	4 to 8
Glass	6 to 10
Mica	4 to 7 1/2
Paraffin Wax	2 to 3 1/2
India Rubber	2 1/2
Paper	2 to 4
Castor Oil	4 to 5
Kerosene	2 to 3 1/2

In this connection, we want you to remember also that the dielectric is a very important part of any condenser because, according to some theories, as long as the condenser is charged, it is under a strain, like the spring in the "Jack in the Box" when the lid is closed. When the condenser discharges, the rebound of the dielectric helps it in its action.

THE FARAD

The former explanations of the different electrical actions included definitions for their units of measure and, for condensers, the capacity is measured in "Farads", a unit named to honor Michael Faraday. In terms of units already explained, we can state:-

A condenser which, at a pressure of one volt, will absorb one coulomb of electricity, has a capacity of one Farad.

You will remember that a current of one coulomb per second is equal to one ampere but, in the case of a condenser, the current is not uniform. While a condenser is charging it absorbs, or soaks up, a certain amount of electrical energy much like a sponge soaks up water.

The farad is a very large unit, so large in fact that for most ordinary work we use but one millionth of it, called a Microfarad. Just to give you an idea here, the ordinary variable condensers used for tuning a Radio Receiver, have a capacity of .00014 to .00035 Mf. This means 14 to 35 hundred thousandths of a microfarad, and it takes one million microfarads to equal one farad.

In order to avoid the use of decimals, it is becoming common practice to use a third unit of capacity, equal to one millionth of a Microfarad. As a microfarad is equal to one millionth of a Farad, this smaller unit is equal to one million-millionth of a Farad, therefore we call it a micro-microfarad or "Mmf".

Saying it another way, to eliminate an "M", or micro, from the terminology used to designate the capacity of a condenser, move the decimal point six places to the left, and to add an "M", move the decimal point six places to the right. For example,

100 Mmf = .0001 Mf = .0000000001 F

COLOR CODE

Many of the later types of small fixed condensers are color coded by means of three small dots but, as the numerical values represented by these colors are the same as explained for the Resistor color code, you have nothing new to learn. The only difference is that resistors are color coded in "OHMS", while condensers are color coded in micro-microfarads, "Mmf". As explained for resistors, the code is as follows.

Color		Figure
Black	–	0
Brown	–	1
Red	–	2
Orange	–	3
Yellow	–	4
Green	–	5
Blue	–	6
Violet	–	7
Gray	–	8
White	–	9

To read the color code properly, the condenser is first turned so that any lettering on it will read properly, or an arrow will point to your right. Then, following the plan explained for axial type resistors, you read the colors from left to right.

For example, suppose a condenser has a red dot on the left, a center green dot, and a right-hand brown dot. From the above table, you can see Red means 2, Green means 5 and Brown means 1. However, the figure represented by the color of the last dot means the number of ciphers which follow the first two figures and thus the condenser has a capacity of 250 Mmf. Moving the decimal point six places to the left, the capacity is .00025 Mf.

This color code is of great help in all Radio work and it may pay you to memorize the color values as listed above. Remember, for condensers the values are in "Mmf." and for resistors, the values are in Ohms.

ANALOGY OF CONDENSER ACTION

Now that we have explained Capacity, Dielectrics, Farads, and other terms connected with condensers, we are going to review condenser action because of its extreme importance to your later work. This time, to establish the action more clearly in your mind, we are going to compare a condenser circuit to a water circuit.

In Figure 5, we have such a circuit and, at the left, show a reciprocating piston with its wall and shaft. There is an opening at each end of the wall and, from these openings, we run lengths of pipe which are connected to the openings of the unit at the right. This right-hand unit is made up of two chambers which are separated from each other by a flexible diaphragm, and has no opening which will permit a direct passage of water from one chamber to the other.

In following our explanation, we want you to assume that the entire system is completely filled with water which, when in motion, can be compared to an electrical current, and that the piston with its wall and shaft will develop a pressure, comparable to a source of E.M.F. which is capable of changing its polarity. Also, the chambers will compare to the plates and the flexible diaphragm to the dielectric of a condenser.

As shown in Figure 5, with the piston in the neutral position, no pressure will be exerted and the flexible diaphragm will be in the position as shown by the heavy black line. This situation compares very favorably to the condition of a condenser which is completely discharged.

Now, if we move the piston to the right, it produces a pressure which will cause the water to travel in the direction of the inner arrows and force the flexible diaphragm downward as shown by the lower broken line. Due to the pressure or strain on this diaphragm, by displacement, there will be a movement of water in the lower pipe in the same quantity and direction of that in the upper pipe.

When the piston is in the extreme right-hand position, so as to exert the greatest pressure, the diaphragm will be bent downward to the maximum position. Comparing this action to a condenser, we can say it is charged. You can see that if the pipes were "capped", when the diaphragm was in this stressed condition, the unit at the right would possess a certain amount of potential energy which would be equal to that of the supply. Notice, although no water passed completely through the right-hand unit, there was a flow of water in both the upper and lower pipes.

Going back to Figure 5, with the piston at the right and the diaphragm bent downward, if the shaft is released the pressure, produced by the diaphragm in trying to return to its original position, will force the water in the direction of the outer arrows and move the piston toward the left. This action will continue until the diaphragm reaches its normal or unstressed position as shown by the solid line in Figure 5. This analogy can be compared to the action of a condenser while discharging.

Should the piston be forced from its neutral position toward the left, the action will be the same as explained above but the water, forced in the direction of the outer arrows, will cause the diaphragm to bend upward, as shown by the upper broken line. Then, with the force removed from the piston, the potential energy possessed by the diaphragm will be released and force the water in the direction of the inner arrows.

Suppose now, that the piston is moved rapidly from one side to the other. You can see this will cause a continual movement of the water in the pipes, the direction and rate of change of which will depend on the position of and speed at which the piston is reciprocated.

Comparing the pressure produced by the piston to an E.M.F. of changing polarity, and the unit at the right to a condenser, there will be current in the circuit although none actually passes through the condenser.

When the piston is at either the right or left and is exerting a pressure in one direction only, the analogy is that of a Direct Current circuit and there is current only while the condenser is charging or discharging. As the charging time is measured in fractions of a second, the exact time depending on the average rate of charging current, capacity and impressed voltage, we conclude that a condenser will not allow any current in a D.C. circuit.

From the two paragraphs above, we want you to remember that, when compared to an electrical conductor, a good condenser will not allow A.C. or D.C. current directly through it, although there can be current in an A.C. series circuit which contains capacity.

PLATE CONDENSERS

One method of building a simple condenser is to use two plates, usually of copper or aluminum, which are separated by the dielectric. Instead of making the plates larger, in order to obtain the required capacity, a larger number of small plates are assembled, one on top of the other.

The general plan of construction is to place a sheet of dielectric on top of a plate which is shaped to form an extension at one side. Then, a second plate is placed on top of the dielectric but with its extension to the opposite side, as compared to the first plate. This same alternate arrangement of plates and dielectric is continued until the proper, or required number have been put in place.

When the assembly has been completed all the extensions on one side are electrically connected to make one condenser terminal, and all the extensions of the other side are connected to make the second terminal. The entire assembly is then dipped in shellac, melted wax, or other insulating compound and usually heated to drive out all the air. After cooling, the compound makes the finished condenser moisture proof.

In some of the larger condenser units, the plates are held in racks of insulating material, but here also, every other plate is electrically connected in the same manner as explained above. In some cases of this kind, air is used as the dielectric, and in others, the plates are covered with an insulating oil which is then the dielectric.

Variable condensers are another form of plate condensers and are made up of two sets, or groups, of plates, the number of plates in each group depending on the capacity of the condenser. One group, known as the "Stator" is insulated from but held stationary by the frame and the plates are electrically connected by metal spacers which hold them the proper distance apart. The other group, known as the "Rotor", is electrically connected in much the same way but is fastened to a movable shaft.

By turning the shaft, the rotor plates move in between those of the stator and thus, by changing the active exposed area, the capacity of the condenser can be varied. It is a good thing to remember here that, even with the moveable plates

turned out as far as they will go, there is still an appreciable amount of capacity present due to the amount and position of metal in the two groups of plates. Therefore, variable condensers are rated as to their values of "maximum" and "minimum" capacity.

ROLLED CONDENSERS

Another very common method in the manufacture of condensers is to take long strips of metal foil and waxed paper and roll them up in a compact package. Of course, by this method, the waxed paper is inserted between the strips of foil and serves as the dielectric. By following this plan, comparatively large capacities can be obtained in a very small space because both sides of both strips of foil will aid in the action.

In order to make a good electrical connection with the metal foil, little pieces of thin copper are laid on the foil and left sticking out as the strips are rolled. All of the pieces of copper touching one foil strip stick out on one side and those touching the other strip stick out on the other side.

By soldering these pieces of copper to a wire, again we have the two condenser terminals the same as with the plate condenser. Here also, after the roll is made, it is usually dipped in melted paraffin to improve the dielectric, drive out all air and prevent moisture from getting in.

A better method of construction, and one which is in more common use, is to make the foil wider than the paper, one strip projecting at one side and the other strip projecting from the other side. This is known as a "Non Inductive" condenser because, with connections properly made to each piece of foil, there is a good contact along the entire length.

When copper strips are used for connection, there are generally several turns of foil between them and, when charging and discharging, the current passes around these turns, causing self induction.

PAPER - MICA CONDENSERS

One common type is called a Paper condenser because the dielectric is paper soaked in wax. You can readily see that if there should be a spot where the wax was thin, a fairly high voltage across the condenser might be able to force current from one tinfoil strip to the other, burn a hole through the paper and "short" the condenser.

For use across higher voltages, and usually in the better grades of small size condensers, you will find thin sheets of

mica for the dielectric. Mica does not puncture as easily as paper and, from the figures that we gave you a few pages back, you will remember that it also has a higher specific inductive capacity.

Mica can be split into very thin sheets and still retain its insulating qualities therefore, the plates in a mica condenser can be placed very close together, thus increasing the capacity. Mica condensers are generally encased in moulded bakelite and you will find them in various sizes and shapes.

ELECTROLYTIC CONDENSERS

Because of its ability to provide greater capacity in less space, the electrolytic condenser has come into common use for a number of important Radio applications. Although its electrical principle of operation is the same as explained earlier in this Lesson, its construction is different in many respects.

In an earlier Lesson on Cells and Batteries, we told you that different metals, when placed in an electrolyte, produced an E.M.F. and certain combinations are in common use as dry cells or storage batteries.

Some metals, of which aluminum is the most common, have an entirely different action when placed in an electrolyte. When a combination of this kind is connected in an electrical circuit, it will allow current in one direction, but not in the other, to form an Electrolytic Rectifier.

When two plates of aluminum are placed in a suitable electrolyte and the combination is connected in a D.C. circuit, the current will be high at first but taper off to a very low value. This reduction of current is caused by an extremely thin film of oxide which forms on the plate connected to the positive terminal of the circuit. Should the circuit connections be reversed, the entire action will be repeated and, again, the film will form on the plate connected to the positive.

After the film has been formed, the other plate can be removed and the combination of plate, film and electrolyte make up a condenser. In this case, the film is the dielectric, the aluminum is one plate and the electrolyte acts as the other plate. As the film is extremely thin, the condenser plates are close to each other and thus, the capacity of the condenser is comparatively large.

Remember here, the film forms on the plate connected to the positive and will not maintain its insulating value if the

direction of current is reversed. Therefore, the common types of electrolytic condensers are useful only in D.C. circuits and are marked plainly to indicate which terminal must connect to the positive side of the circuit.

MATERIAL USED

While aluminum is the most common metal, Magnesium and Tantalum may also be used for the metal plate which carries the film. This plate is known as the "Anode" and, to increase its effective area, the surface may be roughened by an etching process. Because the action occurs on the surface, the anode is sufficiently thin to be classed as a foil.

The electrolyte is held in some porous material, such as gauze or paper, which is made in the form of a sheet and placed in contact with the anode foil. To provide good electrical contact with the electrolyte, a second sheet of thin metal, known as the cathode foil, is placed on the opposite side of the porous sheet. The porous material thus acts as a separator to prevent metallic contact between the anode and cathode foils.

The metal foils and separator are made in strips and assembled on the general plan explained for rolled condensers. Tabs of foil are attached to the strips and brought out for connection to the terminals of the completed unit.

There are two main types of electrolytic condensers, the "Wet" and the "Dry". In the wet types, the electrolyte is quite thin, with about the same viscosity as water while, in the dry types the electrolyte is in the form of paste.

In addition to their capacity, there are two important points to remember when installing electrolytic condensers. First, the terminal marked "Plus", "Positive" or "+" must always be connected to the positive side of the circuit and second, the value of voltage applied across the condenser should not exceed the value of "working volts", also marked on the condenser.

CONDENSER CAPACITY

The capacity of a condenser depends almost entirely on its physical or mechanical construction and, while it is not likely you will ever be required to build one, we want to give you an idea of how capacity is figured.

Suppose we have an ordinary plate condenser and want to know its capacity in Farads. All of the plates will be of the same size therefore, we will first find the area of one of

them in square inches and then multiply it by the number of plates in order to find the total active area. The end plates will be used on one side only while the others will act on both sides therefore, as two outside surfaces are not used, we will subtract 1 from the total number of plates before multiplying the area. Then we must also know the dielectric constant and the distance between the plates.

After we have all of these values, we make use of the formula:

$$C = \frac{A \times K \times (N - 1)}{4.452 \times D \times 1,000,000,000,000}$$

When:–

A is the area of the plates in square inches
K is the dielectric constant
N is the total number of plates
D is the distance between the plates in inches
C is the Farads capacity

In the above formula, the figure "4.452" is known as a "Constant" and is used to make the formula work out correctly. As a common example of a constant, you know that quarts divided by 4 equals gallons and thus, the "4" can be considered as a constant.

As most of the condensers you will work with have very small capacities in Farads, they are rated in microfarads. As a microfarad is one millionth of a Farad, by dropping the last six zeros in the demoninator of the formula, the value of C will be in microfarads.

Variable condensers are seldom built with capacities of more than .0005 Mf. and, to avoid the decimals, you will often find them rated in micro-microfarads. A micro-microfarad, or "micromike", abbreviated "Mmf.", is one millionth of a microfarad therefore, by dropping all the zeros in the formula, the value of C will be in Mmf.

Written out in figures –

500 Mmf. equals .0005 Mf. equals .0000000005 F.

CONDENSER CIRCUITS

Like all other electrical units, condensers can be connected in series, parallel or any of the combinations we have explained. Although they allow no direct current, there are several important points we want to explain at this time. A review of the Lesson on Series and Parallel Circuits will help you follow our explanations here.

The quantity of the charge of a condenser, measured in coulombs and usually indicated by the letter "Q", is equal to the capacity "C" in farads, times the applied voltage "E", in volts. As explained for Ohm's Law, these quantities can be arranged to provide three forms of the equation,

$$Q = CE, \quad E = \frac{Q}{C}, \quad C = \frac{Q}{E}$$

CONDENSERS IN SERIES

To investigate their action, for Figure 6 we show two condensers, C_1 and C_2, connected in series across a supply line or circuit. Reviewing the rules for series circuits, we find first that, at any instant, the current is the same in all parts of the circuit.

Instead of a continuous action, in the circuit of Figure 6, the current will consist of the condenser charges and discharges only. However, to conform to the general current rule for series circuits, here the charge or "Q" of both condensers must be the same and equal to that of the complete circuit.

Also, according to the general laws of series circuits, the total voltage across the circuit is equal to the sum of the voltage drops across the parts connected in series. Applying this Rule to Figure 6, the sum of the voltage drops across the separate condensers will equal the voltage across the complete circuit.

To write these actions in the form of equations, using the terms previously explained, for any circuit like that of Figure 6,

C = combined capacity of C_1 and C_2
E_1 = voltage drop across C_1
E_2 = voltage drop across C_2
E = total supply voltage
Q = the charge

Substituting in the general equation,

$$E = \frac{Q}{C}, \quad E_1 = \frac{Q}{C_1}, \quad E_2 = \frac{Q}{C_2}$$

but, from the second law of series circuits,

$$E = E_1 + E_2$$

Substituting the values of these voltages in terms of charge "Q" and capacity "C", we can write

$$\frac{Q}{C} = \frac{Q}{C_1} + \frac{Q}{C_2}$$

As "Q" has the same value in all these fractions, it does not change the relationship between the capacities therefore, the formula can be simplified by eliminating the quantity "Q", a step which can be done by following the rules for fractions. For example, suppose we have the expression,

$$\frac{3}{4} = \frac{3}{12} + \frac{3}{6}$$

and want to find the value of $\frac{1}{4}$. To do this, we divide all of the terms by 3 but, to divide fractions, the divisor is inverted and the fraction multiplied by it. Following these steps,

$$\frac{3}{4} \times \frac{1}{3} = \left(\frac{3}{12} \times \frac{1}{3}\right) + \left(\frac{3}{6} \times \frac{1}{3}\right)$$

and cancelling the "3's" of each term,

$$\frac{1}{4} = \frac{1}{12} + \frac{1}{6}$$

Following the same plan for the capacity equation and dividing by "Q",

$$\frac{Q}{C} \times \frac{1}{Q} = \left(\frac{Q}{C_1} \times \frac{1}{Q}\right) + \left(\frac{Q}{C_2} + \frac{1}{Q}\right)$$

and cancelling the "Q's" of each term,

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} \qquad (1)$$

and when more than two are used

$$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3} \text{ and so on} \qquad (2)$$

Following the plan explained for resistances in parallel, when two condensers are connected in series, for the total capacity,

$$C = \frac{C_1 C_2}{C_1 + C_2} \qquad (3)$$

Following the same plan for equation (2) we have :-

$$C = \frac{C_1C_2C_3}{C_2C_3 + C_1C_3 + C_1C_2} \qquad (4)$$

However, when equal capacities are connected in series, we can substitute any one for the others and equation (4) becomes :-

$$C = \frac{C_1}{3} \qquad (5)$$

Thus, as a general rule, we can state:- When equal capacities are connected in series, the total capacity is equal to that of one condenser divided by the number of condensers.

To show you how these formulas work out, suppose we connect a .002 Mf. and a .00025 Mf. condenser in series. Using formula (3) for the series connection and substituting .002 for the first capacity and .00025 for the second capacity we have,

$$C = \frac{.002 \times .00025}{.002 + .00025}$$

$$C = \frac{.0000005}{.00225}$$

$$C = .0002222 \text{ Mf.}$$

$$C = .000,000,000,2222 \text{ Farad}$$

So much for series capacity, now let's see about the voltage. With 100 volts across the circuit of Figure 6, the charge of the two condensers, figured as above for total capacity, would be --

$$Q = C \times E$$
$$Q = .000,000,000,2222 \times 100$$
$$Q = .000,000,022,22$$

By simple fractions, such as we used for Ohm's Law, if Q = C x E then E = Q/C and using the formula in this form, for the .002 Mf. or .000,000,002 Farad condenser the voltage would be,

$$E = \frac{.000,000,022,22}{.000,000,002} = 11.11 \text{ volts}$$

For the .00025 Mf. condenser we would have,

$$\frac{.000,000,022,22}{.000,000,000,25} = 88.88 \text{ volts}$$

These figures show two important facts. First, when connected in series, the voltage across each condenser is less than the line voltage and second; when unequal capacities are connected in series, the ratio of the voltages across them will vary inversely as the ratio of their capacities.

In the example we just worked out, the larger condenser, with eight times the capacity, had but one eighth of the voltage across it. With condensers of equal capacity, the voltage across them would be equal and this is also a useful fact to know in your work.

For example, suppose there is 600 volts across the circuit of Figure 6 and you need a capacity of 2 Mf. If you did not have a condenser of the proper size and working voltage, two 300 volt 4 Mf. condensers would do the job.

Using formula (3) of this Lesson, when connected in series their total capacity would be,

$$C = \frac{4 \times 4}{4 + 4} = \frac{16}{8} = 2 \text{ Mf.}$$

and the voltage across each,

$$E = \frac{Q}{C} = \frac{.0012}{.000004} = 300 \text{ volts}$$

You may be wondering how all these figures will help in your work but, as we take up the various electronic problems in our later Lessons, you will find these formulas not only useful but necessary.

CONDENSERS IN PARALLEL

In Figure 7 we show two condensers C1 and C2 connected in parallel and, like the branches of any parallel circuit, the full line or supply voltage will be across each.

Thinking of each of these as a simple two plate condenser, like Figure 2, the parallel connection of Figure 7 really doubles the area of the plates. In other words, we have two plates connected to each side of the supply line or circuit.

If each condenser has a capacity of 1 Mf., two of them, connected in parallel, will have a combined capacity of 2 Mf. The point to remember here is that, when connected in parallel, the total capacity of two or more condensers is equal to the sum of their separate capacities.

Written out as equations and letting C represent the total capacity, for the parallel connection

$$C = C_1 + C_2 \qquad (6)$$

and when more than two capacities are used, the equation becomes,

$$C = C_1 + C_2 + C_3 \text{ and so on} \quad (7)$$

You will find the above equations very useful because it is often necessary to replace punctured and shorted condensers. For example, suppose you need a capacity of 2 Mf., and have nothing but 1 Mf. and .5 Mf. condensers available. By connecting in parallel, you could use four .5 Mf. or two .5 Mf. and one, 1 Mf. to make the required 2 Mf. capacity.

However, you must watch the voltage. Nearly all condensers are marked to show their maximum A.C. and D.C. working voltage. Some also are marked with a "test" voltage. Connected in parallel, each condenser has the full circuit voltage across it which must not be higher than the "WORKING" voltage for which it is marked.

In general, there are but two distinct condenser types and they are known as plate and rolled. There are, of course, variations of these types and plate condensers may be of the fixed or variable variety while the rolled type are of a fixed capacity.

The main points we want to bring out in these explanations are condenser action and the total capacity of condensers connected in series or parallel. If any of these points are not clear, go back over our explanations before going ahead.

GRAPHS

In the Lesson on Multimeters, we explained the drawing of a graph for reading values not on the scale of a meter and in many of the later Lessons, we will show other actions by means of curves, or graphs. It is imperative that you understand them perfectly because more and more electronic data is being published by means of curves and, for that reason, we are going to spend the rest of this Lesson explaining the various types and the methods by which they are drawn.

First of all, remember, the ordinary curve is not complicated, does not depend on higher mathematics and can be read as easily as a map. Once you feel sure of the truth of this fact, curves will lose most of their difficulties for you.

SCALES

On a good map, each inch represents a certain number of miles and all parts are drawn in proportion. Thus, if one inch represents 20 miles, two towns which are actually 20 miles

apart, will be one inch apart on the map. This reduction is what we call the "Scale" and, to be accurate, all parts are drawn to scale. The same idea is carried out in all technical or mechanical drawings where the object has to be reduced, enlarged, or is drawn full size.

The first point to keep in mind then is that the scale is only the amount of increase or reduction. Any scale within reason can be used and going back to a map, one inch can represent 1 mile, 10 miles, 100 miles or 1000 miles. However, and this is important, whatever scale is used, all parts of the map must be reduced in the same proportion. If one inch represents 20 miles in one part, it must represent 20 miles in all parts.

For Radio and other Electronic work, most of the curves are drawn to represent values such as voltage, current, frequency, amplification and so on, but the idea of the scale is the same as for a map, only instead of miles, there are volts, amperes, kilocycles and other scales.

GRAPH PAPER

To save a great deal of measuring, most curves are drawn on specially prepared "CROSS SECTION" or "GRAPH" paper which is made in a number of types to suit various classes of work.

In Figure 8 for example, we show a piece of common graph paper, divided into equal squares with every fifth line heavier to make it easier to follow any line. While this type of paper can be had in many sizes and rulings, the common ones use a length of one inch as a main unit and divide it into 8, 10, 12, 16 or 20 equal parts.

For Radio and other Electronic work, 20 equal divisions to the inch are common because they allow most scales to be divided closely. For example, if you are using a scale in which 1 inch equals 10 volts, then each small square will represent .5 volt. Should the values be larger and you decide to let one inch equal 100 volts, then each small square represents 5 volts.

While there is no hard and fast rule, the scales are usually made so that the largest values will just about take up the full number of squares used for the complete scale.

SIMPLE GRAPH

An actual example makes any explanation easier to follow therefore, suppose you are doing Radio Service Work and are anxious to keep a close check on the number of calls you handle. It would be easy to start a list and, at the end of each day,

mark down the number of calls made. Such a list would look something like this --

DAY	-	NO. OF CALLS
Monday	-	12
Tuesday	-	8
Wednesday	-	7
Thursday	-	11
Friday	-	9
Saturday	-	16

By reading down the column you would see your best day, worst day and so on, but still would not have a good picture of what actually happened. You have two sets of values here, the days of the week, and the number of calls, therefore can make a graph.

To show this information as a graph on a piece of cross section paper like that of Figure 8, your first job is to select the scales. Going across the bottom, you see there are six heavy lines and, as there are six working days in the week, decide to let each heavy line represent one day. Counting across from left to right, each five small squares represent one day.

For the number of calls, you see 16 is the highest, but you could handle 20 or 25 and starting again at the lower left, but going up this time, you let each small square represent one call.

Those are your two scales and we have them all drawn in Figure 9. It might be well to mention here that the lower left corner, where both scales start, or originate, is called the "Point of Origin". These scales are read on the same general plan as a ruler and are considered as extending all the way across the cross section paper. In your mind, you move the bottom scale straight up and the left hand scale straight across to the right.

The line running from left to right, from the point of origin, is also called the horizontal axis, while the line running up from the point of origin is called the vertical axis. The other lines, running up from the horizontal axis, are called "ORDINATES", while those running across from the vertical scale are called "ABSCISSAE".

Going back to the table, you made 12 service calls on Monday therefore, you start at the Point of Origin, Figure 9, go up the "MON" ordinate to the 12th square on the vertical scale, and make a dot or small circle where the lines cross.

For Tuesday, you made 8 calls and to locate this point, you follow up the "TUE" ordinate until it crosses the 8th line, or abscissae of the vertical scale, and again make a dot or small circle.

The same plan is followed for each day and after all the points have been located, they are joined by straight lines as shown.

Figure 9 contains exactly the same information as the table, but gives a better picture of what is taking place. You can see at a glance, just how the number of calls varied, which day was high, which was low and so on. While the graph here is a rather irregular series of straight lines, it is called a curve.

CONVERSION GRAPHS

Following exactly the same plan, graphs can be drawn for many other purposes. For example, 1 inch equals 2.54 centimeters, a fact which can be written as the formula --

Inches = Centimeters ÷ 2.54

or working it the other way around

Centimeters = Inches x 2.54

Taking the formula, we can substitute various values of inches and find the corresponding value in centimeters. For example --

Centimeters = Inches x 2.54

For 1 inch . . . . Cm = 1 x 2.54 = 2.54
For 2 inches . . . . Cm = 2 x 2.54 = 5.08
For 5 inches . . . . Cm = 5 x 2.54 = 12.70

and thus any value in inches can be changed to centimeters.

Working the other way,

Inches = Centimeters ÷ 2.54

For 1 Cm . . . . Inches = 1 ÷ 2.54 = .393
For 5 Cm . . . . Inches = 5 ÷ 2.54 = 1.974

As explained for Figure 9, we could work out a long table of values but instead, have drawn the curve of Figure 10.

The centimeter scale is laid off on the horizontal axis and the inch scale on the vertical axis. The point of origin is

at the lower left corner as before. Checking the scales you will find each small square along the vertical axis represents .2 of an inch while each small square along the horizontal axis represents .4 of a centimeter.

Substituting in the formula, we find 1 inch equals 2.54 centimeters and to locate this point on the curve, we go up the vertical axis to 1 inch and then over to the 2.54 ordinate.

On the drawing we have a "2" ordinate, a "2.4" ordinate and a "2.8" ordinate, but no "2.54" ordinate therefore we estimate about where the 2.54 ordinate would be. You can see that 2.54 will be about 1/3 of the way between the 2.4 and 2.8 ordinates because 2.54 is .14 larger than 2.40 and .26 less than 2.80. We place a mark on the "1" abscissae where the 2.54 ordinate would cross and then go ahead and plot other points. From the formula, 2 inches equal 5.08 Cm., 3 inches equal 7.62 and so on.

After several of these values are located, we find a straight line passes through all of them therefore, in this case the curve is really a straight line.

This curve is called a conversion graph because it shows the value in centimeters for any value of inches. For example, suppose you want to change 1.6 inches to centimeters. Of course you can multiply it out but, looking at Figure 10, it is much easier to follow the vertical axis to 1.6 inches and then go over to the curve. The curve crosses the 1.6 abscissae at the 4 ordinate therefore 1.6 inches equals 4 centimeters.

Any values can be converted from inches to centimeters in the same way and of course, the curve works equally well for changing centimeters to inches.

Where the lines and curves of the drawing do not cross exactly on the corner of the squares, the values have to be estimated. For example, suppose we want to change 6 centimeters to inches. Going up the "6" ordinate to the curve, we find they cross just below the 2.4 abscissae.

To estimate the value, we notice each square represents .2 of an inch. The curve looks to be about 1/4 of the square below 2.5, therefore we take 1/4 of .2 which is .05 and subtract it from 2.4 making the reading of 2.35 inches.

Naturally the results will not be as accurate as those worked out mathematically, but are close enough for many ordinary problems. Conversion graphs can be made for any two sets of values and will be found useful in many ways.

TUNING CURVES

Following the same general idea, in Figure 11 we have the tuning curve of a Radio receiver. The vertical scale represents the older arrangement of dial markings which were equally divided from 0 to 100. The horizontal scale shows the frequencies of the broadcast band in kilocycles.

To make this curve, several actual readings are taken. For example, when a station with a frequency of 650 K.C. is properly tuned, the dial reads 80. Listing several of these,

FREQUENCY	DIAL
770	55
820	48
900	34
980	24
1100	12
1200	8

These points are plotted as explained for Figures 9 and 10 but we notice they do not lie as a smooth curve. Drawing a line to pass through all of them, would make an irregular wavy curve. It has been proven that these small variations are usually caused by slight errors in reading or in estimating the position of the points and a smooth curve really represents the actual conditions very closely. To show the variations, many graphs are drawn like Figure 11 with the smooth curve as close as possible to the actual plotted points which are plainly marked.

With the curve of Figure 11 as a guide, you could tune in any frequency in the range of the receiver. For example, suppose you wanted to listen to a station broadcasting on a frequency of 700 K.C. Going up the 700 ordinate, you find it crosses the curve at approximately 69 on the dial setting scale, therefore turning the dial to 69 will tune the reciever to 700 K.C.

By this time you should be able to see that Figures 9, 10 and 11 are all about the same. The various scales represent different types of values but, when one of a pair of values is known, the curves make it possible to find the other.

In Figure 9, for example, "TUE" shows 8 service calls. In Figure 10, 3 inches equal 7.6 centimeters and in Figure 11 1000 K.C. tunes at a dial setting of 22. The curves make it possible to quickly read any pair of corresponding values.

Several times, in our explanations of Radio, we have mentioned "Tuning" and Figure 11 of this Lesson is a "Tuning Curve" for some particular Radio Receiver. In the later Lessons, curves are used frequently to illustrate various principles and actions therefore, be sure you understand the method of reading them, as explained for Figures 9, 10 and 11.

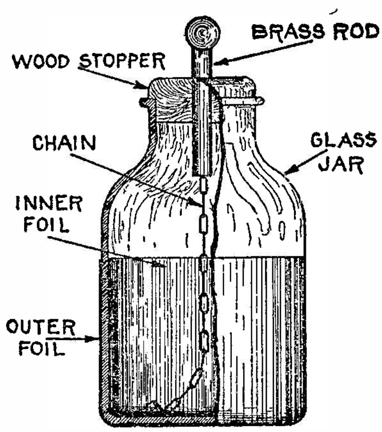


FIGURE 1

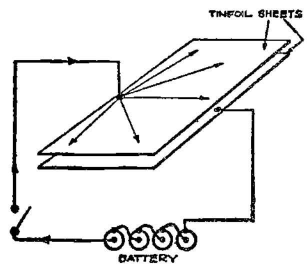


FIGURE 2

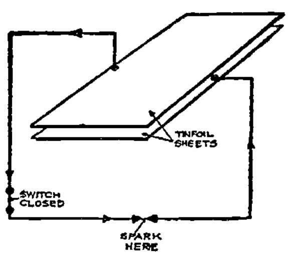


FIGURE 3

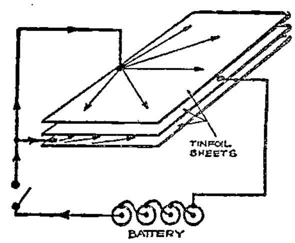
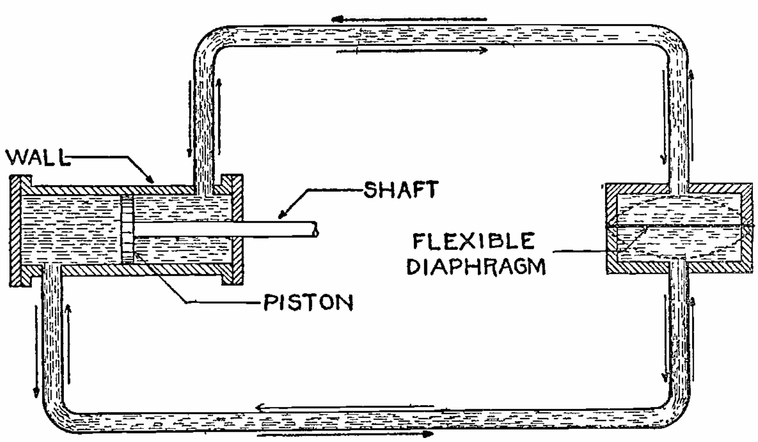


FIGURE 4



P11

FIGURE 5

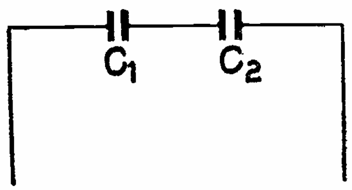


FIGURE 6

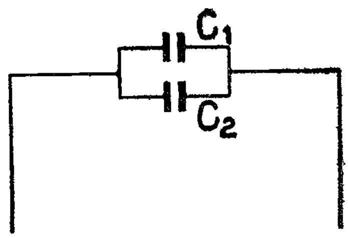


FIGURE 7

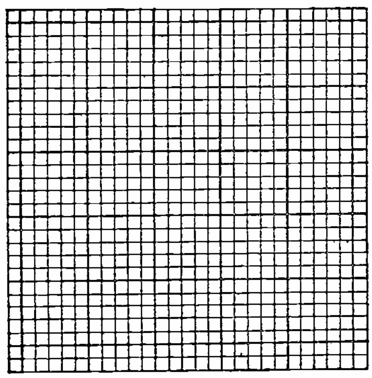


FIGURE 8

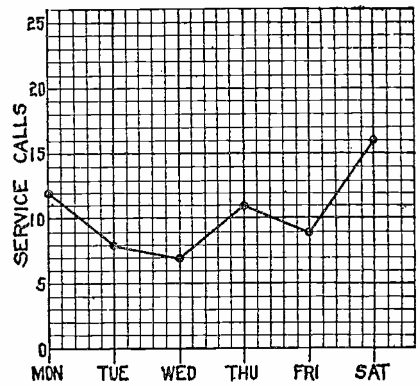


FIGURE 9

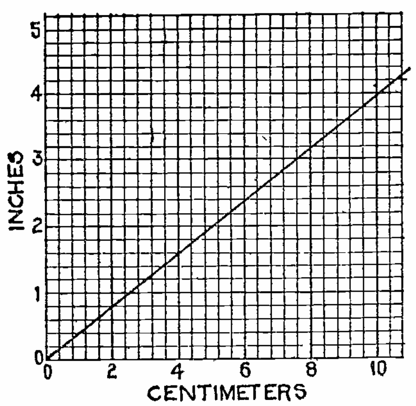


FIGURE 10

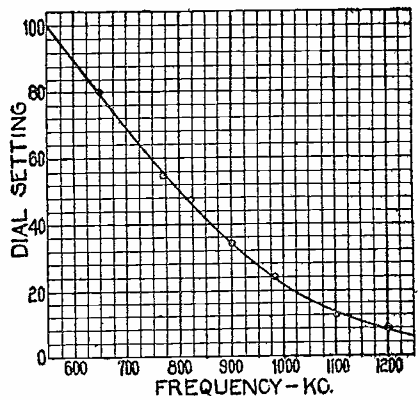


FIGURE 11

DE FOREST'S
TRAINING, Inc.

LESSON FDM - 20

CURRENT GENERATION

Founded 1931 by

RADIO FUNDAMENTALS

LESSON 20

CURRENT GENERATION

Induction In a Loop of Wire------------- Page 1
Action As Loop Is Revolved-------------- Page 2
Direction Of Induction------------------ Page 3
Alternating Current--------------------- Page 4
Difference In Induction----------------- Page 4
Sine Curves----------------------------- Page 5
Simple Generator------------------------ Page 7
The Commutator-------------------------- Page 7
Changing A.C. to D.C.------------------- Page 8
Adding Loops---------------------------- Page 9
Power Supply---------------------------- Page 10

* * * * * *

Opportunity comes like a snail and once it has passed you, it changes into a rabbit and is gone. What is opportunity? It is a chance to do something, to give something, to achieve something, to climb out of the rut. To be somebody of value in the world. Opportunity is life itself.

--Arthur Brisbane

CURRENT GENERATION

Practically all electricity, used for commercial lighting and power is produced mechanically. By that we mean the power house has engines, or prime movers, driven by steam, gas, oil or water. These prime movers produce mechanical energy or motion and drive the generators which, in turn, change the mechanical motion into electrical energy.

While a large percentage of Radio and other Electronic equipment is designed to operate on commercial lighting or power circuits, the larger portable installations usually include a commercial type of generator driven by a gasoline or similar type of engine. Therefore, in a broad sense, commercial types of generators can be considered as a part of a complete Radio Installation.

In addition, the operation of a generator provides a practical yet comparatively simple means of showing the application of the principles of Electro Magnetic Induction, especially in respect to alternating voltages. Therefore, the following explanations of generator operation will serve a double purpose.

INDUCTION IN A LOOP OF WIRE

Reviewing the earlier Lessons, you will remember that, whenever a conductor moves in a magnetic field in a direction to cut through the magnetic lines, an E.M.F. is induced in the conductor. It does not make any difference, electrically, whether the magnetic lines or the conductor move, as long as they cut through each other.

As far as electricity is concerned, a generator is a machine that changes mechanical energy, or motion, into electrical energy and operating on the principle of electro-magnetic induction, it will be necessary to move either the conductor or the magnetic field.

Most smaller generators move the conductor, therefore we will explain that action first and in Firgure 1, have the simplest possible form of such a machine. The conditions here are just about the same as explained before, a magnetic field set up by a permanent or electro-magnet, and a wire to cut the field. Here however, we have bent the wire into the form of a loop, one side near the N pole and the other near the S pole of the magnet.

As the magnetic field is stationary, the loop must be moved therefore, we show it mounted on, but electrically insulated from, a shaft. To complete an electrical circuit through the loop, and still be able to turn it, we have two copper rings, also mounted on the shaft.

A stationary conductor rests on each of these rings and, as the loop and rings turn, the circuit is completed through them. The rings are called "Collector Rings" and the stationary conductors, "Brushes".

In Figure 1, Position 1, the circuit will be from the lower left brush through the ring, along side A of the loop, across the back to side B and forward through the other ring and brush. Remember, here, even though the loop is turned, the circuit does not change.

Now, suppose we turn the shaft in a clockwise direction. As we start from Position 1, Figure 1, the side near the N pole of the magnet on the left, will go up, and the side near the S pole on the right, will go down.

Using the Three Finger Right Hand Rule here, on the left side we find the direction of induction will be from the front toward the back, or away from us and into the paper. On the right side, which is moving down, the induced E.M.F. will be from the back toward the front, or out from the paper. The action of the two induced E.M.F.'s, will be to try and force the current around the loop in the same direction, back on the left side and forward on the right, or around in the same direction that the hands of a clock move.

If you want to think of this induced E.M.F. as a source of electrical energy, the same as a primary cell, then both sides are connected in series and both try to force current the same direction.

ACTION AS LOOP IS REVOLVED

As we continue to turn, starting from Position 1, Figure 1, where the induction is as just explained, at the end of a quarter turn, the loop will be in the position shown at 2. Here, the sides lettered "A" and "B" will be moving parallel to the magnetic lines, will not cut through any of them and therefore there will be no induced E.M.F.

After the next quarter turn in the same direction, the loop will be in the position shown at 3. Now notice, this is exactly like Position 1 except that side "A" is now moving down past the S pole and side "B" is moving up past the N pole.

The induction here will be exactly the same as at Position 1, that is, back along the left side and forward along the right side or around in a clockwise direction. However, the loop has been turned over and the induction is back along "B" and forward along "A". We have reversed the direction of induction, as far as the sides of the loop are concerned, but have turned the loop over at the same time therefore, we still have the same direction as far as the complete loop is concerned.

Completing another quarter turn, we arrive at Position 4, Figure 1, where we have the same conditions as at Position 2, but side "A" is now on the bottom and side "B" on top. Again there is no induction because the sides of the loop are moving parallel to the magnetic lines. Another quarter turn brings us back to Position 1 and all the actions will repeat every time the loop passes through one complete turn.

There are one or two things here that require particular attention. We have simply used the laws of electro-magnetic induction as explained in a previous Lesson but, by bending the wire into a loop and using both poles of the magnet, we have doubled up on the action. As one side goes up, the other comes down, and although the induction pushes back on one side and forward on the other, it pushes around the loop in the same direction.

Did you ever see one of the long two-man saws they use around lumber camps? A man stands at each end and, in order to work together, when one man pulls, the other one pushes. We have the same action in this loop, the induction pushes along one side and pulls along the other, but they both work together.

The other action, perhaps a little harder to see, is how the value of the induced E.M.F. varies at different parts of each turn. To make this easier, we have cut right down through the middle of the positions of Figure 1 and find the conditions shown in Figure 2. Here we have only the back half of the loop, but show it in all four positions.

DIRECTION OF INDUCTION

You can see here that, as far as the poles of the magnet are concerned, there are only two positions of the loop, but by tracing around A-1, A-2, A-3 and A-4 you can follow the motion. As side A-1 goes up toward A-2, the induction is IN toward the paper, but at the same time, side B-1 is moving down toward B-2 and the induction there is OUT from the paper toward you.

In Position A-2, B-2, the wire is moving along with the magnetic lines, does not cut through them and therefore there is no induction.

With the loop turned to Position A-3, B-3, we again have the same conditions as at A-1, B-1, except that the direction of induction is now IN at B-3 and OUT at A-3. Position A-4, B-4 is the same as A-2, B-2 except that the sides have changed places, and again there is no induction. From here on, as the loop is revolved, the action is repeated every complete turn.

ALTERNATING CURRENT

You can easily see that if the loop is turned continuously, the induced E.M.F. will reverse its direction in each side during each complete turn. If the sides A and B are connected to a circuit, through the rings and brushes of Figure 1, then as the loop is turned, the current in the circuit will be first in one direction and then in the other. For the first half turn of the loop, current will go around the circuit in one direction and, for the second half turn, it will go around in the other direction. This periodic change of current direction is what we call Alternating Current.

Now, whether you ever stopped to think about it or not, it is a fact that you can not reverse without coming to a dead stop. As the induction changes direction, or reverses in the sides of the loop, it must come to a stop each time and we are going to show you just what happens.

DIFFERENCE IN INDUCTION

In order to follow the loop around each turn a little more closely, we show it in eight different positions in Figure 3. As you already know the action of the induction in the sides, we will now consider the loop as a whole. We want you to think of the magnetic lines as being evenly spaced and uniform throughout the entire field and that the loop is being turned at an absolutely even and steady speed but in an anti-clockwise direction.

Of course, in our explanations we will have to stop at the various positions to tell you about them but, in practice, unless the wire was kept moving, there would be no induction.

Starting at Position 1, Figure 3 and moving to position 2, the wire will cut but a very few lines and, as the induction is proportional to the rate of cutting, the induction will be very small. Its direction, however, will be IN at the left and OUT at the right.

Going from Position 2 to 3, the angle of cutting has increased and, although we have made only another 1/8 turn, more lines will be cut and while the induction will be greater, its direction remains the same.

On the next 1/8 turn, from 3 to 4, still more lines will be cut and the induction will again increase, but remain in the same direction. From 4 to 5, a still greater number of lines will be cut because the angle of cutting is still increasing.

From 5 to 6 we have conditions similar to those from 4 to 5 but the angle of cutting is decreasing and therefore the induction will reduce. With this exception, 6 to 7 is just like 3 to 4, 7 to 8 is like 2 to 3, and 8 to 1 is the same as 1 to 2.

In our Lesson on induction, we found that the value of the induced E.M.F. is always proportional to the rate of cutting therefore, this loop will have 0 induction at Position 1, but will keep increasing to Position 5, which is its highest point. From Position 5 through 6, 7 and 8 the induction will drop until it is again at 0 in Position 1.

The action during the second half turn is the same as that of the first half turn except that the direction of induction is reversed because the sides of the loop have changed position in respect to the poles of the magnet.

SINE CURVES

We have already told you that the value of the induced E.M.F. is proportional to the rate of cutting therefore, in the arrangement of Figure 3 with a uniform magnetic field and the loop revolving at a uniform speed, the induction will vary with the angle of cutting.

Although an actual magnetic field may consist of thousands of lines, the few shown in Figure 3 are drawn with uniform spacing and, but counting them, we can obtain an approximate idea of the action. As an estimate, moving from Position 1 to Position 2, the loop cuts about $2\frac{1}{4}$ lines, between Positions 2 and 3, about $4\frac{1}{4}$ lines, between Positions 2 and 4, about $5\frac{1}{2}$ lines and between Position 4 and 5, about $6\frac{1}{4}$ lines.

You can think of these values as the rate of cutting at the different positions and for simplicity, we will assume the value of induced E.M.F. is .16 volt per line. Using this value, for one quarter turn the induction will be as follows.

Position		Voltage
1 ----------------	$.16 \times 0 =$	.0
2 ----------------	$.16 \times 2\frac{1}{4} =$	.36
3 ----------------	$.16 \times 4\frac{1}{4} =$	.68
4 ----------------	$.16 \times 5\frac{1}{2} =$	.88
5 ----------------	$.16 \times 6\frac{1}{4} =$	1.00

For the next quarter turn the values will be the same but in the reverse order because Position 6 corresponds to Position 4, 7 to 3 and 8 to 2. For the second half turn, the entire action will be repeated but the direction of

induction will be reversed.

From the table above, we find a series of pairs of values, one dependent on the other therefore, as explained in an earlier Lesson, the action can be shown by means of a graph. With the loop turning at a uniform speed, the time it takes to move from one position to the next will be constant and therefore, the positions can be used for the horizontal scale. The induction at each position varies with the angle of cutting but, considering Position 1 as the starting point, the induction will be proportioned to the distances at which the other positions are above or below Position 1.

In Figure 3, there were 8 positions of the loop, but if you went all around the circle for a complete turn, you would have 16 positions. In Figure 4 on the left we have the same circle with 8 positions but have extended the Position 1 line to the right and divided it into 16 equal parts, one for each position.

We next draw straight lines, up and down, from these 16 divisions, then take our ruler and, keeping it parallel to the long line, lay it across the circle and extended toward the right. Position 1 on the circle lines up with the long line and we put a dot at the first division.

Then we move the ruler up until it is at Position 2 on the circle and draw a line across until it hits the line coming up from division 2 on the long line and make a dot where the lines cross. We then go on around the circle through Positions 3,4,5,6, 7 and 8 making a dot at each point where the line from the circle crosses the line coming up from the division with the same number.

By connecting these dots with a line, which will be curved as in Figure 4, we really have a picture of the value of induction in the loop for the first half turn. Thinking of the long line as showing 0 voltage, then the distance the curved line is above it, shows the value of the induced E.M.F. for all parts of the first half turn. Just check this against our explanation of Figure 3 and you will see that at Position 1, we have 0 voltage which increases up to Position 5, where it drops back through Positions 6, 7 and 8 to 0 again at 1.

For the second half turn, we have exactly the same action and go ahead in the same way but, as the direction of induction reverses in the wire, we show the curve below, instead of above the long straight line. This is called a Sine-Curve but right now, we will not bother you with the mathematical reasons for the name.

Should you desire to read the values of induction, shown by the curve of Figure 4, start at the center of the extreme right hand vertical line and divide it into lengths of 3/32 of an inch. Let each division represent .1 volt and, with "0" at the center, the scale will extend to 1 volt above and 1 volt below. Curve readings taken on this scale will coincide quite closely with the approximate values worked out in the explanation of Figure 3.

SIMPLE GENERATOR

In Figure 1, we show short lengths of wire fastened to each brush and, if we connect these wires to some circuit, the current in it will change in value and direction during each complete turn of the loop.

The curve at the right of Figure 4 will give you a good idea of the current changes because the current in a circuit depends on the voltage, making its values and directions similar.

Alternating current is caused by an alternating voltage which keeps changing its value and direction. This is the type of current and voltage that you will find in most signal circuits of Radio and other Electronic apparatus but there are other circuits where direct current must be used. We have already told you how cells and batteries produce electrical energy but direct current is also secured from generators similar to that of Figure 1. To show you how this is done, for Figure 5 we have rearranged the unit for Figure 1 to form a simple D.C. Generator.

THE COMMUTATOR

As long as we revolve a loop in a magnetic field, the direction of induction will reverse periodically and generate an Alternating voltage. Therefore, in order to use the loop, but prevent these alternations from reaching the external circuits, we install a commutator as shown in Figure 5.

This, you can see, is almost the same as Figure 1 except, that instead of complete rings, the ends of the loop are fastened to half round pieces of copper, called "segments", which turn with the wire. Resting on these pieces, we have two stationary brushes, marked "C" and "D", which connect to the outside circuit. Now let's see what happens here.

Starting at Figure 5-1, as the loop is turned the same as in Figure 1, the direction of the current, caused by the induction, will be back along side A, across the back

and forward along side B to the half round copper segment, through a segment to the stationary brush D, on through the circuit and back to the other brush C, through the other segment and back to side A.

These conditions hold true until the loop is turned as far as Position 2. Here, we already know that the induction is 0 and therefore there is no current. The segments are now in such position that each brush touches both of them.

Still turning the loop, as we leave Position 2 and go toward Position 3, we again have the conditions of Position 1 and, while the direction of induction in the loop has reversed, so has the position of the segments. The path of current now will be back along B, across the back, forward along A, through the segment to brush D, through the circuit to brush C and the segment to side B where we started.

Comparing the direction and path of the current in Positions 1 and 3, you will find that the segments turn with the loop so that, when the direction of induction reverses, the position of the segments under the brushes is also reversed. No matter which side of the loop is moving up past the "N" pole of the magnet, the external circuit connection is made through brush C. In the same way, the side of the loop moving down past the S pole always connects to the circuit through brush D. Therefore, by moving the segments with the loop, the direction of current in the external circuit remains the same.

Mechanically, Position 4, Figure 5, is the same as Position 2, and shows the segments changing position under the brushes, ready to repeat the complete action. Notice here, as far as the induction in the loop is concerned, Figures 1 and 5 are alike. We mention this point because in all generators of this kind, the induced E.M.F. in the armature is alternating while that in the external circuit may be alternating or direct.

CHANGING A.C. TO D.C.

The commutator and brushes have two very important jobs to do. First, they make an electrical contact between the revolving loop and the terminals, or other stationary parts of the machine. Second, by changing the position of the segments under the brushes, the alternating E.M.F. in the loop is changed to a direct E.M.F. in the external circuit.

The two simple machines we have been describing are generators in all senses of the word. The permanent or

electro-magnet of Figure 1 and the permanent magnets of Figure 5, produce the magnetic "Field" while the revolving loop, in which the E.M.F. is induced, together with the commutator or slip rings, is the "Armature".

Of course, generators exactly like these would not be of any great practical value because the induction in the single loop would be small and, even with a commutator, its value would drop to zero twice in each revolution.

Going back to the four factors that control the value of an induced E.M.F., we find there are several things that can be done in order to increase the induction.

The speed at which the loop is moved, or turned, will have a very great effect on the value of the induction. That however, is mechanical and we will not bother with it just now.

The strength of the magnetic field will also affect the value of the induction. Other factors remaining the same, the stronger the flux the greater the induction.

The angle of cutting varies all the way around as the loop is turned therefore we can not very well change it.

The length of wire can be increased by making a loop with several turns, to increase the value of the induced E.M.F. With the field and speed the same, the value of the induction will vary with the number of turns put in the loop but, with a single loop the action will be jerky, because for two positions in each turn, the induction will be 0.

To correct this condition, we can employ the plan used by the automobile manufacturers. Do you remember the old "One Lung" cars that nearly jerked you out of the seat every time the cylinder fired? Then came the 2 cylinder engines in which the explosions came twice as fast, then the four cylinder jobs with explosions twice as often as the two cylinder engines, and so on with 6, 8 and 12 up to 16 cylinders. The main idea, of course, is to have the force, or push, of each explosion come so quickly after the one before it, or even overlap a little, that there will be no jerks in the operation of the engine.

ADDING LOOPS

The same general idea is followed for electrical generators. By adding turns to the single loop, its induction will be increased but, by adding other complete loops and placing them in different positions, a more uniform voltage output is secured.

To obtain the greatest induction from the field, most modern generators have loops, or coils of many turns of wire spaced evenly around the armature. For example, instead of eight positions of one loop in Figure 3, just think of it as showing the positions of eight loops placed around the armature.

By this method, the length of wire, cutting the magnetic field, can be increased to almost any desired value and generators are in use that produce the electrical equivalent of thousands of Horse Power.

POWER SUPPLY

When Radio equipment is operated by batteries, all the power supplied by them is direct current, "D.C.". However, those units which operate from the house lighting circuit, may be supplied with either D.C. or alternating current, "A.C.". The Universal type of unit will operate on both but one, designed only for A.C. operation, will burn out quickly if connected to a D.C. supply of equal voltage.

We will have more to tell you about this later but, for this Lesson, want you to understand the principles on which generators operate and also the series of changes which take place for each turn of the loop in the A.C. generator of Figure 1. All Radio energy is A.C. therefore, a careful study of this simple generator will make it easier for you to understand the actions of the various circuits in which the voltage and current are changing in value at all times and reversing rapidly.

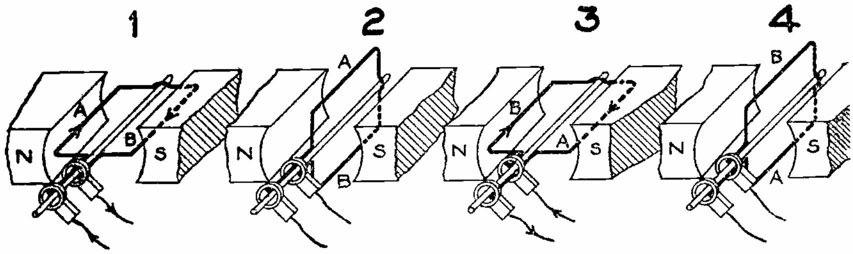


FIGURE 1

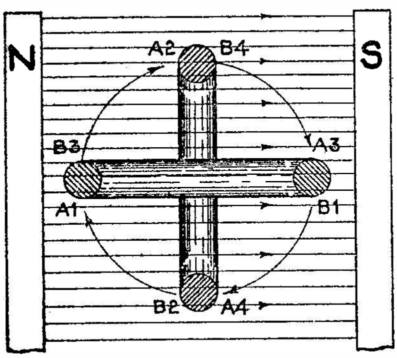


FIGURE 2

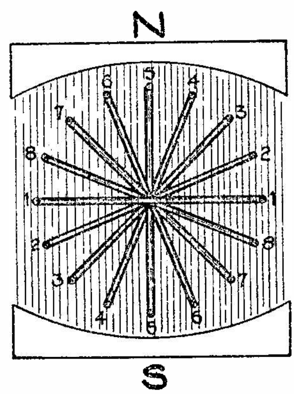


FIGURE 3

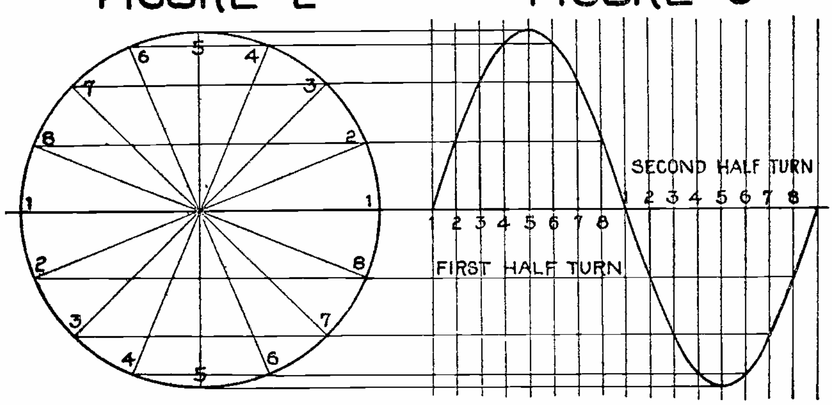


FIGURE 4

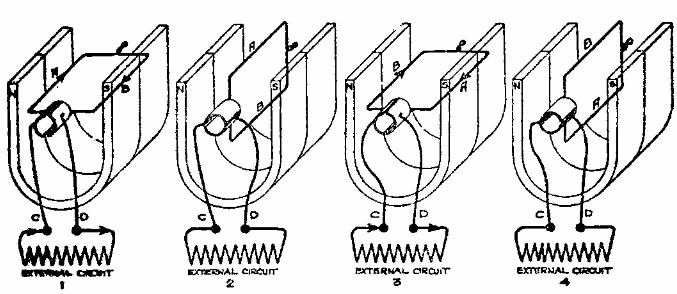


FIGURE 5

DE FOREST'S
TRAINING, Inc.

CONSULTATION SHEETS

Founded 1931 by

Dear Student:

During the study of the various Lessons of your training, there may be explanations or examination questions that you do not fully understand and to help you obtain the necessary information, we are sending this tablet of "Consultation Sheets".

Inspecting one of these sheets, you will find the first paragraph contains blank spaces which, when properly filled in will tell us just where you are having trouble. The second paragraph provides space for your questions or other desired information which may not relate to any specific Lesson. At the bottom, there are spaces for your Name, Student No. and Address.

Whenever, after careful study, you find the explanations of a Lesson are not entirely clear, please fill out the blank spaces of one of the "Consultation Sheets" and send it to us. You can do this either by enclosing it with other Lesson Examinations or by mailing it separately, but do not send in the examination on which you are requesting help, until your difficulties are straightened out. With this information, we will be in a position to send the exact assistance necessary to enable you to obtain the greatest possible benefit from your training.

Use one of these sheets for each Lesson, properly identified such as FDM ----, TRA ----, etc., on which you need help but please do not make the mistake of filling in only the blank space "Lesson ___________" because that would defeat the purpose of this tablet. We cannot rewrite a Lesson in the form of a letter and therefore must ask that you fill in all spaces, regarding pages, paragraphs and questions so that we will know definitely where you need help. Above all, be sure each sheet contains your name, address and student number.

It is our sincere desire to help you advance in the allied fields of Television, Sound and Radio. Therefore, do not hesitate to call on us whenever you feel that we can be of assistance.

Sincerely,

W. H. Littlewood

W. H. Littlewood
Director of Education
DE FOREST'S TRAINING, INC.

P.S. Additional tablets will be furnished on request.

CONSULTATION SHEET

DE FOREST'S TRAINING, INC.
2533 North Ashland Ave.
Chicago 14, Illinois

Date ____________ 19____

Gentlemen:

(1) I am having a little difficulty finding the correct answers to Questions ____________ of Lesson ________________.

Please send Instructional Service.

(2) In addition to the above, please answer the following questions pertaining to Paragraphs ____________, Pages ____________ of Lesson ____________.

____

____

____

____

____

____

____

____

____

____

____

____

____

____

PLEASE NOTE: Have you properly indicated the necessary data in Sections (1) and/or (2)? If you use Section (2), is your statement in the form of a specific question? If not, use a new sheet. We must have adequate information in order to supply you with necessary explanations.

THESE SHEETS ARE FOR INSTRUCTIONAL CORRESPONDENCE ONLY.

Name ______________________________ Student No. ____________

Street ____

City ________________ Zone ____ State ________________

CONSULTATION SHEET

DE FOREST'S TRAINING, INC.
2533 North Ashland Ave.
Chicago 14, Illinois

Date ______________ 19 _____

Gentlemen:

(1) I am having a little difficulty finding the correct answers to Questions ____________________ of Lesson ____________________________.

Please send Instructional Service.

(2) In addition to the above, please answer the following questions pertaining to Paragraphs ________________, Pages ________________ of Lesson ______________.

____

____

____

____

____

____

____

____

____

____

____

____

____

____

PLEASE NOTE: Have you properly indicated the necessary data in Sections (1) and/or (2)? If you use Section (2), is your statement in the form of a specific question? If not, use a new sheet. We must have adequate information in order to supply you with necessary explanations.

THESE SHEETS ARE FOR INSTRUCTIONAL CORRESPONDENCE ONLY.

Name ____ Student No. ________________

Street ____

City ____________________________ Zone _____ State ________________________

CONSULTATION SHEET

DE FOREST'S TRAINING, INC.
2533 North Ashland Ave.
Chicago 14, Illinois

Date ______________ 19 _____

Gentlemen:

(1) I am having a little difficulty finding the correct answers to Questions ______________ of Lesson ______________.

Please send Instructional Service.

(2) In addition to the above, please answer the following questions pertaining to Paragraphs ______________, Pages ______________ of Lesson ______________.

PLEASE NOTE: Have you properly indicated the necessary data in Sections (1) and/or (2)? If you use Section (2), is your statement in the form of a specific question? If not, use a new sheet. We must have adequate information in order to supply you with necessary explanations.

THESE SHEETS ARE FOR INSTRUCTIONAL CORRESPONDENCE ONLY.

Name ______________ Student No. ______________

Street ______________

City ______________ Zone _____ State ______________

CONSULTATION SHEET

DE FOREST'S TRAINING, INC.
2533 North Ashland Ave.
Chicago 14, Illinois

Date ____________ 19 ____

Gentlemen:

(1) I am having a little difficulty finding the correct answers to Questions ____________ of Lesson ____________.

Please send Instructional Service.

(2) In addition to the above, please answer the following questions pertaining to Paragraphs ____________, Pages ____________ of Lesson ____________.

PLEASE NOTE: Have you properly indicated the necessary data in Sections (1) and/or (2)? If you use Section (2), is your statement in the form of a specific question? If not, use a new sheet. We must have adequate information in order to supply you with necessary explanations.

THESE SHEETS ARE FOR INSTRUCTIONAL CORRESPONDENCE ONLY.

Name ____________ Student No. ____________

Street ____________

City ____________ Zone ____ State ____________

CONSULTATION SHEET

DE FOREST'S TRAINING, INC.
2533 North Ashland Ave.
Chicago 14, Illinois

Date ____________ 19 ____

Gentlemen:

(1) I am having a little difficulty finding the correct answers to Questions ________________ of Lesson ______________________.

Please send Instructional Service.

(2) In addition to the above, please answer the following questions pertaining to Paragraphs ____________, Pages ______________ of Lesson ____________.

____

____

____

____

____

____

____

____

____

____

____

____

____

____

PLEASE NOTE: Have you properly indicated the necessary data in Sections (1) and/or (2)? If you use Section (2), is your statement in the form of a specific question? If not, use a new sheet. We must have adequate information in order to supply you with necessary explanations.

THESE SHEETS ARE FOR INSTRUCTIONAL CORRESPONDENCE ONLY.

Name ________________________________ Student No. ____________

Street ____

City ______________________ Zone _____ State ____________________

CONSULTATION SHEET

DE FOREST'S TRAINING, INC.
2533 North Ashland Ave.
Chicago 14, Illinois

Date ______________ 19 _____

Gentlemen:

(1) I am having a little difficulty finding the correct answers to Questions ____________________ of Lesson ____________________________.

Please send Instructional Service.

(2) In addition to the above, please answer the following questions pertaining to Paragraphs ________________, Pages ________________ of Lesson _______________.

____

____

____

____

____

____

____

____

____

____

____

____

____

____

PLEASE NOTE: Have you properly indicated the necessary data in Sections (1) and/or (2)? If you use Section (2), is your statement in the form of a specific question? If not, use a new sheet. We must have adequate information in order to supply you with necessary explanations.

THESE SHEETS ARE FOR INSTRUCTIONAL CORRESPONDENCE ONLY.

Name ____ Student No. ______________

Street ____

City ____________________________ Zone _____ State ________________________

CONSULTATION SHEET

DE FOREST'S TRAINING, INC.
2533 North Ashland Ave.
Chicago 14, Illinois

Date ____________ 19____

Gentlemen:

(1) I am having a little difficulty finding the correct answers to Questions ____________ of Lesson ____________.

Please send Instructional Service.

(2) In addition to the above, please answer the following questions pertaining to Paragraphs ____________, Pages ____________ of Lesson ____________.

PLEASE NOTE: Have you properly indicated the necessary data in Sections (1) and/or (2)? If you use Section (2), is your statement in the form of a specific question? If not, use a new sheet. We must have adequate information in order to supply you with necessary explanations.

THESE SHEETS ARE FOR INSTRUCTIONAL CORRESPONDENCE ONLY.

Name ____________ Student No. ____________

Street ____________

City ____________ Zone ____ State ____________

CONSULTATION SHEET

DE FOREST'S TRAINING, INC.
2533 North Ashland Ave.
Chicago 14, Illinois

Date ______________ 19 _____

Gentlemen:

(1) I am having a little difficulty finding the correct answers to Questions ______________ of Lesson ______________.

Please send Instructional Service.

(2) In addition to the above, please answer the following questions pertaining to Paragraphs ______________, Pages ______________ of Lesson ______________.

PLEASE NOTE: Have you properly indicated the necessary data in Sections (1) and/or (2)? If you use Section (2), is your statement in the form of a specific question? If not, use a new sheet. We must have adequate information in order to supply you with necessary explanations.

THESE SHEETS ARE FOR INSTRUCTIONAL CORRESPONDENCE ONLY.

Name ______________ Student No. ______________

Street ______________

City ______________ Zone _____ State ______________

RADIO FUNDAMENTALS

Final Examination

DE FOREST'S TRAINING, INC.

2533 N. Ashland Ave., Chicago 14, Illinois

FUNDAMENTALS EXAMINATION
QUESTIONS

Print or Use Rubber Stamp:

Name________________________________ Student No.____________

Street____

City______________________ State____________________

1. If the wavelength of an electromagnetic radiation is made longer, what happens to the value of the frequency?

2. What is the assumed commercial direction of current as proposed by Benjamin Franklin?

3. List two common materials used for making electrical resistors.

   Ans. (1)__________________

   (2)__________________

4. What is the resistance of a Radial type resistor which has an Orange body, an Orange end and an Orange dot?

   Ans. __________________

5. What is the resistance of 1500 feet of #20 bare copper wire?

   Ans. __________________

6. Assume three conventional dry cells are available for some electrical circuit requirement. Explain how you would connect all the cells to produce a potential difference of (a) 4.5 volts, (b) 3 volts

7. Referring to the subject of magnetism, what is the meaning of (a) Retentivity, (b) Permeability, (c) Reluctance?

Name_________________________ Student No.___________

8. What two factors determine the magnetic polarity of a solenoid?

9. When applying the Three Finger Right Hand Rule, to indicate the relationship between the direction of flux, direction of current and motion of a conductor, what is indicated by the thumb, the forefinger and the middle finger?

10. (a) How is an ammeter connected to indicate the current carried by an electrical circuit? (b) How is a voltmeter connected to indicate the electrical pressure impressed on a circuit?

11. What is the value of the current in an electrical circuit which has a resistance of 500 ohms and pressure of 10 volts?

Ans. ____________________

12. An electrical circuit is made up of three resistors, respectively 200, 300 and 500 ohms, connected in series across a battery of 100 volts. What is the voltage drop across the 300 ohm unit?

Ans. ____________________

13. Three 14,100 ohm precision resistors are connected in parallel. What is the value of their equivalent resistance?

Ans.____________________

14. The filament circuits of four 1.4 volt vacuum tubes are connected in parallel and each tube requires 50 milliamperes. What value of resistance must be connected in series with them from a 2 volt battery to provide normal operation?

Ans.____________________

Name________________________ Student No.____________

15. A 20 ohm resistor is connected in series with a 50 ohm resistor, and this series combination is connected in parallel with a 70 ohm unit. From one terminal of the parallel network, a 35 ohm resistor is connected in series with the positive terminal of a 350 volt battery, the negative terminal of which is connected to the other parallel terminal. (a) What is the total resistance, (b) What is the total current, (c) What is the voltage across the 50 ohm resistor? (Hint: Draw the circuit for study.)

Ans. (a)____________

(b)____________

(c)____________

16. What value of meter shunt is required to increase the range of a 50 ohm moving coil multimeter, which reads a maximum of 1 ma, to a full scale deflection of 5 ma.

Ans. ____________

17. What is the safe total power dissipation of two 10,000 ohm 5 watt resistors connected (a) in parallel, (b) in series?

Ans. (a)____________

(b)____________

18. A 400 watt soldering iron has a resistance of 25 ohms. (a) What is its rated value of current? (b) What is its rated voltage?

Ans. (a)____________

(b)____________

19. What three general factors determine the inductance of a coil?

Ans. (1)____________

(2)____________

(3)____________

20. What is meant by "Mutual Inductance?"

21. What is Lenz's Law?

Name________________________ Student No.____________

22. What condition is always necessary in order to induce an emf in a conductor?

23. In the construction of a 2 plate fixed condenser, what three major factors determine its capacity?

Ans. (1)____________

(2)____________

(3)____________

24. Two parallel connected 10 mfd condensers are connected in series with a 30 mfd unit, and the entire combination is connected across a 500 volt source. (a) What is the total capacity of the circuit? (b) What is the quantity of charge? (c) What is the voltage across the 30 mfd condenser?

Ans. (a)____________

(b)____________

(c)____________

25. What two factors can be changed to increase the voltage output of a generator without reconstructing the machine?

Ans. (1)____________

(2)____________

TUBES - RECEIVERS - AMPLIFIERS

FINAL EXAMINATION

Questions

Name ______________________ Student No. ____________

Street ______________________________

City ______________ State ______________

1. An alternator supplies an electrical circuit which requires 216,000 alternations every half hour at a maximum value of 165.5 volts. (a) What is the frequency of the alternator in cycles per second? (b) What is the effective value of voltage?

Ans. (a)____________

(b)____________

2. What is the phase relationship between the current and voltage in (a) an inductive unit, (b) a capacitive unit?

3. A series electrical circuit is made up of a capacitive reactance of 60 ohms, an inductive reactance of 120 ohms, a resistance of 80 ohms and is connected across a 120 volt source. (a) What is the impedance of the circuit? (b) What is the current in the circuit?

Ans. (a)____________

(b)____________

4. When the frequency of the voltage applied to a circuit containing an inductance and a capacitance is increased, what happens to the value of (a) inductive reactance, (b) capacitive reactance?

Ans. (a)____________

(b)____________

5. List three ways by which the power factor of an electrical circuit may be expressed.

Name________________________________Student No.______________

6. What is the relative magnitude of current drawn from a source of voltage by a non-resonant (a) series circuit, (b) parallel circuit?

Ans. (a)________________________________

(b)________________________________

7. A power transformer primary operates on a source of 120 volts and has 500 turns on its winding. The secondary has 125 turns. (a) What is the turns ratio? (b) What is the voltage across the secondary winding? (c) What is the impedance ratio?

Ans. (a)________________

(b)________________

(c)________________

8. What two losses in a power transformer tend to reduce its efficiency?

Ans. (a)________________

(b)________________

9. What are the four essential components of a power supply?

Ans. (a)________________

(b)________________

(c)________________

(d)________________

10. What is the principle of operation of a cold cathode gaseous rectifier?

11. List three common types of filaments used as electron emitters of vacuum tubes.

Ans. (a)______________________

(b)______________________

(c)______________________

Name________________________________ Student No.___________

12. What two basic functions may a vacuum tube perform?

13. What is the purpose of a "grid" in a Triode tube?

14. Calculate the amplification factor of a vacuum tube which requires a change of 69 volts on the plate to cause an increase of 2.5 ma plate current; and requires a change from -7 to-12 negative grid volts to cause a reduction of 2.5 ma plate current.

Ans. ______________________

15. What is the reason for increasing the number of elements in a vacuum tube?

16. Calculate the required cathode self bias resistance necessary to provide a negative 13.5 volts grid potential when the plate and screen grid currents, of a 6Y6 tetrode tube, are respectively 58 ma and 3.5 ma.

Ans. ______________________

17. Compared to other common types of detectors, (a) what is an advantage of a diode detector, (b) what is a disadvantage?

18. What is the natural wavelength, in meters, of a 110 foot Marconi antenna?

Ans. ______________________

19. What are the three functions of a Simple Receiver?

Name_______________________________ Student No.__________

20. In a resistance-capacity coupled audio amplifier, what two functions does the coupling condenser perform?

21. (a) What reflected load is offered to the plate circuit of a tube by a 15 to 1 step down transformer coupled to an 8 ohm voice coil? (b) If 4 watts is dissipated in the voice coil, what is the a-c voltage across the primary of the transformer?

Ans. (a)____________________

(b)____________________

22. What electrical unit is almost invariably used to couple the output of an audio amplifier to a speaker or other networks?

23. What are the three distinct types of coupling used in audio frequency amplifiers?

Ans. (a)____________________

(b)____________________

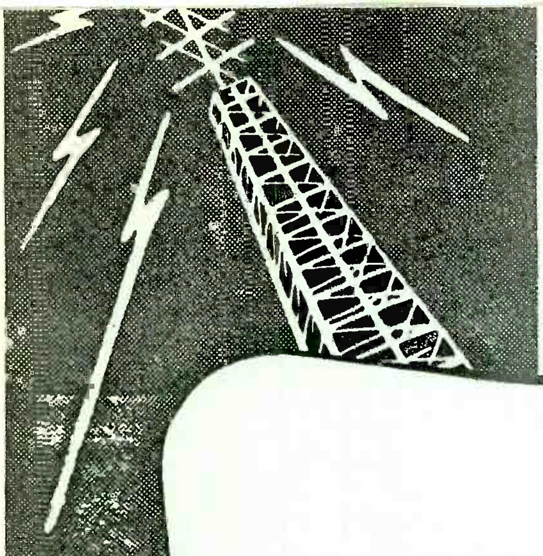
(c)____________________

24. Within limits, what factors control the "Q", or effective resistance, of a coil?

25. (a) What value of inductance in microhenrys is required to tune a 300 mmfd maximum capacity condenser to a wavelength of 500 meters? (b) What is the approximate minimum capacity of the tuning condenser?

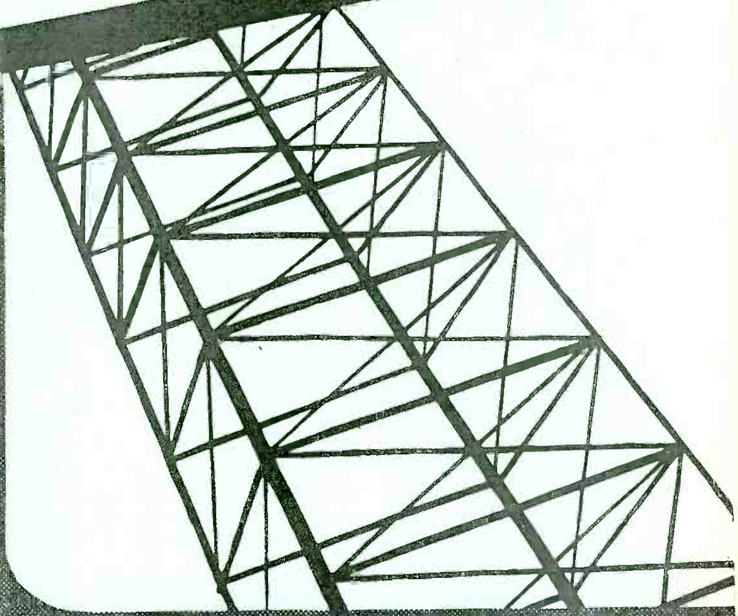
Ans. (a)____________________

(b)____________________



RADIO RECEPTION & TRANSMISSION

Final Examination



DE FOREST'S TRAINING, INC.

2533 N. Ashland Ave., Chicago 14, Illinois

RADIO RECEPTION and TRANSMISSION

FINAL EXAMINATION
QUESTIONS

Name ______________________________ Student No. __________

Street ______________________________

City ______________________________ State __________

1. (a) What electrical unit is needed to transfer energy from a power tube to a low impedance voice coil of a dynamic speaker? (b) Why is a coupling unit necessary?

2. Why is a magnetic type phonograph pickup generally damped?

3. A microphone having an impedance of 40 ohms is to be matched to a 600 ohm transmission line. What is the turns ratio of the transformer?

Ans. __________

4. (a) What is the cutoff frequency of a low pass filter network if the total inductance is 500 millihenrys and the equivalent capacity is 8 microfarads? (b) Into what characteristic impedance should the filter work?

Ans. (a) __________
Ans. (b) __________

5. State 3 advantages of inverse feedback.

6. What two types of Oscillators obtain feedback through the interelectrode capacity of a vacuum tube?

Name ______________________ Student No.______________

7. The input circuit of a superheterodyne receiver is tuned to an incoming signal of 1000 kc and the image frequency is known to be 1960 kc. What is the intermediate frequency (i-f)?

Ans.______________

8. What is the principal advantage in the use of a triode hexode over that of a pentagrid tube as a converter in a superheterodyne receiver?

9. What is the polarity of the avc voltage, with respect to the chassis or ground, when this voltage is obtained from a diode detector load circuit?

10. What circuit does the voltage of an afc network usually affect?

11. If a synchronous vibrator is to be used in an auto receiver, and the grounded "A" terminal is opposite to that specified for receiver operation, what simple circuit change in the set is necessary to permit normal operation?

12. (a) Without circuit modifications, is it possible to use tubes of different filament current ratings in a conventional a-c/d-c receiver? (b) State a reason for your answer.

13. What determines the distance the beam spot is moved on the screen of a cathode ray oscilloscope.

Name ______________________________ Student No. ______________

14. Explain briefly the electrical function of each of the following controls commonly found on the face of a cathode ray oscilloscope. (a) focus, (b) intensity, (c) synchronising, (d) horizontal gain, (e) vertical positioning.

15. State four measurements that can be made by a cathode ray oscilloscope.

16. What is meant by the quasi-optical effect in the propagation of frequency modulated waves?

17. Upon what does the band width of an f-m wave depend?

18. What are two major advantages of f-m compared to a-m reception for equal powers of transmission?

19. Calculate the frequency of an X cut crystal at a temperature of 32° centigrade. The crystal has a frequency of 1050 kc at 20° centigrade.

Name ______________________________ Student No. ____________

20. What is the percent plate efficiency of an r-f amplifier under the conditions given as: E_p = 300 volts, I_L = 700 milliamperes, R_L = 72 ohms, I_p = 200 milliamperes.

Ans. ____________________

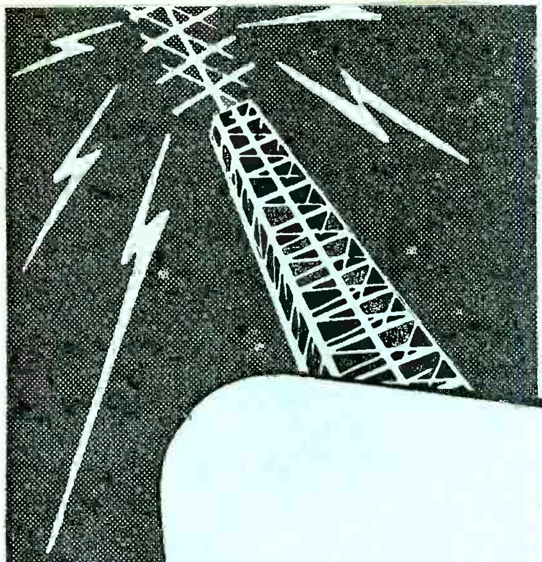
21. If the tuned circuit of a simple oscillator consists of an inductance of 200 microhenrys and a capacity of .00035 microfarads, what is its oscillation frequency?

22. Calculate the percent of antenna current increase when the radio carrier is amplitude modulated 50%?

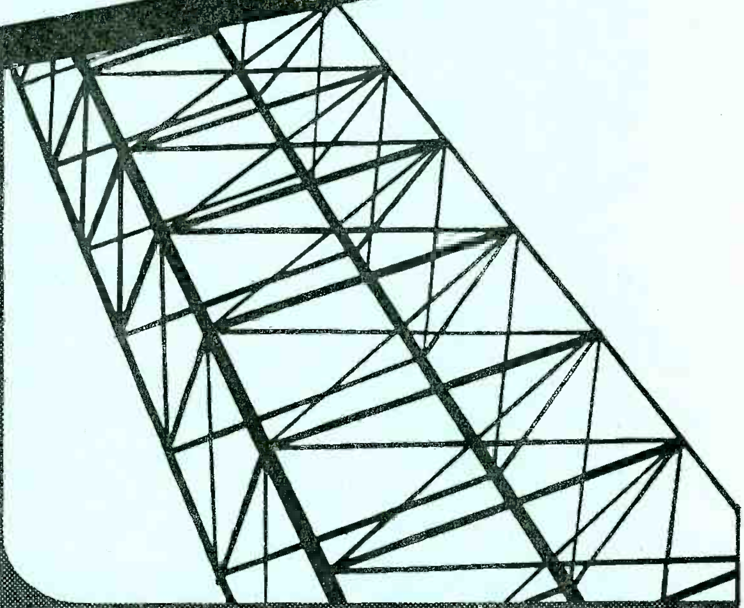
23. What is meant by "carrier shift"?

24. What is the output frequency of an eight pole rotary converter which revolves at a rate of 1800 revolutions per minute?

25. With respect to air navigation, what is meant by the "cone of silence"?



LESSON RTS - 1
TROUBLE SHOOTING



DE FOREST'S TRAINING, INC.
2533 N. Ashland Ave., Chicago 14, Illinois

RADIO AND TELEVISION SERVICING

LESSON RTS-1

TROUBLE SHOOTING

Type of Trouble -------------------------- Page 2
No Signals ------------------------------- Page 2
Antenna Circuit -------------------------- Page 5
Lack of Volume --------------------------- Page 6
Changing Volume -------------------------- Page 8
Broad Tuning ----------------------------- Page 9
Distortion ------------------------------- Page 10
Noisy Reception -------------------------- Page 11

# # # # # #

Things cannot always go your way. Learn to accept in silence the minor aggravations, cultivate the gift of taciturnity and consume your own smoke with an extra draught of hard work so that those about you may not be annoyed with the dust and soot of your complaints.

-- Sir William Osler

TROUBLE SHOOTING

The earlier Lessons of this training program were written to explain the fundamental principles of electronics, the construction and purpose of the various components and the operation of the common types of circuits. This information is a necessity for anyone working in the Radio or Electronic field because, without a knowledge of the purpose and action of parts contained in any complete unit, it would be difficult if not impossible, to efficiently install, operate, maintain or service it.

No matter how well a piece of equipment is designed and constructed, after a period of use, certain parts will weaken or break and repairs must be made to restore proper operation. Therefore, in this and the following series of Lessons, we are going to show you how the knowledge, gained from the former Lessons, can be used to locate the various defects or troubles which will occur.

Perhaps you have seen some rather complicated Radio Test Equipment and are under the impression that, to locate Electronic troubles, it is necessary only to purchase equipment of this kind. However, you will soon find that the most elaborate test instruments, when properly used, will provide definite indications or readings but, it requires a knowledge of Electronic principles and circuits to interpret properly and make use of these readings.

You have the five natural senses of sight, hearing, touch, smell and taste. With the exception of taste, the others, when used intelligently, are perhaps the "equipment" you will use most.

For example, by looking carefully at a defective Radio Receiver, you should see any wires which have broken loose, any component parts which are bent or broken or which have been heated sufficiently to blacken or blister their surface. By listening carefully to the hum, squeals, noise or lack of sound in a speaker, you can often determine the type or general location of trouble.

By feeling of the various parts you can readily locate those which are overheated or loose and your sense of smell will tell you instantly if any parts have been heated sufficiently to burn or char the insulation.

In this way, many common troubles can be located without the use of expensive or complicated test equipment and we want you to form the habit of using your eyes, ears, nose and fingers to their fullest extent.

For example, a Radio receiver might test out perfectly with the most elaborate outlay of meters and yet be inoperative

because the antenna was disconnected. To repair a job of this kind requires only a little common sense plus a knowledge of fundamentals, such as we have been giving you. In much the same way, by simply looking and listening you can generally form a fairly accurate idea of the trouble and then use test equipment to locate it exactly.

Saying it in another way, the untrained, but experienced practical man uses his eyes and ears to the limit, yet is stuck when the trouble goes deeper. The theoretical man, on the other hand, would possibly overlook many simple troubles which the practical man would see at once. We have given you enough theoretical information and, starting with this Lesson, are going to show you how to quickly find the simpler troubles and go right through with the more complicated repairs of Radio and Television receivers.

TYPE OF TROUBLES

Although modern Radio Receivers are well designed and constructed, like any other electrical device, with moving parts, connections and soldered joints, there are bound to be a number of common troubles. From the operation and sound of the receiver, these troubles can be grouped into six general classes.

1. No Signals
2. Lack of Volume
3. Changing Volume
4. Broad Tuning
5. Distortion
6. Noisy Reception

No matter what may be wrong with the receiver, one of these general troubles will be found. While some troubles may produce several results, we are going to give you the more common causes of the above general classes.

NO SIGNALS

When a receiver will not produce any signals, the first thought is to look inside and see if the tubes are lighted. Although you cannot "see" inside the metal types of tubes, you can feel if they warm up after the receiver has been turned on for a few moments. This is a good place to start because it is an indication of the condition of the heater or filament circuits. In fact, it is a good plan to always test the tubes first because, if any of them are defective, it will be impossible to obtain proper operation, even though they do "Light".

For Figure 1, we have drawn a simplified circuit of a somewhat old fashioned battery type of Radio Receiver which has one

stage of R.F., Detector and one stage of A.F., with a separate rheostat in each tube filament. Also, we assume that the batteries are connected properly to the terminals shown at the lower left of the diagram.

We have based our explanations on this simplified diagram so that you can more easily grasp the idea of how to analyze the common troubles. Remember however, the basic principles involved can be applied to Television as well as to a modern all-wave radio receiver.

First, suppose none of the tubes light when the switch is closed. That shows the trouble is in some part of the filament circuit common to all tubes. As drawn in Figure 1, the trouble must be in that part of the circuit between the lower rheostat connections, the switch, the A supply and along the A- wire to the first joint.

Before looking into the circuit however, you had better make sure a voltage source is properly connected to the A terminals. While it is a rather rough test, and one we suggest only in an emergency, you can momentarily short the A terminals and see if there is a spark.

A proper test of course, is to connect a voltmeter across the A terminals and see what voltage is present. The point we want to bring out here is, that until you are sure the A supply is properly connected and you have voltage at the terminals, there is no use in going into the unit itself.

However, if the tubes have been tested and still fail to light, carefully trace and check that part of the A circuit mentioned above. The switch may be defective and can be tested by shorting it out of the circuit. The simplest plan here is to hold a piece of wire across its terminals.

By this time, you will usually have located the trouble but can use a piece of wire to short out other parts of the circuit. For example, by holding a piece of wire from the A- terminal to the F- filament connection at the socket, you will replace all that part of the circuit in between but, before you make this test, DISCONNECT THE HIGH VOLTAGE PLATE SUPPLY by removing the battery wires from the "B+" terminals.

For an A.C. unit, when none of the tubes light, the trouble is much the same except the main A supply is from the 110 volt lighting circuit outlet to the transformer primary. Put a lamp in the receptacle and if it lights, check the plug and cord all the way to the unit. A burned out fuse in the A.C. line or in the unit can cause the trouble.

Going back to the battery receiver of Figure 1 again, if some of the tubes light and some do not, your first test is to try a good tube in place of those which do not light. If you have no extras, in some cases, those in the receiver can be tried in different sockets.

If the tubes are in good condition then, for those which do not light, the trouble is in that part of the A circuit connected to the socket. For example, if the wire was broken at "A", Figure 1, the left hand, or r-f tube would not light, but the others would. In that case, you would spend all your time on that part of the circuit between the A terminals and the dead socket. Placing a jumper wire from A plus to the F plus of the socket would light the tube and locate the trouble by showing the break to be in that part of the circuit between the ends of the jumper.

Instead of a broken wire at "A", a loose connection or contact in the rheostat would open the circuit and, being a moving part, it should be examined first.

For an a-c unit, conditions are somewhat different. There may be several A or heater voltages and, when a new tube does not light, it is best to carefully check the circuits of those which are out.

Suppose you find the unit employs 7 tubes, four of which require 6.3 volts, two 2.5 volts and one 5 volts. If neither of the 2.5 tubes light, their 2.5 volt filament circuit must be traced back to the transformer. In this case, the transformer secondary is considered as the A supply and should be tested along the same general lines explained for the battery type receiver.

In the Universal a-c/d-c type of receiver, the filaments or heaters are all connected in series. Therefore, if any one of the heaters should burn out, the circuit would be broken and none of the tubes would light. A tube tester or ohmmeter could be used to locate the defective tube but assuming the equipment is not available, the tubes should be replaced, one at a time, with tubes known to be good, until the defective one is found. If all the tubes are known to be good and the heaters still do not light up, the trouble is no doubt between the source of supply voltage and the tube heaters and a check of the line cord and any voltage dropping resistors should be made.

One important point in all tube circuits is the contact between the tube prongs and socket springs. The older type sockets, which are still used for the larger power tubes, were

built on the plan shown at the left of Figure 2 and had flat springs which pressed against the bottom of the tube prongs.

These springs are often bent down so far that they do not touch the prongs, causing an open circuit. Before leaving the filament circuits always make sure the socket contact springs are held tight by the terminal screws and bent up far enough to make good contact with the prongs on the tube base.

The later type of socket, shown in one form at the right of Figure 2, has clips which grip the side of the prongs. While this type does not cause much trouble, it is a good plan to check them over the same as the older type.

With the tubes all lighted the set may sound "alive", making a click in the speaker when the switch is turned off, but still not operate.

That is why we suggested that all tubes be tested first because, if the emission of the R.F. tube in Figure 1 were low, the receiver would not operate, yet all the tubes would light properly and the speaker would sound "alive".

When the tubes are known to be good, and still there are no signals, examine the antenna and ground connections. Very often the terminal caps work loose, the lead in wire from the antenna may break, especially if it is brought in under a window sash. However, if everything looks in good order at the receiver, you will have to go further.

ANTENNA CIRCUIT

In Figure 3 we show an antenna circuit which includes all the principal parts. This is the outdoor type which is most commonly found for home receivers and, by inspection, you can see if the antenna is broken or the lead in wire touches the building or drain pipe where it comes over the edge of the roof. All we will tell you here is that the antenna wire should be as high and clear as possible, the lead in joint should be tight and SOLDERED, while the lead in wire should not come closer than 4 inches to any part of the building.

Notice, in Figure 3, the lightning arrestor is connected in parallel to, or across the receiver. The common arrestor is of the gap type and if it breaks down, the receiver antenna and ground terminals are shorted.

For a quick test, disconnect the arrestor from the antenna and ground terminals of the receiver and hook it as shown in Figure 4. If the gap is broken down or the arrestor is shorted, there will be a click in the phones when the test circuit is complete.

If you want to make sure of the antenna circuit, ground the outer end as in Figure 5 and then, when the test circuit is completed between lead in and ground connections, there should be a loud click in the phones.

To complete the antenna circuit, there must be a good ground connection and, wherever you are testing an antenna circuit, make sure the ground wire is not broken and all joints and connections are clean and tight.

As the average ground, in the cities at least, is made to a water pipe, pay particular attention to the clamp or pipe connection. Make sure the pipe is clean, without paint or rust, and the connection is tight.

After the antenna circuit has been gone over, if the receiver still fails to operate, turn it on and then, starting at the last audio tube, remove and replace each tube in its socket. As you do this, notice carefully the intensity of the click in the speaker. Whenever you remove and replace a tube without hearing the click, it tells you at once there is trouble in the plate circuit of that tube.

The plate current is furnished by the B supply which may be batteries, or a-c power pack. Regardless of the type of supply, check its voltage while the receiver is ON.

When the B supply voltage is correct, yet the speaker does not click, when the tube is removed and replaced, there is possibly an open in the plate circuit. By tracing the plate circuits of Figure 1 you will have a good idea of the units they contain.

If the plate circuits all seem good, you can make a quick test on the grids by touching some exposed part of the grid circuit with a piece of metal or your finger. If the circuit is in good condition it will cause a click in the speaker when touched but, if shorted or grounded, no sound will be heard.

About the only other condition you will find on a "dead" set is where the speaker makes absolutely no sound at all, does not click when the switch is turned off or on nor when any of the tubes are removed and replaced. Usually this condition is caused by an open plate circuit in the last audio tube or in the speaker itself. If a good tube does not correct the trouble, and the speaker connections are properly made, further electrical tests will be necessary.

LACK OF VOLUME

Another common trouble is lack of volume and here there are two points to learn before any tests can be made. (1) Has

If you want to make sure of the antenna circuit, ground the outer end as in Figure 5 and then, when the test circuit is completed between lead in and ground connections, there should be a loud click in the phones.

To complete the antenna circuit, there must be a good ground connection and, wherever you are testing an antenna circuit, make sure the ground wire is not broken and all joints and connections are clean and tight.

As the average ground, in the cities at least, is made to a water pipe, pay particular attention to the clamp or pipe connection. Make sure the pipe is clean, without paint or rust, and the connection is tight.

After the antenna circuit has been gone over, if the receiver still fails to operate, turn it on and then, starting at the last audio tube, remove and replace each tube in its socket. As you do this, notice carefully the intensity of the click in the speaker. Whenever you remove and replace a tube without hearing the click, it tells you at once there is trouble in the plate circuit of that tube.

The plate current is furnished by the B supply which may be batteries, or a-c power pack. Regardless of the type of supply, check its voltage while the receiver is ON.

When the B supply voltage is correct, yet the speaker does not click, when the tube is removed and replaced, there is possibly an open in the plate circuit. By tracing the plate circuits of Figure 1 you will have a good idea of the units they contain.

If the plate circuits all seem good, you can make a quick test on the grids by touching some exposed part of the grid circuit with a piece of metal or your finger. If the circuit is in good condition it will cause a click in the speaker when touched but, if shorted or grounded, no sound will be heard.

About the only other condition you will find on a "dead" set is where the speaker makes absolutely no sound at all, does not click when the switch is turned off or on nor when any of the tubes are removed and replaced. Usually this condition is caused by an open plate circuit in the last audio tube or in the speaker itself. If a good tube does not correct the trouble, and the speaker connections are properly made, further electrical tests will be necessary.

LACK OF VOLUME

Another common trouble is lack of volume and here there are two points to learn before any tests can be made. (1) Has

the receiver worked satisfactorily in its present location with its present antenna and ground? (2) Did the volume reduce suddenly or gradually?

It often happens that a radio receiver is located where reception is poor such as: in a steel constructed building which prevents radio waves from reaching it; in a locality where outside interference makes reception difficult or far from a broadcasting station.

For these reasons, whenever a receiver is first installed in a new location, its operation should be compared with others in the same locality before looking for trouble in the receiver itself. On the other hand, if the receiver has previously worked well in its present location but has lost volume, the trouble is no doubt in the receiver or antenna circuit.

Compared to the dead set, a receiver with lack of volume shows at once that it is working to a certain extent and to help run down the trouble, ask the owner whether the volume dropped suddenly or gradually.

If the drop was sudden, it is best to check the antenna and ground as explained for the dead receiver. Here however, there must be a partial circuit at least and therefore, the trouble is probably high resistance. Going back to Figure 3, the joint between the antenna and lead in may have broken leaving only the lead in for the antenna. Any of the other connections may have broken off therefore the antenna tests, already explained, should be followed.

Should any of the antenna insulators be cracked, replace them. Three common types of ground clamps are shown in Figure 6 and in each case there must be a good clean contact between pipe and clamp and also between clamp and wire.

It may be necessary to change the clamp to another grounded object as rust, forming between the pipe joints, often causes high electrical resistance. In some cases the ground of Figure 7 is better than the usual water pipe.

A ground of this type is made with a piece of galvanized iron pipe, driven four or five feet in damp soil and then packed around the outside with salt. Damp earth is a much better electrical conductor than when dry and, by absorbing moisture the salt has a tendency to keep the earth damp. To complete the ground, a clamp, like those of Figure 6, is placed on the upper end of the pipe.

After the antenna circuit has been checked, the tubes of the receiver should be tested. Earlier in this Lesson, we stated

the tube test should be made first but, as outdoor antennas are subject to the troubles just described, it is often a good policy to check it first.

If the tube test was made first, replacement of a weak tube might improve the operation to such an extent that the owner would not consent to your making a check of his antenna. Then, should the antenna develop trouble in a short time, you would be blamed for not doing a good job.

If a tube tester is not available, try moving the tubes in their sockets. A film sometimes forms between the socket springs and tube prongs. By moving the tube, or removing and replacing it, the film is wiped off and normal conditions are restored. When the volume has dropped down gradually, the heater, plate and grid voltages should be measured and the tubes shifted or replaced as explained for a dead set.

A gradual loss of volume may also be caused by trouble in the antenna circuit. A coating of soot on the wires and insulators may produce a partial short. The supports may sag, changing the height of the antenna wire, or the ground connection may gradually corrode.

As explained in the early Lessons, the tuning condensers of a modern receiver are usually ganged and, to compensate for the difference in the capacity of the connecting wires, each section is provided with a small "Trimmer". After being in service for a time, the setting of the main condenser rotors may change slightly making it impossible to tune all stages at exactly the same point on the dial. This causes a loss of volume which can be remedied by adjusting the trimmers.

There are many other causes for loss of volume but more complicated testing is required to locate them therefore we will explain their action later. Quite often a man engaged in this work receives a complaint of low volume only to find the owner is trying to receive some distant station. Naturally the receiver cannot be blamed entirely but, a poor tube in the High Frequency Stages will cut down the sensitivity and reduce the volume.

In cases of this kind, it is best to find out what the receiver has done in the past. A didtant station which formerly came in with good volume may have changed its location, frequency or power, any of which may make it more difficult to receive.

CHANGING VOLUME

Another common trouble is changing volume. The signals come in loud for a while and then die out partially or entirely.

They may come back by themselves, in a few seconds or minutes, or perhaps only when the receiver is retuned.

For battery operated units, this trouble is usually due to the condition of the batteries. When the A battery is low, the receiver operates with good volume when first turned on but gradually dies down. B batteries sometimes cause the same trouble therefore, the best plan is to measure the voltage of all batteries when the volume is correct and again when it is low.

Do not confuse this trouble with that known as "Fading". When listening to a distant station, the volume may reduce gradually or suddenly, the signal often disappearing entirely. Then, without touching the receiver controls, the signal will return and the volume comes up to normal.

This condition may be caused by some action in the space, between the Broadcasting Station and the receiving antenna, but is no fault of the receiver. About the only remedy here, for receivers without avc, is to adjust the volume control for each change of signal strength.

Changes of volume are also caused by the swinging of a loose antenna or lead in wire, a loose connection in the receiver, a defective tube or other part. This type of defect is known generally as "Intermittent Trouble" and a later Lesson will be devoted entirely to this subject.

BROAD TUNING

Broad tuning, or lack of selectivity is the inability of a receiver to separate the signals of two or more stations. At present, the Broadcasting Stations in every locality are separated from each other by a frequency of at least 10 Kilocycles.

The majority of receivers are considered very good when separating stations 10 kilocycles apart but, usually will not separate a distant from a powerful local station when they are less than 15 or 20 kilocycles apart. While there are many complaints of this kind, a large number are due to the original design of the receiver and cannot be repaired like other troubles.

When a receiver, which was originally selective, becomes broad in tuning, it indicates trouble which can be remedied Although few owners realize it, the selectivity can be controlled to a large extent by proper operation of the volume control. For best results, the volume should never be turned any higher than necessary. When you increase the volume of

one station, you also increase the volume of other you do not want.

Proper adjustment of the trimmer condensers will often increase the selectivity. An easy, but rough, method is to tune in some distant station and then adjust for the greatest volum

Reducing the length of the antenna will usually increase the selectivity. This may be done by actually shortening the wire or by connecting a condenser in series with the lead in. The effect is the same either way but the condenser is often more convenient. By trying several sizes of fixed condensers, from .0001 mfd up to .001 mfd, the best combination can be found.

Like all other troubles we have mentioned, here again, the tubes must be good and be supplied with the correct voltages.

DISTORTION

While the tone quality of Radio receivers has been greatly improved, you will find there is no definite standard. One owner enjoys the deep base notes, another likes high notes and so on. However, there is a distinct difference between tone, pitch and distortion.

When the music becomes raspy or "Tinny" and voices are blurred or "Fuzzy", there is something wrong, and we say the signal is distorted. In many of the older, and present lower priced receivers, there is a certain amount of distortion due to the use of poorly designed parts. Of course, the only remedy is to replace the parts with others.

For this Lesson however, suppose the receiver has been producing excellent tone but now produces badly distorted sounds. Like many other troubles, the cause may be poor tubes and it is important to test them before looking further.

In those receivers with "Push-Pull" amplifiers, both tubes must be the same type and have similar operating characteristics. For example, if the emission of one tube drops below normal, the amplifier is thrown out of balance and distortion results.

The next common cause of distortion is low plate voltage. For battery sets, the B voltage should be tested while for a-c receivers, it is a good plan to try a new rectifier tube. In general, any troubles which cause low volume will also have a tendency to produce distortion and the explanations we gave for lack of volume will hold here also.

In addition, distortion is often caused by defects in the speaker. Any loose parts will rattle, especially when the volume is increased, causing a variety of sound effects.

In this connection, it is well to remember that the tubes of an ordinary receiver will carry only a certain load. If the volume is raised above this point, as in receiving a strong local station, the tube is overloaded and distortion results. Therefore it is a good plan to listen carefully and decide whether the distortion is present at all times or only on loud signals. All speakers are limited as to the volume they can produce and, if the signal strength goes too high, they become overloaded and distortion results.

NOISY RECEPTION

By noisy reception, we mean all the unwanted sounds such as hum, buzzing, crackling, rattling, frying, clicking and so on. Regardless of their sound, they are caused by conditions either outside or inside the unit. That sounds simple, but keep it in mind and you may save yourself many hours of unnecessary work.

Suppose you are called on to repair a noisy receiver. If the trouble is outside, there is nothing to do with the receiver itself. To find out where the noises are coming from, the best method is to turn the receiver on, disconnect the antenna and then short the "Ant." and "Gnd." terminals of the receiver. If the noises disappear, or are greatly cut down, you know at once they are coming in over the antenna and are not caused by trouble in the receiver itself.

Should the noise be found to be coming in through the antenna, look and see that the connections are not loose or corroded and that good electrical contact is being made. A poor electrical connection in the antenna will cause considerable noise in a radio receiver and this fact is especially true if the wind is causing the system to swing.

Another common cause of noise is due to the antenna being placed close to a-c power lines. You know that any conductor, carrying current, has a magnetic field set up around it and this magnetic field keeps expanding and contracting with the same frequency as the current causing it. It follows then that an antenna, erected parallel and close to a power line is cut by the changing field and has an emf induced in it. This emf being of the same frequency as the power line, may cause a low pitched hum in the receiver.

By placing the antenna at right angles to the power line, this action is reduced to a minimum and therefore the hum in the receiver is cut down. While it is not always possible to have

the antenna at right angles to the power lines, always have it placed with as large an angle as you can. If, after checking the above, the noise still persists and you feel quite sure that the interference is coming in through the antenna, about the only thing you can do is to locate and remove its source or install a noise-reducing antenna system.

Should you be convinced that the antenna is not at fault, for A-C receivers it is possible that the interference is entering the unit through the power supply circuit. For this condition, you can make use of the line filters which are explained in an earlier Lesson. These filters consist of inductances, condensers or a combination of both. The inductances or chokes are connected in series while the condensers are connected across the circuit.

Should the trouble be traced to the receiver itself, there are many causes and perhaps the most common are, noisy parts, such as resistors condensers chokes, transformers, tubes and loose or dirty connections. With the exception of the tubes you can quite easily and effectively check the parts for noise by simply making use of the "test set" explained for checking the lightning arrestor of Figure 5.

To show you how this is employed and to make our explanations definite, we will assume you want to test the secondary of the audio transformer of Figure 1. The two leads of the headphones and battery, which were connected across the lightning arrestor of Figure 6, are now connected across the secondary. The instant the connection is completed there will be a click in the headphones, but, by maintaining a good contact, a "noise" free sound indicates a good winding. However, should a noise be heard in the phones, then the winding is defective and the transformer should be replaced.

As you were told above, this same method can be used for checking a large number of the parts in a complete electronic unit but be sure the "test set" leads make good contact with the part or else noise will result in the phones and you may condemn a good part. Also, the part under test should be disconnected from all associated circuits. The reason for this is that you may be testing one part, across which another is connected and thus not get a good check of either one. A good example is the grid circuit of the r-f tube of Figure 1, where we have the secondary of the r f transformer and the variable condenser connected in parallel.

As a test for noisy tubes, it is only necessary to gently tap each one with your finger or else use some rather light object such as a pencil. Of course, when doing this, the unit should be turned on and when an increase in the noise heard in the speaker is noted, that tube which caused it should be replaced.

To find out if the noise is due to a loose or dirty connection follow the above plan but here, tap the chassis. In some cases, it is a good idea to gently shake the complete assembly. Also, it is a good plan to move the tubes slightly up and down in the sockets. This will serve to clean the electrical contacts and thus improve the connections.

The majority of modern electronic devices are usually quite well shielded and often the shield is a part of some electrical circuit. In nearly all cases, the shields are grounded and a loose connection or contact of the shield and metal base will cause troublesome noise.

At times, the plates of the radio receiver tuning condensers will warp, or become bent enough to touch each other. This will cause a loud cracking noise but only when the tuning dial is moved or when receiving certain stations. In other receivers, a thick coating of dust on the condenser plates will cause a similar action but this is easily remedied by pulling an ordinary pipe cleaner between the plates. In still other cases, the contacts are corroded. To remedy this, the contacts should be scraped until bright and clean, then fastened firmly in place.

It is not at all uncommon to find noisy wave band switches, volume and tone controls. To eliminate the interference due to the band switch, clean the contacts by polishing them with some abrasive, such as fine emery paper.

The volume and tone controls, of the wire wound type, can be cleaned quite effectively with carbon tetrochloride. This can be applied to the resistance wire and "wiper" of the control with a soft cloth.

For the noisy carbon type control, the best plan is to replace it with a new one. However, a temporary job may sometimes be effected by taking it apart and carefully cleaning the wiper. Then, a small portion of the lead from a soft lead pencil is crushed very fine and applied lightly with your finger to the carbon section of the control. This will tend to fill in any rough spots and thus reduce noise.

In this Lesson, we have tried to give you a panoramic view of many of the problems encountered in an electronic unit. As you advance, you will find all these problems are taken up in detail so that you may find and remedy any technical difficulties with Radio and Television receivers. What we want to make clear here is that you must use your natural senses, as well as your technical knowledge, in solving many of the baffling problems which are continually encountered by men employed in the Electronic field.

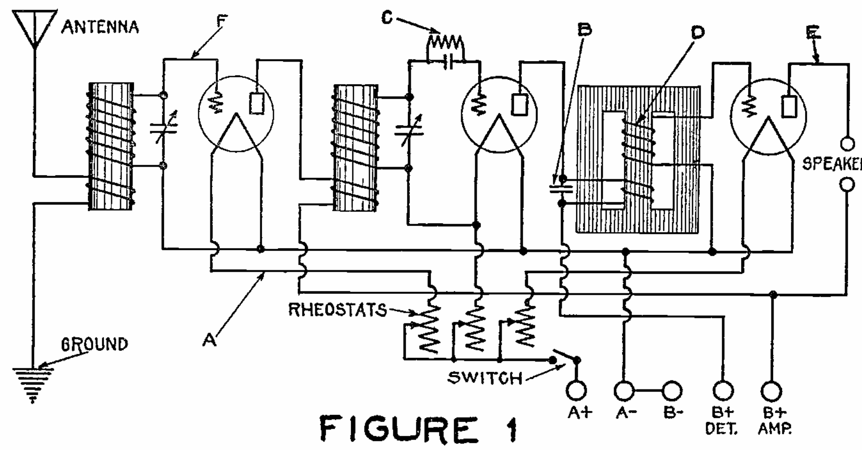


FIGURE 1

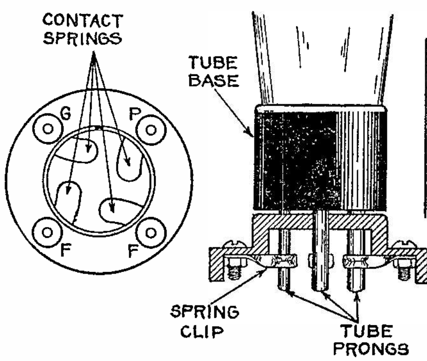


FIGURE 2

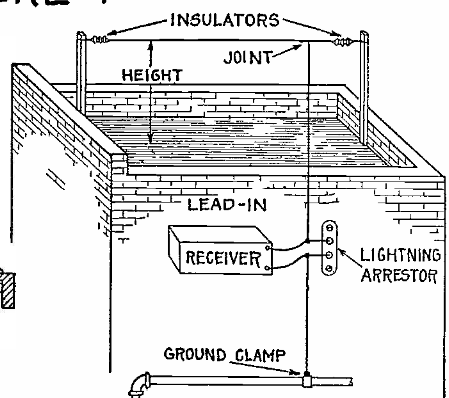


FIGURE 3

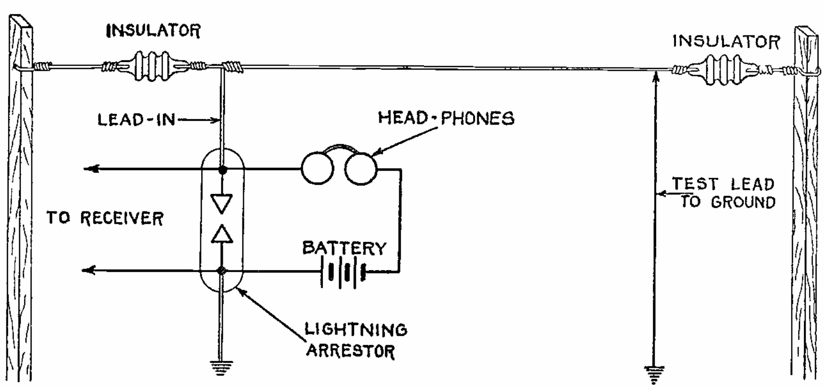


FIGURE 4

FIGURE 5

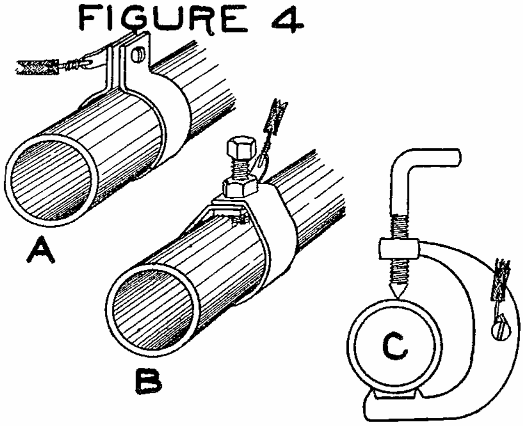


FIGURE 6

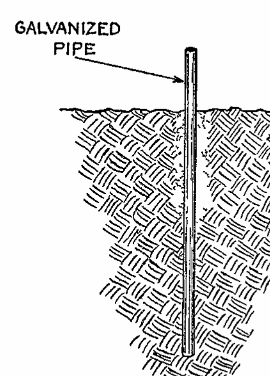
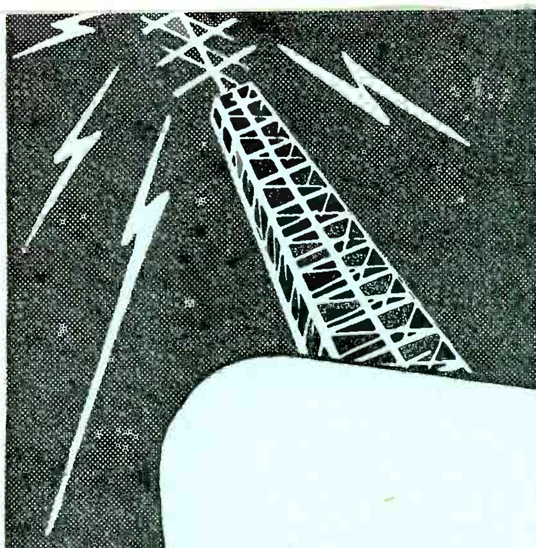
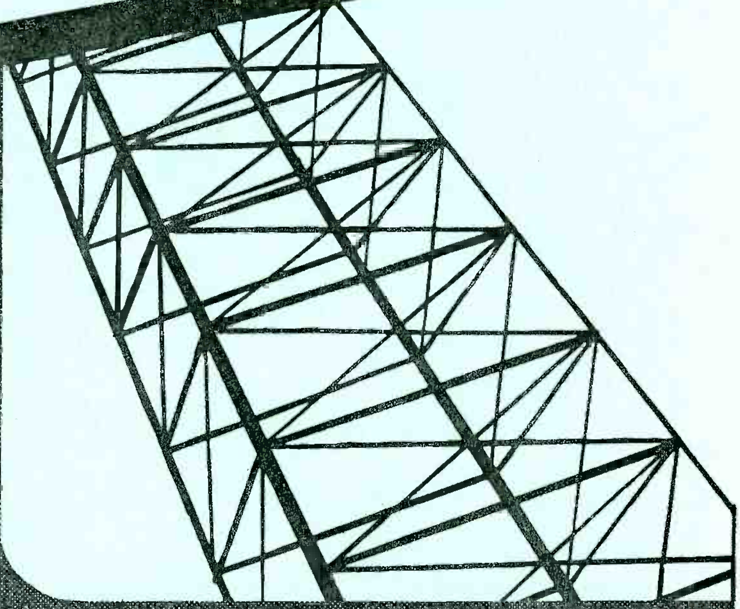


FIGURE 7



LESSON RTS - 2

GENERAL DIAGNOSIS



DE FOREST'S RADIO ELECTRONICS TRAINING, INC.

DE FOREST'S TRAINING, INC.

2533 N. Ashland Ave., Chicago 14, Illinois

RADIO AND TELEVISION SERVICING

LESSON RTS-2

GENERAL DIAGNOSIS

Tubes ------------------------------------ Page 1
Identification of Cicruit ---------------- Page 2
Combination Receivers -------------------- Page 3
A.C. Receivers --------------------------- Page 4
Auto Receivers --------------------------- Page 4
Heater Circuit Check --------------------- Page 5
Rectifier Tube Inspection ---------------- Page 7
Speaker Action --------------------------- Page 8
Audio Amplifier Tests -------------------- Page 9
Detector Operation ----------------------- Page 10
I.F. Amplifier Operation ----------------- Page 10
Oscillator Tests ------------------------- Page 10
Mixer Stage Tests ------------------------ Page 11
R.F. Amplifier Tests --------------------- Page 12
Input Circuit Tests ---------------------- Page 13

= = = = = =

Life is not easy for any of us. But what of that? We must have perseverance and above all confidence in ourselves. We must believe that we are gifted for something and that this thing, at whatever cost, must be attained.

-- Madame Curie

GENERAL DIAGNOSIS

In our last Lesson, we gave you a general idea of the main types of Radio Receiver troubles together with some simple methods of making preliminary tests. Although these basic ideas hold true in all cases, the wide variety of makes, models, and types of Receivers makes it necessary for you to learn how to identify them quickly.

Should you want to test the output circuit, by removing and replacing the output tube, you must be able to identify and locate it. Should you want to place your finger on the detector grid, you must know which is the detector tube.

To help you in this respect, for the illustrations of this Lesson we have shown plan views of seven different Radio Receiver chassis which represent the common types now on the market. These are "Pictorial" drawings which show the size, shape and location of the various component parts as they are mounted on the base. These views show the appearance of the chassis when looking down on the top.

TUBES

As we mentioned before, the tubes are perhaps the most important parts of a Radio Receiver, especially from a service standpoint, and therefore we will check them first. To aid in this work you will find all tubes are marked with their type and can thus be readily identified. This marking is usually about half way up on the bulb of the glass type tubes and in a similar location on the metal tubes. In some cases, you will find the type marking on the base but these are usually the older models of glass tubes.

Starting with Figure 1, you will see it contains five tubes marked as 25L6, 6J7, 25Z6, 6SK7 and W-46416. Here, the function or purpose of each tube is also shown but, if you had the actual receiver instead of Figure 1, there would be no indication as to the purpose of each tube.

To obtain this information, it will be necessary for you to check the "Type Number" marked on the tube, against the information given in a tube table or Manual such as that sent you as an earlier Lesson. With the large number of tube types now in use, it is almost impossible to memorize all of them therefore a good tube table must be considered as an essential part of your test equipment.

Referring to a tube table, you will find the "25L6" is classed as a Tetrode and used as a Power Amplifier, the 6J7 is classed as a Pentode and used as a Detector or Amplifier, the 25Z6 is

classed as a Duodiode and used as a Rectifier-Doubler while the 6SK7 is classed as a Pentode and used as an Amplifier. The "W-46416" does not appear in the ordinary tube table and thus you know it is not a tube in the usual sense of the work. We will give details on this unit a little later.

Perhaps this identification of the tubes will seem of more importance if we refer to Figure 2 because there, the functions of the tubes are not listed. Referring to the tube table you will find the following information.

Type	-	Class	-	Use
1A7-GT	-	Heptode	-	Converter
1N5-GT	-	Pentode	-	R-f amp
1H5-GT	-	Diode-Triode	-	Det.-amp
1A5-GT	-	Pentode	-	Power amp
35Z5GT	-	Diode	-	Rectifier

With this information, you will have a better idea of the layout of the circuit and be able to make the simple tests outlined in the previous Lesson. For example, although the 1H5 and 1A5 are both equally spaced, in respect to the speaker, the 1A5 is listed as a power amplifier and therefore is the last audio tube which drives the speaker.

Following this same plan, we suggest you check the tube types of all the receivers which are shown, whether or not their function is indicated on the drawings. This will give you good practice in using the tube table, and help you to become familiar with some of the common tube type combinations.

IDENTIFICATION OF CIRCUIT

In addition to learning their location and function, a study of the tube types is also of great help in identifying the type of circuit used in the receiver.

Reviewing briefly, you will remember that practically all commercial Radio Receivers employ either a Tuned Radio Frequency, (trf), or Superheterodyne, (Super) type of circuit, The super requires a local oscillator and i-f transformers, neither of which are required in the trf circuit.

In respect to the type of Power Supply, there are "Battery" Receivers, operated by dry cells, a-c receivers, which plug into the house lighting circuits and require a power transformer, as well as a-c - d-c types which also plug into the house lighting circuits but have no power transformer.

With these facts in mind, let's go back to Figure 1 and see what we can learn by checking the functions of the tubes.

The 6SK7 is listed as an R.F. amplifier, the 6J7 as a detector and the 25L6 as a Power amplifier or Output tube. As the rectifier tube is not considered as a part of the signal circuits, and there is no Oscillator, Mixer or Converter tube shown, it is evident the circuit is of the TRF type. As a further check, there are no IF coils therefore the receiver can not be a Super.

Although not shown in Figure 1, there would be an attachment cord and plug which indicates the receiver operates on the house lighting circuit but, as there is no power transformer, it must be of the AC-DC type.

Checking back in the tube table again, you will find all of the tubes require a heater current of .3 ampere and thus they can be connected in series, the common arrangement for AC-DC circuits. Also the tube table shows you the 25L6 and 25Z6 heaters each require 25 volts for proper operation while the 6J7 and 6SK7 heaters each require 6 volts.

In a series circuit, the voltage drops are added and here, the total drop for the four tube heaters will be 25 + 25 + 6 + 6 which is 62 volts. The usual home lighting circuit is rated at 110 volts but due to variations is considered as 117 volts in Radio calculations.

Here then, a resistance of some sort, must be connected in series with the tube heaters and its value must be such that it will cause a drop equal to the difference between the 117 volts of the line and the 62 volts of the tube heaters. Subtracting 62 from 117 we have 55 volts and as the current is .3 ampere, according to Ohm's Law the resistance must be equal to 55 volts divided by .3 ampere which is $183\frac{1}{3}$ ohms.

For the receiver of Figure 1, this resistance is mounted inside the W-46416 tube which is known as a "Ballast". Once you become familiar with the regular tube types, you will have no difficulty in identifying the ballast tubes as their numbers are entirely different. Thus, when you decide a Receiver is of the AC-DC type and find it contains an odd type of tube, you are reasonably sure that this odd type is a ballast tube.

Checking back, by looking up the functions of the tubes and making a visual inspection of the chassis, we have determined the receiver operates on A.C. or D.C. and is of the TRF type. To do this, we did not need any test equipment but the knowledge we have gained will be needed for further tests.

COMBINATION RECEIVERS

Following this same general procedure for the receiver of Figure 2, you will find the tube table rates the filaments,

of all except the 35Z5 tube, at 1.4 volts, .05 ampere. With equal current ratings, these tubes could be connected in series but, the low values of voltage and current indicate the tubes were designed for battery operation. An examination of the cabinet of the Receiver of Figure 2 would reveal a battery compartment and, if brought in by a customer, the batteries would probably be in place.

The 35Z5 is a rectifier tube and, as batteries supply direct current, this receiver must be designed to operate on lighting circuits as well as batteries. Thus an examination of the functions or ratings of the tubes identifies the receiver of Figure 2 as a "Super" designed to operate on either batteries or home lighting circuits.

In comparison, the receiver of Figure 3 has the same tube types as that of Figure 2 but, with no rectifier tube, it is evidently designed for battery operation only. Later on, we will take up the circuit details but now, we want to show you only that, by a careful inspection of tubes and other visible component parts, the general type of circuit and power supply can be quite completely identified.

A.C. RECEIVERS

Going ahead to Figure 4, but omitting a few details, you will see a power transformer in the upper right corner and thus know immediately that this is an A.C. type of Receiver. About the center of the chassis there are two I.F. transformers which, in conjunction with the 6SA7 type of tube, indicate definitely a superheterodyne circuit.

The three 6J5 tubes, which are listed as "Detector-Amplifier-Triode" indicate a detector and two stages of audio amplification while the two 6V6-G output tubes can be assumed to comprise a push-pull output stage. The 6SK7, which is a high gain pentode, undoubtedly is installed as the I.F. amplifier.

Here again, a close inspection of the tube types and main components, visible on top of the chassis, makes it possible to quickly identify the type of circuit, the type of Power Supply and the function of each tube.

AUTO RECEIVERS

For the Receiver of Figure 5, conditions are somewhat different. Here again there is a Power Transformer but, in addition to the 6X5G Rectifier tube there is a "Vibrator". This indicates a D.C. supply but, as all the tubes have a 6.3 volt heater or filament, it is reasonable to assume the Receiver is designed to operate on a 6 volt D.C. circuit such as is found in the ordinary automobile.

If further identification is needed, practically all auto receivers are housed in rather odd shaped metal cabinets and, in many cases, are provided with remote control for tuning, volume and "OFF-ON" switch. On general appearance alone, it is not likely that you will confuse an Auto Receiver with those designed for Home or Portable use.

Checking further on Figure 5, you will find a "6A8" mixer tube, a "6K7" high gain amplifier, a "6Q7G" Duo-Diode-Triode, and a "6K6G" Power Amplifier Pentode. This information, together with the two i-f transformers mounted on the chassis are complete proof the circuit is a Superheterodyne.

For Figure 6 we show a small 6 tube Table Type of Receiver while for Figure 7, we have an older type, 10 tube chassis which normally would be installed in a full sized console cabinet. For practice, we want you to check these two receivers, following the plan we have explained for Figures 1 to 5 inclusive, and see how much information you can obtain in regard to the type of circuit, kind of Power Supply, function of each tube and other useful details.

HEATER CIRCUIT CHECK

The explanations of this Lesson are written on the assumption that you, as a professional serviceman, have been given a defective Radio Receiver for repair--that you have no circuit diagram and may never have seen this particular make and model before--that you must make a quick diagnosis of the trouble, without elaborate tests, in order to give the customer an estimate of what a repair will cost.

With this in mind, our explanations will follow the mental reasoning which takes place in the mind of the serviceman as he "sizes up the job" and makes a few simple tests to determine, not the actual defect, but the general type of trouble. With this information, his experience will enable him to estimate quite accurately how much time and material will be needed.

Estimates of this kind require not only a rather complete knowledge of the various circuits but also of their more common troubles. Due to the many details which must be included, for this Lesson we will explain the methods by which a defect can be roughly isolated in some particular stage or circuit and then, in the following Lessons, we will take up the details of the troubles and tests for the different circuits.

Naturally, there is a wide variation in the step by step details by which these tests are made by different men. Such things as personal preference, available test equipment, type

of Receiver, Personality of the customer and general policies of the shop all affect the actual routine. No doubt, you will develop your own personal routine and therefore, our explanations may not be given in the order which you think best.

As we have mentioned before, it is a very good policy to always test the tubes first. This is true for two reasons: First, a large percentage of troubles are caused entirely by defective tubes and Second, no circuit can operate properly unless all the tubes are in good condition.

Sometimes, a tube tester is not available or the receiver chassis must be removed from the cabinet in order to make the tubes accessible. In cases of this kind, many service-men check the heater circuit by simply turning on the receiver and inspecting the tubes.

For glass tubes, the glow of the operating heater can be seen while, for metal type tubes, a check can be made by touch, to feel if they are warm after a few minutes of operation.

In making tests of this kind, you must remember that although a heater does "Light up", it does not prove the tube is in good working order. Some of the elements may be shorted or the emission may be low, but the "Lighted" heater does show that its circuit is in operation. Also, it is difficult to see whether some types of tubes are lighted or not unless the room is dark.

The identification of the circuit is of benefit here because, for the series connection of the Receiver of Figure 1, any broken heater would prevent all tubes from "lighting". In the circuit of Figure 3, the tube filaments are in parallel across the "A" battery and, if one were defective it would not light but the others would.

The circuit of Figure 4 is somewhat similar and all of the 6 volt tubes are connected across a secondary winding of the Power Transformer. Here again, the defective tube only, would not light. There is another detail here however. The heater or filament circuit of the 5Y3G rectifier tube is separate from that of the other heaters. Thus, if the rectifier tube does not light, the trouble may be in the tube or its connections to the power transformer.

For the auto receiver of Figure 5, all of the tube heaters or filaments are connected in parallel across the battery and thus, as explained for Figure 3, the good tubes would light while the defective filaments would not.

You can use this same general plan to check the heater circuits of Figures 6 and 7 against the identification which we

suggested you make of their circuits. In a large receiver, like that of Figure 7 however, there may be more than two heater circuits.

Thus, by testing the tubes first, you can use them as a heater circuit check, looking for the "glow" in the glass types and feeling the heat of the metal types.

RECTIFIER TUBE INSPECTION

All AC-DC, Battery Combinations, AC and many Auto Receivers require a Rectifier tube and fortunately, most of these are glass types. With the exception of one or two types, such as the OZ4 and older type BH, all rectifier tubes have a heater or filament which can be tested as explained for the other tubes.

As you already know, the rectifier tube is the source of high voltage for the plate and screen grid circuits of the other tubes and therefore its action will indicate some types of defects in the high voltage circuits.

For example, suppose you have an inoperative receiver in which all of the tubes are known to be good and all of them "Light". An inspection of the rectifier tube shows that its plate or plates become red hot after the power has been turned on for a few seconds. Less frequently, you will find an inoperative Receiver in which the entire bulb of the rectifier glows or sparks jump from the filament to the plate when the power is turned on.

Analyzing this condition, you will remember the plates are in series with the high voltage supply circuit and that the excessive heat must be caused by high current values. Higher current, without an increase of voltage, must be caused by reduced resistance.

Thus, the red hot rectifier plates indicate a low resistance or "short" in the rectified high voltage circuit and, thinking of the units and connections in the circuit, you will see that a shorted filter condenser could cause the trouble. Usually, the defective condenser will be in the power supply filter but a shorted plate to ground bypass condenser can produce the same results.

Occasionally, a connecting wire or coil will make a contact with the chassis, to create a short but, in most cases of this kind, the trouble will be found in defective condensers.

In contrast to the "short" mentioned above, you may find the high voltage circuit is open. This "open" or high resistance

may be in the power supply filter choke or anywhere in the plate or screen circuits. However, as the output tubes usually draw the major portion of the total high voltage current, their circuits are most important.

An open in any part of these high voltage circuits, which include the supply filter, as well as their cathode or filament circuits, would prevent current in them. With not current in these circuits, the total current will be greatly reduced and may cause the supply voltage to rise sufficiently to damage the filter condensers. Therefore, to play safe, never turn on the power of a receiver, having a dynamic speaker, unless the speaker is properly connected.

While we have mentioned the extreme conditions which cause a Receiver to be completely inoperative, these troubles do occur in varying degrees therefore, a close inspection of the rectifier tube is an important part of a general diagnosis.

SPEAKER ACTION

So far, you have been looking at the tubes and other parts, but now you can use your ears to listen to the speaker. As you perhaps know, even when in perfect condition, any Receiver operating on a-c, will have a slight hum in the speaker when no signals are being received and the volume control is turned all the way down.

Then, as the volume is turned up, there will be a sort of "Live" sound even when no signals are being received. The higher the volume control is turned up, the louder this live sound until natural static and other disturbances are heard. In modern receivers with avc, these disturbances reduce greatly as each Broadcast station is tuned in.

Keeping these conditions in mind, suppose you have an inoperative Receiver but, by the checks we have explained, know the tubes are in good order and that all of them "light".

You turn it on and, after waiting for the tubes to warm up, place your ear close to the speaker. If it is absolutely dead, with no trace of him or "live" sound, you are safe in assuming there is trouble either in the speaker, the output transformer, the plate circuit of the output tube, or the plate voltage supply.

This diagnosis is quite simple because the speaker is coupled to the plate circuit of the output tube and, if the circuits and coupling were in good order, you would hear a slight hum at least.

If you should hear the hum, but no live sound or other noise, as you rotate the volume control back and forth from low to high, it is a good indication of trouble in the audio section of the Receiver circuit.

Should the speaker have the "live" sound, which can be varied by operating the volume control, it indicates the audio amplifier is working and the signal is lost somewhere between the detector and the antenna.

These are quite definite indications in the case of a Receiver which is completely inoperative but can be used in conjunction with others for a Receiver which operates poorly. For example, a receiver with low signal volume but high hum level will indicate defective filtering due usually to trouble in the filter condensers.

Thinking back to the circuits and operation of the conventional type of power supply, you will remember that the filter condenser, connected across the rectifier output, exercises an important control over the D.C. output voltage. Thus, if the capacity of this condenser should reduce, because of age or other causes, there would be less filter action, causing increased hum, as well as lowered D.C. voltage to cause reduced signal volume.

AUDIO AMPLIFIER TESTS

As explained above, the routine of speaker listening tests may indicate the condition of the audio amplifier in a general way when the movement of the volume control causes a difference in the volume of speaker noise. This test applies to the common type of circuit in which the volume control is connected across the input circuit of the first audio amplifier tube. In older models, the volume control may be connected in other parts of the circuit, in which case its action will be different.

Therefore, to make a quick check on the audio amplifier section of the receiver circuit, it is common practice to touch a finger to the grid of the first audio tube. In any building wired for common A.C. house lighting, this test will cause a loud A.C. hum in the speaker if the circuits are operating properly.

For the common type of circuit, with the volume control in the grid circuit of the first audio tube, the finger can be placed on the high side or ungrounded terminal of the volume control. The hum should then be heard in the speaker but now, its level, or intensity can be controlled by adjusting the volume control. Incidentally, this test will also give an indication of the condition of the volume control.

Of course, if these tests produce no sound in the speaker, although the slight power supply hum is present, it indicates trouble in the audio amplifier circuits.

DETECTOR OPERATION

This same test can be made to include the detector by moving the finger to some exposed metal part of the detector input circuit.

For the grid leak type of detector, the hum should be heard when either connection of the grid condenser is touched with the finger. When this condenser is in good condition, touching the grid end will cause a louder hum than touching the other end.

For the bias and diode types of detector, the finger should be placed on or as near the grid or diode of the tube as possible.

I-F AMPLIFIER OPERATION

When your inspection of the receiver identifies it as a "super" there will be an i-f amplifier ahead of the second detector input and here again, a finger test is often of benefit. Because the circuits are tuned to a comparatively high frequency, instead of a hum, there will be a click in the speaker when the i-f amplifier tube grid circuit is touched.

Contact can be made with a finger on a piece of metal such as a screwdriver blade. However, your finger should be in contact with the metal in order to obtain the full effect of your body capacity.

In the receivers of Figures 3, 5 and 7, the i-f amplifier tube has a grid cap which makes the grid circuit readily accessible. However, in receivers like that of Figure 4, the i-f amplifier tube is of the single ended type and thus it may be necessary to go underneath the chassis to make contact with the circuit.

As an alternate test, you can remove and replace the tube in the socket and, as explained previously, listen for the click in the speaker.

OSCILLATOR TESTS

Thinking back to the explanations of the earlier Lessons, the operation of a Superheterodyne receiver depends on the heterodyne action of the incoming signal carrier frequency and a

local oscillator. Therefore, if the oscillator is not operating, the i-f frequency will not be produced and the receiver will be inoperative.

As we mentioned for the speaker listening tests, there may be the "live" sound, which can be varied by the volume control, but no signals are reproduced. If the tests we have explained indicate the i-f amplifier, detector and audio amplifier are working, the next step is to determine whether or not the oscillator is in operation.

The oscillator or mixer tube should have been located when the tubes were checked and the type of circuit identified but there are a few variations we want to mention at this time.

In order to produce the intermediate frequency at all points of the tuning range, the oscillator must be tuned with the input circuits and therefore, in the common types of receivers one gang of the tuning condenser is a part of the oscillator circuit.

In Figures 2, 3, 4, 5 and 6, a single tube serves the dual purpose of oscillator and first detector or mixer while, in Receivers like that of Figure 7, a separate tube serves as the oscillator.

While a positive test for oscillator operation requires some equipment and will be explained later, some men make a rough test by placing a finger on the stator plates of the oscillator section of the main tuning condenser. This increases the capacity of the circuit and detunes it sufficiently to stop its normal operation.

Thus, if the oscillator is operating, placing a finger on the stator of its tuning condenser should cause a "soft click" or "plop" in the speaker. We use the term "soft click" to distinguish this sound from the rather sharp click which is heard when the grid circuits of the amplifier tubes are touched.

MIXER STAGE TESTS

When making this general diagnosis, the mixer stage can be considered much the same as an i-f amplifier. Even though the oscillator is not working, touching the mixer grid should produce a click in the speaker.

Like the oscillator, one section of the tuning condenser is connected across the mixer input grid circuit and contact can be made by touching the stator plates of this section.

Sometimes, this test will cause signals to be heard and, when such is the case, it indicates trouble in the circuits between the mixer grid and the antenna.

R-F AMPLIFIER TESTS

Going back to the operation of a superheterodyne circuit again, the oscillator and mixer input must be tuned in order to bring in the various carrier frequencies. Therefore, all receivers of this type, employing a tuning condenser, require two sections or gangs. This is the arrangement in Figures 2, 3, 5 and 6.

In the receiver of Figure 4, you will see a three gang tuning condenser yet a check of the tubes and their functions, with the exception of the audio stages, is the same for Figures 2, 3 and 5. Therefore it is evident the receiver of Figure 4 employs an additional tuned input circuit, possibly some form of a bandpass filter.

For the receiver of Figure 7, you will find a four gang tuning condenser which indicates two tuned circuits between the first detector or mixer input and the antenna. Checking up on the tubes and high frequency transformers, there is a complete stage of amplification ahead of the mixer tube, the tuning of which requires an additional condenser gang. Then, as explained for Figure 4, there is probably a bandpass filter arrangement, the tuning of which makes use of the fourth gang of the condenser.

The tests for an r-f amplifier stage are similar to those explained for the mixer and here again, by making contact with the grid circuit, the receiver may operate. With this in mind, it is always a good idea to rotate the tuning condenser control in order to pick up a signal from a powerful or nearby Broadcast station.

In practically all of these tests, we suggest making contact with the various grid circuits because, as previously explained, the plate circuits can be checked by removing and replacing the tubes in their respective sockets. In addition, the plate circuits carry high voltage and therefore may cause an unpleasant shock if your finger comes in contact with them.

Also, the grid is a part of the input, or signal circuits, and by making contact with this circuit, a signal of some sort is produced, if it and all the following stages are in good order. That is why we start at the speaker and work back, stage by stage, toward the antenna.

The common type of input circuit consists of a transformer, the primary of which is a part of the antenna circuit while the secondary is tuned and connected across the grid circuit of the following tube. In some of the later models, the secondary winding is made quite large in size and acts as a loop antenna.

The common test here is to shift the antenna connection from the primary to the secondary because, if there is trouble in the primary, signals will be heard when the antenna is connected to the secondary. If you live reasonably close to a Broadcast station, your body makes a fairly good antenna and therefore you need only touch an exposed part of each circuit to make a quick test.

However, as one side of both the primary and secondary are usually grounded, be sure you make these tests by touching the high or ungrounded end of the windings.

While the explanations of this Lesson may seem somewhat lengthy, with a little experience you will be able to complete them all in a matter of a very few minutes. This routine of quick tests willgive you a good idea of the receiver and, in a general way indicate the general location and nature of any trouble which may be present.

To prevent complications, we have assumed a receiver which will not reproduce signals because, in many cases, the owner does not call on the service-man until such a condition occurs.

Once again, let us remind you these tests make up a diagnosis which will help only in locating the trouble in a general way. When some certain stage or circuit appears to be at fault, the following Lessons, will take up the details of that part of the work.

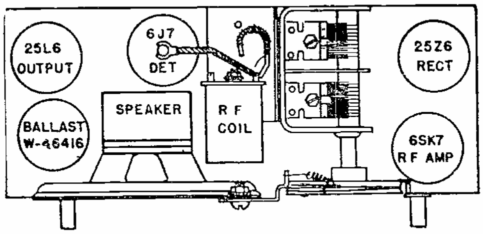


FIGURE 1

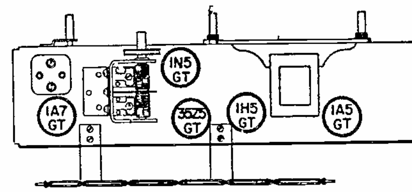


FIGURE 2

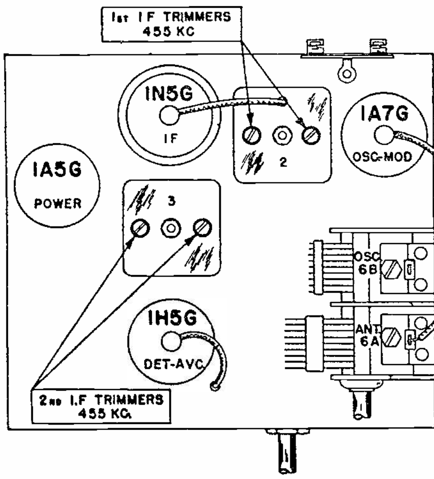


FIGURE 3

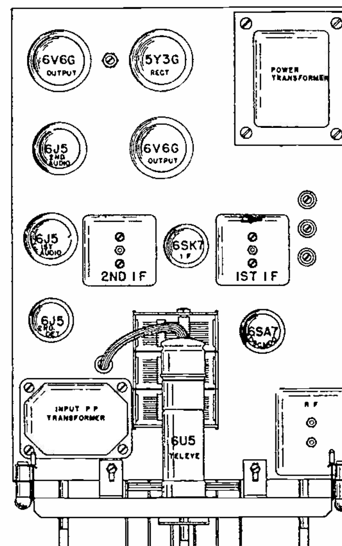


FIGURE 4

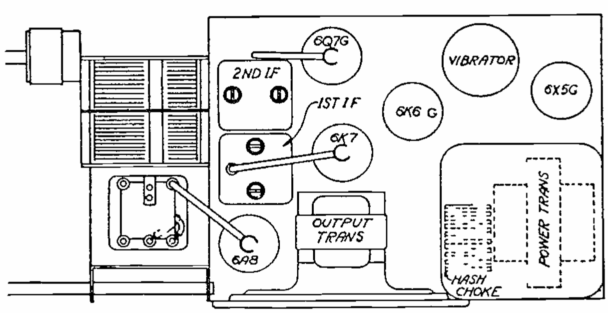


FIGURE 5

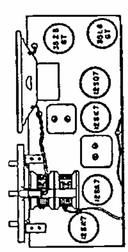


FIGURE 6

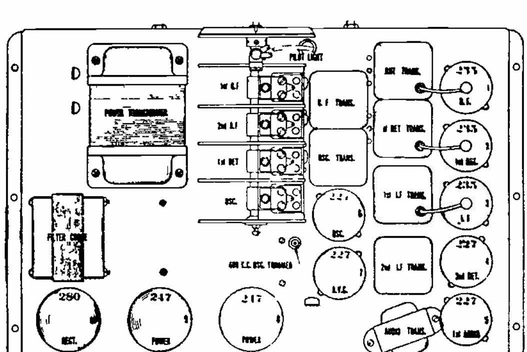
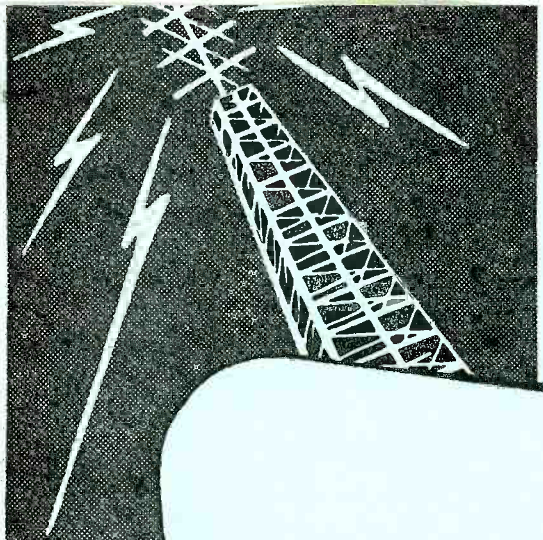
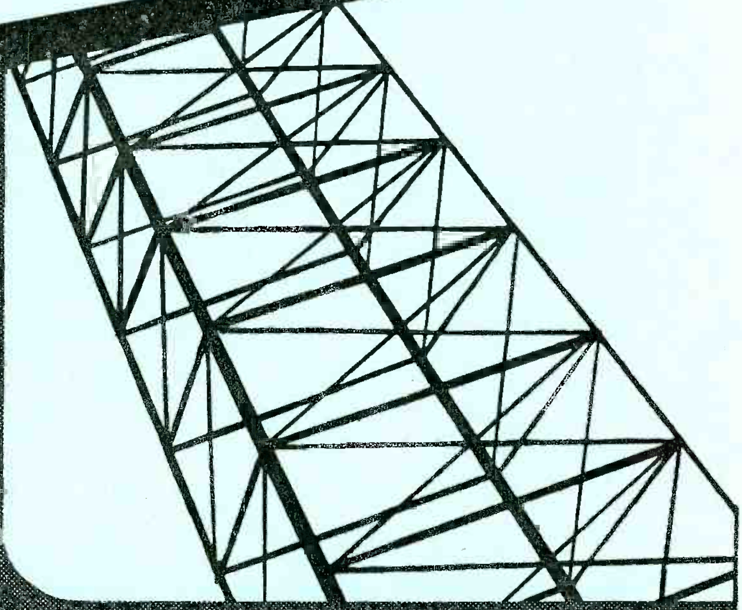


FIGURE 7



LESSON RTS - 3
CONTINUITY TESTING



DE FOREST'S TRAINING, INC.
2533 N. Ashland Ave., Chicago 14, Illinois

RADIO AND TELEVISION SERVICING

LESSON 3

CONTINUITY TESTING

Circuit Trouble -------------------------- Page 1
Test Meters ------------------------------ Page 1
Testing With the Voltmeter --------------- Page 2
Voltmeter Test Circuit ------------------- Page 3
Continuity Testing ----------------------- Page 3
Condenser Testing ------------------------ Page 6
Voltmeter Tests, Using Power Supply ------ Page 8
Open Circuit Tests ----------------------- Page 9
Short Circuit Tests ---------------------- Page 10
Headphones For Testing ------------------- Page 12
Point to Point Testing ------------------- Page 13

# # # #

Andrew Carnegie, when asked on one occasion whether he was not worried for fear some of the young people he was training would take his place, shook his head and replied, "All that worries me is that they won't."

-- Walter Hoving

CONTINUITY TESTING

After making a general diagnosis of a defective Radio Receiver, by following the explanations of the preceding Lesson, the type and location of the trouble should be fairly well established. However, to locate exactly the point of the circuit or component part which is defective, it is usually necessary to make electrical tests.

In this Lesson therefore, we are going to explain the fundamental applications of various test meters so that, in the later Lessons we can show you how to use them to simplify the more complicated problems which will come up.

CIRCUIT TROUBLE

Reviewing briefly, you will remember that every electronic unit is made up of a number of circuits, all of which must be in good condition to allow proper operation. The various types of circuits have been explained and we want to remind you that the rules and laws which have been given hold true for all Radio and other Electronic equipment.

In order to have electrical action, a circuit must be complete. There must be a complete and continuous path from one side or terminal of the supply, through all the components and connecting wires, to the other side or terminal of the supply. Also, there must be a continuous path through the supply itself. A great many of the troubles in Radio, Television and other Electronic equipment are caused by breaks or "opens" in the continuous path as well as by unwanted paths which are known as short circuits or "shorts".

You can readily see that anyone, working in the Electronic field, must have not only a good understanding of circuits but be able to make tests which will determine accurately whether they are "open", "shorted" or in proper condition.

TEST METERS

Thinking of a simple circuit, there are three quantities or values which must be considered. First, the voltage impressed on the circuit, Second, the current in the circuit and Third, the resistance of the circuit. In order to test or measure these values you will use Voltmeters, Ammeters and Ohmmeters which may be separate instruments or made in combination to measure two or all three values. Switches or terminals are mounted on the panel of the meter to make the various ranges and scales available.

As you already know, a voltmeter measures the difference of electrical potential, or pressure, between any two points and,

to make a voltage test, it is not necessary to change or disturb the circuit. The meter wires, or test prods, are simply placed in contact with various parts of the circuit and the meter reading shows the voltage between them. This connection places the meter in parallel with the unit or units being measured, and is the proper position for making a voltage check.

An ammeter, used to measure current, must be connected in series with the circuit under test in order to carry the circuit current. This means the circuit must be broken at some point and the ammeter connected in the break, in order that it can indicate the current through it.

An ohmmeter, which is really a modified form of voltmeter, usually contains a source of voltage, often in the form of a battery, and therefore can be used with no other voltage or current in the circuit under test. Like a voltmeter, its prods are placed in contact with two points of a circuit and the reading which is obtained indicates the resistance between these points.

In a complete electronic unit, there are a number of circuits and frequently, there will be two or more parallel paths between the points on which the ohmmeter test prods are placed. The meter will indicate the total resistance which, from the laws of Parallel Circuits will be less than the resistance of any one branch. Keep this fact in mind as we will have more to say about it later.

TESTING WITH THE VOLTMETER

When using a voltmeter for testing, you must be sure the voltage, of the part of the circuit being tested, is not greater than the highest voltage on the scale of the meter. Meters in use for this work often have several scales, with a common negative, and terminals corresponding to each scale on the face of the meter.

For example, suppose you had a meter with voltage scales of 5, 50, 250 and 1000, and wishes to measure the plate voltage of the output tube in an a-c/d-c receiver. Knowing the voltage is not over 250, you would make connections at the negative and the 250 terminal causing the pointer to read on the 250 volt scale. However, when you are not sure of the peak voltage of the circuit being tested, always make the connections to the highest scale of the meter then, if necessary, you can move to a lower range.

Your voltmeter may have only one scale but the reading can be doubled by using a series connected resistance. To add a resistor for this purpose, you must first determine the resistance of the voltmeter, in ohms, and knowing this, use a resistance of the same value.

Usually, the resistance of a voltmeter is given in ohms per volt. For example, suppose your voltmeter has a 0-125 scale and the resistance is 1000 ohms per volt. To change it to a 0-250 scale requires an additional resistance of 1000 x 125 or 125,000 ohms. Using a resistance of this value, connected in series, every reading on the scale of the meter will be doubled.

VOLTMETER TEST CIRCUIT

A very simple yet useful test circuit can be made with a voltmeter in series with a battery, composed of two or more dry cells. Two wire leads, each at least three feet in length should be used. Solder a spring clip on one lead and, on the other, install some kind of sharp pointed device. This will enable you to clamp one lead in place and leave the other free to move from one position to another. Instead of the clip on one wire, two sharp points, or prods, can be used, like those of Figure 1, which shows the complete test circuit. A commercial tester of this type would be called an "Ohmmeter" and the scale would be calibrated in ohms.

Whenever this tester is connected to a circuit having an "Open" the meter will not register because there is no current through the circuit to operate it. This is true in Figure 2 where we show the tester of Figure 1 connected across the winding of a transformer. The wires in the winding are completely broken, preventing current through the meter and causing the pointer to remain at zero.

If the tester is used in a circuit including a resistance, as in Figure 3, a closed circuit results and there is current from the battery, through the resistance and the meter. The pointer will move over the scale and the distance it moves will depend on the amount of resistance in the unit.

The less the resistance, the higher the reading and, the greater the resistance, the lower the indication on the meter. This is true because, with equal voltage, a high resistance allows less current than a low resistance. Therefore, with a resistance in the circuit, the test will not show the full battery voltage but, if the hand moves, does show a closed circuit.

CONTINUITY TESTING

By continuity tests, we mean any sort of test which shows a circuit to have an unbroken or continuous path. For this work, the circuit of Figure 1 can be used with good results.

When the prods are touched on each other, or shorted, the meter will simply register the battery voltage, proving a

complete or continuous path through the tester. By placing the prods at various points, of a circuit under test, a meter reading shows a complete path between the prods but should the circuit be broken, the meter would read 0.

For example, suppose you are working on an electronic unit in which the speaker is absolutely dead and will not click when the tubes are removed and replaced. As we have explained, the trouble is possibly in the plate circuit of the last audio tube. The first test, of course, is to try a good tube but, when that does not cure the trouble, we make use of a tester like that of Figure 1.

Because there are batteries in the test circuit, the electronic unit should be shut off and the test prods placed across the primary winding of the output transformer as in Figure 2. If the transformer winding is broken, as shown, there will not be a complete test circuit and the meter will read 0. The zero reading, with the test prods on the B and P terminals of the transformer, proves there is a break, or open, in the winding connected to these terminals.

A similar test can be made on the secondary winding by placing the test prods on the "S" terminals. In the same way, the R.F. and I.F. transformers of a radio receiver can be tested by placing the prods across the primary and secondary windings.

This same test can be applied to the power transformer. However, when testing the power transformer, be sure that you place the prods across each secondary separately. This brings up another point to remember when making continuity checks for a defective part. "That part, which is being tested, should be disconnected from all associated circuits."

For example, suppose all the tubes are in place and the power cord plugged into a suitable supply but the heaters of the tubes fail to light. Naturally you would suspect that the secondary winding of the power transformer was not supplying the necessary voltage. However, with the receiver turned off, and the test prods of Figure 1 across the winding, the meter indicates a closed circuit.

By carefully checking through the heater circuits, you would no doubt find that the heaters and their winding are all connected in parallel. Therefore, if the prods are placed across the winding, the meter current will divide to complete its circuit. Also, with the prods across the heater secondary, if any one of the circuits were complete, the pointer of the meter would move.

Therefore, to get an actual check of the heater winding, it would be necessary to disconnect it from the heaters. Then, there would be only one path for the current and an accurate check for an "open" could be made. Removing the tubes from their sockets, would be the easiest way to do this.

Remember, when using the test circuit of Figure 1, if the windings are not broken, or open, the pointer will move across the scale of the meter when the prods are placed on the termi-als. The distance the pointer moves is also a help in locat-ing the various troubles because it gives a rough indication of the amount of resistance between the test prods.

Earlier in this Lesson, we told you how to connect a resist-ance to double the meter reading and, using the values given for that explanation, the meter had a resistance of 125,000 ohms. Remembering the action of a voltmeter, it is the cur-rent in it which causes the hand to move.

By Ohm's Law, a meter with a 125 volt scale and an internal resistance of 125,000 ohms, would have a current of 1 milli-ampere at 125 volts and the pointer would move all the way across the scale. Adding an additional 125,000 ohms in series, the resistance of the meter circuit would be 250,000 ohms which would allow a current of but .5 milliampere at 125 volts. The current is but half of its former value and thus the pointer would move but half way across the scale.

In other words, by doubling the resistance of the meter cir-cuit, it requires double the voltage to cause enough current to move the pointer across the scale. Therefore, with the extra resistance in use, every meter scale reading must be doubled.

The same effect will be present when the test circuit of Figure 1 is used. The transformer windings of Figure 2 will have a fairly high resistance and, when in good condition, the test will give a reading lower than the battery voltage.

Perhaps you will see this better in Figure 3, where we are using the tester of Figure 1 to check a long tubular resistor. If the resistance wire is broken, the meter will read 0 and show an open circuit exactly as explained for Figure 2. How-ever, you will notice the circuits are the same as explained for extending the range of a voltmeter therefore, the greater the value of resistance being tested, the lower the meter reading will be.

To sum it all up, for the test circuit for Figure 1, the prods are placed on the points of a circuit between which we want to test. A 0 reading indicates an open, a low reading indicates

a closed circuit with high resistance and high reading indicates a closed circuit with low resistance.

Remember here however, that the ordinary voltmeter has a high resistance and it requires a fairly high resistance, in the circuit being tested, to cause a drop in the meter reading. Low values of resistance, such as found in the primary and secondary windings of r-f coils would have little, if any, effect on the meter reading.

CONDENSER TESTING

The circuit of Figure 1 can also be used as a rough check for "shorts" and "opens" in condensers because it includes a direct current supply and a good condenser does not provide a circuit for direct current.

In the circuit of Figure 4, for example, we have a transformer and choke coil with a condenser connected across them. Connecting the tester as shown, there is a circuit through the choke and transformer primary which will cause a reading on the meter. If the condenser is shorted, there will be a low resistance path through it and the meter will read full battery voltage.

As previously explained, a test of this kind is not satisfactory because it does not definitely locate the trouble. The proper method is to disconnect one side of the condenser and then place the prods on its terminals. If it is of the paper type and in good condition, there is no complete circuit and the meter will read 0. For the electrolytic type, you must observe the polarity and with the condenser in good shape, there will be a small leakage current. However, after a little practice, you will be able to determine between good and bad electrolytics.

For paper condensers of fairly large capacity, say from .5 mfd up, when the prods are first placed on the terminals, the pointer will move slightly and then drop at once to 0. This shows the direct current charges the condenser, but the pointer, dropping back to 0 indicates the dielectric is in good shape and the condenser is all right.

When the dielectric is broken down, or punctured, there is direct current through the condenser and the meter will give a steady reading. When this condition occurs, the condenser must be replaced.

Sometimes the condenser plates will become disconnected from the terminal and cause an open circuit. While not entirely

satisfactory, with a little practice, the test set of Figure 1 can be used. On test, a good condenser causes the pointer to jump slightly when the prods are first placed on the terminals. Placing them on the terminals, with the same polarity, a second time will cause no action, the pointer remainint at 0.

To check up on this test, the prods may be reversed on the terminals. This will allow the condenser to discharge and then charge in the opposite direction. As the current must go through the meter, it will cause the pointer to jump.

Another method is to first discharge the condenser, by shorting across the terminals, and then, when the test prods are again placed across it, the pointer will jump slightly. When a condenser is open, the test is the same, except the pointer does not make the slight jump when the prods are first placed on its terminals.

Often, the plates of variable tuning condensers, are bent out of shape sufficiently to touch and cause a short. To test for this trouble, after one circuit wire is disconnected, the tester of Figure 1 is connected across the condenser, one prod on the rotor terminal and the other on the stator terminal.

The tuning dial is then turned slowly and, when the plates touch, the pointer indicates full battery voltage. Of course, if the plates are correct, the meter will read 0 during the full turn of the dial.

Many times a coil, resistance and condenser are found as shown in Figure 5. A grid resistance is connected in series with the secondary of a radio frequency transformer and this circuit may become grounded either at "A" or "C". Before making any tests, be sure that you disconnect any natural grounds, and it is also a good idea to disconnect the condenser from the circuit.

Using the voltmeter tester of Figure 1, on Figure 5, with one side connected to the coil at D, the other end can be grounded or touched at points A and C to locate the trouble.

If the coil is in good condition, touching the tester at D and ground will show no reading. If, however, a ground occurs at A, the voltmeter will show almost full battery voltage. With a ground at C, the test meter will not show full battery voltage, but a somewhat lower value, depending on the amount of resistance in the circuit. A zero reading on the test meter, with the prods on D and ground, shows the circuit is not grounded.

Quite often a number of parts, like the coil, condenser and resistance of Figure 6, will be found in the same circuit. Here, any one of the parts may be open, grounded or short circuited and the best method is to disconnect each part from the others and test it separately.

To test all the parts connected in the circuit, first place one prod at A. Touching the other prod at B, will give a full battery voltage reading on the meter if the condenser is shorted. Should the pointer move slightly then drop back to zero it indicates a good condenser.

Now, with a good condenser, if you move the test prod from B to either points C or D, the pointer probably will not move. Do not consider this as conclusive indication of an open circuit because the small fixed condenser does not require much charging current and the meter needle will register little if any reading. This shows how necessary it is, in a circuit of this kind, to test each part separately.

The circuit tester can be used in much the same way for locating trouble in the filter of the power supply. In this part of Radio and Television equipment, most of the troubles are due to defective condensers or chokes. By applying the tester to points B and D, Figure 7, you can test the two choke coils in series. The meter should not indicate full battery voltage since the d-c resistance of the chokes may be fairly high. When the pointer remains at zero, there is an open circuit and to find which choke is open, place one prod at the common point C, completing the test circuit first at D and then at B.

In this circuit, with the tester connected at A and B, the condensers will all be in parallel and should be disconnected at points B, C and D. A separate test can then be made on each one of them between A and the disconnected end.

VOLTMETER TESTS - USING POWER SUPPLY

The voltmeter itself is one of the handiest devices for testing. Instead of the circuit of Figure 1, you can quickly locate and overcome troubles in many of the parts by using the power furnished by the batteries or supply of the unit under test.

For example, in Figure 8, we have a simplified circuit of a tube and audio transformer and we can find the condition of the filament circuit with a voltmeter at (1), the voltage across the tube plate is obtained with a voltmeter at (2) and the voltage drop across the primary of the audio transformer can be measured with the voltmeter at (3). Open

circuits, short circuits and grounds can be determined by the readings obtained when the meters are placed in the various positions.

In making voltmeter tests, you must always keep the test circuit in mind. Using the circuit of Figure 1, with its own battery, a high reading indicates low resistance between the test prods as explained for Figures 3 and 4.

Position 3 of Figure 8 is about the same as Figure 2, but, the meter readings are different. In Figure 8, the meter has no separate supply and measures only the voltage drop between the test prods. Under these conditions, a high resistance will cause a high reading and a low resistance a low reading.

For example, if the transformer primary of Figure 8 were shorted, there would be a very low resistance between the B and P terminals to which the meter is connected in Position 3. By Ohm's Law, Voltage equals Current times Resistance therefore, with a low resistance, the voltage drop will be low. In the same way, a high resistance will cause a high voltage drop.

OPEN CIRCUIT TESTS

To show you how to use a voltmeter for open circuit tests, we will assume you have constructed the a-f amplifier stage of Figure 8 but, after properly connecting the batteries, the filament fails to light. A tube, known to be good, also fails to light when placed in the socket, therefore you know the filament circuit is at fault.

Using a voltmeter only, you first place one test prod on the "A" battery positive, then touch the other to "A" battery negative. With these connections, the meter is across the battery and should read the full battery voltage.

Leaving one prod on the battery negative, you move the other one up to the moveable contact of the rheostat. If the meter again reads full battery voltage, you know the circuit between the positive terminal of the battery up to the moveable contact of the rheostat is complete.

Next the prod is moved from the moveable contact to the upper connection to the rheostat. With the tube in the socket and the other prod on the battery negative, the meter reads zero.

With the prods on battery negative and moveable rheostat contact the meter reads full battery voltage but across battery negative and the upper end of the rheostat the meter reads 0.

Therefore, you will be safe in concluding the rheostat is open.

SHORT CIRCUIT TESTS

Another common form of trouble, which occurs in electronic devices, is a short circuit in the various units and connecting wires. A "short" is a condition which allows current in part of the circuit but prevents the units from operating properly. It is also defined as a low resistance path which reduces the current in the units of the complete circuit.

In Radio and Television equipment, shorts are usually caused by defective parts, such as tubes, condensers and by wires running close to each other, or becoming bent and touching. Also, where the frame, or metal base, is used for one side of the circuit, or as ground, the other side may become grounded and form a short.

The best way to locate a short is by means of the tester of Figure 1 but a voltmeter can also be used. To show you how this works out, we will use the filament circuit of Figure 8 and assume that the filament leads are shorted at the tube socket.

The low resistance of the short will allow a large current in the circuit, but reduce the current in the filament to practically zero. Under these conditions, the tube filament will not light but the connecting wires and units in series will often get hot enough to smoke and possibly make them defective.

To make a voltmeter test, the meter is connected across the A+ and A- terminals to determine if the proper voltage is applied. Assuming this to be correct, the meter would then be connected across the rheostat and here you would find the full supply voltage due to the filament short. With the meter connected across the filament connections at the socket, it would read zero, indicating the short was somewhere between the upper rheostat connection and A-. An inspection of this part of the circuit would reveal exactly where the short is located.

Although the above explanation of locating "shorts" and "opens" have been on the filament circuit, the same ideas and procedure may be employed for all circuits on which a potential is applied. Remember, however, you must analyze the circuits as well as the readings in order to determine the trouble. The amount of resistance in the circuit will have a direct bearing on the voltage readings you obtain.

All short circuits do not allow excessive current but, in circuits connected to the supply, usually cause the parts to heat up. For battery type equipment, a short causes the batteries to discharge quickly. For a-c equipment, a short usually allows the windings of the power transformers to heat up sufficiently to cause a disagreeable odor. Also, where there is a short to the power supply, it is not at all unusual for the plates of the rectifier tube to get red hot. A short of this kind is most generally due to a defective, or shorted, filter condenser.

For example, if a voltmeter test in a power supply indicates a high voltage between the rectifier filament or cathode and ground but zero voltage between the receiver side of the filter and ground, it would indicate an open circuit and no doubt the trouble would be found in the choke coil.

However, should you find zero, or very low, voltage between the rectifier filament and ground, the trouble may be caused by a defective transformer, rectifier tube or a short circuit. To check on the rectifier tube and power transformer, disconnect the filter circuit from the rectifier and then measure the voltage from the rectifier filament or cathode to ground. Should it still be very low or zero, then you know your trouble is in these circuits.

In a case of this kind the first thing to do is try a new rectifier tube. Should this fail to bring up the voltage, you can assume that the power transformer is defective. However, before condemning it, check all the leads from it to see that there are no external shorts. Should the circuits be found satisfactory, then the transformer will have to be replaced with a new unit. Transformer trouble of this kind is generally caused by shorted windings and it is impractical to try and repair it.

Now let us assume that when the filter is disconnected the voltage from the rectifier to ground is normal. Under these conditions, the trouble would be in the filter or the receiver itself. A condition of this kind is generally due to a short circuit and the unit which most commonly causes this trouble is a "shorted" filter condenser.

The filter condensers are all connected in parallel and, as explained for Figure 7, they must be disconnected from associated circuits and checked individually. The test set of Figure 1 may be used here and the prods should be placed across the terminals of the condenser. A high reading on the meter indicates a shorted or partially shorted condenser. Remember, however, that when checking electrolytic condensers, the polarity must be observed and the "+" test prod must connect to the "+" terminal of condenser.

After you have checked all the condensers and found them in good shape, then check the connecting wires to see that none of them are touching each other or the chassis, to form a short.

Another trouble in the filter circuits is an open condenser and it will generally manifest itself by causing a loud a-c hum in the receiver. In some cases, where the open condenser is connected directly across the output of a rectifier, the d-c voltage output of the filter will be reduced. As previously explained, you can check for open condensers by the use of the test circuit of Figure 1.

In all cases of shorts, whether the supply is from batteries or the a-c power line, disconnect the supply as quickly as possible and locate the short before trying to operate the equipment. By following this method, there is less chance of damaging some other good part connected in series with the shorted circuit.

HEADPHONES FOR TESTING

Sometimes a voltmeter is not handy and an ordinary pair of headphones, connected in series with several dry dells, is suitable for testing. This form of tester is not as accurate or reliable as the meter because we must depend on our sense of hearing to determine the "clicks" in the phones.

The test circuit will be the same as Figure 1, by substituting the headphones for the voltmeter, and when the two leads of the tester are touched to an ordinary circuit of low resistance, a click will be heard in the phones. When the circuit is open, disconnected, or parts burned out, no click will be heard. In a circuit with a resistor, the intensity of the click will depend on the amount of resistance but a click can be heard through a fairly high value of resistance.

When connected to a condenser circuit, the loudness of the click depends on the capacity of the condenser. When first connected across a condenser, this tester will charge it, then, touching the condenser terminals a second time, will not produce a click of enough loudness to be heard. To be sure of the condition of the condenser, the test leads should be reversed. If in good condition the condenser will then discharge, causing a click in the phones.

You may have noticed, by now, that practically all the units of a radio receiver are connected in some tube circuit. Therefore, if all the tubes are supplied with correct voltages, nine times out of ten, the receiver itself is in good operating condition. There are conditions, however, which will cause a receiver to be inoperative although all voltages are correct.

Some of these troubles are shorted turns in the high frequency transformers, shorted variable condensers, open voice coil in dynamic speakers and faulty antenna and ground connections. However, these troubles are not nearly as common as those which affect the values of voltage and current.

POINT TO POINT TESTING

"Point to Point" testing is generally considered as a form of continuity testing in which the resistance, between various points in the circuit, is measured. This is accomplished by using a test circuit similar to that of Figure 1, but the meter is calibrated to read directly in ohms and is called an "ohmmeter."

As we previously explained, a common trouble in a-c operated units is shorted filter condensers which cause an excessive current drain on the power supply. Should you find zero plate and screen voltages on a unit of this kind and suspect a shorted filter condenser, the simplest and quickest way of finding the trouble is by making a "Point to Point" test from the rectifier filament or cathode to ground. A low resistance reading indicates a short and, to determine the defective unit, it is only necessary to follow the previous explanations of this Lesson.

The majority of units, on the commercial market today, are very compact, shielded and many of the connections to the various parts are out of sight. Therefore, in order to determine if the circuit is correct, the only practical method is by making continuity tests.

Remember, a reading on the meter tells you that the circuit is complete and then you must analyze the circuit to see if the resistance reading is approximately correct. A zero reading indicates an open circuit and can be run down by moving one prod along the circuit, touching the exposed parts.

To make accurate tests, no matter what equipment is used, you must keep the circuits in mind, not only those being tested, but those of the tester itself. Unless you do this, the meter readings, while showing the actual conditions, will be of little benefit as you may not interpret them correctly.

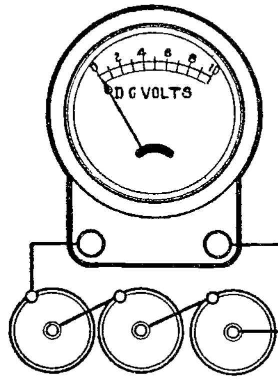


FIGURE 1

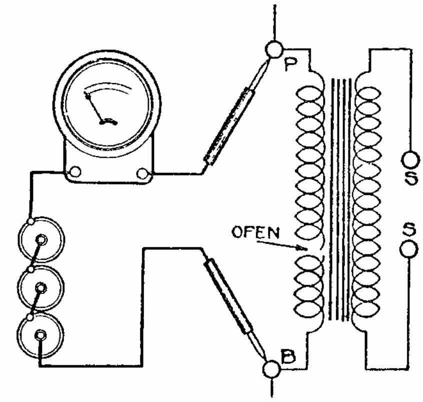


FIGURE 2

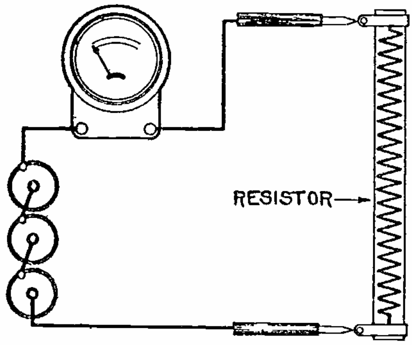


FIGURE 3

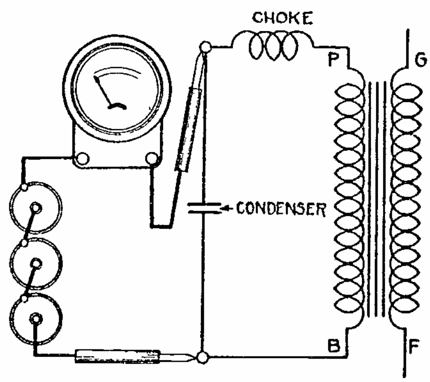


FIGURE 4

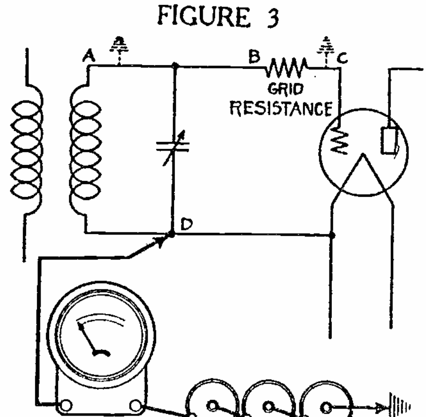


FIGURE 5

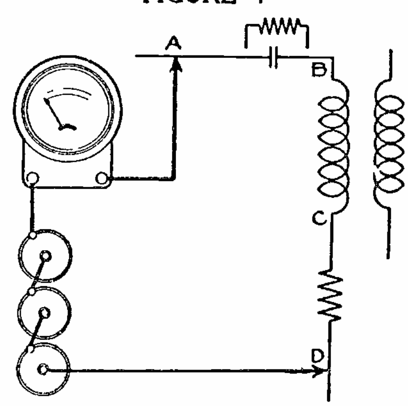


FIGURE 6

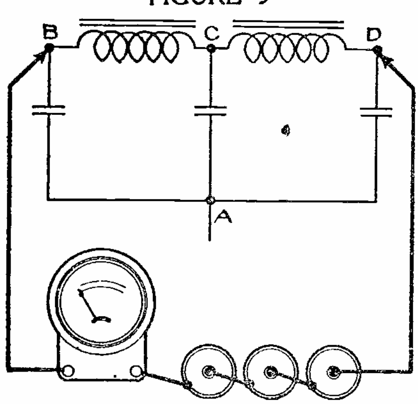


FIGURE 7

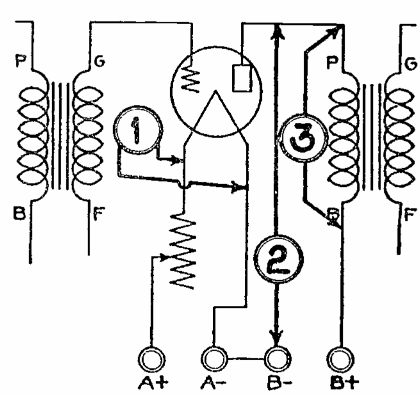


FIGURE 8

LESSON RTS - 4

CIRCUIT TRACING

DE FOREST'S TRAINING, INC.

2533 N. Ashland Ave., Chicago 14, Illinois

RADIO AND TELEVISION SERVICING

LESSON 4

CIRCUIT TRACING

Schematic Diagrams ---------------------- Page 1
Isolation of Circuits ------------------- Page 3
Location of Component Parts ------------- Page 6
Common Connections ---------------------- Page 7
Continuity Testing ---------------------- Page 8
Interpretation of Readings -------------- Page 10
Tabulation of Readings ------------------ Page 11
Layout of Circuits ---------------------- Page 11
Elimination of Duplicate Tests ---------- Page 13
Condenser Tests ------------------------- Page 13
Combining Visual and Electrical Tests ---- Page 15
Complete Diagrams ----------------------- Page 15

There are millions of opportunities around us every day. Some we see and know that they are beyond us, or believe they are beyond us and do not try.

Others we see and look upon them as beneath us -- and in considering an opportunity too low, we often miss the opportunity that is the best.

-- Arthur Brisbane

CIRCUIT TRACING

In our explanation of Continuity Testing we showed how meters are used to check the electrical paths through component parts of Radio and Television apparatus or the wires by which they are connected in their respective circuits. Carrying this idea a little further, you can test all of the various paths in a complete unit.

When carried out on a more complete plan, continuity testing is commonly known as "Circuit Tracing" and is often done to determine the various circuits although they may not be defective. When diagnosing many symptoms of trouble, it is necessary to know the actual circuit connections and, if a diagram is not available, the circuits must be traced.

Perhaps the greatest asset of any Radio and Television service man is his ability to visualize the electrical circuits while looking at an actual unit such as a Receiver or Amplifier. At first, you may find this rather difficult but, with a little practice, you will be surprised at the speed at which you can develop this ability.

SCHEMATIC DIAGRAMS

If you have examined the under side of an ordinary Radio receiver chassis, you must agree that it is quite difficult to follow wires which connect the various units, such as resistors, condensers and coils. A photograph or line drawing of the actual locations of the wires would be just as difficult to follow therefore, it is common practice to simplify the arrangement, without changing the electrical connections, to make up what is known as a schematic diagram.

In these diagrams, the component parts are shown by means of simplified symbols arranged so that the circuits can be completed with the smallest number of lines which represent the connections. Thus, at first glance, the schematic diagram may not even resemble the actual equipment although the electrical circuits are identical.

For example, Figure 1 of this Lesson is the schematic diagram of a 4 tube, A-C/D-C, TRF receiver which, with the exception of the tube types and ballast, could be the unit shown in Figure 1 of the "General Diagnosis" Lesson. To follow these explanations more easily, refer to this former lesson and turn out the illustration sheet so that you can compare its Figure 1 with Figure 1 of this Lesson.

To avoid confusion, we will call Figure 1 of the former Lesson a Pictorial Diagram and Figure 1 of this Lesson a Schematic

Diagram. You will find diagrams of both these types are used in describing certain units but, it is the schematic diagram which contains most of the technical data.

Looking at the Pictorial Diagram you will find the 6SK7 "R-F Amp." tube at the lower right with the "25Z5 Rect." tube directly behind or above it. Going to the left there is the two gang tuning condenser, the "R-F Coil" and then the "speaker" with the "6J7 Det." tube directly above or behind. The "25L6 Output" tube is in the upper left and, as mentioned before, we will omit the ballast as it does not appear in the schematic diagram.

Following the signal, you know its path will be from the antenna, through the r-f amplifier, then the detector, through output tube and through the speaker. With this in mind, look at the Schematic Diagram of Figure 1 in this Lesson. Here, the 12K7GT is the r-f amplifier tube, the 12F5GT is the detector tube, the 50L6GT is the output tube and the 45Z5GT is the rectifier.

The signal circuit starts with the antenna symbol, at the upper left and continues straight across to the right, over to the speaker. The power supply, which includes the rectifier tube, filter and heater circuit is shown below because it can be considered as separate from the actual signal voltage paths. Thus, while the schematic diagram includes symbols which represent all the components, as well as the connections between them, it does not indicate the location of the parts as they are mounted on the chassis.

On the Pictorial Diagram, you see the two gang tuning condenser is located between the r-f coil and the r-f amp. tube. In the schematic diagram, you will find one gang of the tuning condenser, marked 365 mmfd and shown with its trimmer, tunes the grid circuit of the 12K7GT, r-f amplifier tube.

The other section of the tuning condenser is shown in the grid circuit of the 12F5GT detector tube, completely separate from the r-f section. To show that both sections are connected mechanically, some schematic diagrams include a broken line between the condenser symbols, an example of which will be found in the circuit of Figure 3 of this Lesson.

Thus, the lines of the schematic diagram, which indicate the electrical connection between the component parts, seldom resemble the arrangement or location of the actual connecting wires as they are placed in the unit. For example, in the schematic diagram of Figure 1, the high voltage supply wire is shown as a single horizontal line with vertical lines up

to the screen grid of the 12K7GT tube, to the primary of the r-f transformer, to the 1 megohm resistor in the plate circuit of the 12F5GT detector tube and to the screen grid of the 50L6GT output tube. The line continues to the right, down and back to the 4700 ohm filter resistor.

In the actual circuit, as wired in the receiver, the outer end of the 4700 ohm resistor might be connected directly to the screen grid terminal of the 50L6GT tube socket. One end of the 1 megohm detector plate resistor might also be connected to the same socket terminal together with a wire, the other end of which might connect to the screen grid terminal of the 12K7GT tube socket. The supply end of the transformer primary might also be connected to this same screen grid socket terminal.

Thus, while the electrical paths would be identical, the actual arrangement in the receiver would not resemble the layout of the schematic diagram. The point to remember here is that the electrical action is almost instantaneous therefore it makes no difference in what order the parts are connected.

In the example we have just explained, the outer end of the 5700 ohm resistor must connect to four points of the circuit. Therefore, any plan of wiring which accomplishes these connections will complete the electrical circuit properly. Should you be making a continuity test, there would be practically no resistance between the outer end of the resistor and the other four points.

ISOLATION OF CIRCUITS

The arrangement of the schematic diagram also separates or isolates the various circuits, to make them easy to identify. Also, it separates the various stages to show the components which they contain.

Going back to the schematic diagram of Figure 1, you will find the heater circuit is drawn separately at the bottom although the heaters are actually located inside the tubes and connections must be made to the proper tube socket terminals. The heater of the 45Z5GT rectifier tube is shown inside the tube symbol where it belongs but, instead of drawing lines up to the other tube symbols, the heaters are shown in a row and labeled to indicate in which tube they are located.

This arrangement makes it possible to see at a glance that all the heaters are in series across the supply line and that the heater of the rectifier tube has a tap to permit the #47 Mazda dial lamp to be connected across a part of it.

In much the same way, the high voltage plate supply circuit is isolated sufficiently to make it easy to follow. Starting at the lower prong of the attachment plug, the circuit is down and over to the right to the connection between the dial lamp and the 45Z5GT heater. Passing through the lamp and part of the tube heater, these parallel paths join and continue on up to the rectifier tube plate.

The action of this tube allows only the positive alternations of the a-c to pass to the cathode which therefore carries pulsating d-c. Thus, we consider the path as continuing from the plate to the cathode and then on up, through the primary of the speaker or output transformer, to the plate of the 50L6GT tube.

This path or circuit continues inside the tube, from plate to cathode and through the 150 ohm resistor to ground. To complete the path, it is necessary to return to the attachment plug and this can be done by picking up the ground at the lower left of the diagram, going up to the power line, to the right of the switch, through the closed switch and to the upper prong of the plug.

Notice here, considering the prongs of the attachment plug as the source or supply, there is a complete and endless path from the lower prong, through various components of the receiver and back to the upper prong. Thus, with voltage across the plug, there will be voltage across the circuit. All grounds are connected to a common conductor, usually the metal base or chassis of the unit, and therefore are electrically connected to each other.

To avoid confusion, remember, when tracing any circuit the object is to follow the shortest and most direct path from one terminal of the supply back to the other supply terminal. However, it is not necessary to trace the complete circuit every time because certain parts of one path may be common to others.

For example, it is common practice to consider the cathode or filament, depending on the type of rectifier tube, as the positive terminal of the d-c supply. Starting here, there is a path through the 5700 filter resistor, up, over to the left and up to the screen grid of the 50L6GT tube. From here, the path continues inside the tube to the cathode and through the 150 ohm resistor to ground.

The complete path extends to the attachment plug but those parts between the lower prong of the plug and rectifier tube cathode, as well as between ground and the upper prong of the plug, were a part of the 50L6GT plate circuit and therefore need not be traced again. In fact, the outer end of the 5700

ohm filter resistor and ground can be considered as the terminals of the d-c supply for all but the 50L6GT plate circuit.

With this in mind, there is one path up through the one megohm resistor to the plate of the 12F5GT detector tube, and through the tube to the cathode which is grounded. Another path is seen up through the r-f transformer passing to the plate of the 12K7GT tube as well as one to the screen grid of the same tube. Both of these continue inside the tube through a part of the 25,000 ohm control to ground.

Checking back, you will find we have traced all the paths connected to the power supply and if these are all complete with the component parts of each in good order, all of the tubes will receive their proper operating voltages.

The remaining circuits carry only the signal voltages and with the exception of the antenna path, include the control grids of the tubes. The antenna path of Figure 1 includes a .001 mfd condenser and the primary winding of the antenna transformer, the lower end of which is grounded.

The upper end of this winding connects also to one end of the 25,000 ohm control to provide a path of variable resistance in parallel to the winding. This arrangement provides a volume control with a double action because, if the center grounded contact is moved to provide greater resistance in parallel to the coil, it will also reduce the resistance in series with the 12K6GT tube cathode. An increase of parallel resistance will permit a higher signal voltage across the coil while a decrease of cathode resistance will reduce the grid bias and allow greater amplification by the tube. Moving the contact in the opposite direction will reverse both actions.

The grid circuits must be traced completely from the grid to the cathode of each tube. For the 12K7GT tube here, the path is from the grid, through the secondary winding to ground and from the grounded contact up through part of the volume control to the cathode.

The secondary winding is tuned by the 365 mmfd variable condenser connected across it. In case you may have a question, that hooked line, extending from the upper end of the secondary over toward the primary represents a turn or two of wire, wound on the primary but not connected to it. The purpose of this arrangement is to provide some added capacity between the windings and thus provide a more uniform gain over the tuning range.

The grid circuit of the 12F5GT detector tube includes the 5 megohm grid leak and .005 mfd grid condenser as well as the tuned circuit consisting of the r-f transformer secondary,

and 365 mmfd condenser, the lower end of which is grounded. The path is completed to the cathode through the ground.

For the 50L6GT tube, the grid circuit contains a one megohm resistor, the lower end of which is grounded, and is completed to the cathode through the 150 ohm bias resistor.

The voice coil of the speaker is connected across the secondary of the output transformer which provides a complete circuit with the induced voltage of the secondary as the source.

There are nine fixed condensers shown in figure 1. Starting at the left, there is the .001 mfd in series with the antenna. Then the .01 mfd connected from the cathode of the 12K7GT tube to ground, an arrangement which places it in parallel to that part of the volume control resistance in the cathode circuit.

The .005 mfd grid condenser has been mentioned and the 100 mmfd unit, connected from the plate to cathode of the 12F5GT detector tube, acts to bypass any high frequencies in the plate circuit.

The .01 mfd condenser, connected between the detector plate and output tube grid, allows the signal voltages to be carried over but prevents the d-c plate voltage from reaching the grid.

The .02 mfd condenser connected across the output transformer primary, acts somewhat as a tone control by providing a low reactance path for the higher signal frequencies and also tends to prevent oscillation in the output tube.

The 16 mfd condensers, connected from each end of the 5700 ohm resistor, make up the filter to eliminate the pulses which are present in the rectifier output. The .02 mfd condenser, connected from one side of the supply line to ground, placing it across the line electrically, provides a low reactance path for any radio frequencies which may be present in the supply..

LOCATION OF COMPONENT PARTS

As we mentioned earlier in this Lesson, the mechanical arrangement of the component parts may not even resemble the lay out of the schematic diagram although the electrical circuits are identical. This fact is of great importance when tracing circuits because the circuits must be the same regardless of the location of the component parts.

Looking at the circuit of Figure 1 again, the primary of the output transformer is connected in series with the plate of the 50L6GT tube while the secondary is connected across the voice coil of the speaker. Actually the transformer may be

mounted on the speaker which, in turn, may be mounted separately or on the chassis. Again, the transformer may be mounted on the chassis, on top or underneath.

The transformer has four connecting wires, two for the primary and two for the secondary. When mounted on the speaker, the connecting wires to the primary must be long enough to reach the plate of the tube and the high voltage d-c supply. When mounted on the chassis, the connecting wires to the transformer secondary must be long enough to reach the speaker voice coil.

The same general idea is applied to all of the component parts although it is good practice to keep all connecting wires as short as possible especially those which are attached to the grid and plate terminals of the tubes. Long wires may have sufficient capacity to cause feed back which, in turn, produces oscillation with its resulting squeals and howls. This subject will be taken up in detail a little later.

COMMON CONNECTIONS

In tracing circuits diagrams, as well as the wiring of Radio Receivers and Amplifiers, you will find a number of wires connected to a single terminal. This is sometimes known as a "common" connection and may cause confusion. However, if you will think of each of them as merely a junction of several branch circuits, they become as obvious as the other connections.

For example, in the circuits of Figure 1 you will find eleven ground symbols which indicate that eleven points of the complete circuits have a common connection to the metal chassis. Each of these points may be connected separately to the chassis at a most convenient point or several may be connected at the same point.

Another common arrangement is to connect one or more of these grounded points to a grounded point of another circuit. Looking at Figure 1 again, the cathode of the 12F5GT detector tube is grounded and this socket terminal may make a convenient point at which other wires can be connected. For example, the 1 megohm grid resistor and 150 ohms bias resistor of the 50L6GT tube might be mounted with one end on the detector tube cathode terminal but, because this cathode is grounded, the electrical circuits would be the same as those of Figure 1.

Component parts, such as resistors and small condensers, are commonly supported by their connecting wires which are soldered to a terminal of some other part. The terminals ofthe tube sockets are very convenient for this purpose and often, if all

of the terminals are not required for the tube, the spare ones will be used as a mounting point for other components or connecting wires.

The high voltage plate supply usually has a common connection because there are branches of this circuit to practically all of the plates and screen grids of the different tubes. Earlier in this Lesson, we traced the plate supply circuit of Figure 1 and you can see now that some point of the actual circuit could serve as a common connection for all four branches.

CONTINUITY TESTING

In order to make full use of a schematic circuit diagram, in locating a fault in a defective receiver, it is often necessary to make a few continuity tests. This can be done with the test outfit described in an earlier Lesson or with a commercial type of Ohmmeter. The ohmmeter is of greater assistance because its readings can be compared directly to the values shown on the schematic diagram.

To illustrate this part of the work, we will assume you have a battery type receiver with the circuit of Figure 2. Following the plan of the earlier Lessons, your general diagnosis indicated trouble in output stage which includes the 1C5G tube, output transformer and speaker.

The diagram shows you all of the circuits, including the component parts of each, and as your job is to find what is wrong, you are going to trace the circuits of this stage. As the common types of Ohmmeter, or continuity testers contain their own voltage source, the power supply of the receiver is shut off.

Before you can start testing, you must know which tube socket terminals connect to which tube elements and with the great number of tube types in use, it is not practical to try and remember all of them. Instead, you consult a tube chart or manual, look up the base diagram of the particular type and make a pencil sketch of it or else mark the prong numbers on the diagram symbol of the tube.

Looking it up, you will find the 1C5G has an octal base with the following connections.

Pin No.	-	Tube Element
1	-	No Connection (N.C.)
2	-	Filament Pos. (F+)
3	-	Plate (P.)
4	-	Screen Grid (G_2)
5	-	Control Grid (G_1)
6	-	No Connection (N.C.)
7	-	Filament Neg. (F-)
8	-	No Connection (N.C.)

With this information, the diagram, an ohmmeter and the receiver chassis upside down, you are ready to go ahead but be sure the receiver switch is off. In making these continuity tests, you can follow any sequence you desire provided you follow a definite plan and test all of the circuits.

For this explanation we will assume you start with the high voltage circuits and place one meter test prod on the switch which connects to the +90V of the battery, making sure the switch is open and the prod is on the terminal which does NOT connect directly to the battery. The other prod is then placed on the No. 3, or plate terminal of the socket and, if the circuit is in good condition, the meter should read a value of a few hundred ohms.

Moving the test prod from plate terminal No. 3 to screen grid terminal No. 4, the meter should read approximately zero ohms. You can check these readings on the diagram because, between the switch and screen grid, there is nothing but the connecting wire while between the switch and the plate, you will find the primary of the output transformer. Should either of these tests give an extremely high reading, it would indicate an open circuit.

Should the plate circuit test read zero ohms, it would indicate a shorted primary winding in the output transformer or a short between the wires connected to the winding. A visual inspection will usually reveal a short in the wiring.

To test or trace the control grid circuit, one test prod should be placed on socket terminal No. 5 and the other one on ground. The reading here should be a little over 3 megohms because the diagram shows a 3 megohm and an 820 ohm resistors between the grid and ground. A much lower or higher resistance would indicate trouble in these resistors or the connecting wires between them.

When making these tests, be careful to keep your fingers off the metal tips of the test prods because, should you happen to touch them both, the meter would indicate your body resistance, usually from 50,000 to 100,000 ohms.

To complete the tests of this circuit, one test prod should be placed at each end of the 3 megohm resistor, then at each end of the 820 ohm resistor and finally, one at the junction between the two resistors and the other on the "B-" terminal of the battery.

For the filament circuit test, the tube should be removed and one test prod placed on the "A" switch terminal, NOT connected to the battery, and the other on the No. 2 terminal of the

socket. Like tests should be made between the No. 7 socket terminal and ground, also between ground and the A battery negative. The readings for each of these tests should be zero ohms.

Before replacing the tube, tests should be made between the No. 5 grid terminal of the socket and the plate terminal of the preceding tube socket, as well as between the No. 3 plate terminal of the 1C5G tube socket and ground. These tests place the ohmmeter across the coupling condenser and plate by-pass condenser and should each indicate and "infinitely" high resistance.

The output transformer secondary and speaker voice coil circuit present a little different problem because it is impossible to connect the tester across one without connecting across the other. To overcome this difficulty, one connecting wire is unsoldered, either at the transformer or speaker, whichever is most convenient.

After this has been done, the tester can be connected first across the secondary winding and then across the voice coil. In both cases, if the circuit is complete the tester will indicate a low resistance.

INTERPRETATION OF READINGS

In making these various tests, with the schematic diagram before you, it is very easy to see at which positions of the test prods the resistance readings should be high or low. On the actual receiver however, it is often impossible to follow the connecting wires by sight and therefore the readings must be interpretated in order to trace the circuit properly.

In the tests explained for the 1C5G tube in Figure 2, you will remember that, when testing from the B+ switch to screen grid, the reading was approximately zero ohms, while from the switch to the plate, the indicated resistance was a few hundred ohms. While this is a very simple example, it illustrates the need of circuit knowledge to interpret the readings properly.

From your earlier Lessons, you know the screen grid of Pentode type output tubes usually has a direct connection to the power supply while the plate circuit must contain some sort of a load, usually the primary of an output transformer. With this knowledge, you can check your readings and if as given above, you can assume them to be correct. Should the screen grid circuit indicate an appreciable amount of resistance with practically none in the plate circuit, remembering the basic circuit you would immediately suspect a misconnection or other defect.

The point we want to emphasize here is that, when circuit tracing with an ohmmeter, the readings are of little value unless you are sufficiently familar with the circuit to interpret them properly.

Looking at Figure 2 again, a test from the 1.5 volt A battery negative to ground should show zero resistance or a short, while a test from the 90 B battery negative to ground should show a resistance of approximately 800 ohms. If you did not have the circuit diagram you might be suspiscious of this resistance value but most likely a close inspection of the wiring would show the wire from the B battery negative to one end of the 820 ohm resistance.

Then, one test from the B- to the ungrounded end of the resistor would show a short while a test from ground to this same end of the resistor would show the 820 ohms. Thus you would know the resistance was not accidental and was placed in the circuit for a definite reason.

TABULATION OF READINGS

To aid in locating circuit defects, some manufacturers list the proper value of resistance which should be found between all the important points of the complete circuit. These are usually tabulated with values between ground or B+ and the socket terminals which connect to the different tube elements. By following this information, a complete circuit tracing job can be done and a great majority of circuit defects can be definitely located.

We have already traced the circuits of the 1C5G tube of Figure 2 and, assuming the switch to be "off", with the tube out of the socket, the correct tests could be tabulated as follows.

Plate to B+ switch	- 400 ohms
Screen grid to B+ switch	- short
Control grid to gnd	- 3 megohms
Fil. neg. to gnd	- short
Fil. pos. to A+ switch	- short
B neg. to gnd	- 820 ohms

The readings of the circuits for all of the tube elements can be made on the same plan and, if a circuit diagram is available, a check of the tabulated values against those shown on the diagram will readily disclose any discrepancies.

LAYOUT OF CIRCUITS

In case a prepared schematic diagram is not available, the tabulated readings can be used in making your own circuit.

This work is not difficult, if you follow a definite plan, and often may prove of great benefit.

Your inspection of the receiver, including a check of the tubes and type of circuit should give you a complete idea of the general arrangement, particularly of the path of the signal from antenna to speaker. To follow conventional practice, your diagram should be laid out with the antenna at the upper left with the signal path straight across from left to right.

To begin, select a fairly large sheet of paper, the common 8-1/2 x 11" size will do, and turn it so that the 11" sides will be at the top and bottom. Then, evenly dividing the space between them, draw in the tube bases as they appear from the bottom. These should be placed in a straight line across the paper, about 1/3 of the way from the top and, if they are crowded, the rectifier tube socket can be drawn below or omitted until the other circuits have been drawn in.

By consulting the tube base charts of the tube manual or table, you can draw in the socket terminals as they actually appear, but it is well to mark them according to the tube element to which they connect. Thus, for a 6F6 tube the No. 2 terminal connects to the heater, the No. 3 to the plate, the No. 4 to the screen grid and so on.

After the sockets are drawn, you can start to sketch in the component parts which , according to your identification of the circuit, should be close to certain tubes. In the circuit of Figure 2, for example, you know the plate of the mixer tube connects to the primary of an i-f transformer, the secondary of which connects to the grid of the 1N5G, i-f amplifier tube.

In much the same way, the plate of the 1N5G tube connects to the primary of a second i-f transformer, the secondary of which connects to the detector. As the 1H5G contains a diode plate, this is most likely to be the detector.

These connections can be taken from your tabulated test readings because the windings of the usual i-f transformers have an approximate d-c resistance of from 25 ohms to 50 ohms. This gives you a direct check on the connections between B+ and the plate but may be a little confusing for the grid to ground tests.

Checking the grid to ground circuits of Figure 2, you will see the avc arrangement includes the 3 megohm resistor of the filter as well as the 1 megohm volume control. Therefore a direct test from the grid of the r-f or i-f tubes to ground would show a resistance of 4

megohms. When making the tests, this high value should have caused you to make an additional test or two, as explained for the grid circuit of the 1C5G tube, to show you where this high resistance was located.

ELIMINATION OF DUPLICATE TESTS

From the explanations of this Lesson, you can see there are a number of common connections in the circuits of any Radio Receiver and, keeping them in mind, you can eliminate many tests which are duplicates. In the grid to ground circuits of the mixer and i-f amplifier tubes of the circuit of Figure 2, the 3 megohm resistor and 1 megohm volume control are common to both.

Instead of testing each circuit separately, all the way to ground, two circuit tests would show a low resistance from each of these grids to one end of the 3 megohm resistor and the 4 megohms to ground. Thus, that part of the circuit containing the resistors need be tested but once.

Following the same plan, the circuit from the +90V switch can be tested up to some common connection which can then be considered as the B+ supply for the plate and screen grid circuits.

With a little practice, you will find many similar short cuts which eliminate duplicate tests and therefore speed up the work. Should you be in doubt, regarding any common connection, make enough tests to give you a complete picture of the circuit.

CONDENSER TESTS - PAPER AND MICA

The other common units in these circuits are the condensers which generally are used for bypass, coupling or filtering. For the type of testing we have been explaining, the paper and mica types should read about the same as an open circuit. However, real sensitive Ohmmeters which read 10 or 20 megohms and higher may indicate a definite resistance reading when connected across a condenser of this type. This may be due to a parallel circuit therefore, to make sure, it is best to completely disconnect one end of the condenser. Also, all condenser tests should be made on the highest ohms range of the meter.

The dielectric of a condenser is not a perfect insulator therefore it will have some definite value of resistance. However, present standards give this value of "Insulation Resistance" as 500 megohms per Microfarad so that, with the common types of ohmmeter, a good condenser should test the same as an open circuit. In general, whenever a steady resistance value is shown, when an ohmmeter is connected across a paper or mica type condenser only, that condenser should be replaced.

When making these tests, you will find that, in some cases, the ohmmeter hand will jump when the test prods are first placed in position but it immediately drops back to its starting point. This does not indicate any defect but shows the condenser is being charged and the charging current causes the meter hand to deflect. The amount of "kick" depends upon the sensitivity of the ohmmeter used and the capacity of the condenser.

Sensitive ohmmeters, VTVM's in particular, will show a kick when first connected to condensers having capacities as low as .001 mfd or even lower. Less sensitive meters may give an indication only if the capacity is .05 mfd or greater. Because of the wide variation of ohmmeter design it is good practice to check the action of the instrument when testing units known to be good. Then it is easy to compare the reading of similar units and judge their worth.

If a .01 mfd condenser causes a deflection of the meter pointer and the unit being tested is the same capacity but does not give any indication, it is reasonable to assume that the condenser is "open" and requires replacement. If, on the other hand, you have a unit that is below the minimum capacity value required to give a "kick", you cannot tell if the unit is open, although a steady reading will still indicate a leaky paper or mica condenser.

It is a good plan to reverse the meter connections and obtain another kick if there is any doubt, and the charge already present on the plates of the condenser will act to give a greater kick than the first. Some circuits are very critical and a slight leakage will cause series trouble, whereas other circuits may be relatively unaffected.

The coupling condenser between audio stages is a common source of condenser failure. A typical example of this is the .05 mfd condenser between the 12SQ7 plate and 50L6 grid in Figure 3. A leakage resistance in this part forms a d-c path from B+ through the 12SQ7 plate resistor, through the defective condenser and the grid resistor of the 50L6 to ground or B-. The voltage drop tends to make the grid of the tube positive in respect to ground. This positive grid voltage changes the operating "point" of the tube and causes serious distortion. (In service work a voltage across this grid resistor indicates a possible defective coupling condenser and a further test should be made. A gassy output tube can also cause this condition and it is best to substitute a good tube before going further.)

CONDENSER TESTS - ELECTROLYTIC

Electrolytic condensers present a little different problem because they are polarized and, when in good condition, allow

a leakage current. When using an ohmmeter for testing, the prod connected to the positive of the meter battery should be placed on the positive terminal of the condenser. Under these conditions, when the test prods are placed in position the meter will indicate a comparatively low resistance. If the condenser is good the meter pointer will swing almost immediately toward an indication of a fairly high value of resistance.

A high voltage (300 - 500 volts) electrolytic condenser of 8-16 mfd may have 300,000 - 500,000 ohms resistance, although this may vary with different units. A condenser that has been in stock for some time may have considerably lower resistance. Low voltage "electrolytics" (25 - 50 volts) usually have around 50,000 ohms resistance, but here again a wide variance may be found. In terms of current, the leakage through a good electrolytic condenser should be from 50 to 100 microamperes per microfarad at its rated voltage.

By watching the ohmmeter hand, you can check the condition of an electrolytic condenser quite accurately. Let us remind you here that most electrolytic condensers are connected in parallel to a resistance or coil and therefore at least one condenser connection should be isolated before the tests are made.

When the meter hand indicates a low resistance and retains this reading for a minute or so, you are safe in assuming the condenser is shorted and must be replaced.

As explained above, when the meter shows an initial low resistance but changes quite rapidly to higher and higher resistance values, the condenser is presumably in good condition. When the meter hand shows little or no deflection, when the test prods are placed in position, it indicates either an open condenser or one which has lost its capacity. In either case it should be replaced.

COMBINING VISUAL INSPECTION WITH ELECTRICAL TESTS

In all of this work, you can save time by making a close visual inspection as you select the various points for placing the meter test prods. Many of the connecting wires are visible for their entire length, many resistors and condensers are supported by the connecting wires or "leads" and thus their individual circuits can be seen.

Thus it is possible to combine visual inspection with electrical tests by placing the test prods on the visible terminals of a component or connecting wire. For example, if you see a length of hook-up wire which connects from a terminal of one

socket to a terminal of another, you know there should be a direct connection or "short" between the two terminals. Placing the test prods on the terminals should indicate a short but, if a high resistance reading is obtained, it indicates either a break in the wire, inside the insulation or else a poorly soldered connection at either end.

This same general plan can be used for other components such as coils, resistors and condensers and the meter readings should approximate the values your visual inspection leads you to expect. A paper condenser, with the wax melted out or a resistor with the paint blistered should arouse your suspicions in respect to that particular component and a test of it will often locate a defect.

COMPLETE DIAGRAMS

Getting back to the diagram you started to draw, from the information you obtained by a general diagnosis and the tabulated resistance readings, you continue to sketch in the various components, placing them as close to the tube symbols as convenient and, by means of straight lines, indicating their connections to the tubes.

The other ends of these components generally connect to ground or some other common connection and, with one end shown connected to the tube, the common connections can be drawn in as straight horizontal lines with vertical lines to each component.

A good example of a completed drawing of this kind is shown in Figure 3 which is the circuit of a 5 tube, a-c/d-c superheterodyne type of radio receiver. For actual use, the socket terminal numbers of the various tube elements could be added.

Notice here, the path of the signal starts at the upper left, at the antenna and continues straight across to the right, terminating at the speaker. The input and oscillator circuit, with their coils and condensers are shown between the antenna and "Osc-Mod" tube.

The i-f transformer in the plate circuit of this tube carries the signal over to the grid circuit of the "i-f" tube. In turn, the second i-f transformer carries the signal voltage over to the diode plates of the "Det" tube. As the cathode of this tube is grounded, the demodulated signal voltage appears across the 1/2 megohm volume control because, being grounded at one end, it is in series with the cathode and secondary of the 2nd i-f transformer.

The movable contact of the volume control permits any part of the signal voltage to be applied across the path made up of the .003 mfd condenser and the 10 megohm resistor. The resulting voltage drop across the 10 megohm resistor is applied across the grid circuit of the triode section of the 12SQ7 tube.

The plate of this tube is coupled to the grid of the 50L6GT power tube through the .05 mfd coupling condenser. Finally, the output transformer, in the plate circuit of this tube, converts the variations of plate current in its primary to corresponding voltage changes in the secondary and the secondary voltage drives the speaker.

Although the heaters are shown properly in the tube symbols, the heater circuit is drawn in at the lower right as a part of the Power Supply which includes the rectifier tube and pilot lamp.

For the common connection, the grounds are shown directly below the respective parts, one horizontal line takes care of all the high voltage circuits while a second horizontal line completes the avc circuit. As a matter of convenience, the power supply filter is shown above and to the right of the rectifier tube, in line with the common high voltage connection.

With a little practice, you will find it not at all difficult to make your schematic diagrams of any unit you have available and on which you can make the necessary circuit tests. Try it in some simple unit first because, even if you do not make many diagrams of this kind, the experience you gain in drawing them will help you greatly in reading prepared or published diagrams.

Now that the circuits and circuit diagrams have been gone over, for our next Lesson we are going to analyze the distribution of the supply voltage and show you how, by measuring the voltage at various parts of the circuit, you can make a further diagnosis of trouble and simplify the location of defects.

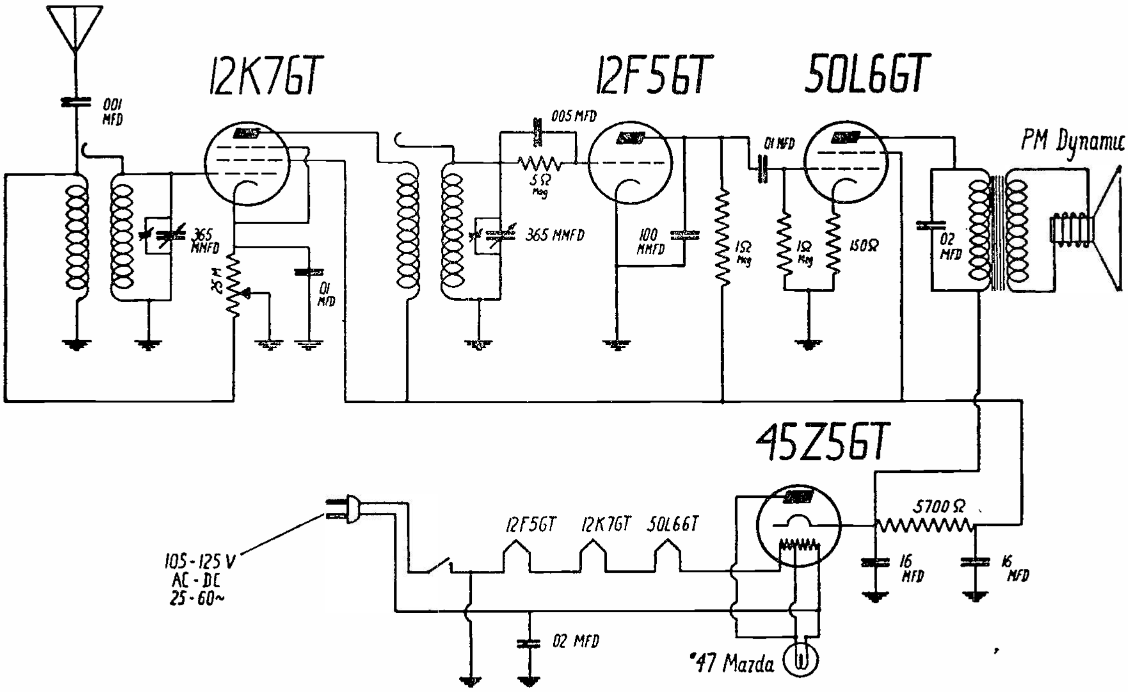


FIGURE 1

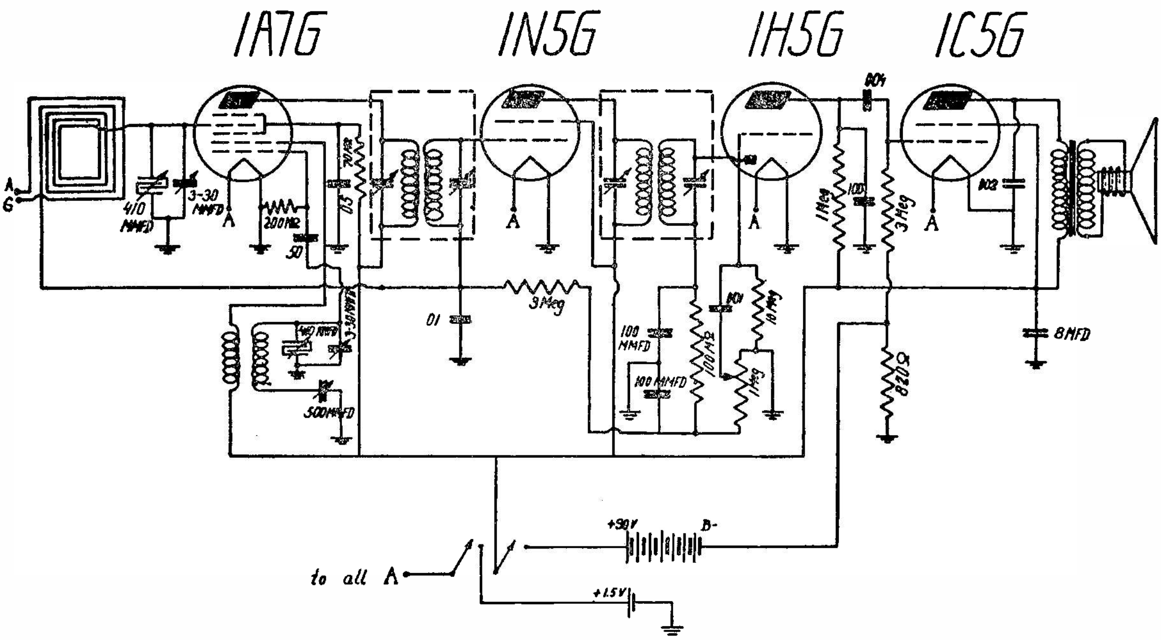
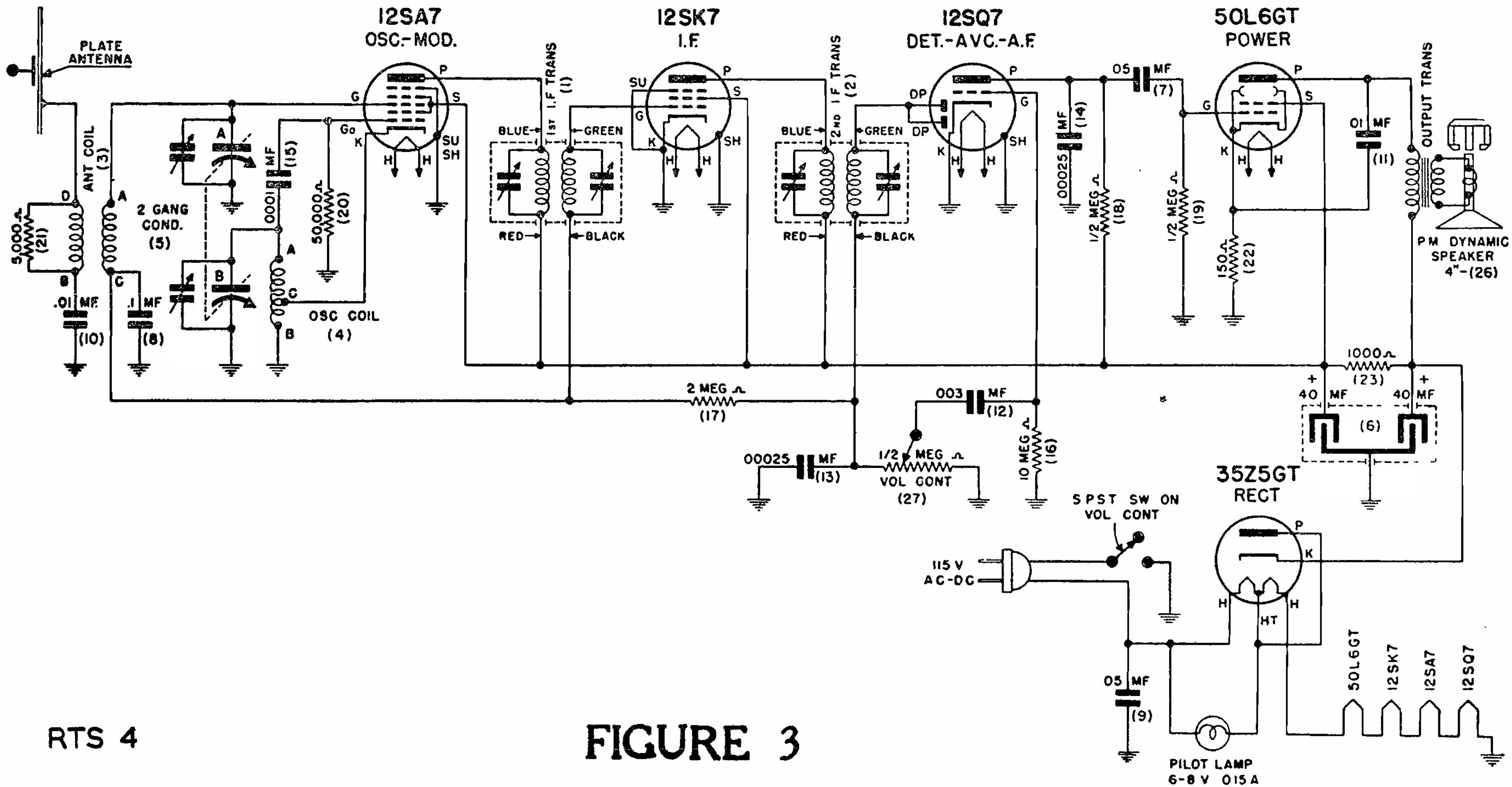


FIGURE 2

RTS 4



RTS 4

FIGURE 3

LESSON RTS - 5

VOLTAGE ANALYSIS

DE FOREST'S TRAINING, INC.

2533 N. Ashland Ave., Chicago 14, Illinois

RADIO AND TELEVISION SERVICING

LESSON 5

VOLTAGE ANALYSIS

Supply Voltages ——————————————Page 1
Ballast Tube ——————————————Page 3
Auto Transformer ——————————————Page 4
AC-DC Battery Combination ——————————————Page 4
Storage Battery Supply ——————————————Page 6
A.C. Supply ——————————————Page 6
High Voltage Supply ——————————————Page 7
Voltage Dividers ——————————————Page 10
Plate Voltage ——————————————Page 13
Screen Grid Voltage ——————————————Page 14
Grid Bias Voltage ——————————————Page 15
Cathode Voltage ——————————————Page 17
Series and Parallel Heater Voltage ——————————————Page 19

x x x x x

OPPORTUNITY

They do me wrong who say I come no more
When once I knock and fail to find you in;
For every day I stand outside your door
And bid you wake, and rise to fight and win.

—Malone

VOLTAGE ANALYSIS

The explanations of the earlier Lessons emphasized the fact that electrically, direct current circuits contained but three quantities, Voltage, Current and Resistance. For A.C. circuits, we added Inductive and Capacitive Reactances which, with Resistance made up the Impedance of a circuit. In the Circuit Tracing Lesson, all of the tests were made with an Ohmmeter or Continuity Tester, using a battery as a source of voltage and therefore they were "Resistance" Tests.

As a battery produces D.C., reactance was not considered and, when testing a coil, which might have a fairly high inductive reactance, only the Ohmic resistance was considered. With a D.C. source, only the charge, discharge and leakage currents of condensers could be tested but as explained, it is possible to obtain fairly accurate indications.

For this Lesson we are going to use Voltage as the main factor of testing, with the Power Supply of the Receiver as the source. In many ways, these voltage tests parallel the resistance tests, as far as results are concerned but, from a practical standpoint, they are sometimes more convenient to make.

Thinking back to Ohm's Law, you can readily see the relationship between Voltage, Current and Resistance is such that, with correct values of Voltage and Resistance, the current must be correct. In a radio receiver, the value of the supply voltage is fairly well standardized or can be measured and thus, by checking the resistance of the various branch circuits, their condition can be determined.

In much the same way, by turning on the power supply and measuring the actual voltages across various points of the complete circuits, the operating conditions can be learned. Thus, by making an analysis of the operating voltages, the electrical condition of the circuits can be determined.

While similar in many ways, Continuity Tests and Voltage Tests each have their own advantages. Complete continuity tests will indicate the condition of all the circuits but show nothing in respect to the operation of the power supply. Voltage Tests will indicate the operating conditions, as far as the voltage supply is concerned but are of no benefit in checking the signal circuits. Therefore, the type of test you make will depend on the information you desire.

SUPPLY VOLTAGES

As we have mentioned before, the actual circuits of most Radio Receivers are quite similar, the difference between them

being mainly in the type of Power Supply. The tube heaters may be operated on either d-c or a-c, but in all types, the plate, screen grid and grid bias voltages must be d-c.

To illustrate the common types of Power Supply, for the illustrations of this Lesson we have selected typical circuit diagrams, each of which has some important variation. To start, we will consider as supply voltages only those which are applied to the tube heaters or filaments and to the rectifier tube, if one is used.

Looking at the circuit of Figure 1 you will see a 4 tube trf a-c/d-c type of receiver with a supply marked "100-120 volts, a-c or d-c", but for purposes of calculation this is usually assumed to be 117 volts. Ordinarily, the common House Lighting circuit is the actual source of voltage.

For the heater circuit you will find the 25Z5, 43, 6D6 and 6C6 tubes are in series with a "Line Cord Resistor" marked 150. These figures must refer to the resistance in ohms and the wording indicates the resistance wire is actually located in the extension cord which plugs into a lighting outlet. This is the type in which the attachment cord becomes quite warm while the receiver is in operation.

To make a voltage test of the circuit, the meter must be the same type as the supply. That is, a D-C Voltmeter will be required for a d-c supply and an A-C Voltmeter for an a-c supply. The frequency of an a-c supply is of no importance here and the tests are the same for the common frequencies of 25, 50 or 60 cycles per second.

For the first voltage test, the meter should have a scale of about 150 volts and, with the attachment cord plugged in and the switch turned on, the meter test prods should be placed on the ends of the cord and its points of connection inside the chassis. The diagram of Figure 1 shows these points to be at the plate terminals of the rectifier tube socket and the metal chassis base.

The full line voltage should be indicated on the meter when the test prods are placed on these points and you will see that the complete heater circuit is also connected across these points and therefore should have the full line voltage across it.

To test the voltages of the individual tube heaters, the voltmeter test prods are placed on the socket terminals which connect to the heater, inside each tube. All the tubes of Figure 1 have six prong bases with the heaters connected to the two larger pins, numbers 1 and 6.

With the voltmeter test prods on terminals 1 and 6 of the 25Z5 tube, the reading should be approximately 25 volts. The type 43 tube should have the same reading while the 6D6 and 6C6 tubes should read from 6 to 6.5 volts each. The total drop across all four tubes, in series, should be the sum of the separate voltages which is 25 + 25 + 6.5 + 6.5 = 63 volts.

The difference between this value and the line voltage, 110-63 = 47 volts should appear across the line cord resistor. To make a test here, one voltmeter test prod could be placed on the plate terminals of the 25Z5 tube socket and the other prod on the heater terminals of the same tube. Although the diagram shows one heater inside and another heater outside the tube symbols they are actually one and the same for each tube.

Thus, from the plate to one heater terminal of the 25Z5, the meter reading should be 47 volts but, from the plate to the other heater terminal, the reading should be 47 + 25 = 72 volts. The lower reading indicates the heater terminal connected directly to the line cord while the higher reading indicates the voltage across both the line cord resistor and the 25Z5 heater.

This test procedure will locate open circuited or short circuited heaters. When the heater is open, the voltmeter reading across it will be high and may approximate the value of the line voltage. This is due to the fact that the voltmeter has a comparatively high resistance and, when connected across an open filament, is in series with the other heaters. The high resistance of the meter reduces the total current in the circuit, thus reducing the voltage drops across the other units so that practically all of the voltage is across the meter.

When a heater is shorted, the low resistance causes little or no voltage drop and thus, a voltmeter connected across it reads zero.

BALLAST TUBE

The heater circuits of Figure 2 are quite similar to those of Figure 1 except that the line cord resistor is replaced with the L-49C ballast tube. The 25L6 output tube has the same heater specifications as the type 43 tube of Figure 1.

The "L-49-C" number of the ballast tube can be interpreted as follows. The "L" indicates that 6.3 volt, .25 amp. dial lamps are to be used. The "49" indicates the total voltage drop across the ballast at the normal current of .3 ampere while the "C" indicates the circuit arrangement as shown.

Voltmeter tests can be made for this circuit as explained for that of Figure 1 except that the heaters are not grounded

directly to the chassis at any point. The full line voltage should be found by placing one test prod on the 25Z5 socket terminals, connected to the plates, and the other test prod on the switch.

AUTO-TRANSFORMER

The circuit of Figure 3 appears to be of the conventional AC-DC type but a close inspection of the supply circuit reveals an auto-transformer, arranged to provide a higher voltage for the plate of the 35Z5GT rectifier tube. When making a general diagnosis of this particular unit, the auto-transformer could easily be mistaken for a choke because it has but a single winding with three connections. However, a check of the circuit would show the supply voltage connected directly across a part of the winding, making it evident that the receiver was designed for A.C. operation only.

The tube heaters are connected in series in the usual way but their voltages add up to a total of 12 + 12 + 12 + 50 + 35 = 121 volts, therefore no ballast or dropping resistor is needed. That is one reason for the popularity of these higher voltage heaters and, in addition, none of the energy or power in the heater circuit is wasted.

The sequence, or order in which the heaters are arranged is done to reduce the possibility of hum, due to A.C. potentials between the heaters and cathodes. As the detector tube is usually the most sensitive in this respect you will find its heater connected at the low potential or "ground" end of the circuit. The rectifier tube operates normally with an A.C. input and therefore its heater is connected at the high potential or "Hot" end of the circuit. As there is no amplification beyond the output tube, its heater connects to that of the rectifier and so on back to the detector.

AC-DC BATTERY COMBINATION

For Figure 4, we show the circuits of a popular type of Battery portable arranged to operate also on A.C. or D.C. house lighting circuits. As a battery operated Receiver, these units can be taken anywhere but the battery life is increased by plugging them into a lighting circuit whenever one is available.

As shown in our drawing, the "Battery-Line Switch" is in the battery position and there is a 6 volt "A" battery for the tube filaments and a 90 volt "B" battery for the plates and screen grids. The "ON-OFF" switch merely connects the "B" battery negative and "A" battery positive to ground.

The specifications of the tubes show all filaments designed for operation at 1.4 volts and .05 ampere or 50 milliamperes of current. Thus, with a 6 volt supply, the filaments are connected in series.

Unlike the heater type tubes, here the filaments must carry the plate and screen currents and provisions must be made to prevent a dangerous increase of total filament current. In the circuits of Figure 4, this is done by resistors connected in parallel to the different filaments.

For example, the 600 ohm resistor is in parallel to the filaments of the 1H5GT, 1A7GT and 1N5GT tubes which means there is approximately $4\frac{1}{2}$ volts across it. At $4\frac{1}{2}$ volts, a 600 ohm resistor will carry a current of 7.5 milliamperes which is equal to the sum of the plate and screen grid currents of the 1T5GT tube. Therefore, in effect, the 600 ohm resistor carries the plate and screen currents of the 1T5GT to ground and the current in the other filaments is not increased.

The plate and screen currents of the 1N5GT add up to but 1.5 MA. and pass through the heater of the 1A7GT which has a total of about 2.5 M.A. in its plate and screen circuits. This extra 4 M.A. of current is then carried by the 350 ohm resistor connected across the 1H5GT tube.

You can make voltage tests here, exactly as explained for the usual AC-DC types but, of course, will need a D.C. voltmeter with a scale of not over 10 volts. Higher scales will do no harm but will be more difficult to read accurately.

When the "Battery-Line" switch is thrown to the Line (L) position, both battery circuits are opened and connections made to the 2000 ohm and 1900 ohm resistors connected to the cathode of the 35Z5GT tube, which operates when the attachment cord is plugged into a home lighting circuit socket.

The heater of this tube, in series with a 600 ohm line cord resistor, operates properly when connected across the 117 volt line. The plate of the tube also connects to the line so that the rectified line voltage is present from rectifier cathode to ground.

The filament circuit is now from rectifier cathode through the 1900 ohm dropping resistor and through all four filaments in series to ground. The plate supply circuit is through the 2000 ohm dropping resistor to that point of the circuit which also connects to the 90V "B" of the battery.

Voltage tests on the filaments should be the same as for battery operation but, if you want to test the voltage across

the 1900 ohms dropping resistor, the meter should have a scale of at least 125 volts.

STORAGE BATTERY SUPPLY

The Auto Radio, using only a 6 volt storage battery as its supply, is common enough to be considered as a distinct type therefore we show a circuit for Figure 5.

As all of the tube heaters are rated at 6.3 volts, the same value as that of the supply, they are connected in parallel to each other. Also, as one terminal of the auto storage battery is grounded to the metal frame of the car, one side of each tube heater can be grounded to the metal chassis of the Receiver which, in turn, is connected to the car frame.

In the circuits of Figure 5, the ungrounded or "Hot" terminal of the battery connects at the lower right to the point marked "To Ammeter." The heater terminals of the tube symbols show only "arrows" but, near the lower right you will find another pair of arrows marked "To Heaters."

This is a common method of simplifying a circuit diagram and you need only assume that one arrow of each tube symbol connects to one of those marked "To Heaters." With this in mind you can see that one end of each heater connects to the hot battery terminal through the switch (34) the R.F. choke (6) and the "9 Amp. Fuse" while the other end is grounded.

For a voltage test here, you can connect a D.C. voltmeter from ground to the "Hot" or ungrounded terminal of each tube socket and should obtain a reading the same as that across the battery.

A.C. SUPPLY

The conventional type of A.C. power supply is shown in the circuits of Figure 6, the main unit of which is the power transformer. The primary connects to the house lighting circuit, which must be A.C., and the various radio receiver circuits are supplied by the secondary windings.

The upper secondary, as shown in Figure 6, supplies current to the Rectifier tube filament only. The center tapped winding supplies high voltage A.C. to the plates of the rectifier while the lower secondary supplies the heater current for the other tubes.

The diagram here is much like that of Figure 5, as far as the heater circuits are concerned because one end of each tube heater is grounded while the other terminates in an arrow

marked "F". This corresponds to the markings of the transformer secondary and indicates that all of the "F" arrows are connected to each other.

Here again, voltage tests can be made by grounding one test prod of an a-c voltmeter and placing the other test prod on the ungrounded heater terminal of the other tubes, excepting the type 80 rectifier. A voltage test of the rectifier is made by placing the test prods on the heater terminals of the socket but great care must be taken not to touch any other terminals as this circuit is at a high potential, in respect to ground.

All of the transformer windings can be tested by connecting a voltmeter across their terminals but here again, be sure the meter scale is sufficiently high. Connected across the outer ends of the rectifier plate secondary, there may be 600 or 700 volts so, if you use a voltmeter, always start with its highest range. If the reading is low, you can always go to a lower scale.

HIGH VOLTAGE SUPPLY

To continue with these explanations, we are going back to the circuit of Figure 1 and check the high voltage supply which includes the rectifier and filter for the usual plate and screen grid circuits.

Following the former explanations, an a-c voltmeter, connected from the plate terminals of the 25Z5 rectifier tube socket to ground, will indicate the value of voltage actually impressed on the circuit. This will be a-c or d-c in accordance with the type of supply.

The next test can be made by placing one meter test prod on the cathode terminal of the rectifier tube socket with the other test prod on ground. Regardless of the type of supply, the voltage here should be d-c. A-c voltage at this point would indicate a defective rectifier tube or shorted wiring between the cathode or heater and plate terminals.

In general, the d-c voltage at the rectifier cathode should be approximately equal to the supply voltage, either a-c or d-c. This is because the maximum value of a-c is 1.4 times the stated value of effective voltage but there are some unavoidable losses in the tube.

Assuming the rectifier tube to be good, a zero value of d-c voltage between cathode and ground would indicate a short in the high voltage circuit. This action has already been explained and will produce excessive heating of the rectifier.

Should the cathode voltage be low, say about 1/2 of the line voltage, the trouble is often caused by an open filter condenser, or one which has lost its capacity. The first filter condenser is possibly at fault because its charges and discharges have an important effect on the D.C. voltage.

Should the cathode voltage be appreciably higher than the A.C. supply voltage, there is probably an open in the high voltage circuit, usually in the filter choke or output tube circuits.

The voltage test, between the rectifier filter and ground shows the input voltage to the filter while a similar test, between the receiver end of the filter choke and ground, shows the output voltage which is available for the circuits of the other tubes. The current, drawn by the other tubes, will cause a voltage drop across the filter choke and thus its output voltage will be lower than its input voltage.

For example, if the plate and screen currents of the other tubes of Figure 1 total 40 milliamperes, the 200 ohms resistance of the choke will cause a drop of 200 x .04 = 8 volts. In other receivers, using the field winding of a dynamic speaker as a filter choke, this drop may be 100 volts or more. To obtain sufficient excitation, the speaker field circuit in Figure 1, is connected in parallel to the filter choke and plate circuits of all but the rectifier tube.

For most receivers, with low rectifier or filter voltages and without the symptoms of a short, a quick test is to merely take a good electrolytic condenser, about 8 mfd at 450 volts and, watching polarity, touch its lead wires to the connections of the installed filter condensers. If this test restores the voltages to normal, it indicates the installed condenser is defective and must be replaced.

Turning now to the circuits of Figure 2, the high voltage supply is electrically about the same as that of Figure 1 except that the supply line is not grounded. Instead, the filter choke is placed in the negative side of the circuit, between the ground and one side of the supply circuit.

Voltage tests here are similar to those explained for Figure 1 except, for D.C. voltage output, the positive test prod can be placed on the rectifier cathode terminal and held there while the other test prod is moved from the switch side of the supply to ground.

The test between the rectifier cathode and line switch will indicate the rectifier output or filter input voltage while

the tests between rectifier cathode and ground will indicate the filter output voltage.

In Figure 1, the two filter condensers have a common grounded negative, the positive terminal of each being connected to one side of the filter choke. In the circuits of Figure 2, the two filter condensers have a common positive terminal connected to the rectifier cathode, the negative terminal of each being connected to one side of the filter choke. The action of the filter choke is the same, whether connected in the positive or negative side of the high voltage circuit but, when in the negative side, the voltage drop across it can be used for other purposes. The details of this arrangement will be given later in this Lesson.

The high voltage circuit of Figure 3 is almost the same as that of Figure 1 except that the auto-transformer will increase the values of both the input and output voltages of the rectifier. The filter choke is really the field winding of the dynamic speaker, having a resistance of 450 ohms. A 20 mfd condenser, connected between each end of the field and ground, completes the filter.

For the high voltage supply of Figure 4, when the receiver is operated on the home lighting circuit, again we have an arrangement similar to that of Figure 1. Here, however, there are two filters, one for the filaments and one for the plate and screen circuits.

Instead of a choke or speaker field coil, these filters are made up of resistors and condensers. This arrangement does not alter the method of making voltage tests except that here, there will be a large voltage drop across the 1900 ohm resistor to provide the low voltage needed for the filaments.

Going now to the auto receiver circuits of Figure 5, we start with a 6 volt, D.C. supply. The vibrator shown at the lower left is really a switch which rapidly changes the connections to permit current alternately in the halves of the power transformer primary. This produces an alternating magnetic flux in the transformer core and it, in turn, induces an A.C. voltage in the secondary.

By a proper turns ratio between the primary and secondary, the low primary voltage is increased, usually to 200 volts or better in the secondary and this high voltage A.C. is the rectifier input voltage. From here on, the circuits are essentially the same as explained for the previous circuits. In making voltage tests here, you will need a low scale D.C. meter for the primary and a high scale A.C. meter for the secondary. Also, as the OZ4G tube of Figure 5 is a full wave

rectifier, input voltage tests should be made between each of the rectifier plates and ground. The rectifier output and filter voltage tests are the same as explained previously.

With the exception of the higher voltage a-c supply, the voltage tests for the rectifier of Figure 6 are the same as those explained for Figure 5. As the type 80 rectifier tube has no separate cathode, the heater or filament is a part of the high voltage circuit and the tests are made by holding one test prod on the filament terminals of the socket.

The filter arrangement of Figure 6 is about the same as those already explained but here, two resistances are connected between ground and the center tap of the high voltage secondary. For this common type of the supply, the high voltage secondary winding is the source, as far as the radio receiver circuits are concerned, there being no direct or metallic connection to the primary winding which, in turn, connects to the house lighting circuit.

VOLTAGE DIVIDERS

In the earlier Lessons, we described a voltage divider as an arrangement, made up usually of resistors, by which two or more values of voltage could be obtained from a single source of voltage. In the High Voltage supplies, explained in this Lesson, the rectifier output provides a single value of high voltage therefore, when lower values of voltage are required for certain circuits, it is common practice to install a voltage divider.

An example of this type of circuit is shown in Figure 2 where you will find three resistors, in series to each other, connected in parallel to, or across, the speaker field. From the laws of parallel circuits, you will remember that all branches have equal applied voltage so that here, the voltage drop across the field will be the voltage across all three resistors.

Tracing the diagram, you will find the cathodes of all but the rectifier tube are grounded and thus all the plate and screen grid currents will return to ground. To complete their circuits, these currents will reach the supply line by passing through the field because it is grounded at one end while the other end connects to the line.

Checking in a tube manual, you will learn that the plate and screen currents of the three tubes in the signal circuits have a total value of approximately 75 milliamperes. Therefore, by Ohm's Law, the voltage drop across the field winding will be equal to .075 amp times 455 ohms which is 34 volts.

Actually, the multiplication shows 34.125 volts but, as the .125 amounts to only 1/8 of a volt, it can be dropped without causing any practical difference because normally this variation is less than the tolerance of a test meter.

From the laws of series circuits, with 34 volts across all three resistors, the drop across each will be proportional to its resistance. As shown on the diagram, the values are 350 M, 100 M and 50 M for a total of 500 M. Compared to the total resistance, the ratios are as follows.

$$\frac{50\text{ M}}{500\text{ M}} = \frac{5}{50} = \frac{1}{10} = .1$$

$$\frac{100\text{ M}}{500\text{ M}} = \frac{1}{5} = .2$$

$$\frac{350\text{ M}}{500\text{ M}} = \frac{35}{50} = \frac{7}{10} = .7$$

With 34 volts across all three, each one will have the following voltage drop.

50 M has 34 x .1 = 3.4 volts
100 M has 34 x .2 = 6.8 volts
350 M has 34 x .7 =23.8 volts
Total = 34.0 volts

To make voltage tests here, the meter can be connected from the line switch to ground and should indicate the full 34 volts. Notice, the line is the most negative point of the circuit therefore, the positive test prod must be placed on the ground.

To test the voltage across the sections of the divider, circuit conditions must be considered quite carefully. Thinking of the common 1000 ohms per volt type of voltemter, the meter current does not exceed one milliampere for any of its ranges therefore, when connected across the field, the meter current is but a negligible part of the total current.

Suppose the test meter is set on its 50 volt range which means the meter circuit has a resistance of 50 M or 50,000 ohms. Connecting this meter across the 50 M resistance of the divider will thus mean the total resistance of that section will drop to 25 M ohms because there are two 50 M resistances in parallel.

Under this condition, the divider will be made up of a 350 M, a 100 M and a 25 M section for a total of 475 M ohms. For the 25 M section the ratio is .052 of the total resistance

QUESTIONS

How many advance Lessons have you now on hand? ______________

Print or use Rubber Stamp:

Name ________________________________ Student No ______________

Street ____

City ______________ State ______________________

1. For what circuits of a Radio Receiver are Supply Voltage Tests of no benefit?

2. When testing the voltage across each heater of a series circuit, what does an exceptionally high reading indicate?

3. Should an a-c or d-c meter be used for testing power transformer voltages? Why?

4. Should an a-c or d-c meter be used for testing the rectifier tube output voltage? Why?

5. What circuit of an Auto Radio power supply requires an a-c meter for a voltage test?

6. Will a voltmeter reading be higher or lower than normal circuit values when measuring the voltage drop across a high value of resistance? Why?

7. At which points should the prods be placed to test the plate voltage of a tube?

8. Using the usual type of test meter in resistance coupled stages, will the indicated value of plate voltage be accurate? Why?

QUESTIONS (Continued)

Name Student No.

9. Using the usual type of test meter, what plan can be followed to measure more accurately the grid bias voltage of resistance coupled stages?

10. Should the circuit arrangement affect the voltage tests of individual tube heaters? Why?

and .052 of the 34 volt total is 1.768 volts. Connecting the voltmeter across the 100 M section will reduce its resistance to 33 M, giving it a ratio of .076 of the total. Under this condition, the drop across the 100 M section would be 2.58 volts.

Following the same plan, with the voltmeter connected across the 350 M section, its resistance would reduce to 43,750 ohms and the drop would be 7.82 volts. These values of voltage drops would be read on the meter and, adding them up, would give 1.768 + 2.58 + 7.82 for a total of 12.168 volts instead of the 34 volts measured across the entire divider of all three.

Setting the test meter to a lower range, say 10 volts, would increase the deflection of the meter hand but would make the readings even more inaccurate. A meter with 10,000 ohms resistance connected across the 50 M section of the divider would reduce the total resistance to 8,333 ohms which is .018 of the total resistance. The meter then would read .018 x 34 or .612 volts instead of the 1.768 volts with a 50 M ohm meter or the 3.4 volts which should be present without any meter.

While a continuity or resistance test would possibly be more satisfactory for this particular circuit, the voltage test will provide a fairly accurate indication if the effect of the meter is kept in mind. For example, the voltage across the field can be measured accurately and the divider has sections of .1, .2 and .7 of the total. With 50 M ohms resistance in the test meter, the readings were approximately 1.7, 2.6 and 7.8 and, to a certain extent, follow the resistance ratio. Thus, by comparing the voltage readings across the sections, rather than the value of the separate readings, the condition of the divider can be checked.

With either a short or open in any of the voltage divider sections, the voltage across the circuit may be correct and when testing across an open section, the indication may appear to be correct. However, the voltage across a shorted section will be zero and, with one section open, the voltage across the other sections will be low, or zero. Thus, by comparing the voltages across all of the sections, the condition of each can be checked.

You will find similar voltage divider circuits in various parts of the high voltage supply but, in every case, there is a complete circuit across all or part of the supply with connections made in between as shown in the divider of Figure 2.

PLATE VOLTAGE

The plate voltage is generally the highest to be found in all but the rectifier tube circuits because the plate circuits usually connect to the high voltage filter output. The plate voltage must not be confused with the supply voltage because plate voltage is measured from the plate to the reference point of each tube.

For the indirect heater types, the cathode is the reference point. For D.C. operated filament types, the negative leg of the filament is the reference point. For A.C. operated filament types, the electrical center of the filament is the reference point. Practically, the electrical center is a center tap of a Power Transformer secondary or resistance connected across the filament.

Going back to Figure 1, to measure the plate voltage of the type 43 tube, one test prod would be placed on the plate terminal of the socket and the other on the cathode terminal. The indicated voltage here would be equal to the supply voltage less the D.C. drop across the output transformer primary and the drop across the 700 ohm cathode resistor.

For the 6C6 detector tube, the test prods would be placed on the plate and cathode terminals of the socket but here, there is a 500,000 ohm resistor between the plate and supply as well as a part of the volume control resistance between the cathode and ground.

The current to operate the test meter must be carried by the 500 M plate load resistor and an increase of current will cause a larger voltage drop which must be subtracted from the supply voltage. As a result, the indicated value of plate voltage would be very low but, a deflection of the meter hand would show the circuit to be complete and possibly in operating condition.

For the 6D6, R.F. amplifier, the plate voltage test would be made in the same way but, because the R.F. transformer primary has a comparatively low resistance, the indicated voltage should be approximately equal to the supply voltage.

These conditions apply in general to all Radio receivers and the plate voltage of transformer coupled R.F. and I.F. stages should be approximately equal to the supply voltage. For detector tubes, resistance coupled to the audio amplifier, the plate voltage will be very low compared to the supply voltage.

For the diode type of detector, as shown in the circuits of Figures 3, 4, 5 and 6, there should be no plate voltage, in

the ordinary sense, as these circuits operate by the signal voltages only.

Resistance coupled audio amplifier tubes, like the triode section of the diode-triode tubes of Figures 3, 4, 5 and 6, will test low plate voltage, as explained for the triode or pentode type of detector.

Transformer coupled audio amplifier tubes will test about the same as output tubes because there will be a drop across the transformer primary winding in the plate circuit and thus the plate voltage will test lower than the supply voltage. While values vary greatly in different models, the voltage drop across the plate load will always be equal to the D.C. resistance of the load times the value of plate current in amperes.

SCREEN GRID VOLTAGES

In many ways, screen grid voltages can be tested the same as plate voltages by placing one test prod on the screen grid terminal of the socket and the other test prod on the cathode or reference point.

For the smaller AC-DC types, as shown in Figures 1 and 2, the screen grid and plate circuits are almost alike and their indicated voltage should also be about the same. The R.F. amplifier tube screen grid connects directly to the high voltage supply and thus the screen grid and supply voltages should be approximately equal.

The detector tubes of Figures 1 and 2 include a high value of resistance in their plate circuits and a higher value of resistance in their screen grid circuits. For these tubes therefore, the indicated screen grid voltage will be very low.

The screen grids of the output tubes connect directly to the high voltage supply and thus the screen grid voltages may test as high, or perhaps a little higher than the plate voltage.

Looking at the output tube circuits in Figure 5, you will find the plate circuit connects to the input end of the 2700 ohm filter resistance, while the screen grid connects to its output end. Thus, if the voltage drop across the filter is greater than that across the primary of the output transformer, the screen grid voltage will be lower than the plate voltage.

Tracing the screen grid circuits of the 6SA7GT and 6SK7GT tubes of Figure 5, you will find a 33 M ohm resistor in series

with the supply. The screen grid currents in this resistor will produce a voltage drop and thus reduce the tested screen grid voltage. This resistor has an .05 MF. condenser at the screen grid end and thus the combination acts as a filter to maintain a more uniform voltage on the screen grids.

GRID BIAS VOLTAGE

For some unknown reason, grid bias voltages seem to cause more confusion than plate or screen grid voltages although basically they are the same. In every case, the voltage is that which exists between the element and the reference point of the tube. About the only difference is that, for nearly all receiver circuits, the grid is negative, in respect to the reference point, while the plate and screen grid are positive.

Starting with the circuits of Figure 1 once again, the grid circuit of the 6D6 tube is from the cathode, through the 150 ohm resistor and part of the 25 M control to ground, from ground through the secondary of the antenna transformer to the grid.

Notice here, that part of the grid circuit, between cathode and ground is also a part of the plate and screen grid circuits and therefore carries the plate and screen grid currents. These currents in the resistors will cause a voltage drop with a polarity that makes the cathode positive in respect to the ground which, in this circuit, is the negative of the supply.

With no signal, there will be no induced voltage in the antenna coil secondary and thus, the only voltage in the grid circuit will be the drop caused by the plate and screen grid currents in the resistances between cathode and ground. Therefore the grid potential will be the same as that of the ground.

Here is the point to remember. If the grid is at ground potential and the cathode is positive, in respect to ground, then the ground and grid are negative, in respect to the cathode. Thus, the voltage between cathode and ground is the "Grid Bias Voltage".

The 25 M variable resistance acts as a volume control because, when the movable contact is turned to place more resistance between the 150 ohm resistance and ground, the grid bias voltage will be greater and the grid will be more negative in respect to the cathode. The more negative the grid the lower the amplification of the tube. When the control contact is turned to reduce the resistance in this circuit, the actions are reversed and the signal output of the tube is increased.

The 6C6 detector tube grid circuit is much the same except that the control is the only resistance between the cathode and ground. Here, the low plate and screen grid voltages, caused by the high values of resistance in the circuits, cause the tube to operate as a detector.

As far as the cathode circuits are concerned, the action of the control is opposite. When the resistance of the 6D6 cathode circuit is reduced, to allow stronger signals, the resistance of the 6C6 cathode circuit is increased to increase the bias and permit the stronger signals to be handled properly.

To make a grid voltage test here, the positive prod of the test meter could be placed on the cathode terminal of the socket and the negative test prod on the grid terminal. This would cause the meter current to pass through the secondary winding, but its resistance is negligible in respect to that of the meter.

For a complete test, the meter prods should be held in position, while the volume control is turned from one extreme to the other. With the control turned "ON" all the way, the voltage should be minimum and compare with the values given in a tube table. Then, as the control is turned down, the voltage should increase.

In this particular circuit, the voltage readings should be the same from cathode to ground as from cathode to grid. Keep this fact in mind because it is not true in many circuits.

The tests for the 6C6 should be made in the same way but, as the control is turned, the action should be opposite to that for the 6D6. Here, at high volume, the voltage should be maximum, dropping to zero at low volume.

For the type 43 output tube, the plate and screen currents reach ground through the cathode and the 700 ohm resistor. This arrangement is similar to that of the 6D6 cathode and the voltage drop across this resistor will make the cathode positive in respect to ground. The control grid circuit is grounded through a 500 M resistor but, with no current or voltage drop here, the grid bias will be the same as the drop across the 700 ohm resistor.

To make a test here, the voltmeter could be connected to the grid and cathode terminals of the tube socket but, under this condition, the 500 M resistor would be in series with the meter across the bias resistor. As the voltage is developed across the bias resistor, this high resistance would cause a low voltage reading.

With a meter of the usual sensitivity, 1000 to 5000 ohms per volt, a better plan is to test the continuity of the grid circuit first and then test the voltage between cathode and ground.

CATHODE VOLTAGE

This particular test is often classed as the "Cathode" voltage and, in the circuits of Figure 1, is the same as the grid bias voltage. In the circuits of Figure 2 however, referring to the 25L6 output tube, conditions are different.

The cathode connects directly to ground and thus, with ground as a reference point, the cathode voltage would be zero. The control grid circuit is grounded through the 150 M grid resistor as well as the 100 M and 50 M resistors of the voltage divider.

As we have already explained the action and voltages of this divider, with the positive end grounded, the grid bias voltage will be the sum of the voltage drops across the 100 M and 50 M section. This is not a self bias arrangement because the voltage drop across the divider depends upon the sum of the plate and screen grid currents for all of the tubes, not of the 25L6 only.

Here a voltage test across the sections of the divider would give the best indication of the actual circuit conditions but, as previously explained the test readings may be low.

The cathode voltage of the 6C6 tube is zero, in respect to ground but the 50 M section of the divider is in series between the grid and ground. Thus, the drop across the 50 M section of the divider is the grid bias voltage.

In the circuit of Figure 3, the 50L6GT output tube circuits are the same as explained for Figures 1 and 2, the grid bias voltage being obtained by the drop across the cathode or bias resistor. All of the other cathodes are grounded directly and thus the cathode to ground voltage should be zero.

For the 12SA7 and 12SK7 tubes, the bias voltage is developed by the signal in the 1/2 megohm volume control because this is the only current carrying resistance between the control grids and ground. Thus, with no signal voltage there will be no external grid bias voltage.

For the triode section of the 12SQ7 tube, a slight grid current in the 5 megohm grid resistor will provide proper bias.

In the circuits of Figure 4, the filaments of the tubes are supplied with d-c and the voltage drop across them provides the necessary grid bias. Remember, in circuits of this type, the negative end of the filament is the reference point for each tube.

With this in mind, you will find the control grid of the 1T5GT tube is grounded through the 3 megohm resistor but, looking at the filament circuit shown at the lower left, the filaments of the 1N5GT, 1A7GT and 1H5GT are connected in series between the negative of the 1T5GT filament and ground. At 1.5 volts per filament, there will be a 4 1/2 volt bias on the 1T5GT grid.

The 1N5GT control grid circuit connects back to the negative end of its own filament to provide zero bias, as recommended in the tube manual.

The control grid circuit of the 1A7GT tube is completed to ground through the 10 megohm avc filter resistance and 1 megohm volume control but includes the 1H5GT filament between ground and its own filament negative. Thus, with no signals, there will be a fixed or minimum bias of 1.5 volts on this tube.

The 1H5GT filament negative is grounded thus there is zero external bias on the grid. However, as explained for Figure 3, the high value of grid load resistance, 10 megohms in this case, provides proper operation.

Voltage tests can be made on the general plans already explained, testing from the control grid to the reference point terminals on the socket, only when the total resistance in the grid circuit is low. For avc circuits and resistance coupled stages, the grid circuit can be tested for continuity and voltage tests made from the reference point to the grid return.

The grid and cathode voltages of Figure 5 are very similar to those of Figure 3. All cathodes, except that of the output tube are grounded and voltage tests can be made as before.

For the circuit of Figure 6, all but the cathode of the type 75 tube are grounded at the socket and the grid bias voltages are obtained from a voltage divider between ground and the center tap of the high voltage secondary winding which, for circuits of this type, is the negative of the high voltage supply. The arrangement here follows the general plan of that explained for Figure 2 and tests can be made in the same way.

SERIES AND PARALLEL HEATER VOLTAGE

In all of these circuits and tests you should have noticed many points of similarity, the principal difference being in the connections of the heaters. For the a-c/d-c and combination battery types, the heaters are commonly connected in series in order to operate at a low value of current while, for the auto and a-c types of circuit, the heaters are connected in parallel to provide operation at low values of voltage.

As far as voltage tests are concerned, each individual heater should operate at its rated voltage, regardless of the circuit arrangement. Thus, you can make the same tests for all types provided you place the test prods on the heater or filament terminals of each individual socket.

To save time, some men place one test prod on ground or other reference point and then move the other prod to the heater terminals of the other sockets. Using this plan, the circuit must be kept in mind because, for a parallel circuit, all the test readings should be equal while for the series circuits, the reading will increase as the test prods are placed across additional heaters.

Thinking in reverse, this method of testing can be used to determine if the heaters are connected in series or in parallel, should you have a doubtful case on which no continuity tests had been made.

For the next Lesson, we are going to take up what is known as "Dynamic Testing" a method which checks a Radio receiver under actual operating conditions.

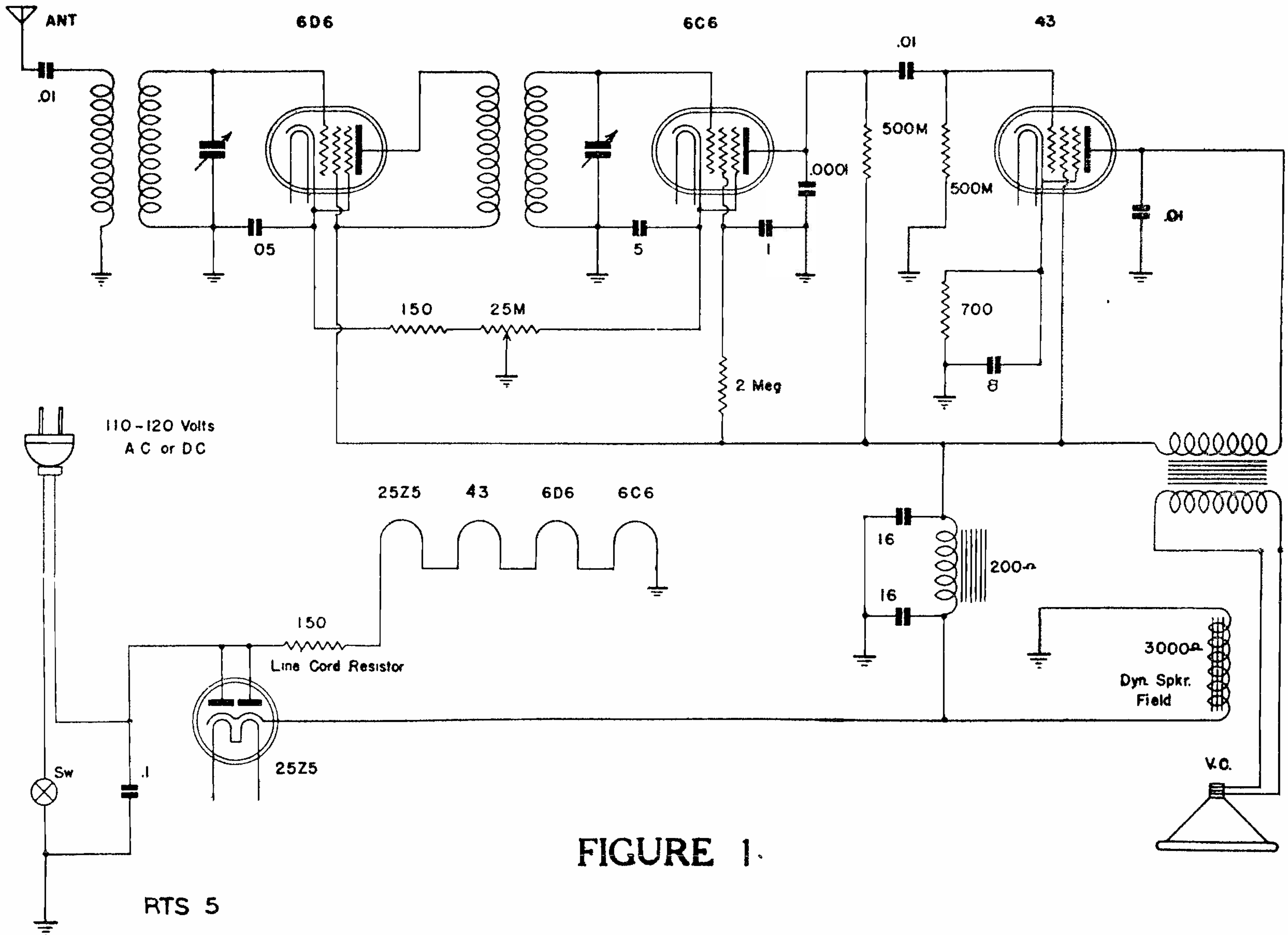


FIGURE 1.

RTS 5

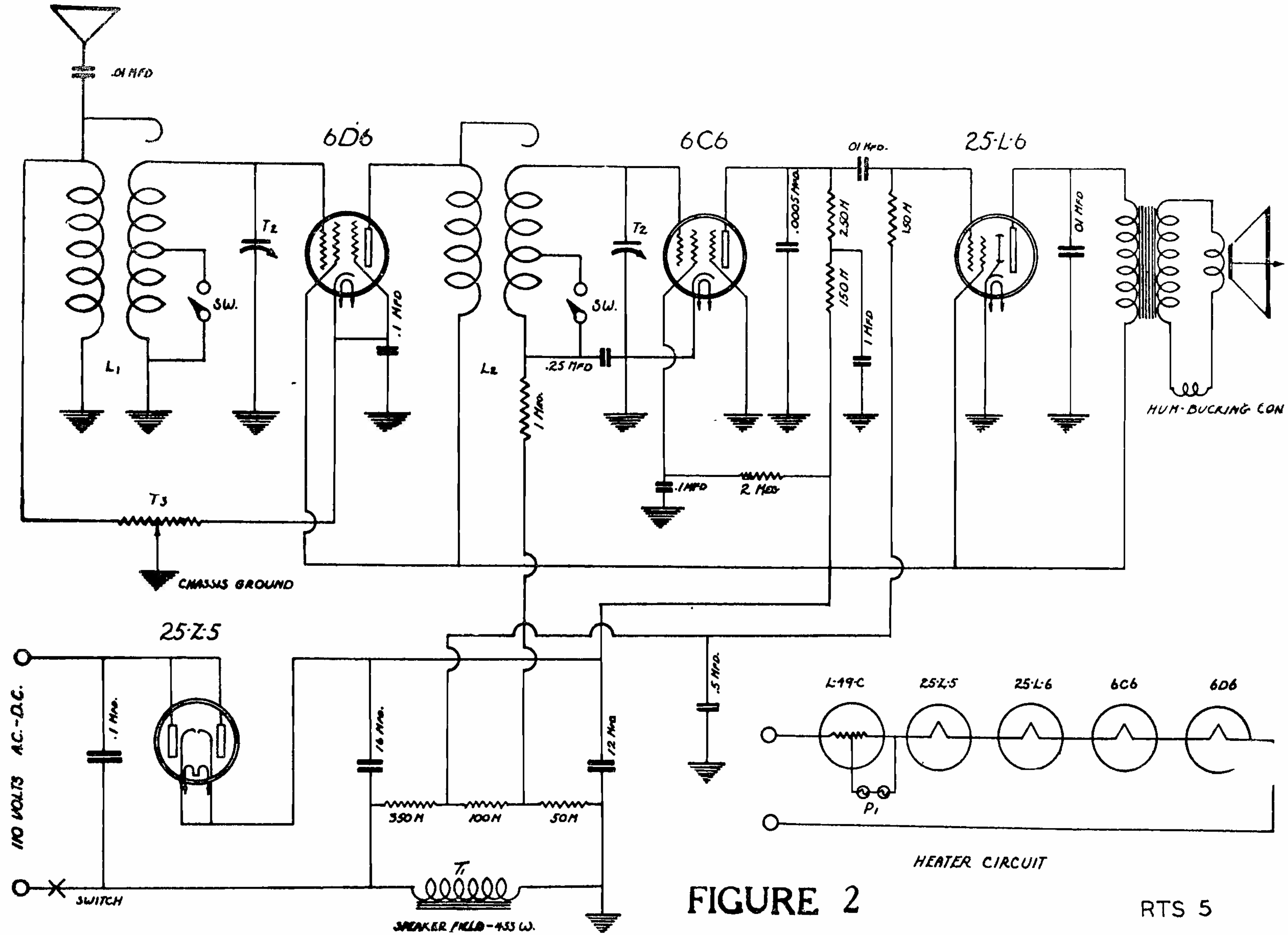


FIGURE 2

RTS 5

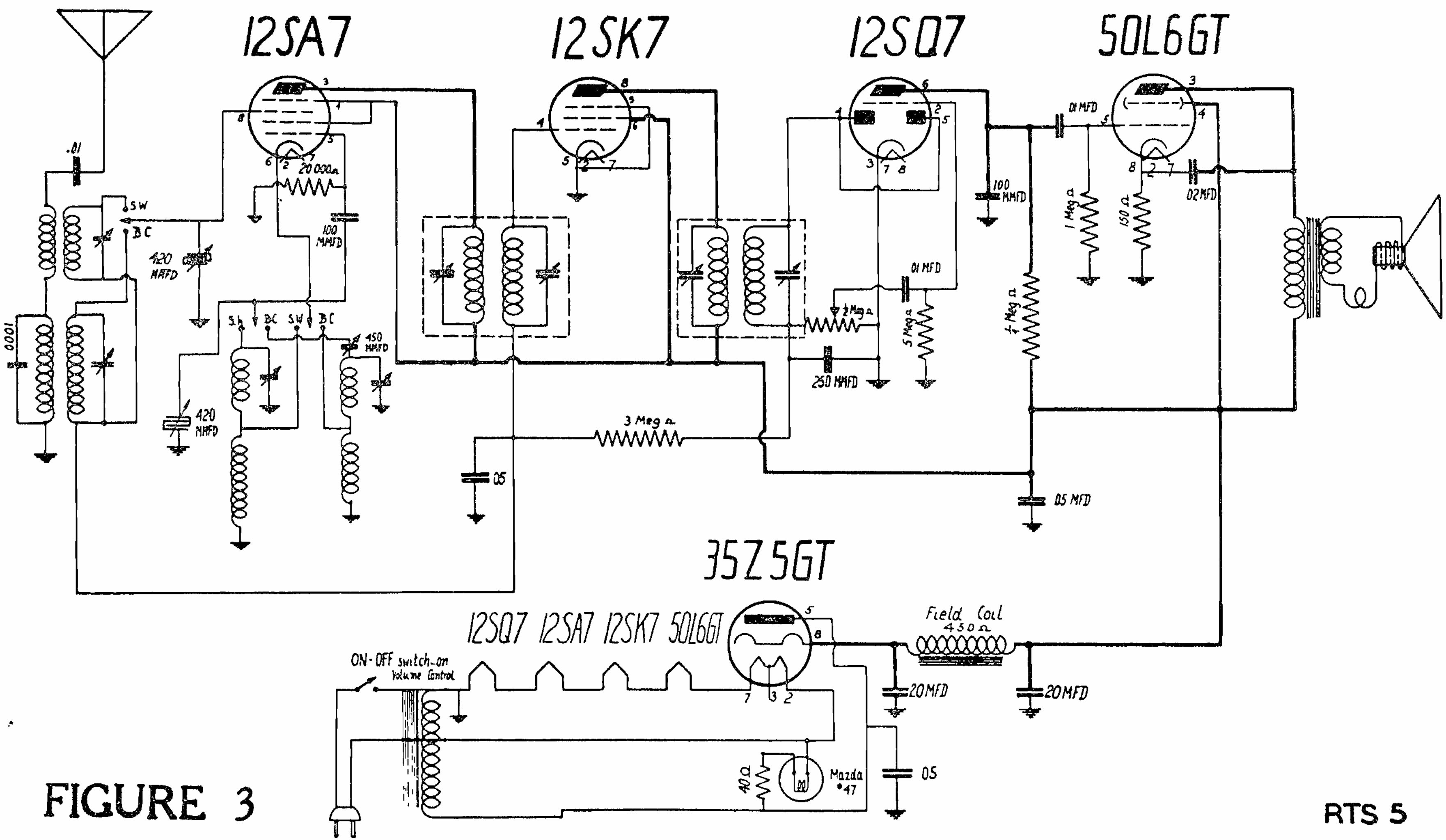


FIGURE 3

RTS 5

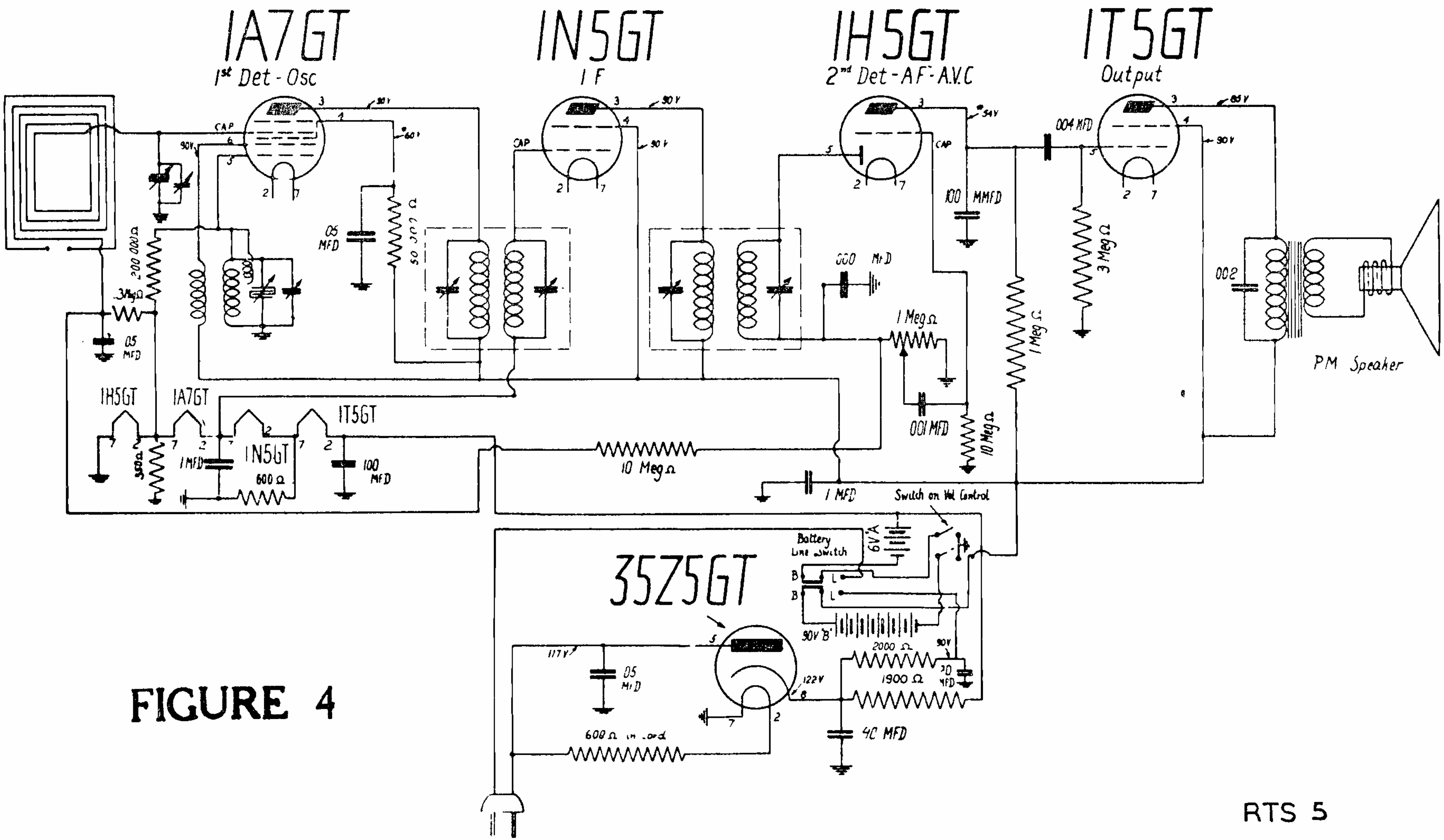
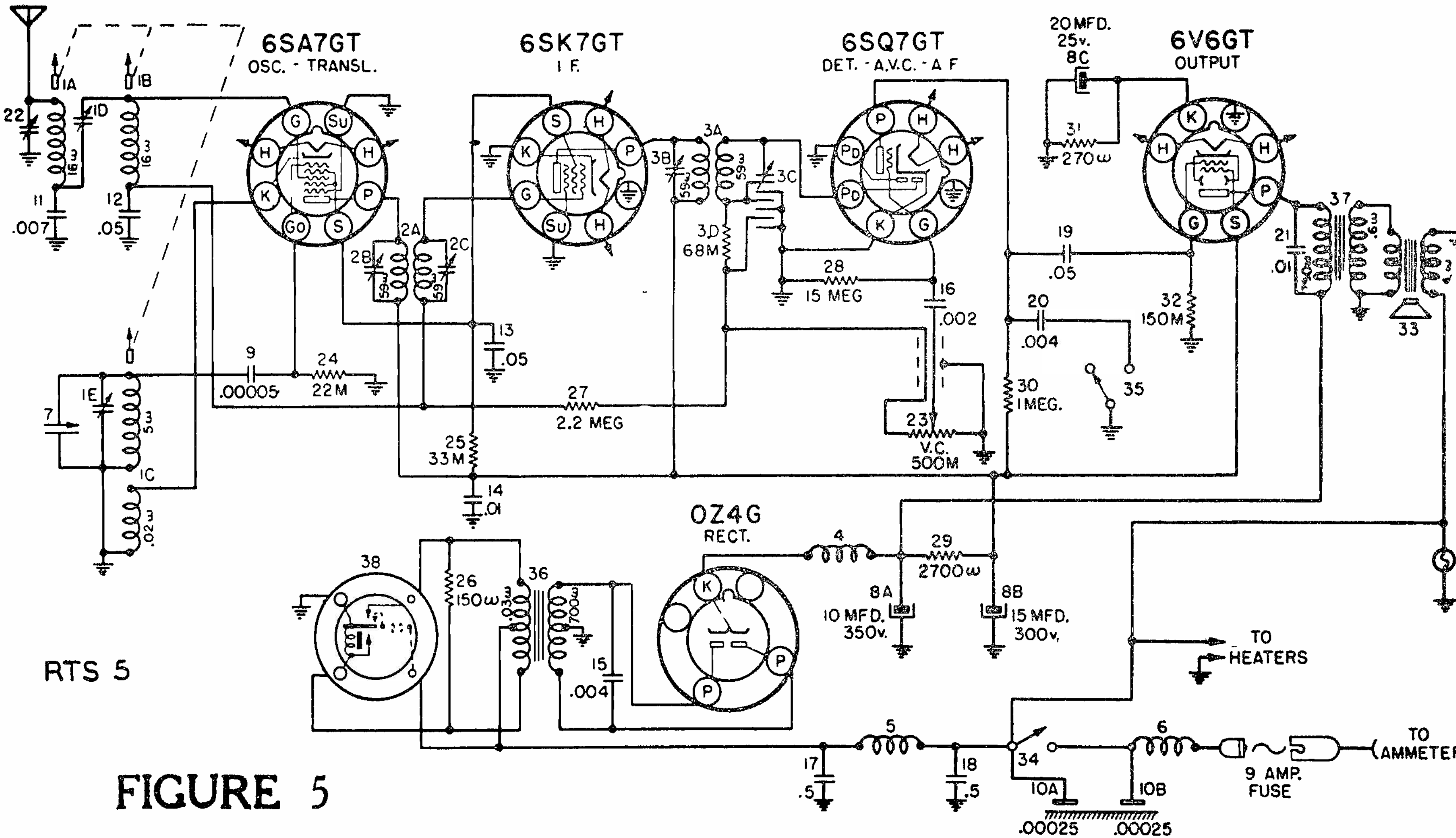


FIGURE 4

RTS 5



RTS 5

FIGURE 5

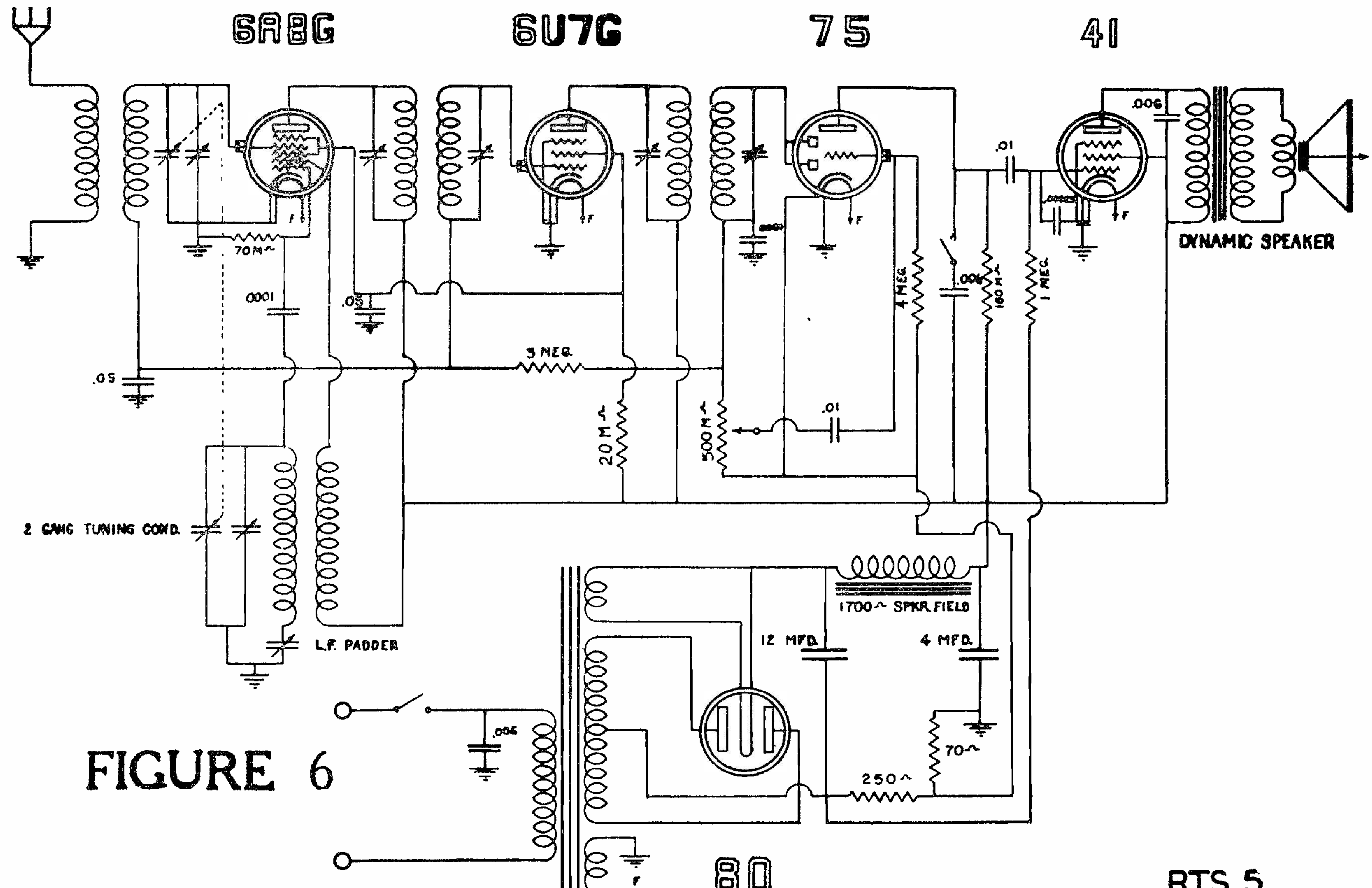


FIGURE 6

RTS 5

LESSON RTS - 6

DYNAMIC TESTING

DE FOREST'S TRAINING, INC.

2533 N. Ashland Ave., Chicago 14, Illinois

RADIO AND TELEVISION SERVICING

LESSON RTS-6

DYNAMIC TESTING

Checking Power Supply -------------------- Page 2
Vibrator Type Power Supply --------------- Page 4
Operating Characteristics ---------------- Page 5
Audio Circuit Tests ---------------------- Page 7
Second Detector And AVC Tests ------------ Page 10
The Rider "Chanalyst" -------------------- Page 11
The RF-IF Channel ------------------------ Page 13
The 6E5 Indicator Eye -------------------- Page 13
Multiplier And Level Control ------------- Page 13
Electronic Voltmeter In RF-IF Channel ---- Page 15
How The RF-IF Channel Can Be Used -------- Page 16
The Oscillator Channel ------------------- Page 17
The Oscillator Level Control ------------- Page 17
Uses of the Oscillator Channel ----------- Page 18
The Audio Frequency Channel -------------- Page 18
The Level Control And Multiplier --------- Page 19
How The AF Channel Is Used --------------- Page 20
The Electronic Voltmeter ----------------- Page 20
The Wattage Indicator Channel ------------ Page 22
General Summary -------------------------- Page 22

* * * * *

The whole object of education is, or should be, to develop the mind. The mind should be a thing that works. It should be able to pass judgment on events as they arise, make decisions.

-- Sherwood Anderson

DYNAMIC TESTING

During the past few years, a great deal of publicity has been given to "Dynamic Testing" as applied to Radio and Television equipment. In order to emphasize its merits, this method is often compared to "Static Testing" and, as the terms are sometimes confusing, we want to explain their meaning.

In the dictionary you will find that "static" means "causing to stand" and thus it is similar to the more common word "stationary'" Also, back in the early Lessons on the "Forms of Electricity" we told you that electricity at rest was known as "static."

Going back to the dictionary again, "Dynamic" means active or effective action and indicates a condition opposite to that of static.

Applying those terms to the ordinary types of Radio and Television equipment, even if all of the switches are turned on and everything is in proper working order, without a signal, the unit is at rest or in a static condition as far as its intended use is concerned.

However, in the explanations of the preceding Lessons, this is the condition under which most of the tests were made. For example, we told you to turn on the power supply and measure the socket voltages of the various elements of the tubes. Then, to turn off the power and measure the resistance or capacity between the socket prongs and the chassis or ground.

The first of these is an operating voltage test while the second is commonly called a "point-to-point" test. As no signal is present, for either of these tests, we can tell you now that they are considered as a "static" analysis.

On the other hand, should we apply a signal of suitable frequency and amplitude to the input circuit of the unit, and then check its effects on the various tubes and circuits, we will have made a "Dynamic" analysis.

Neither method is entirely complete by itself because, when a dynamic analysis indicates trouble in some certain circuit, it is usually necessary to make static tests to determine exactly what part or component of the circuit is at fault.

On this basis, the dynamic method saves time as it eliminates all parts and circuits which are in good order and makes static tests necessary only on those parts which are defective.

As we explained in the earlier Lessons, there are a number of important signal circuits which are not included in the usual static analysis and therefore it may be necessary to make a dynamic test after a static analysis has been completed.

You may have seen the words "Static" and "Dynamic" used frequently in the description of tube testers and, in general their meaning is the same as explained earlier in this Lesson.

The "static" type of tube tester usually measures the emission under fixed values of plate and heater voltages while the "dynamic" type tests the tube under conditions similar to those at which it operates in normal service.

The better types of test equipment, designed for Dynamic analysis and usually known as "Signal Tracers", employ some form of cathode ray tube as an indicator and, under the proper conditions, the ordinary oscilloscope will make a satisfactory "meter" especially when wave form is to be checked. For other tests, where the amplitude is the important factor, the common "Tuning Eye" tube is used to advantage.

Before taking up the commercial types of Signal Tracers, we want to show you how a cathode Ray Oscilloscope can be used as a meter for dynamic tests because it indicates both the amplitude and wave form of voltages in the various tube and supply circuits.

In general, the vertical plates of the Cathode Ray tube are used as the test circuit and test prods, connected to this circuit can be placed across the grid and plate loads of the tubes. By starting at the antenna or input circuit, and follow the signal, stage by stage, a dynamic test, of the r-f and i-f amplifier of a receiver, can be made.

To complete the test, it will be necessary to check the audio amplifier as well as the power supply and, to begin, we want to tell you how the oscilloscope can be used for this part of the work. From a practical standpoint, the power supply should be tested first because, if the proper values of voltage and current are not available, none of the other circuits will operate correctly.

CHECKING POWER SUPPLY

In following these explanations it may help you to think of the oscilloscope as merely a form of voltmeter which, instead of employing the usual scale and pointer, indicates conditions by means of a pattern on its screen. Therefore, to use the equipment efficiently, you will have to learn to "read" the various patterns which appear.

A reading on an ordinary type of voltmeter is actually nothing but a comparison between the voltage across the meter and an arbitrary unit of measure, in this case the volt. The same general idea is carried out in the use of the oscilloscope as

we simply compare the pattern, actually obtained on the screen, with one known to be correct.

Thinking of the usual type of power supply, operating from an a-c lighting circuit, there will be a definite relationship between the frequency of the supply and the pulsations in the output of the rectifier and filter.

With this in mind, the vertical plates of the oscilloscope are connected across the supply circuit and the linear time base, or horizontal sweep circuit, is adjusted until two complete cycles appear on the screen. The synchronizing control is then advanced until the pattern is stationary. Of course the positioning and amplifier controls are adjusted until the pattern has the desired size and location on the screen.

The supply voltage is then removed, one vertical plate is connected to the chassis of the unit and a test prod is connected to the other vertical plate.

Under these conditions, when the test prod is placed on the output of a rectifier tube, cathode or filament as the case may be, which is operating as a full wave rectifier and feeding a condenser input type of filter, the pattern of Figure 1 should appear on the screen. Under the same conditions, but with a choke input type of filter, the pattern of Figure 2 should be seen.

Moving the prod to the output end of the choke, the pattern of Figure 3 should appear but the amplitude of the waves will be but 10% or less of those of Figures 1 and 2.

For half wave rectifiers, the wave form of Figure 4 should appear when the prod is placed on the rectifier output of a condenser input filter. For a choke input filter, the wave should have the form of Figure 5 while, at the output of the filter, a wave like that of Figure 6 will be seen. As explained for Figure 3, the amplitude of the wave of Figure 6 will be much lower than those of Figures 4 and 5.

With the oscilloscope connected and adjusted as explained and keeping the curves of Figures 1 to 6 in mind, we are ready to make a dynamic test on any conventional a-c power supply.

For example, suppose we connect the test prod to a circuit which should produce the curve of Figure 1 but instead, we see the curve of Figure 2. Checking back, Figure 1 is correct for a condenser input filter, full wave rectifier, while Figure 2 is correct for a choke input filter.

As the circuit under test apparently has condenser input but the oscilloscope shows that actually it is choke input, we

know at once that the first filter condenser is open or has lost its capacity, due to some defect.

For another example, suppose that instead of the expected curve of Figure 1, we see the curve of Figure 4 which indicates at once that, instead of a full wave rectifier, the circuit actually is operating as a half wave rectifier. The trouble may be either in the tube or in one half of the high voltage secondary of the power transformer. By replacing the tube with one known to be good and again checking the pattern on the oscilloscope screen, the trouble can be definitely located.

We could go on, almost indefinitely with similar examples but feel the two above will give you the general idea and show you how dynamic tests of this kind can be used to advantage. You know that the output of the common rectifier tube is pulsating d-c and the purpose of the filter is to reduce or eliminate the pulsations in order that the other tubes may have a uniform or steady d-c supply. Using the oscilloscope, as explained above, you simply place the test prod on various points along the current path and, by checking the resulting patterns, see exactly what is actually taking place. The final output of a properly filtered supply will appear on the screen of the oscilloscope as a straight horizontal line.

VIBRATOR TYPE POWER SUPPLY

With the development of the Auto Radio, the vibrator type of high voltage power supply has become sufficiently common to warrant special consideration. In fact, with the exception of portable units, it has almost entirely replaced "B" batteries, for units which must operate without connection to a commercial power line.

Thinking of an automobile installation and briefly reviewing an earlier Lesson, the vibrator acts as a sort of a switch to rapidly reverse the direction of the battery current in the primary winding of a transformer. The changing primary current, which can be considered as a-c, induces a voltage in the secondary by the usual transformer action.

With a large number of turns, the secondary voltage is high, compared to that of the primary, but it is a-c and must be rectified and filtered before reaching the tube circuits. In some systems, rectification is accomplished by means of additional vibrator contacts.

Those vibrators which interrupt the primary and also rectify the secondary current of the transformer are called "Synchronous" or "Sync." types while those which interrupt the primary only are known as "Non-Sync." types.

In connection with vibrator testing there are several important points we want to mention.

First:- To be of real value, tests should be made only while the vibrator is properly connected in the receiver and is operating with the transformer, buffer condensers and other units of the power supply of which it is a part.

Second:- Due to the variation of automobile supply voltages, four storage battery cells should be available for test purposes with provisions to vary the supply voltage from about 4 volts to 8 volts.

Third:- Due to the low cost of replacement and the difficulty of making proper vibrator adjustments without special tools, jigs or other fixtures, it is usually a good policy to replace defective units.

To make an oscilloscope test, we follow the general plan explained for a-c power supplies, the horizontal plates being connected to the internal linear sweep with adjustments made so that the resulting horizontal line extends across the screen of the tube.

The vertical plates are then connected across the transformer primary and, with the unit in operation, the linear sweep is adjusted until two complete cycles appear. The "Sync." control is then advanced until the pattern is stationary.

Under these conditions, a non-sync vibrator, operating properly under load, will produce the pattern of Figure 7, while the sync. type will produce the pattern of Figure 8.

It may be well to mention here that, with the load removed from the filter output, the sync. type of vibrator will produce the pattern of Figure 7. With the exception of the small points at each end of the horizontal portions of the trace, Figures 7 and 8 are alike.

The points are caused by the secondary, or high voltage contacts which close slightly after and open slightly before the primary contacts. While the secondary contacts are closed, the circuit is loaded and thus the primary voltage is reduced. Thus, as mentioned above, it is good practice to remove the load and see if the curve of Figure 8 assumes the shape of Figure 7.

OPERATING CHARACTERISTICS

A study of Figure 7 will reveal practically all of the important operating characteristics of a vibrator and you will

notice the wave approaches a square form. The flat tops and bottoms indicate the periods during which the contacts are closed and the slanting portions show the time required for the vibrator armature, or reed, to swing from one contact to the other.

The time efficiency of a vibrator is the length of time the contacts are closed divided by the time of the cycle. In Figure 7, this would be equal to the length of the horizontal traces divided by the total length of the cycle. While time efficiencies have varied in the past, at present, most vibrators operate between 85% and 90%.

Starting at the left of Figure 7, one pair of contacts have just opened but, due to the presence of a buffer condenser, the voltage dies out gradually, instead of suddenly, causing the slanting part of the trace.

During this time, the vibrator reed is swinging over and makes contact at the time indicated by the left end of the lower left horizontal trace. Because mechanical contact is made, while the buffer condenser is still discharging, the light vertical section of Figure 7 may not be seen on the oscilloscope. The heavy portions show the important parts of the cycle and, for proper operation, the upper and lower portions of the wave should be symmetrical.

The buffer condenser, often called the "Timing Capacity", is an important unit of the power supply because it prevents sparking, or arcing, at the vibrator contacts and thus prolongs their life. Also, acting as a sort of "tank" by absorbing energy while the contacts are closed and releasing energy when the contacts are open, the capacity prevents excessive voltage which would break down the insulation of other parts.

To produce correct wave forms, as shown in Figures 7 and 8, the buffer condensers must have a capacity value which is correct for the vibrator frequency and time efficiency as well as the design of the transformer. Therefore, whenever a vibrator is replaced, although it is marked as an exact duplicate, it is a good plan to make an oscilloscope test of its operation.

Should the capacity of the buffer condenser be too large, a wave form like Figure 9 will appear when a non-sync type of vibrator is operated under load. Compared to the correct wave of Figure 7, you will notice the slanting part of the trace is short and the remedy, of course, is to install a buffer condenser of smaller capacity.

Should the capacity of the buffer condenser be too small, the wave will have the general appearance of Figure 10. However, as this pattern may be easily confused, the load should be

removed from the output of the filter and the wave will then take the form of Figure 11. The remedy here is to increase the capacity until the wave form of Figure 7 is obtained.

The sync. type of vibrator can be checked more accurately with the d-c load removed and, as we have mentioned before, this means to remove the load at the filter output. Always make sure that the filter condensers and choke are properly connected across the transformer secondary.

Under these conditions, too large a buffer capacity will produce the wave form of Figure 9 and too small a capacity the wave form of Figure 12.

Remember, the wave forms shown will not always be exactly duplicated in practice and naturally will vary with different units and circuits. However, the shapes and variations we show are representative and should be easily recognized.

In addition to checking the actual wave forms, the supply voltage should be varied to test the action under the conditions found in the usual automobile. As we mentioned earlier in this Lesson, a variable voltage supply should be available and it should be possible to check the actual voltage being used.

After a satisfactory wave form has been obtained at the normal value, the supply voltage should be reduced until the vibrator stops operating. Next, the supply voltage should be increased slowly until operation starts and a record of this voltage made. Then, increasing the supply up to its maximum of 8 volts, the pattern should be watched closely. The higher voltages will cause a "higher" wave, but its general form should remain steady and of the same shape.

Ordinarily, a vibrator which will start at 5.25 volts and operate steadily up to 8 volts, will work satisfactorily under all ordinary conditions of the average automobile electrical system.

While these dynamic tests will insure proper operation of the vibrator, static tests should be made to determine the values of voltage and current in both the input and output circuits of the unit.

AUDIO CIRCUIT TESTS

In the earlier Lessons, we gave you a general idea of audio distortion and, at this time, will go further and show some of the common wave forms which may be obtained on the screen of the oscilloscope.

For audio work, it is necessary to have some form of signal generator and most r-f oscillators contain such a unit for modulating their high frequencies. Usually, this type of audio oscillator operates at 400 cycles and its output is available separately.

While a source of this kind is satisfactory for certain routine tests, to make a complete audio analysis, it is necessary to have an audio oscillator with an output, the frequency of which can be varied over the entire audio range.

As you already know, the input and output voltages of an audio amplifier should be identical with the exception of amplitude. In other words, the purpose of the amplifier is to increase the amplitude of the signal but all frequencies should be treated alike and, as far as wave form is concerned, the output and input voltages should be alike.

As we mentioned earlier in this Lesson, the oscilloscope is "read" by comparing the patterns, which appear on the screen, with those known to be correct. Therefore it is important that the signal generator produce a true sine wave in order that any variations may be readily detected.

To test audio circuits, the horizontal plates of the oscilloscope tube are connected across the internal or sawtooth sweep circuit and the vertical plates connected across the voltage to be tested. To make sure of the audio oscillator, it is always a good plan to first connect its output across the vertical plates and check the wave form. As previously explained, the sweep frequency is adjusted until about 2 complete cycles appear while the horizontal and vertical controls are moved until the pattern occupies nearly the full area of the screen.

As an added precaution, the output control of the oscillator should be turned from minimum to maximum and the pattern closely watched to make sure the wave retains its proper form. It may be necessary to reduce the vertical gain control of the oscilloscope, as the oscillator output is increased, in order to keep the entire pattern on the screen.

To check the overall fidelity of an audio amplifier, the oscillator output is connected across the amplifier input. For the later type Radio receivers, the volume control can be considered as the input circuit. The vertical plates of the oscilloscope are then connected across the amplifier output which is usually the voice coil circuit of the speaker.

Knowing the input is a sine wave, the output wave form can be easily checked and the volume control of the amplifier should be turned slowly from minimum to maximum position. It will

usually be necessary to reduce the vertical gain control of the oscilloscope, as the amplifier control is turned up, in order to keep the pattern on the screen.

When operating properly, the pattern of the amplifier output will maintain the sine wave form of the input voltage for all positions of the volume control. However, if the operation is not correct, the wave form of the output will be distorted and we want to show you representative traces caused by the more common defects.

For example, if the wave form assumes a shape like that of Figure 13 with sharp positive peaks and rounded negative peaks, it indicates even harmonic distortion. The presence of even harmonics, such as the second, fourth and so on will produce a wave form of this general type and the greater the distortion, the more pronounced the effect.

Should the output wave form assume the general shape of Figure 14, it indicates odd harmonic distortion. Compared to Figure 13, you will notice that distortion of 3rd, 5th and so on harmonics produces a wave in which both the positive and negative halves are alike. Thus you will find the statement that even harmonic distortion produces non-symmetrical waves while odd harmonic distortion produces symmetrical waves.

A third common form of distortion, due to overload of some tube circuit, produces an output wave form of the general shape shown in Figure 15. For single tube circuits, the distortion will appear as shown while, for push-pull circuits, the negative peaks will have the same shape as the positive.

Usually, this latter form of distortion will appear as the gain of the amplifier is advanced and is commonly caused by the signal voltage exceeding the grid bias voltage of some tube.

Remember here that distortion occurs whenever the plate current does not vary uniformly and in proportion to the grid voltage. Therefore, wrong values of plate voltage, plate load, grid bias voltage, bias resistors and so on, will produce distortion.

The value of the oscilloscope test is to indicate the presence of distortion and then, by advancing the connection of the vertical plates from the voice coil circuit toward the second detector, it is comparatively easy to determine where the distortion arises. The various units of this circuit can then be given the usual static tests to determine which of them is at fault.

SECOND DETECTOR AND AVC TESTS

To complete the dynamic tests of a receiver it will be necessary to check the second detector which, in many cases, includes the automatic volume control, (AVC) circuits.

For this work, a modulated R-F signal is needed and, as previously explained, tests should be made to make sure that the signal generator furnishes a pure sine wave at this audio modulation frequency.

The signal generator is connected to the antenna and ground posts of the receiver, through a dummy antenna. and adjusted to any frequency in the Broadcast band.

The oscilloscope connections and settings are similar to those explained for the audio amplifier tests except, for all types of diode detectors, the vertical plates are connected across the detector output. For other types of detectors, such as triodes, the vertical plates may be connected across the grid load of the following tube.

For a general procedure, turn the oscillator output down to the lowest point which will provide a satisfactory vertical height of the pattern on the oscilloscope screen and then adjust the horizontal sweep circuit until two complete cycles appear. As mentioned before, the "Sync." control is then advanced until the pattern is stationary.

The receiver is then carefully retuned, to make sure it is in exact resonance with the signal generator after which the shape of the wave is examined.

Assuming that the preceding R-F and I-F stages have been properly aligned and that the signal generator is producing a pure sine wave, distortion of the pattern at this point indicates trouble in the detector circuit. Following the former explanations, the various units of the circuit can be tested separately.

The next step is to slowly increase the output of the signal generator while closely watching the pattern on the oscilloscope screen. For receivers without AVC, the vertical amplitude of the pattern will increase in proportion to the increase of generator output and it may be necessary to reduce the vertical gain control to keep the trace on the screen. When the circuits are operating properly, the pattern will maintain its sine wave form up the rated output of the unit.

For receivers with AVC, as the output of the signal generator is increased, the vertical amplitude of the pattern will also increase in proportion at first and then more slowly as

the avc operates. Here again, the pattern should retain its sine wave form up to the rated output of the unit.

Should distortion appear, as the generator output is increased, the circuits should be checked, unit by unit, for defects such as leaky, open or shorted condensers and open or defective resistors.

The actual sequence, in which these various tests are made depends greatly on the nature of the complaint or the symptoms of trouble which are found in the receiver. Some men prefer to make tests only on these parts, or circuits, in which trouble is apparent while others feel it profitable, because of the comparatively short time required, to make a complete dynamic test to make sure that the cause as well as the effect of improper conditions will be found and remedied.

THE RIDER "CHANALYST"

As we have explained in this Lesson, the cathode ray oscilloscope is a very good output meter for dynamic tests especially when wave form is the basis of checking.

However, dynamic tests can be made efficiently on an amplitude basis and, for this type of work the small and inexpensive "Tuning Eye" tube can be used satisfactorily as an indicator or output meter.

Working along these lines, a complete method of dynamic testing, or analysis of a complete receiver has been developed around an instrument known as the 'CHANALYST".

Through the courtesy of John F. Rider, the designer, the following explanations are taken directly from the Manual of Instructions supplied with each "Rider Chanalyst".

"One of the major obstacles presented to the successful maintenance of radio receivers in years past has been that the basis of the servicing procedure was not fundamental. In other words, circuit and tube design changes introduced limitations which prohibited universal application of any one particular method of trouble localization. This has been solved by the Chanalyst by utilizing as the basis of operation, the most fundamental of all items associated with radio receiving systems, the signal itself.

"Inasmuch as the sole function of any receiver of any age, type or circuit design is to operate upon the received signal pulse, it stands to reason that the signal is the most important item associated with the receiver. Furthermore, since the function of every electrical component of the complete

receiving system is to perform a definite role with respect to that signal, defects in one or more of these components will have an effect upon the signal. In addition, observation of the character of the signal as it passes through the radio receiving system can be interpreted in terms of existing defects and the localization of this defect. And last, but by far not the least, is the fact that the use of the signal as a basis of trouble localization is independent of circuit design, tube design, age or type of receiver; therefore, this testing system overcomes the limitations which have heretofore confronted various methods of trouble shooting.

"Expressed in the simplest words, the Rider Chanalyst is a device whereby it is possible to trace the passage of a signal through a radio receiver, establish the character of the signal in any portion of the radio receiving or amplifying system, and to identify the nature and location of the fault existing in the receiver or amplifier with maximum accuracy and the greatest possible speed. To accomplish this end, the Rider Chanalyst contains a series of electrical circuits whereby it is possible to probe in EVERY portion of the receiver WITHOUT INTERFERING WITH ITS OPERATION.

"The manner in which the Chanalyst is used for trouble shooting is as follows:

1. To check the power consumption of the radio receiver under test.

2. To feed a signal of known frequency into the receiver, across the antenna-ground terminals.

3. To check the passage of this signal through the r-f, i-f and audio systems of the receiver, inclusive of the operation of the receiver oscillator, and note its general character.

4. To measure d-c voltage in whatever portion of the receiver comes under suspicion as a result of the conclusions derived from the signal tracing test.

5. To apply other tests in accordance with the conclusions derived from the signal tracing test.

"Of utmost value during the process of trouble localization is the fact that as a result of the design of the Chanalyst BOTH SIGNAL AND VOLTAGE conditions existing in ANY portion of the radio receiver CAN be checked simultaneously and NOTHING NEED BE TAKEN FOR GRANTED.

THE R-F - I-F CHANNEL

"The r-f i-f channel, shown in schematic form in Figure 16, is a three state tuned radio frequency amplifier, terminating in a diode detector and an electron-ray indicator tube. This entire assembly constitutes a three-band receiver operative over a frequency range from 95 kc to 1700 kc, thus embracing the complete intermediate frequency range found in commercial broadcast receivers and the conventional broadcast band. Some of the frequencies within the i-f band are also identified as the "weather" band in broadcast receivers. The three frequency bands covered by this channel are:

Band A 94 kc to 260 kc

Band B 240 kc to 650 kc

Band C 600 kc to 1700 kc

"These three bands are identified upon the frequency scales engraved upon the panel and the band switch also bears identifying letters.

THE 6E5 INDICATOR EYE

"If you examine the schematic in Figure 16, you will note that the r-f/i-f assembly of parts comprises what is a complete trf receiver, with the 6E5 electron-ray tube as the final output indicator. Indications upon the electron-ray tube appear as changes in the shadow angle. Without any signal input into the r-f/i-f channel, the 6E5 "eye" is wide open, that is, maximum shadow angle exists. When a signal voltage is present across the input terminals and the channel is resonated to the signal frequency, the indicator tube shadow angle decreases and approaches zero, that is, the "eye" closes. Thus, the variations in shadow angle upon the indicator tube can be interpreted in variations of signal voltage at the input of the channel.

"If the signal voltage at the input of the channel is sufficiently great, the "eye overlaps". Reducing the signal voltage at the input of the channel causes the eye to open or the shadow angle to increase. Thus the 6E5 is a reference indicator which shows the presence of a signal at the input of the channel.

MULTIPLIER AND LEVEL CONTROL

"By means of the combined action of the Multiplier and Level Control it is possible to check or compare signal voltages over a calibrated ratio of 10,000 to 1. The Level Control

covers a continuous range of 10 to 1 and the Multiplier covers a range of 1000 to 1 in three fixed steps which vary by a factor of 10. Therefore, it is possible by means of these two controls to maintain a constant indication upon the r-f/i-f "eye" when the signal voltage at the input of the r-f/i-f channel (the tip of the r-f/i-f probe) varies over a range of 10,000 to 1.

"In turn, it is possible to approximate the change in signal voltage values at the input of the Channel by noting the adjustment of the Multiplier and Level Controls required to maintain a constant indication upon the "eye". To secure proper action of the Multiplier Control, the r-f/i-f pick-up cable must be used.

"When the r-f/i-f pick-up cable is not used and contact is made by means of a direct connection with the grid circuit of the first amplifier tube, the Multiplier is not used. Here the Level Control provides for operation over a range of a 10- to-1 change in signal voltage.

"The general operation of the r-f/i-f "eye", Multiplier and Level Control is as follows Let us imagine that we have two signal voltages of like frequency secured from two different sources. The frequency is not important, but for the sake of illustration we will say that it is 600 kc. Call one voltage "A" and the second voltage "B". To check the relative values of these two voltages, a reference indication must be established upon the "eye" for one of these voltages, say the weaker of the two.

"This is done by first setting the Multiplier and Level Controls at (1) and feeding voltage "A" into the Channel by means of the r-f/i-f probe and tuning the Chanalyst to resonance with this 600 kc signal. Let us further assume that this signal voltage is just sufficient to close the "eye", that is, the shadow angle upon the indicator is zero.

"We now have the initial reference indication upon the "eye" with a certain setting of the Multiplier and Level Control. If we remove signal voltage "A" and apply signal voltage "B", the "eye" will overlap, thus showing an increase in signal voltage at the probe tip. To ascertain just how much greater voltage "B" is than voltage "A", the Multiplier and Level Controls are adjusted until the original reference indication appears upon the "eye" -- in this case the overlap is cleared and the "eye" just closes.

"Now we examine the calibrations indicated by the Multiplier and Level Control knobs. If the Multiplier is at (1), the second voltage "B" is greater than the first voltage "A" by

the figure indicated by the Level Control pointer. If this pointer is set at (4), then voltage "B" is 4 times greater than voltage 'A". If the Multiplier is set at (10), then the second voltage "B" is greater than the first voltage "A" by the figure indicated by the Level Control at 8, voltage "B" is 10 x 8 or 80 times greater than voltage "A".

"Such is the combined action of the Multiplier, Level Control and indicator "eye" to check increase or decrease in signal voltage at the pick-up probe. To establish the extent of loss in voltage, the reference indication is established with the greater voltage and the Multiplier and Level Controls then are retarded when the weaker voltage is checked. The ratio between the two establishes the extent to which the second voltage is less than the first.

"If at any time only the Level Control is used and the reference setting is obtained with the Level Control at some Figure other than (1), then the ratio between the second setting required to restore the indicator to the original reference value and the original setting is the gain in voltage. For example, if original reference indication upon the eye or the voltmeter is secured with the Level Control at (2) and the second setting of the Level Control is (9), the gain in voltage is 9/2 or 4.5. If the original setting of the Level Control was 1.5 and the second setting was 7.5, then the gain in voltage is 7.5/1.5 or 5, etc.

"The accuracy of these gain calibrations is about 20 per cent. You may, of course, find if a quantitative check is made, that the accuracy is greater because the Multiplier capacities are held to within a 5 per cent tolerance, but in general, the aforementioned variation is quoted. This degree of accuracy is sufficient for all general use, particularly for service work.

ELECTRONIC VOLTMETER IN R-F - I-F CHANNEL

"Chanalysts bearing serial numbers above 199 are equipped with a pin-jack located on the front of the panel adjacent to the R-F/I-F Input Jack. The purpose of this jack is to enable connection of the Electronic Voltmeter to the control grid of the r-f/i-f indicator eye. This connection is made by inserting the metal tip of the voltmeter pick-up cable probe into the pin jack, and the plug end of this cable is inserted into the voltmeter jack.

"The purpose of the connection is to enable the use of the voltmeter as a reference indicator in addition to the r-f/i-f eye, particularly with weak signals. It is easier to follow the movement of the meter pointer at low signal levels, than small variations of shadow angle upon the indicator tube.

"In addition, the meter type reference indicator functions in excellent manner when the Chanalyst is used as a field intensity meter or for checking antenna pick-up. A similar pin jack is located in the Oscillator Channel and its use is discussed in the chapter devoted to the Oscillator Channel.

HOW THE R-F/I-F CHANNEL CAN BE USED

"Speaking in generalities, the following are the uses to which the complete R-F/I-F Channel can be put. These uses naturally embrace all minor applications which come within these main headings.

"1. As a conventional comparison broadcast receiver, (without audio amplifier), substantially free from distortion and which operates over a range from 95 kc to 1700 kc. (To listen to the signal a pair of high impedance headphones are plugged into the output jack J-5 in Figure 16, or if desired, a separate audio amplifier can be connected to this jack so as to amplify the signal still further.

"2. As a simple field intensity meter operated over the frequency range from 95 kc to 1700 kc, with the voltmeter connected to the 6E5 tube control grid and with the channel calibrated in signal input and d-c voltage at the 6E5 control grid. (As a receiver, the various channels are substantially flat in gain over the various ranges and will develop about 1.0 volt d-c at the 6E5 control grid for each 12 microvolts of signal at the first r-f tube control grid.

"3. As a means of establishing antenna pick-up of signals from broadcast transmitters operating over the 95 kc to 1700 kc frequency range.

"4. As a means of ascertaining the approximate frequency of any unknown signal, modulated or unmodulated and lying within the 95 kc to 1700 kc range. The source of the unknown signal is of no consequence.

"5. As a resonated vacuum tube voltmeter to establish the relative strength of r-f, i-f and oscillator signals present in the different parts of a radio receiver.

"6. As a means of establishing the presence, absence, and level of signals at points in a radio receiving system where they are supposed to exist and also their presence where they are not supposed to exist. The latter includes conditions when signals of one frequency find their way back into circuits tuned to other frequencies.

"7. As a means of listening to or viewing the signal in any portion of the r-f or i-f systems of a radio receiver, when these systems operate within the frequency range of 95 kc to 1700 kc. This can be done by listening to the signal with headphones or observing it with an oscillograph.

"8. As a means of establishing the origin of noise developed in the r-f or i-f system of a receiver.

"9. As a means of identifying an oscillating r-f or i-f stage in a receiver.

"In these nine general applications of the Chanalyst will be found myriad tests which may be required during the process of trouble shooting.

THE OSCILLATOR CHANNEL

"This Channel is a single-stage, three-band tuned radio frequency mplifier, terminating in a diode detector and an indicator. It operates over the frequency range from 600 kc to 15,000 kc in three bands.

Band A 600 kc to 1700 kc

Band B 1650 kc to 4900 kc

Band C 4800 kc to 15000 kc

"These bands are identified upon the tuning scale engraved upon the panel and also upon the oscillator band switch.

"The Oscillator Channel pick-up cable and probe is similar to that used for the R-F/I-F Channel. In general, the Oscillator Channel is like the R-F/I-F Channel, except that it operates over a different frequency range and is less sensitive.

"Since this channel is intended primarily for application in conjunction with the oscillator in the receiver, lower sensitivity is satisfactory. The operation of the indicator in this system is identical to that of the R-F/I-F Channel in that the eye is a reference indicator used to show the presence of the signal. As such, it serves to check the frequency of the signal voltage applied to the input of the Channel.

THE OSCILLATOR LEVEL CONTROL

"The function of the Level Control in the Oscillator Channel is primarily to enable correct tuning of the Channel with the 6E5 as the reference indicator. By manipulation of the Level Control it is possible to reduce the gain of the Channel so that

the "eye" does not overlap and correct resonance can be obtained between the tuned circuit in the Oscillator Channel and the frequency of the input signal voltage.

USES OF THE OSCILLATOR CHANNEL

"Some of the general applications of the Oscillator Channel are listed below.

"1. Compare signal voltage levels from oscillators.

"2. Check the frequency of signal voltages, as for example, the frequency of the signal voltage developed by the oscillator tube in a radio receiver.

"3. As a resonated vacuum tube voltmeter for qualitative comparison of voltages in excess of .1 volt.

"4. As a constant monitor of the receiver oscillator output and frequency during checking of an intermittent superheterodyne receiver.

"5. As a frequency monitor and voltage level monitor of signals secured from a signal generator or test oscillator. Once again we remind you that in these five general applications of the Oscillator Channel will be found all of the individual tests which are required to locate trouble in oscillating systems of radio receivers operative over the 600 kc to 15,000 kc range.

THE AUDIO FREQUENCY CHANNEL

"The Audio Frequency or A-F Channel is very easy to understand. Like the R-F/I-F and the Oscillator Channels, it is a basic network. The A-F indicator tube, the 6E5, is located adjacent to and to the right of the r-f indicator tube. Next to the A-F Channel indicator is the A-F Level Control and to the right of this Level Control is the Multiplier. Both of these last two controls bear similar identifying names upon the schematic. The input A-F Jack, shown as J3 in Fig. 16, is located at the bottom of the panel and is marked "A-F". The pick-up probe and cable used for this channel is shown in schematic form in Figure 16, and is a direct lead within a shielded braid.

"An output jack, J-6, in Figure 16, is shown connected into the input circuit of the A-F Channel diode. A pair of high impedance phones (Brush Crystal), and oscillograph or another amplifier may be plugged into this jack in order to make audible, visible, or still further amplify the signal present in the output circuit of the A-F Channel. When a device is plugged into this output jack, the a-f diode and indicator are automatically disconnected.

THE LEVEL CONTROL AND MULTIPLIER

"The Level Control and Multiplier in the A-F Channel are used in conjunction with the indicator "eye" and can be employed to ascertain values of a-f voltage and also to compare the relative strength of two a-f voltages ... Once more the eye is a reference indicator. The sensitivity of the A-F Channel is approximately .15 volt.

"To determine the audio voltage at the probe tip, the Level Control and Multiplier are manipulated until the "eye" just closes. This is the reference setting of the a-f "eye". Then, the Level Control and Multiplier readings indicate the value of this audio voltage within 15 or 20 percent.

"If the Multiplier is at (1), the audio voltage at the probe tip when the "eye" is just closed is equal to the number indicated by the position of the Level Control knob times 1.5 ... If the Multiplier is at (100), then the audio voltage at the a-f probe, is equal to the setting of the Level Control required to just close the "eye" multiplied by 150.

"As a means of establishing the difference between two audio voltage levels, the "eye" is used as the reference indicator and the two voltage values are established. The ratio between the two values is the gain or loss, depending upon the indications.

"For example, if one voltage requires that the Multiplier be at (1) and the voltage indicated by the Level Control setting is .5 and the second voltage requires that the Multiplier be at (100) and the Level Control is at .2, then the two respective voltages are .5 for the first and 100 x .2 or 20 volts the second and the gain is 20/.5 or 40 times.

"The audio voltage calibrations apply to constant audio voltages from 150 to 50,000 cycles. The calibrations indicated upon the Level Control and multiplier are within 15 to 20 percent accurate. These voltage calibrations do not apply to 25 to 60 cycle a-c line voltage or to hum voltages.

"This sacrifice of voltage calibrations at these low frequencies is deliberate in order to be able to distinguish hum voltages from the normal modulating voltages.

"The control grid circuit of the amplifier tube is isolated from external d-c voltages, which means that the a-f channel can be used to check an audio signal any place in a radio receiving system or in an audio system where such an audio signal may exist.

"The blocking condenser C-29 enables application of the channel to points which carry d-c voltages not exceeding 1,000 volts. The high impedance input enables application of the A-F Channel to grid as well as plate circuits in audio systems WITHOUT INTERFERING with the normal operation of the amplifier system. The input impedance of the audio channel is about 2,000,000 ohms.

HOW THE A-F CHANNEL IS USED

"1. As an independent single-stage, high-gain amplifier having flat response over the high-fidelity audio range. (The output of the RF-IF Channel can be amplified by the A-F Channel).

"2. As an independent single-stage, high-gain voltage amplifier coupling two separate audio amplifiers, or an amplifier and another audio device.

"3. As a means of checking different audio voltage levels, in different units or the same unit.

"4. As a means of listening to or visually observing an audio signal present at any point in an audio system, at places where the signal is supposed to be present and at points where the signal is not supposed to be present. For visual observation an oscillograph is necessary.

"5. As a means of checking the presence of hum by listening or by approximating the level.

"6. As a means of checking noise in audio systems.

THE ELECTRONIC VOLTMETER

"This device is unique in every respect and like the other Channels in the Chanalyst, has no counterpart in the servicing industry. Also, a single instrument, we identify it as the Voltmeter Channel because of the many functions it performs.

"Unlike the other Channels, the Electronic Voltmeter does not use an electron-ray indicator tube; instead it employs an amplifier tube utilized as a d-c vacuum-tube amplifier. Therefore, it is a vacuum-tube voltmeter of the d-c variety and is not suitable for a-c voltage measurements.

"The Electronic Voltmeter will read both positive and negative voltages without any switching of leads or connections. In other words, one-half of the total scale is devoted to d-c voltages which are negative with respect to the common lead, which may be connected any place in the receiver or amplifier

being checked, and the other half of the total scale is devoted to d-c voltages which are positive with respect to this common lead. The meter is calibrated in four ranges:

-5 volts to 0 to +5 volts
-25 volts to 0 to +25 volts
-100 volts to 0 to +100 volts
-500 volts to 0 to +500 volts

"All of these voltage ranges are available with a constant input impedance of approximately 10,000,000 ohms.

"Special design features enable the Electronic Voltmeter to measure ANY D-C VOLTAGE, either operating or control, ANYWHERE IN THE SYSTEM WITHOUT INTERFERING WITH THE OPERATION OF THE RECEIVER OR AMPLIFIER AND WHILE THE SIGNAL IS PRESENT IN THE CIRCUIT. Furthermore, this voltage may be EITHER POSITIVE OR NEGATIVE with respect to ground or any selected point in the system being checked.

"As a result of its extremely high input impedance, high resistances which so greatly hamper the average high-resistance voltmeter have very little if any effect upon the indications obtained with the Electronic Voltmeter. The d-c voltage present in any point in the radio receiver, amplifier or device being checked can be established by simply placing the Electronic Voltmeter probe tip in contact with that point.

"A brief resume of general tests of all-embracing character which can be made with the Electronic Voltmeter are as follows:

"1. Measure any d-c voltage between 0 and 500 volts, plus or minus with respect to any common point.

"2. Measure rectifier voltages between 0 and 500 volts plus or minus, at the place where rectification takes place without interfering with the operation of the circuit.

"3. Measure d-c voltages at the control grid, screen grid, cathode and plate terminals of oscillating, rectifying or amplifying vacuum tubes without interfering with the function of the tubes, with the signal present in the tube circuits.

"4. Measure leakage voltages through various radio devices.

"5. Measure very low values of voltage developed by sources which do not permit current drain in excess of 1 or 2 microamperes, such as bias cells:

THE WATTAGE INDICATOR CHANNEL

"The Wattage Indicator Channel does just what the name denotes. It indicates the wattage consumption of the radio receiver, amplifier, or device being tested. It is operative upon a-c and a-c/d-c devices. On a-c devices, it is based upon an 80 percent power factor, which is the power factor of the power transformer under load as used in the average radio receiver.

"Referring to the schematic wiring diagram in Figure 16, the wattage indicator as well as the complete Chanalyst power supply circuit is shown.

"The wattage indicator circuit consists of a current transformer, diode rectifier and indicator. The power circuit of the device under test is placed in series with the current transformer by means of the power receptacle located at the rear of the Chanalyst chassis, and identified as "Test Watts". The wattage indicator Level Control is calibrated in Watts with respect to zero shadow angle upon the 6E5 electron-ray, that is, with the eye just closed. The power consumed by the device under test, assuming it to be an a-c device, then is indicated by the setting of the "watts" control when the eye "just closes." This is the actual power consumption within about 10 percent, which is normal tolerance. The range of indications is from 25 to 250 watts. When checking devices of unity power factor the power consumption indications are multiplied by 1.25.

"The idea behind the use of the wattage indicator is that it provides an extremely rapid method of establishing power supply short circuit and other conditions which prohibit further voltage or signal tests. When made simultaneously with a d-c voltage test, it furnishes positive identification of the type of trouble in a "dead" receiver or amplifier or one with reduced sensitivity. The power consumption can be compared with data furnished in Rider's Manual or in service notes secured from other sources. The power consumption test supplemented by the simultaneous d-c voltage test will show "opens" as well as "shorts" upon B supply circuits, as well as subnormal or abnormal loads upon the power supply due to discrepancies in the various tube circuits. All this can be done instantaneously and without endangering the components in the device by prolonged exposure to overloads or extremely high voltages.

GENERAL SUMMARY

"We have completed a general description of the Rider Chanalyst and have described in brief just which elements constitute the various channels, the location of the respective controls upon the panel and a general idea of what these channels will do.

"All of the circuits employ a single free return or "ground" which, however, is not a ground in the ordinary sense of the term. It may be connected to the chassis for signal checking or to a cathode for voltage measurement, if the return for the voltage points is the chassis, it remains at that point for all measurements. It is a "free" ground. In other words, it may be connected to whatever point is the return circuit for signal or d-c voltage measurement.

"Concerning this ground, it is not connected to the primary circuit other than through the filter network C25-C26, hence the Chanalyst can be used with all receivers, providing that AC power is available to operate the Chanalyst."

Although the above explanation gives only the general tests which can be made with this instrument, you should not have any difficulty in determining many specific applications of it to an inoperative receiver. In fact, by properly using this instrument, considerable time will be saved in trouble shooting.

These explanations conclude our description of general testing methods therefore, starting with the next Lesson, we will take up the application of these methods for locating the common causes of Radio Receiver defects.

"All of the circuits employ a single free return or "ground" which, however, is not a ground in the ordinary sense of the term. It may be connected to the chassis for signal checking or to a cathode for voltage measurement, if the return for the voltage points is the chassis, it remains at that point for all measurements. It is a "free" ground. In other words, it may be connected to whatever point is the return circuit for signal or d-c voltage measurement.

"Concerning this ground, it is not connected to the primary circuit other than through the filter network C25-C26, hence the Chanalyst can be used with all receivers, providing that AC power is available to operate the Chanalyst."

Although the above explanation gives only the general tests which can be made with this instrument, you should not have any difficulty in determining many specific applications of it to an inoperative receiver. In fact, by properly using this instrument, considerable time will be saved in trouble shooting.

These explanations conclude our description of general testing methods therefore, starting with the next Lesson, we will take up the application of these methods for locating the common causes of Radio Receiver defects.

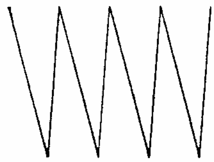


FIGURE 1

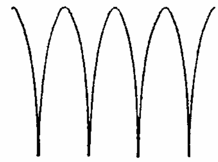


FIGURE 2

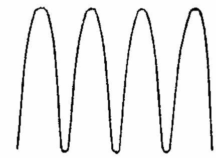


FIGURE 3

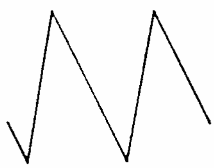


FIGURE 4

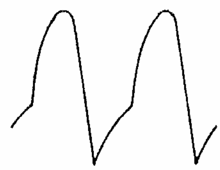


FIGURE 5

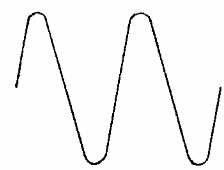


FIGURE 6

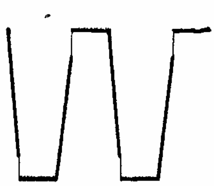


FIGURE 7

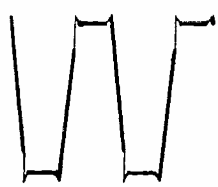


FIGURE 8

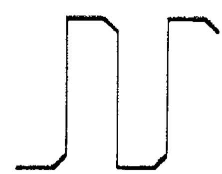


FIGURE 9

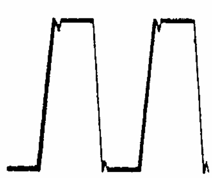


FIGURE 10

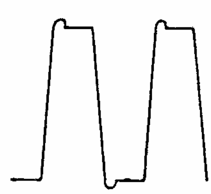


FIGURE 11

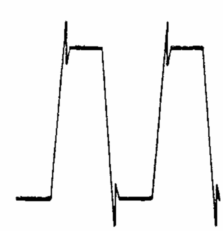


FIGURE 12

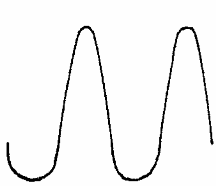


FIGURE 13

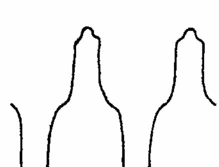


FIGURE 14

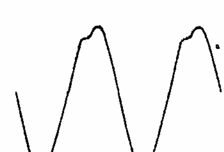
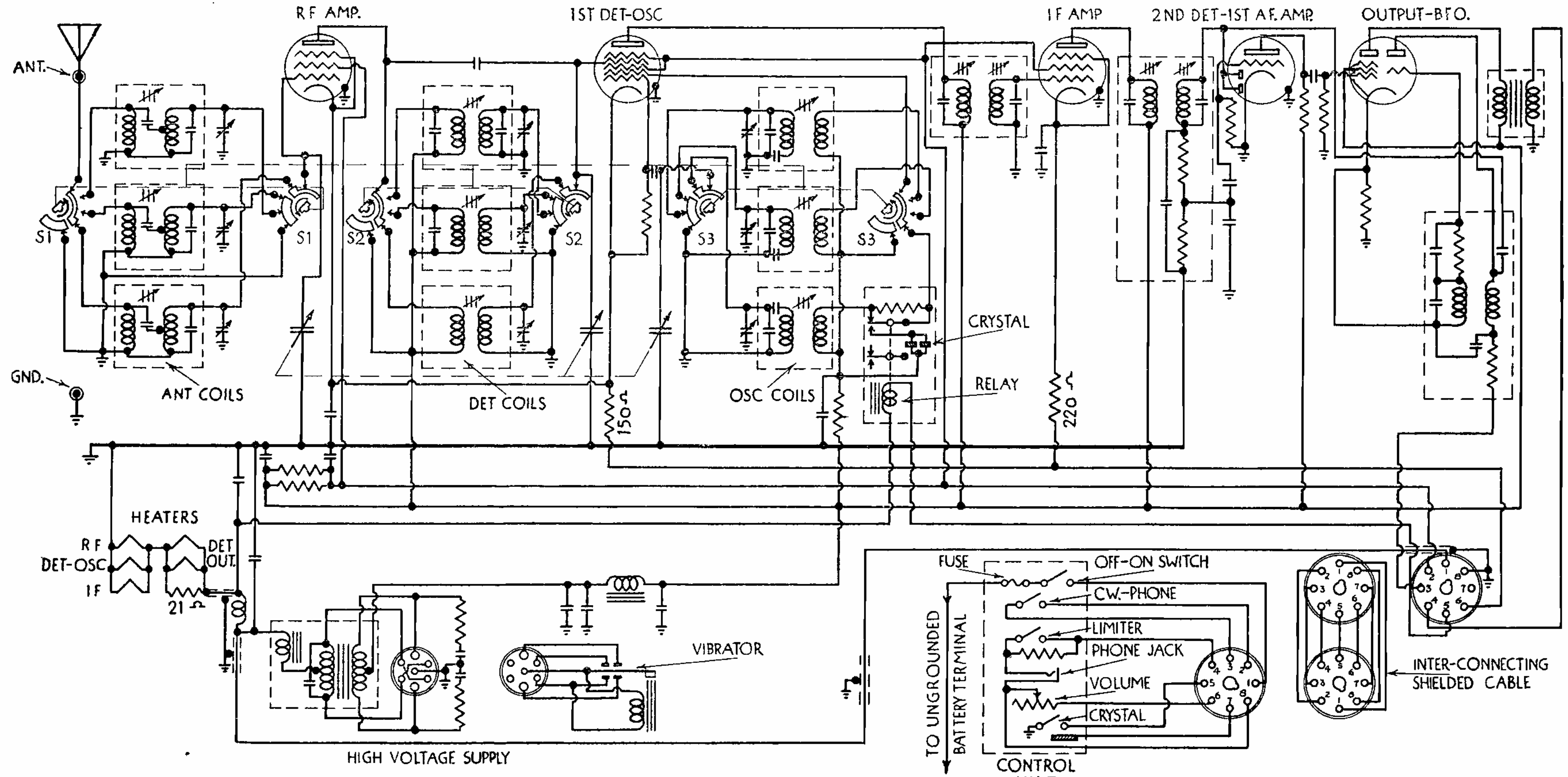


FIGURE 15



ANT.
GND.
ANT COILS
S1
S2
S3
R F AMP.
1ST DET-OSC
DET COILS
OSC COILS
150 Ω
220 Ω
CRYSTAL
RELAY
I F AMP
2ND DET-1ST A.F. AMP.
OUTPUT-BFO.
HEATERS
R F
DET-OSC
I F
DET OUT.
21 Ω
HIGH VOLTAGE SUPPLY
VIBRATOR
TO UNGROUNDED BATTERY TERMINAL
FUSE
OFF-ON SWITCH
CW.-PHONE
LIMITER
PHONE JACK
VOLUME
CRYSTAL
CONTROL UNIT
INTER-CONNECTING SHIELDED CABLE

FIGURE 1

QUESTIONS

How many advance Lessons have you now on hand? ____________

Print or use Rubber Stamp.

Name ______________________ Student No. ____________

Street ______________________________________

City ______________ State ______________

1. What is meant by "Dynamic" testing?

2. How are we able to interpret the "readings" on the screen of a cathode ray tube, used for dynamic testing?

3. What is the advantage of dynamic testing?

4. Under what conditions should a vibrator be tested?

5. Why is it generally a good plan to replace defective vibrator units?

6. What is the time efficiency of a vibrator?

7. What should be the relation between the upper and lower portions of the wave of a properly operating "non sync" vibrator?

8. As a general rule, between what range of input voltages should a good 6 volt vibrator remain operative?

QUESTIONS (Continued)

Name ______________________________ Student No. ____

9. What is the main difference in the patterns produced by odd harmonic and even harmonic distortion?

10. What commonly causes an overload pattern, like Figure 15, to appear on the screen of an oscilloscope?

LESSON RTS - 7

TYPICAL FAULTS - NO SIGNALS

DE FOREST'S TRAINING, INC.

2533 N. Ashland Ave., Chicago 14, Illinois

RADIO AND TELEVISION SERVICING

LESSON 7

TYPICAL FAULTS - NO SIGNALS

Typical Faults ---------------- Page 1
No Signals --------------------- Page 1
Tube Troubles ------------------ Page 2
Power Supply Failure ----------- Page 4
Output Circuit Faults ---------- Page 11
Faulty Component Parts -------- Page 12
Tuning Condenser --------------- Page 13
Oscillator Circuits ----------- Page 14
Input Circuits ----------------- Page 15
Circuit Variations ------------ Page 15

* * * * *

Knowledge is of two kinds: We know a subject ourselves, or we know where we can find information upon it.

-- Samuel Johnson

TYPICAL FAULTS

In the first Lesson of this Radio and Television Servicing Section, we listed six general types of trouble as follows:

No Signals
Lack of Volume
Broad Tuning
Distortion
Noisy Reception
Intermittents

This grouping was made on the basis of customer complaints, rather than electrical defects because, in almost every case, the complaint is the starting point of a diagnosis, test and final repair. Also, as one defect can cause more than one of the general types of trouble, by basing our explanations on the complaint, we can follow practical procedure more closely.

With this general plan in mind, the former Lessons included instructions on making a general diagnosis, identifying the circuit, making continuity tests, tracing circuits, analysis of operating voltage tests and dynamic testing. These explanations covered all service work in a general way and, starting with this Lesson, we are going to show you how to apply these various tests to the six general types of trouble listed above.

NO SIGNALS

Thinking of all the component parts of a complete Radio receiver, there are possibilities for an almost unlimited number of defects, any one of which could prevent operation and produce the condition of "No Signals." Instead of considering these individually, our general plan is to think of the function of the parts and thus, by grouping on this basis, all possible defects will fall into four general classes or locations.

1. The tubes
2. The power supply
3. The supply circuits
4. The signal circuits

A little thought will show that these four divisions include all of the parts of any receiver and the failure of any one could make the set inoperative. Fortunately, most failures are caused by a single defect but there are cases in which the original failure, or defect, produces circuit conditions which cause a second and perhaps a third defect.

For example, as explained in the earlier Lessons, an open in the high voltage supply circuit might cause a filter condenser to puncture therefore, the first defect could be the direct cause of the second.

Going further, the punctured filter condenser might allow sufficient current to burn out some other component and thus the second defect could be responsible for the third.

Of course, if the power supply was turned off when the first defect occurred, the others would not happen but the average owner waits to see if the set will not start again after it has stopped and may forget to turn off the switch.

We mention this condition mainly because it is often puzzling to diagnose a case of trouble which has several defects, anyone of which could produce the "No Signal" complaint. However, the main job is to find and remedy the trouble no matter how many defects are present.

For this Lesson, we will assume a Radio Receiver which will not reproduce any signals or as the owner will usually say, "It won't play."

TUBE TROUBLES

Going back to the earlier Lessons of this series, when a receiver is in this condition, it is best to make a quick visual inspection, paying particular attention to the general condition of both the chassis and cabinet. The accumulation of dust on the tubes and other components mounted on top of the chassis will indicate whether or not it has been worked on recently. Sometimes, the lack of dust or presence of finger marks will contradict the owner's story that no one has touched it.

An inspection of the attachment cord and plug will sometimes reveal a broken wire or other defect while an examination of the cabinet will show whether the receiver has been dropped or received other abuse. No matter what seems to be wrong, the receiver is your responsibility and even though the owner's story is contradictory to the symptoms of your inspection, it is poor business policy to argue with him.

Instead, take a somewhat sympathetic attitude, encourage him to tell you all of the details because, his complete story in conjunction with your inspection, will usually provide a fairly accurate history of the job. While not strictly technical, information of this kind is often helpful in making a complete diagnosis and repair.

Whenever possible, do not make any extensive tests in the presence of the customer, especially if it is necessary to remove the chassis from the cabinet. His conversation and "advice" may be distracting to you and seeing his property "torn down" may be irritating to him. The better plan is to have him leave the receiver for an estimate on the cost of repair.

This arrangement saves you unpaid time, spent in conversation, and permits you to make your diagnosis without distraction. Some service men have a fixed "Service Fee" which they charge for making a diagnosis while others include the time spent for this work in the repair bill. The service fee has the advantage of allowing the service man to collect for his time even though the customer does not permit him to make the repair.

Some customers may insist on an immediate estimate and, following the explanations of the earlier Lessons, you may be able to make a complete diagnosis. The method of estimating your charges will be taken up later but there is one point we want to mention here.

From the standpoint of profit, you are better off to lose a repair job than to do the work at a loss. Therefore, do not cut your estimate for the "shopper" type of customer if he threatens to take his work elsewhere.

Getting back to technical subjects, and assuming that you are ready to go to work on a receiver which has been brought in because "it won't play", the first step, after your general inspection, is to test the tubes.

When a tube tester is available, it should be used to make the tests and, of course, all bad tubes must be replaced. As we have told you before, the tubes must be in good order to obtain proper operating conditions and that is why the tubes should be tested first. This is also the reason why a tube tester is one of the first units a Radio serviceman should purchase.

When starting a service business on limited capital, some men take the tubes to an established dealer and let him make the tests but this is satisfactory only as a temporary arrangement. In most cases, the dealer does service work also and objects to the use of his test equipment by a competitor.

With a stock of new tubes on hand, tests can be made on the replacement plan. The original tubes are replaced, one at a time by new tubes of the same type but, this method is

satisfactory only when the circuits are in proper operating condition. While a defective tube will not operate in a good circiut, a good tube will not operate properly in a defective circuit.

Because of this situation, the common procedure is to test the tubes first and then, knowing them to be good, go to work on the circuits. This method has the advantage of immediately locating faults due to defective tubes and thus eliminates any unnecessary tests or work on the circuits.

The explanations of this Lesson are based on the typical circuits of Figures 1 and 2 where you will find several dual purpose tubes such as the 6A8G and 75 of Figure 1 with the corresponding 6SA7 and 6SQ7 of Figure 2. When tested, these tubes should be checked for both their functions, the "Osc" and "Amp" sections ofthe mixer tubes as well as the diode and triode sections of the 75 and 6SQ7.

Following the same plan, the 80 rectifier of Figure 1 and the 5Y3GT of Figure 2 both contain two plates, each of which should be tested separately. No natter what you may suspect, always make a complete test of the tubes not only to locate the immediate defect but to prevent future failures.

POWER SUPPLY FAILURE

Should a receiver still fail to reproduce signals, when all of the tubes are known to be good, the next logical step is to check the power supply. Even good tubes must have the proper voltages applied to the various elements, in order to perform properly and the proper place to make initial tests is at the voltage source.

However, in this case, there are no signals and the defect may be a short which, if the power were turned on, would cause further damage. Therefore it is best to make a few preliminary tests before starting your regular routine.

In the previous Lessons on Continuity Testing, Circuit Tracing and Voltage Analysis, the a-c/d-c type of Power Supply was explained in detail therefore for Figures 1 and 2 of this Lesson we have shown the conventional a-c type with a power transformer and full wave rectifier.

Starting with the power transformer of Figure 1, there are four windings with a total of nine terminals. The primary, at the left connects to the supply line through the "On-Off" switch and the circuit includes the .006 mfd line condenser from switch to ground.

There are three secondary windings and, as shown in the diagram, the upper one supplies low voltage at comparatively high current to the rectifier filament. The middle secondary, with a center tap connection, supplies high voltage at comparatively low current to the plates of the rectifier tube. The center tap is the common return for both plate circuits.

The lower winding supplies low voltage at comparatively high current to the heaters of all the other tubes. The complete heater circuits are not shown on the diagram but one end of this winding is marked "F" while the other end is grounded. Then, as each of the heaters is marked in the same way, it indicates that all of the "F" points are connected to the transformer "F" which means that all the heaters are in parallel across this winding.

A short in any of these windings would cause the transformer to overheat but the action would be comparatively slow and would not injure any other parts although it might cause the fuse of your lighting circuit to "blow". A short in the circuits connected across the low voltage windings would have a similar effect and, ordinarily would not damage any other components. However, a short in the high voltage circuit would allow excessive current, through the rectifier tube and other components, which could cause additional damage.

One method of checking this condition is to arrange a special lighting circuit outlet connected in series with an ordinary 60 Watt Lamp. This can be done by cutting one wire of an ordinary extension cord and connecting the cut ends of the wire to the terminals of a standard lamp socket or outlet.

The line cord of the defective radio is plugged into this outlet which, electrically, places the receiver in series with the 60 watt lamp. If there is no short, the lamp will glow when the receiver is turned on, the intensity of the glow depending on the number of tubes in the Radio. Should the lamp light at full brilliance, a short is indicated and it will not be safe to connect the radio directly to the lighting circuit.

When a short is indicated, many men remove the rectifier tube because, if the brilliance of the lamp reduces noticeably when this is done, the short is in the high voltage circuit. Other men make a continuity or resistance test between the rectifier tube output terminal and ground. An indicated resistance of less than about 2000 ohms indicates trouble in the high voltage circuit.

A zero, or very low resistance reading, indicates a short in the first filter condenser and one of its connecting wires can be removed. Should the resistance reading increase to

2000 ohms or more, when this wire is removed, you can assume the trouble is in the condenser and the short has been removed.

Because this test must be made after the test lamp has indicated trouble, some men do not bother with the lamp test at all but make the continuity test first.

Should the continuity test indicate a resistance of from 200 ohms to 1000 ohms, it would indicate trouble at the filter output, possibly in the filter condenser connected across the output. Here again, removal of one condenser wire will show if the condenser is at fault.

When the short still remains, it is necessary to follow the high voltage circuit and disconnect one wire of all bypass condensers connected to it. Removing the connecting wire of the defective unit will cause the indication of the rectifier to ground resistance to be normal. As soon as this condition is obtained, it is usually safe to plug in the receiver for further tests.

A voltage test is perhaps the most convenient and, as a transformer operates on a-c, an a-c voltmeter must be used. With the switch turned on and the attachment cord plugged into a lighting circuit outlet, the full line voltage should be indicated on the voltmeter when it is connected across the primary and, as most home lighting circuits are rated at 100-120 volts, the meter range should be about 150 volts.

To test the secondary voltages, the test meter can be connected across the transformer terminals or the proper terminals of the rectifier and other tube sockets. Usually there are four wires between the power transformer and rectifier tube, two for the heater or filament and two for the plates. A check on the base diagram of the tube will enable you to identify the socket terminals.

Before making the tests, remember the heater operates at a low voltage, suitable for a 10 volt scale while the plates operate at a high voltage which requires a 1000 volt scale for the first readings at least.

With the test meter on the 10 volt range, place the test prods on the filament terminals of the rectifier tube socket and the reading should be approximately the specified value as given in a tube chart, which is 5 volts for a type 80. Be very careful that the test prods do not come in contact with the chassis or any other socket terminals.

To test the plate voltage, make sure the test meter is on a high range, preferably 1000 volts, and then place one test prod on the chassis. The other test prod is placed first on

one plate terminal of the rectifier tube socket and then on the other plate terminal. Both these tests should indicate the same value of voltage, usually somewhere between 250 volts and 450 volts.

One word of caution here. The plate to plate voltage of the rectifier is twice that between either plate and the chassis therefore, unless your test meter has a sufficiently high range, do not place one test prod on each of the plate terminals. This test is really not necessary because, if both plate to ground tests are equal, that is the correct operating condition.

The third transformer secondary supplies the heater current for the other tubes and operates at a voltage comparable to that of the rectifier heater secondary. For a circuit like Figure 1, this voltage can be measured by placing one test prod on the chassis and the other on the "F" terminal at the transformer or the tube sockets.

Transformer troubles consist of opens or shorts. An open circuit in any winding will prevent current and thus, an open primary will prevent voltage in any of the secondaries. An open in a secondary will cause zero voltage across that winding only.

In cases of zero voltage, make a close inspection of the transformer wires or lugs at the transformer. Sometimes the open occurs at the junction of the wire of the winding and the external connecting wire and can be repaired. However, if the open is somewhere inside the winding, it is seldom practical to attempt a repair.

When a short circuit occurs, the transformer will overheat, or blow a fuse, when one is provided. Shorts which occur in the external circuits can be corrected but, as explained for opens, when a short occurs inside, between the turns of a winding, it is seldom practical to attempt a repair.

Going back to Figure 1, the output circuit of the rectifier is from the filament to the center tap of the high voltage secondary and, due to the action of the tube, all voltages in it are D.C. Thus, to test the voltages here, a D.C. meter is required.

As the D.C. output voltage of the rectifier is comparable to the A.C. plate voltage, the test meter scale must be quite high. For ordinary receivers, 500 volts may be sufficient but, for the first tests at least, a 1000 volt scale will provide greater protection for the meter.

The d-c output voltage of the rectifier can be measured by placing one meter test prod on a heater terminal of the rectifier tube socket and the other test prod on the chassis or center tap of the high voltage secondary. As this is d-c, the "+" terminal of the test meter must be connected to the rectifier heater. Sometimes it is difficult to determine the polarity of the test circuit therefore, should the meter hand deflect in the wrong direction, reverse the positions of the test prods.

Looking at Figure 1, you will see that this test places the meter across the first filter condenser and, should the condenser be shorted, the test reading would be zero. This defect has been mentioned before and should be corrected before the receiver is plugged into the lighting circuit. Often, the receiver will reproduce signals as soon as this condenser is removed from the circuit. The remedy here is to replace the condenser but be sure the new one has the same capacity and voltage ratings.

In case an exact duplicate is not available, the capacity of the new condenser may be larger or smaller by 20% without causing any appreciable difference in operation but, its d-c operating voltage should be at least one and one half times the a-c plate voltage of the rectifier tube. A higher voltage rating will increase the expected life of the condenser.

An open condenser, connected across the rectifier tube output circuit will cause an appreciable drop in the d-c voltage. For the a-c/d-c type of power supply this reduction of voltage may be sufficient to prevent operation but, for their a-c types, the reduced voltage is usually sufficient to permit some signals to be heard.

For this power supply test, if the d-c output voltage is appreciably lower than the a-c plate voltage on the rectifier, it is a good plan to connect a good condenser temporarily in parallel to the original condenser. When this addition to the circuit causes an appreciable rise of d-c voltage it is safe to assume that the original condenser is open or has a greatly reduced capacity. In either case, it should be replaced.

The actual capacity of condensers can be measured with "Condenser Testers", now on the market and, if one is available it can be used. However, at this time we are testing the output voltages of the power supply and, knowing the purpose and effect of the filter condensers, can make the voltage tests serve also as capacity tests.

For the next test, referring to Figure 1, the 1100 ohm field winding of the Dynamic Speaker is used as the filter choke and, the voltage across the rectifier output is also the voltage input of the filter. To measure the filter output voltage, the positive test prod is moved to the other end of the field winding while the negative prod is held on ground or the center tap of the high voltage secondary.

Checking up in a tube manual, you will find the normal plate and screen currents of all the other tubes add up to a total of approximately 60 milliamperes and, as there are no voltage dividers, this can be considered as the field current.

By Ohm's Law, 60 milliamperes through 1100 ohms will cause a drop of 66 volts therefore, for normal operation, the filter output voltage should be 66 volts less than the filter input voltage.

If the difference in voltage is less, it indicates a high resistance or open in the plate or screen grid circuits of the other tubes. If the difference in voltage is greater, it indicates a low resistance or short, in the plate or screen grid circuits of the tubes.

With an indicated value of filter input voltage but zero output voltage, either a short or open might be indicated. However, as a short would overload the rectifier and cause it to heat, a short can be identified easily and should be found in the first test, made before the power was turned on.

When the test indicates an open, it must be in the speaker field circuit. As the field winding is located in the speaker, the connecting wires are usually quite long and often include a plug and socket. The best plan here is to shut off the power and make a continuity test of the complete circuit.

As explained for the transformer windings, any external defect can usually be remedied but an open, inside the winding, makes a replacement necessary. Replacement field windings are avilable but must be of the proper dimensions and have the required d-c resistance. A 10% variation of resistance will cause no appreciable difference in performance.

As we mentioned before, when the original test continues to indicate a short, even with the filter output condenser disconnected, the complete high voltage circuit must be checked. Thinking of condensers, in the circuit of Figure 1, there is an .006 mfd condenser connected between the 6AC5G plate and ground. A short in this unit would cause test indications about the same as a shorted filter output condenser.

There is a .05 mfd condenser between the 6A8G screen grid and ground and while a short here would allow high current, it would pass through the 20 M ohm resistor, in series between the filter output and screen grid. This value of resistance is sufficiently high to pass the original test for shorts and, with the power turned on, would allow a fairly high value of voltage to be indicated on the test meter at the filter output. However, the excess current in the resistor would cause it to overheat and usually a visual inspection would show it to be charred or its paint blistered.

Like the filter condenser, these bypass condensers can be disconnected or, with the power shut off, they can be tested with an ohmmeter. However, due to parallel paths in the complete circuit, one side of the condenser should be disconnected to make an accurate resistance test.

With all bypass condensers disconnected, a low voltage at the filter output would indicate high current due to defective wiring or high tube currents. The wiring troubles are mainly mechanical and can usually be found by inspection, paying particular attention to those points at which the wires cross or touch exposed points of the circuit.

As the tubes were tested and found to be good, excessive plate and screen currents must be caused by circuit defects, the most common of which is low voltage due to a defective bias resistor or its bypass condenser. Sometimes, a leaky coupling condenser in a resistance coupled stage will allow the plate voltage of the preceding tube to be impressed on the grid. This condition produces a positive grid bias which results in excessive plate and screen grid currents.

In the ordinary Receiver circuits, only the output tubes will draw sufficiently high plate and screen currents to produce a distinct drop of filter output voltage therefore you can concentrate on the circuits of the output stage when this condition is found.

In the circuits of Figure 1, you will find a 50 ohm resistance connected between ground and the center tap of the high voltage secondary of the power transformer. The current of approximately 60 milliamperes (current drawn by 75 tube is small) is carried by this resistor to produce a 3 volt drop to bias the grids of the 6A8G and 6U7G tubes. You can check this by noting that the cathodes are grounded while the grid circuits connect directly to the center tap of the high voltage secondary of the power transformer, through avc circuit.

Thus, to complete the voltage tests of the power supply it is necessary to check the voltages at the socket terminals of

the tubes. The general plan to be followed for this work was explained in the "Voltage Analysis" Lesson.

To provide some practice, we want you to apply our explanations for Figure 1 to the circuits of Figure 2. You will find the circuits are very similar, a fact we want you to remember because it is true for all receiver circuits of the same general type. The plan which we followed for the power supply of Figure 1 will apply to all receivers of this type.

OUTPUT CIRCUIT FAULTS

To cover as many defects as possible, we will assume that the receiver of Figure 1 has all good tubes, everyone of which is supplied with proper operating voltages and still, "it won't play." Thinking of the four general classes of trouble, listed earlier in this Lesson, the first three have been checked leaving only "The Signal Circuits."

These signal circuits extend from the antenna to the speaker but, following general practice, we will start at the speaker and work back to the antenna.

Before going further it is well to make use of some simple tests mentioned in the former "General Diagnosis" Lesson. Removing and replacing the output tubes should cause a click in the speaker or placing your finger on the detector grid or diode should cause a hum.

If you have a modulated test oscillator with provision for obtaining the 400 cycle modulation frequency at separate terminals, this voltage can be applied to the grids of the output tubes and should produce a 400 cycle note in the speaker.

Should the speaker still fail to produce sound, the trouble must be in the output transformer secondary or the speaker voice coil circuit, because the field winding was checked as a part of the power supply filter and the tests explained in this Lesson cover the plate circuit of the output stage and thus include the primary of the output transformer.

As this circuit carries signal voltages only and there are no signals, it is best to make a continuity test in conjunction with a visual and mechanical inspection. For the continuity test, one voice coil connecting wire should be disconnected, preferably at the speaker. Then, with one test prod on the connected terminal of the voice coil and the other test prod on the disconnected terminal, the continuity

of the voice coil can be tested. By moving the test prod from the disconnected terminal of the voice coil to the end of the wire which was removed, the continuity of the output transformer secondary can be tested. Should either the voice coil or secondary winding test open, a replacement is necessary.

For the mechanical inspection, the voice coil can be moved by pressing the center of the cone with your finger and its movement should free without binding or scraping. Sometimes, the voice coil will expand sufficiently to wedge it in the air gap and when this happens, there will be no sound even though the circuits are in good order. A scraping voice coil can often be cured by centering, a subject which will be taken up in a later Lesson on Distortion.

FAULTY COMPONENT PARTS

For the preceding explanation, we assumed correct operating voltages on all of the tube elements but, checking the circuit of Figure 1, you will find a number of component parts which do not carry any of the power supply current.

We have already mentioned the voice coil circuit of the speaker and moving back toward the antenna, you will find a one megohm resistor in the 6P5G grid circuit, a ten megohm resistor in the triode grid circuit of the type 75 tube as well as the 500 M control and 50 M resistor in the diode circuit of this same tube.

Defects in any of these components could cause the "No Signal" condition but they are not included in the tests of the power supply voltages. The usual procedure is to make continuity tests on these parts, checking the complete circuit in which they are connected.

The diode circuit of the type 75 tube as well as the control grid circuit of the 6U7G tube include the tuned secondary of an i-f transformer. As we mentioned before, the resistance of the common types of i-f transformer windings varies from about 25 ohms to 50 ohms and the trimmer condenser, connected across the winding, should have a resistance too high for the ordinary ohmmeter. Thus, a continuity test from the tube to the opposite end of the winding should indicate the comparatively low resistance of the coil only.

An open or shorted coil, indicated by a high or low resistance, usually makes a replacement necessary but, as explained for other windings, a visual inspection may locate trouble at the joint between the coil and connecting wires.

TUNING CONDENSER

The tuning condenser is a simple unit, both mechanically and electrically and ordinarily does not cause trouble. However, due to an accident, tampering or an accumulation of dust, an electrical short may occur between the stator and rotor plates.

The circuit of Figure 1 shows a 3 gang condenser, two of which are employed for the band pass filter between the 6A8G control grid and antenna while the third gang tunes the oscillator.

Should any of these gangs short, the coil they are connected across would also be shorted and could not develop a signal voltage. Thus, with all of the other parts in perfect condition, a shorted tuning condenser can prevent signals from reaching the tube and naturally, under these conditions, they could not be heard in the speaker.

The circuit arrangement of the coil and tuning condenser is like that of the speaker voice coil and output transformer secondary therefore, to make a separate continuity test of the tuning condenser, one set of plates must be disconnected from the circuit.

As the rotor plates are often grounded, the connecting wire is removed from the stator plate terminal. The continuity tester is then connected from the stator terminal to the rotor and the meter is watched as the tuning dial is turned from one extreme to the other.

The test meter should indicate infinite resistance, when the tuning condenser is in proper condition, but will indicate a short if the plates touch. When making this test be sure the rotor plates are turned for the complete distance they can move.

When a short is indicated, it can usually be eliminated by bending the plates slightly. This job, usually done with a thin bladed knife, is known as "Knifing the Plates" and a visual inspection, looking through between the plates, will usually show the points of contact.

Before reconnecting the condenser, always make a continuity test of the coil. It contains a comparatively small amount of wire and, on the ordinary ohmmeter, may test as a short. If the ohmmeter has a "Lo Ohms" scale, it is usually possible to read a value of about 5 ohms for Broadcast Coils down to less than .1 ohm for short wave coils.

OSCILLATOR CIRCUITS

In the common types of mixer tubes, such as the 6A8G of Figure 1 and the 6SA7 of Figure 2, the anode voltages are checked on the supply voltage tests but even when these are correct, the oscillator may not operate.

The grid next to the cathode or "G_1" is the oscillator grid for both the mixer tubes mentioned above and, like the signal circuits, it does not carry any of the power supply current. However, a voltage test can be made to determine whether or not the oscillator is working.

In the circuit of Figure 1, you will find a 50 M ohm resistor connected between G_1 of the 6A8G tube and ground. On the same plan, there is a 20 M ohm resistor connected between G_1 of the 6SA7 tube and ground in the circuits of Figure 2.

To cause oscillation, sufficient energy from the plate or anode is fed back to the grid to cause grid current and this current will cause a D.C. voltage drop across the grid resistor. The polarity of this voltage drop will make the grid end of the resistor negative.

While actual values will vary in the different circuits, there should be from about 4 volts to 15 volts developed across the grid resistor of an oscillator which is working properly. However, when making this test, be sure and rotate the tuning condenser for its full travel to make sure the oscillator operates over the entire frequency range. For all wave receivers, the test should be repeated for each band.

Usually, this test can be made by connecting the test meter between the G_1 terminal of the mixer tube socket and ground. When a separate oscillator tube is used, you can test from its control grid to ground.

Some tubes which test good in the ordinary tube tester, will not oscillate when placed in the receiver therefore, when your test indicates the oscillator is not working, it is a good plan to try another tube or two, if you have them, before making any further tests.

Should none of the new tubes oscillate, then the oscillator coil and tuning condenser should be checked the same as the secondaries and other tuning condenser gangs. Also, a continuity test should be made for the oscillator grid circuit and, if a coupling condenser is used, it should be tested also.

In the circuits of Figure 1, there is an .05 mfd condenser between G_2 of the 6A8G tube and the lower end of the oscillator coil. In the circuits of Figure 2, there is an .00005 mfd condenser between G_1 of the 6SA7 tube and the wave band switch which connects to the different oscillator coils. A short or open in these coupling condensers could prevent oscillation.

It is usually worth while to reverse the connections to one winding of a double coil or one section of a tapped coil as circuit changes, which reverse the polarity of the feed back voltage, may have been made.

When all other remedies fail and the circuit tests out properly, it is usually necessary to replace the oscillator coil.

INPUT CIRCUITS

The only remaining part of the circuits of Figure 1 is the antenna or input circuit. It consists of a single coil, connected to the antenna at one end and grounded at the other.

Like other circuits of this type, it should be tested for shorts and opens and the tests should include all connecting wires. To be sure, make your tests all the way from the terminal or jack, to which the external antenna is connected, to the actual ground.

For receivers with circuits like that of Figure 2, these tests should be made in every position of the wave band switch. Always check the input circuit carefully to see if it contains a switch of this kind because, especially in the smaller two band receiver models, the switch may not be marked plainly or may be mounted on the side or back of the chassis.

Many valuable hours have been wasted in hunting for trouble in a Receiver which would not reproduce broadcast signals only to find eventually that an inconspicuous wave band switch was in the short wave position.

CIRCUIT VARIATIONS

The circuits of Figures 1 and 2 are quite similar and typical for receivers of this type but they have several variations we want to point out.

For Figure 1 there is a band pass arrangement between the antenna and mixer tube control grid to provide greater selectivity. In comparison, the circuit of Figure 2 includes

the r-f amplifier stage of the 6SD7GT tube which is resistance coupled to the control grid of the 6SA7 mixer tube. The band pass arrangement requires a third gang in the tuning condenser while the r-f stage, operating with a two gang tuning condenser, requires the additional tube and coupling components between it and the mixer.

The i-f stages, Detector, avc and Power Supply are almost identical although, in Figure 2, there is a switch to accommodate a phonograph pick-up. This switch, with its "Phono" terminals, makes it possible to use the audio amplifier for playing records.

The last two stages of the audio amplifier of Figure 1 are direct coupled as the control grid of the 6AC5G is connected directly to the cathode of the 6P5G driver tube. This is a special case and the output tube grid operates at a positive bias of about 13 volts, equal in value to the negative voltage on the control grid of the driver tube.

The output stage of Figure 2 consists of a pair of 6K6GT tubes in push pull, the proper phasing of the signal voltage being obtained by the 6J5 inverter tube.

With these variations in mind, we want you to check the various tests, explained for Figure 1, to see that in practically every case, they will apply equally well to the circuits of Figure 2. Voltage tests can be made on the same plan, regardless of the number of tubes, continuity tests are made in exactly the same way, no matter what circuit contains the parts. The signal voltages pass through the same types of circuits and undergo the same changes.

Thinking along these lines, all receivers are pretty much alike and when the tubes are all good, the power supply is working properly, the supply circuits are correct and the signal circuits are in order, the receiver must operate.

It takes much longer to explain these tests than it does to do the actual work. With a little experience, you should be able to make every test explained in this Lesson in a matter of 10 to 15 minutes and, if you follow a complete and logical routine, you will find that there are very few "tough" repair jobs.

For our next Lesson we will continue this same general type of explanation and take up complaints and troubles which are caused by weak signals or Lack of Volume.

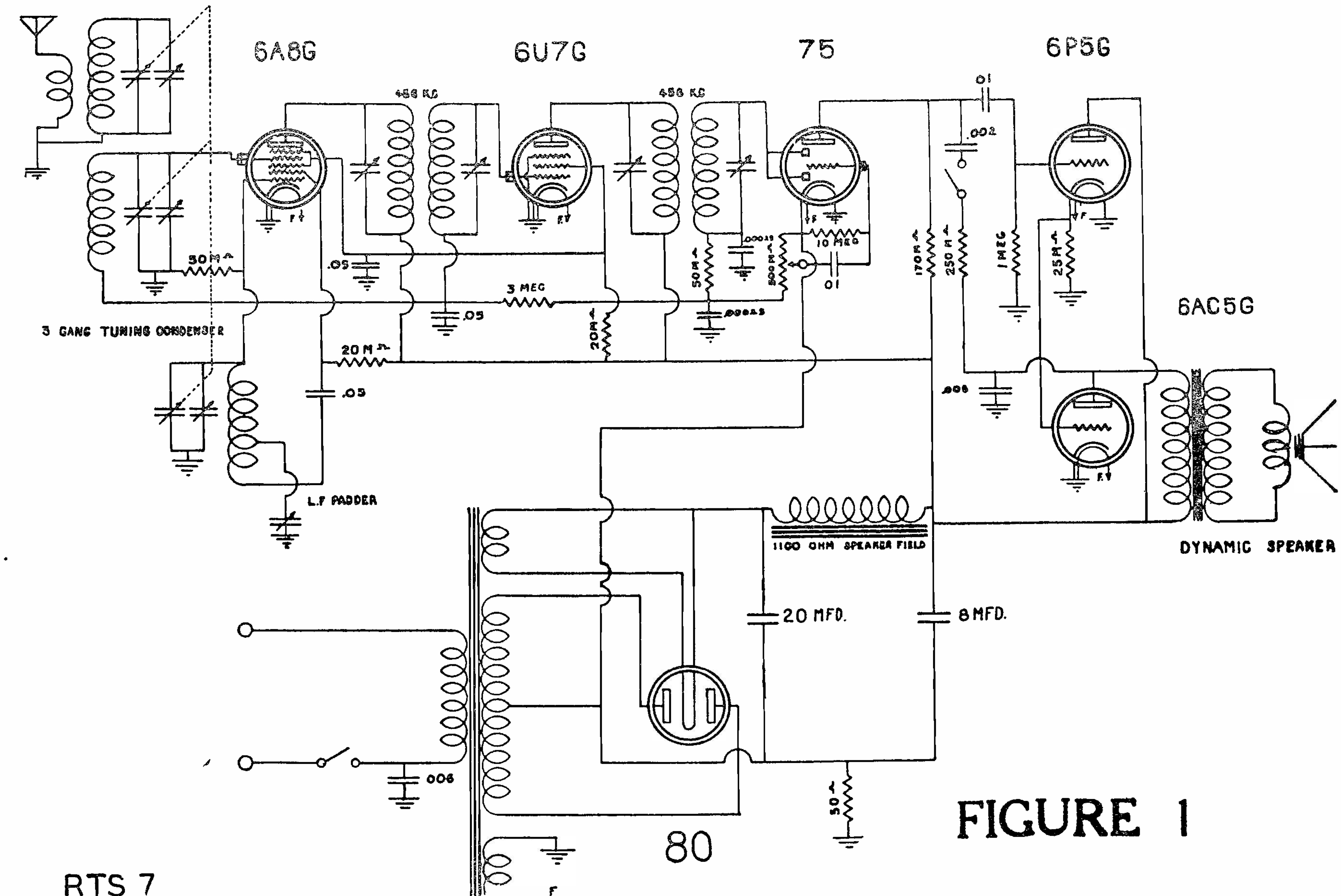


FIGURE 1

RTS 7

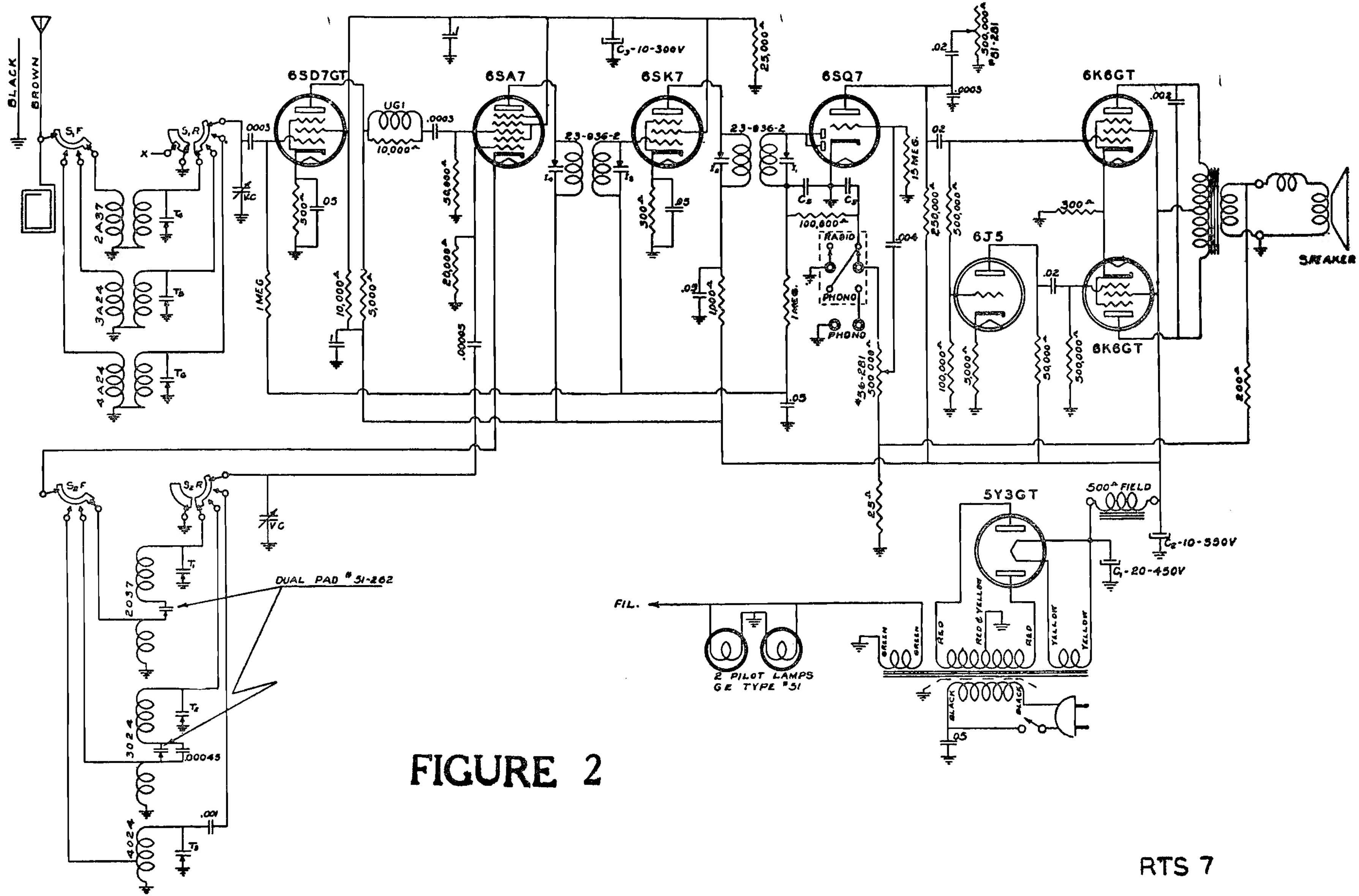


FIGURE 2

RTS 7

QUESTIONS

How many advance Lessons have you now on hand? ____________

Print or use Rubber Stamp.

Name ____________ Student No. ____________

Street ____________

City ____________ State ____________

1. In what four general classes or locations will all Radio Receiver defects be found?

2. After a general inspection of a defective Radio Receiver, what test should be made first?

3. What should be done before "plugging in", or turning on the power of a Radio Receiver which does not "play"?

4. What effect will an open filter input condenser have on the rectifier output voltage?

5. What defect is indicated and in what section is the fault when, without any symptoms of a short, the filter input voltage is high and the filter output voltage is zero?

6. In the grid circuit of a tube in a resistance coupled stage, what effect will a leaky coupling condenser have on its grid bias voltage and plate current?

7. What must be done to make a continuity test of a speaker voice coil only?

8. What must be done to make a continuity test of a tuning condenser?

QUESTIONS (Continued)

Name____Student No.___________

9. In a superheterodyne Receiver, what test can be made to determine if the oscillator is working?

10. In an output stage with self bias, what effect will a shorted bias resistor, or its bypass condenser, have on the grid bias voltage and plate current?

LESSON RTS - 8

TYPICAL FAULTS - LACK OF VOLUME

DE FOREST'S RADIO ELECTRONICS TRAINING, INC.

DE FOREST'S TRAINING, INC.

2533 N. Ashland Ave., Chicago 14, Illinois

RADIO AND TELEVISION SERVICING

LESSON 8

TYPICAL FAULTS - LACK OF VOLUME

Lack Of Volume ——— Page 1
Comparison To "No Signals" ——— Page 3
Tube Troubles ——— Page 5
Improper Plate And Screen Voltages — Page 6
Grid Bias Voltages ——— Page 10
Input Circuits ——— Page 12
Tuned Circuit Adjustments ——— Page 15

* * * * *

The important thing in life is to have a great aim, and to possess the aptitude in perseverance to attain it.

— Goethe

LACK OF VOLUME

Next to the condition of "No Signals," lack of volume is perhaps one of the most common complaints of Radio Receiver owners. Like all other humans, their ears will become adjusted to a comparatively high degree of distortion, they will tolerate a lack of selectivity, as long as they can tune their favorite programs without interference but usually call the service man when the signals are not loud enough to be heard easily.

Although these Lessons are mainly technical, the successful Radio Service Man must have and practice good Salesmanship, Psychology and Business methods. Technical knowledge and ability alone is not enough, although it is the foundation on which the business must be built.

Therefore, in our technical explanations we will include some of the more common customer complaints and reactions because, regardless of its technical perfection, your repair job is a failure unless it satisfies the customer. He may disclaim all technical Radio knowledge but he does have very definite ideas as to what his receiver did, or should do, and you must satisfy those ideas.

There is a common slogan that "The Customer is always Right" to which someone has added, "Even when he is wrong" and cases of this kind require Salesmanship or Diplomacy rather than Technical Knowledge. It is not only a waste of time but a liability for your business to carry on a technical argument with a non-technical customer.

Make it a general rule to avoid all arguments and never contradict a customer. You can not agree with him at all times, and may have to convince him that he is mistaken, but this should be done as a friendly discussion without visible irritation or anger. Under normal conditions, most of us are quite reasonable but, when angry, become unreasonable and will not admit a mistake even though we know we are wrong.

Knowing these conditions, most misunderstandings can be avoided. For example, suppose a customer brings in a Receiver, three or four years old, and the accumulation of dust on the chassis makes it evident that there have been no replacements for a long period of time. In discussing the trouble with the owner, you become quite certain that all of the original component parts are still in place and your tests indicate that one tube has "burned out".

From a technical standpoint, replacement of this one tube restores the operation of the receiver and the repair job is complete. From a business standpoint, there are other factors

to consider, factors which may result in the dissatisfaction or loss of a customer.

Your inspection and tests indicate that all the tubes are of the same age and have passed the limit of their normal life yet, all but one still test fairly good. However, as one tube has gone bad, it is reasonable to expect the remaining life of the others will be quite short.

Suppose you replace the one bad tube, return the Receiver to the customer and, a week later he comes back and says his set is "Dead again". You test the tubes and find another of the original ones is bad, although your replacement tube is as good as new. What are you going to do?

Right or wrong, the customer feels the responsibility is yours. He is not technical, he brought the job to you, paid you your price and now, a week later he is back where he started. He doesn't know and doesn't want to know the difference between the rectifier tube you replaced a week ago and the mixer tube which is dead now. The only fact which interests him is that your repair job lasted but one week, a fact which all your technical "alibis" can not alter.

You can not afford to give him a new tube without charge, when the fault is not yours, because that obligates you for all the other old tubes as they go bad, one by one. Yet, if you do not make some sort of an adjustment, you may lose a customer and a certain amount of prestige.

All customers are not alike. In the case we are explaining, some of them would not even bother to come back and complain. They would simply assume you are incompetent and go somewhere else. Others will accept your statement of the facts and pay for the second tube without question. Your main problems concern the customer who comes back and complains.

Instead of trying to work out a compromise for a situation of this kind, our suggestion is to avoid them entirely. When all the tubes of a receiver are old, and about the same age, sell the customer a new set then, if one goes bad in a short time you can make good on a guarantee basis.

Should the customer refuse to purchase all new tubes and insist on replacing the bad one only, you can explain the situation to him and safely prophesy that some other one will go bad in a short time, also you can emphasize and make a written record of the type of the new tube you install.

Then, when he comes in the second time, in a diplomatic way of course, you can say, "I told you so".

The same general idea holds in other cases. For example, when one section of an electrolytic condenser block goes bad, it is good business to replace the entire block instead of the defective section only. As we explained for the tubes, replacement of the defective section may restore normal operation but, as the other sections of the block are the same age, it is reasonable to expect their future life to be short.

From a financial angle, the replacement section may be less expensive than the complete block but the installation time will be about the same. Thus, the difference in cost to the customer will be small. However, if the block has three sections which are replaced one by one over a period of a few weeks, the total cost to the customer will be more than twice as great as if the entire block were replaced the first time.

Thus, a good complete job the first time may appear to be higher priced but, in the long run, it saves the customer money as well as the inconvenience of having his receiver laid up for repairs more than once. Also, a good complete job the first time will permit you to stand back of your work and donate a little time for minor adjustments which may be needed.

To meet this situation in a different way, some men present their customers with two itemized estimates for a repair: One, to place the receiver in operation and the other for a complete job which they can guarantee. Should the customer take the job for operation only, he has no ground for complaint if it goes bad in a short time.

COMPARISON TO CONDITION OF "NO SIGNALS"

Getting back to our technical subject, in the last Lesson we explained a condition of "No Signals" and now are going to explain another common complaint, "Lack of Volume." In general, you can think of Lack of Volume as a mild case of No Signals but, as some signals can be heard it is evident that all of the circuits are operating to a certain extent at least.

In our discussion of the No Signals complaint, we covered all of the circuits of a receiver and the various defects that we mentioned were assumed to be severe enough to stop the operation completely. Many of these same defects occur in varying degrees and will permit a certain amount of operation therefore, some of the explanations of this Lesson will be similar to those of the last.

After you have studied all the Lessons of this series, you will find that they can be consolidated into one general and complete test routine which will include all ordinary complaints.

Therefore, in order to take up all of the many essential symptoms and tests, it is necessary that we mention the similarity and differences of the different complaints.

In general, when a receiver is brought in because of Lack of Volume, you know most of the tubes are operating to a certain extent, the power supply is providing some voltage, and in most cases, the circuits are complete. Strange as it may seem, most cases of Lack of Volume are not due to defective volume controls, therefore their troubles will be discussed later.

Like the condition of "No Signals" all possible defects which could cause "Lack of Volume" can be grouped into the four general classes or locations of:

1. The Tubes
2. The Power Supply
3. The Supply Circuits
4. The Signal Circuits

So far, the two complaints appear to be the same but, for lact of volume, the test routine is usually more definite and not as complete as for a case of No Signals.

The wiring diagrams, used for the illustrations of these Lessons have been selected to show the various arrangements and features which are commonly found in the usual run of service work. The successful service man should be able to recognize these variations and similarities in order that he can make a rapid and correct diagnosis of the symptoms of trouble.

For the illustration of this Lesson, we show a 7 or 8 tube, 2 band superheterodyne receiver of the a-c type. The 6U5 Tuning Eye Tube is included in the 8 tube models and omitted in those of 7 tubes. Although intended to show the resonant point of the tuned circuits, a tuning eye is a convenient output meter for the r-f and i-f sections of the receiver.

Checking the diagram of Figure 1, you will find the grid circuit of the 6U5 is connected across the 1/2 megohm volume control in series with the 2 megohm resistor in the A.V.C. circuit, Thus, the voltage on the grid will be proportional to the detector output and, the stronger this voltage the smaller the shadow angle on the tuning eye.

For a complaint of Lack of Volume, the receiver can be turned on and the action of the tuning eye checked as the tuning dial is turned. When the shadow angle closes sharply, as different carrier frequencies are tuned in, it indicates trouble in the audio section of the Receiver, between the detector and speaker.

Should the shadow angle of tuning eye show but a slight or zero deflection; as different carrier frequencies are tuned in, it indicates trouble between the detector and the antenna.

Thus, when making a general inspection of a receiver, the action of the tuning eye can be of assistance.

TUBE TROUBLES

Like most other repair jobs, it is essential to start by testing the tubes. This statement has been repeated a number of times but it can not be over emphasized. We are all prone to play "Hunches" to such an extent that frequently we allow them to over ride our better judgement.

You may feel absolutely sure that some certain condenser, resistor or coil is the cause of trouble in a receiver and will be tempted to go to work on it before doing anything else. Your "hunch" may be right but the law of averages is against you. Even if you are right, the tubes should be tested before you deliver the job therefore, it is good common sense to test the tubes first.

For example, the 6SF5 inverter tube or one of the 6K6G output tubes, in the circuit of Figure 1 of this Lesson, might be completely dead to cause the lack of volume complaint. The resulting poor quality of the signals might cause you to blame the speaker but, until good tubes were installed, no speaker could operate satisfactorily and time spent on the speaker might be wasted.

Low emission in the rectifier tube may cause a marked reduction in all plate and screen grid voltages, a condition which would not only cause reduced volume but might produce symptoms of entirely different defects.

Another fairly common trouble, especially in certain types of tubes, is a short between the cathode and heater. Looking at the Output Tubes in the circuit of Figure 1, you will see that a tube defect of this type would short out the 400 ohm bias resistor and naturally, other tests would indicate this condition. However, if you took the time and trouble to remove the resistor and found it to be in good condition, you would be "stuck" unless you remembered that the tube elements are a part of the various supply circuits.

In cases of this kind, some men remove the tubes and make a continuity test of the circuit. However this method is not conclusive because, if the circuit checks properly when the tubes are out but the signals are faulty when the receiver is

in operation, the trouble may be in a circuit component which becomes defective only when operating at its rated voltage and current values.

In the case we have been explaining, this component was the tube and therefore its condition should be tested as completely as that of any other component.

Many other similar examples could be mentioned but, in every case, you would find that, by testing the tubes first, the following tests, if necessary, would be simplified.

IMPROPER PLATE AND SCREEN VOLTAGES

With the Manufacturers circuit diagram and other specifications available, it is a simple routine test job to compare the actual operating voltages with the correct values. Usually the diagram and data you need most is the information you do not have and therefore it is necessary to work out your own solution.

We have mentioned the value of a tube table for checking the base connections of the different types of tubes and now, want you to look at the other data which is given. You will find one or more values of Plate Voltage with corresponding values of screen grid voltage, control grid voltage, plate current, screen grid current and often the total cathode current. In addition you will find the plate resistance and, depending on the type of tube, the amplification factor, transconductance, load resistance and Power Output.

Except when substituting tubes of different types, the interelectrode capacities and dissipation values are not of great importance.

To show you how this information can be put to practical use, we will assume that a receiver, with the circuit of Figure 1 of this Lesson, has been brought in with the "Lack of Volume" complaint. You have no diagram but, following the routine of tests we have outlined, you find the power supply is delivering 250 volts to the plate and screen circuits and your voltage tests at the sockets indicate what might be a low value at the screen grid of the 6SK7 tube and also the grids, G_2 and G_4, of the 6SA7 tube.

A continuity test of the circuit indicates that these screens both connect to the same point with a resistance in series between them and the output of the power supply filter. You have no diagram and therefore do not know what the value of this resistance should be.

Looking at a tube manual or chart, you find that, with 250 volts on the plate, the screen grid of a 6SK7 tube should operate at 100 volts and carry a current of 2.6 milliamperes. In the same way, for the 6SA7, the screen grid should operate at 100 volts and carry a current of 8.5 milliamperes.

As your continuity tests indicate that both screens connect directly to the series resistor, it must carry the total current of 2.6 + 8.5 = 11.1 milliamperes. Also, with a 250 volt supply and a desired operating value of 100 volts, there should be a 150 volt drop across the resistor.

Knowing the normal values of current and voltage, by substituting in Ohm's Law, the proper value of resistance can be calculated. Using the values of this example:

$$R = \frac{E}{I} = \frac{150}{.0111} = 13{,}513 \text{ ohms}$$

As commercial resistors are made in even hundreds or thousands of ohms, usually with a tolerance of 10%, by adding 10% or 1,351 to the above value the total is 14,864 ohms and thus, a 15,000 ohm unit is the correct one to use. Referring to Figure 1, you will find this is the value shown on the diagram.

Going back to the tube manual, you will find screen voltage and current values for operating with 100 volts on the plate. This condition is found in the ordinary a-c/d-c type of receiver and the screens operate approximately the same as for the higher plate voltage. With a 100 volt supply and a recommended 100 volts on the plate it is not necessary to install any series resistance in the screen grid circuits. In the a-c/d-c circuits of the earlier Lessons you will find the screen grids connect directly to the output of the Power Supply filter.

Comparing the other listed values of a 6SK7 tube, you will find that when the plate voltage is increased from 100 to 250 volts, the screen grid voltage does not change at all. The plate current decreases 3.8 milliamperes, from 13.0 to 9.2 while the screen grid current reduces 1.4 milliamperes from 4.0 to 2.6. Thus, the total cathode current will vary 5.2 milliamperes as the plate voltage is increased from 100 to 250 volts.

The transconductance decreases from 2350 to 2000 micromhos but the plate resistance increases from .12 to .80 megohm. Thus, as far as the operating voltages are concerned, the listed values of the tube chart will furnish all the in-

formation you need to determine whether or not the tested values are sufficiently low to cause "Lack of Volume".

The recommended operating voltage values for triodes and Power Output tubes, of both Pentode and Beam Power types, can be checked in much the same way and a variation of 10% between recommended and tested values will seldom be sufficient to cause any complaint.

However, you will find some receivers in which the voltage output of the Power Supply varies 20% or more from the values given in the tube chart. In cases of this kind, the following plan is particularly useful for output tubes.

Suppose, for the circuit of Figure 1, all parts of the Power Supply test properly and appear to be in good shape with a tested output of 200 volts. Most tube charts list the operating conditions of type 6K6G tubes at 100, 250 and 315 volts, the 250 volt value being closest to the tested value of 200 volts.

Thus, there is a ratio of 200 divided by 250 which is equal to .8 and this can be used as a factor to calculate the screen grid and control grid voltages for the lower plate voltage. The tabulation can be worked out as follows.

Chart Values		New Values
Plate Volts -	250 x .8 =	200 Volts
Grid Volts -	-18 x .8 =	-14.4 Volts
Screen Volts-	250 x .8 =	200 Volts

All the other specified values can be adjusted but the calculations are not quite as simple. If we think of the plate voltage ratio as "Fe", then the factor for finding the new values of plate and screen grid current is:

$$F_i = F_e^{\frac{3}{2}} = \sqrt{F_e^3}$$

For the power output,

$$F_p = Fe^{\frac{5}{2}} = \sqrt{F_e^5} = F_e F_i$$

For the mutual conductance

$$Fgm = \sqrt{F_e}$$

For the plate impedance and load resistance,

$$Fr = \frac{1}{\sqrt{Fe}} = \frac{1}{Fgm}$$

Using the factor of .8 as mentioned above, these other factors work out as follows.

$$F_i = \sqrt{F_e^3} = \sqrt{.8x.8x.8} = \sqrt{.512} = .7155 = .72$$

$$F_p = F_eF_i = .8 \times .7155 = .5724 = .57$$

$$Fgm = \sqrt{Fe} = \sqrt{.8} = .894 = .89$$

$$Fr = \frac{1}{\sqrt{F_e}} = \frac{1}{\sqrt{.8}} = \frac{1}{.89} = 1.12$$

Checking the other listed characteristics of the 6K6G tube we have,

Chart Values New Values

Zero Signal Plate Current = 32 x .72 = 23 ma
Zero Signal Screen Current = 5.5 x .72 = 3.96 ma
Power Output = 3.4 x .57 = 1.94 watts
Conductance = 2300 x .89 = 2047 micromhos
Plate Resistance = 68000 x 1.12 = 76160 ohms
Load Resistance = 7600 x 1.12 = 8512 ohms

These various factors are quite accurate at comparatively small voltage ratios from about 1/2 to 2, for practically all types of tubes but are of particular value for power tubes. Thus, for cases of low volume, with questionable values of plate and screen grid voltages, it is possible to calculate the recommended values for any voltage developed by the Power Supply.

In most cases of "Lack of Volume", due to improper plate and screen grid voltages, the tested values of the defective circuit will be so different from those of other similar circuits that they will be detected immediately.

Going back to the circuits of Figure 1 again, we have mentioned the 15000 ohm resistor in series with the screen grids of the 6SA7 and 6SK7 tubes and will imagine that a defect in this unit has raised its resistance to 30,000 ohms. According to Ohm's Law, the normal current of 11.1 milliamperes for this circuit would cause a drop of .0111 x 30,000 = 333 volts across the resistance but, with a 250 volt supply, this condition could not exist. Instead, as the resistance increased, the voltage drop across it would also increase and cause a reduction of screen voltage which, in turn, would cause a reduction of screen current. Thus, the voltage drops and current values would balance each other with the total drop across the circuit equal to the supply voltage. Due to the increase of the resistance value of the resistor, the greater part of the drop would be across it, leaving a noticeably low screen grid voltage.

Looking at the circuit again, you will see a .1 Mf condenser connected between each end of this 15000 ohm resistor and ground. Should a short occur in the condenser at the supply end, it would cause a short across the filter output as previously explained.

Should a short occur in the condenser at the screen grid end, the screen grid circuit of the tube would be shorted out, the drop across the resistor would be equal to the filter output voltage and thus, the voltage between the screen grid and ground would be zero.

Assuming a supply voltage of near normal value, low plate and screen grid voltages are usually caused by high resistances in series with the circuit, while zero voltage is generally due to an open in the circuit or a shorted bypass condenser. Either of these defects can be located by a continuity test of the circuit.

GRID BIAS VOLTAGES

In most modern receivers, the manual volume control is in the detector circuit while the A.V.C. is located in the return of the control grid circuits of the R.F. and I.F. amplifier tubes. Some older models of Radio receivers placed a variable resistance between cathode and ground of the R.F. and I.F. amplifier tubes in order to obtain manual volume control.

We mention these points to emphasize the fact that the grid bias voltage is important in controlling the amplification of a tube and therefore the volume of the signal. For complaints of "Lack of Volume", the grid bias voltages should be checked very carefully.

While explaining the circuits of the previous Lessons, we have traced most of the common arrangements for obtaining anegative grid bias and also suggested a combination of continuity and voltage tests by which the grid bias voltage could be measured quite accurately.

Referring to a tube chart, you will find recommended values of grid bias voltage for each type of tube and, as explained for the plate voltages, the recommended voltages can be adjusted to suit any ordinary ratio of supply or plate voltages.

For the tubes of the circuit of Figure 1 you will find the following recommended values:

6SA7 - 0 volts
6SK7 - −3 volts
6SQ7 - −2 volts
6SF5 - −2 volts
6K6G - −18 volts

Checking the diagram, the 6SA7 cathode is grounded through the oscillator coils which have a low value of d-c resistance and therefore the cathode to ground voltage will be low or practically zero. The control grid circuit is grounded through two 2 meg resistors and the .5 meg volume control of the avc and, with no signals there will be no voltage drop across any of these resistors.

The control grid of the 6SK7 also grounds through the avc circuit but there is a 500 ohm bias resistor between the cathode and ground. In this resistor, the total cathode current will cause a voltage drop which, with no signals, will be the grid bias voltage for this tube.

For the triode section of the 6SQ7 tube, the cathode is grounded and the control grid grounds through a 4 megohm resistor. The tube chart recommends a 2 volt negative bias and, if you want to figure it out, you will find that a leakage grid current of .5 microampere in the 4 megohm grid resistor will cause the required 2 volt drop. This arrangement has become quite popular for high mu tubes, especially of the diode-triode types, as it simplifies the circuits by eliminating the usual bias resistor.

It will be difficult to measure the bias voltage in circuits of this kind, when using the ordinary type of meter but, as previously explained, a continuity test of this part of the circuit is usually sufficient.

The characteristics of the 6SF5 are very similar to those of the triode section of the 6SQ7 and therefore, its cathode is grounded and the voltage between cathode and ground will be zero. In high mu tubes, the control grid is placed quite close to the cathode and an appreciable number of emitted electrons, attracted by the positive plate, are captured by the grid. This causes the small leakage grid current mentioned for the 6SQ7 and the usual cathode bias resistor is not needed. Thus while the grid bias voltage is obtained across a high grid resistance, it can not be measured with the conventional type of test meter, a continuity test of the grid circuit will usually be sufficient.

For the 6K6G output tubes, there is a 400 ohm bias resistor, between the cathodes and ground, the arrangement being similar to that of the 6SK7 tube. Here, as both cathodes are connected to this resistor, it will carry the total current of both tubes and the voltage drop across it can be measured in the usual way.

There is no condenser connected across this bias resistor because, in a Class A push pull stage, the total current of both tubes should remain at a fixed value. That is because the signals on the grids are 180° out of phase and, as the plate current of one tube increases, the plate current of the other should decrease by an equal amount.

This balance does not always hold true in practice and therefore you will find many push pull output stages of this kind with the usual condenser connected across the bias resistor.

The omission of the condenser also provides an inverse feed back action because, without it, the voltage drop across the resistor will vary with the current in it. Thus, if the total current should increase, the voltage drop would also increase and provide a greater negative grid bias which would tend to reduce the current.

High negative grid bias voltages are a common cause of "Lack of Volume" and a voltage test from the reference point to the grid return, (usually cathode to ground), plus a continuity test of the circuit, from the grid to the grid return, will usually provide all the information you need in respect to their operating voltages.

INPUT CIRCUITS

The input circuits are also common offenders in cases of "Lack of Volume." The situation here is much like that of the supply voltages because, without the proper source, the following voltages can not be correct. Strictly speaking, the input circuit consists of the anténna and all component parts connected between it and ground.

One point to keep in mind here is that each model of Receiver, when operating properly, has a very definite value of sensitivity. That is, for every micro volt of signal developed across the input circuit, there will be a definite value of output voltage or power.

Some manufacturers publish the sensitivity specifications as part of their alignment data while others do not but many Radio Service Men do not have the equipment to make accurate measurements of this kind. Therefore, the following general suggestions should be helpful.

The sensitivity of most older model Receivers was so low that for good reception of all but local Broadcasting stations, an outdoor antenna was necessary. As later models were de-

signed with greater sensitivity, the required length of the antenna was reduced but an external antenna was still recommended.

Still later, some models had 25 ft to 50 ft of flexible wire permanently attached to the Receiver and this wire was stretched out around the picture moulding or under the rug in a room to provide sufficient signal in the antenna or input circuit.

To eliminate the antenna, as far as the Receiver owner is concerned, many modern Receivers are equipped with a "Built In" antenna, usually made in some form of a loop. Some of these are comparatively large and are mounted inside the con sole while for the table models, the tuned coil of the input circuit is wound as a flat spiral of wire with dimensions a little smaller than the length and height of the cabinet.

Many complaints of "Lack of Volume" can be traced to the input circuit alone and are not due to defects in the Receiver. Any defect in an outdoor antenna will cause a reduction of signal input voltage with a corresponding lack of volume.

An outdoor antenna may look to be in good condition but a corroded connection or high resistance joint can greatly reduce its electrical efficiency. When a Receiver is brought in with a lack of volume complaint but performs satisfactorily on your antenna, you are justified in blaming the owner's antenna for the trouble.

Again, one of the attached antennas may be accidentally cut to a fraction of its original length and the resulting loss of signal input voltage will cause a "Lack of Volume" complaint.

Loop antennas are quite directional and, when fastened permanently to the Radio Receiver chassis sometimes make it necessary to place the Receiver in a certain position to receive desired signals satisfactorily. With no external antenna, it is a simple matter to move the Receiver from one part of the room to another. However, this change may place the loop in a "North-South" instead of an"East-West" position, and signals which had plenty of volume in the original location may be too low in the new location.

When this type of trouble is encountered, you can make a convincing demonstration by tuning in some weak station and then, without touching any of the controls, turning the Re-

ceiver to different positions on your work bench or counter. The signals should be loudest when the longest dimension of the loop points directly toward the Broadcast station.

The input circuit has a double duty to perform. First, it must intercept the radiated Radio energy traveling through space and second, convert this energy into signal voltages which will be carried through the receiver. The interception of the Radio energy depends mainly on the physical characteristics of the antenna which include its length, height and location while the conversion of this energy depends on the electrical constants of the input circuit.

As we explained in the earlier Lessons, external antennas are not an integral part of a Radio receiver, as far as mechanical construction is concerned but electrically, are an important part of the input circuit. From a service standpoint, that part of the input circuit, built in as a part of the Radio receiver can be checked electrically and then when the receiver is installed in the owner's home, the external part of the antenna should be checked.

In the circuit of Figure 1 in this Lesson, the input circuit of the receiver extends from the "A" terminal at the upper left to the ground or metal chassis. Tracing between these points, you will find a few turns around the loop as well as the primary of the short wave antenna coil. A continuity test here should show a very low resistance because the total length of wire is comparatively short.

For strong Broadcast Signals the loop itself provides sufficient pick up for satisfactory reception but, for distant Broadcast and short wave Stations, an external antenna is required. In the arrangement shown, the wave band switch does not connect to this input circuit.

Carrying only the usual signal voltages, there is apparently little possibility of trouble here but, in practice, you will find quite a number of these circuits badly burnt. One common cause of this defect is that the owner is told the lighting circuit wires make a good antenna and, to take advantage of this fact, makes a connection from the antenna terminal of the Receiver to a lighting circuit outlet. In some cases this arrangement does provide good reception but, in others, it forms a short across the lighting circuit and the resulting high current often burns off a wire before the lighting circuit fuse blows. When the outdoor antenna is used, the same result may be caused by lightning although the owner may not know that his antenna was struck.

Burned wires are replaced quite easily but many antenna coils have a primary made up of quite a number of turns and, if a break occurs in the coil it is usually necessary to replace it. For this work "Slip Over" or Replacement coils are available in sizes which can be slipped over the original coil form.

This type of replacement reduces the required work and does not disturb the original secondary winding which is matched to those of similar coils to provide proper tuning.

When a Receiver is in operating condition, the input circuit can be tested for defects by moving the antenna to the secondary circuit of the antenna coil or directly to the control grid of the input tube. When this change causes a pronounced increase in signal strength at the speaker, there is usually trouble in the input circuit.

TUNED CIRCUIT ADJUSTMENTS

In every Radio receiver, there are a number of circuits which must be tuned to resonance to provide maximum signal voltages. Some of these, controlled by the tuning dial, make it possible to select individual Broadcast Stations while others, like the I.F. transformers of superhetrodyne circuits, are tuned to some definite, fixed frequency.

Should any of these circuits become detuned, the signal voltage will be reduced and "Lack of Volume" will result although all supply voltages are correct and all circuits in good condition as far as their continuity is concerned.

Looking at the circuits of Figure 1, the Band Switch is shown in the short wave position and you will find the secondary of the antenna coil is connected across section "A" of the 2 gang tuning condenser. Also, there is a 2-40 Mmf trimmer condenser connected directly across the coil which places it in parallel to the tuning condenser.

Section "B" of the tuning condenser is connected across the secondary winding of the upper oscillator coil in parallel to section "B" of the 3 gang trimmer. The trimmer condensers are provided with a "screw" adjustment while the tuning condenser is moved to bring in the different stations. For maximum signals, these condensers must be set so that the resonant frequency of the oscillator will always be equal to the resonant frequency of the tuned loop plus the intermediate frequency.

The I.F. transformers consist of primary and secondary windings each of which has a trimmer condenser connected in

parallel. These trimmers are adjusted so that the circuits will be resonant at the proper intermediate frequency and thus will provide maximum signal voltages.

The method of making these adjustments will be explained completely in later Lessons on "Alignment" therefore, at this time, we want to point out only that a "Lack of Volume" complaint may be caused by the improper adjustment of any one of these tuned circuits.

Should some inquisitive owner tighten all of these trimmer condenser adjusting screws, because they appear to be loose, the circuits may be detuned sufficiently to cause a complaint of "No Signals".

After all the routine voltage and continuity tests have been made it is usually a good plan to make a check of all the various controls. Starting at the left of Figure 1, you will find the Band Switch Control. This is a simple four circuit double throw switch but not all of the contacts are used. Make continuity tests up to and through the switch in each of its positions.

The tuning condenser is shown as having two gangs, the rotor of each being grounded. As already explained, a short between the plates most likely would cause a complaint of No Signals, but it is well worth the time it takes to inspect the plates for clearance and check the connections for resistance.

The next control is a single pole, double throw switch, shown just above the power transformer. It makes the audio amplifier available for either Radio or Phonograph signals.

A simple continuity test here is usually sufficient but there must be a good "zero resistance" contact across the switch in either position. In arrangements of this kind there is sometimes enough capacity in the switch to allow some strong Radio signals to pass even when the switch is in the "Phono" position.

Thus, if this switch was accidently turned to the Phono position, it might not be noticed by an owner not using it yet could cause a complaint of "Lack of Volume". Things of this kind are easily found by making a thorough inspection and check of a Receiver but can cause endless trouble if overlooked.

The Volume Control, shown directly above the "Radio Phono" switch is the usual type of Potentiometer and can be checked by a continuity test. A good plan here is to place a test

prod on the center terminal and, holding the other prod on one end terminal, turn the control knob for its entire arc of travel. The indicated resistance should increase or decrease steadily as the knob is turned. For a more complete check, move the test prod from one end connection to the other and turn the control knob again. When the meter hand is jumpy and does not always move the same way, as the knob is turned in one direction, it indicates trouble in the control and usually a replacement is advisable.

The tone control, shown to the right of the volume control is usually made as a three terminal potentiometer but often, only two of the terminals are used. This makes the unit operate as a rheostat and it can be tested exactly as explained for the volume control. According to the diagram notation the "ON-OFF" power switch is mounted on the tone control.

The moving arm of this 1/2 megohm tone control connects to ground through a .003 MF. condenser. This circuit might easily be overlooked when making the routine voltage and continuity tests but, should this condenser be shorted, it could reduce the plate voltage of the triode section of the 6SQ7 and thus cause a Lack of Volume at some positions of the tone control knob.

Thus, as a part of your general inspection of a Radio Receiver, make a close inspection to locate all of the control knobs and switches. Then find out their purpose, by tracing circuits if necessary and, when the Receiver power is on, try them in all positions. You can not be too careful and often it is the little details, easily overlooked, which cause the most trouble.

As we stated earlier in this Lesson, "Lack of Volume" can be considered as a mild case of "No Signals" and the possible causes for both conditions are quite similar. However, with even faint signals in the speaker, there is something to work on and, with a little experience you will find the variations in the quality of the weak signals often provide good clues as to the location of the defect.

To continue with the general classes of trouble, for our next Lesson we will take up the subject of Broad Tuning in which the customer complains that he can hear two or more Broadcast stations at the same time.

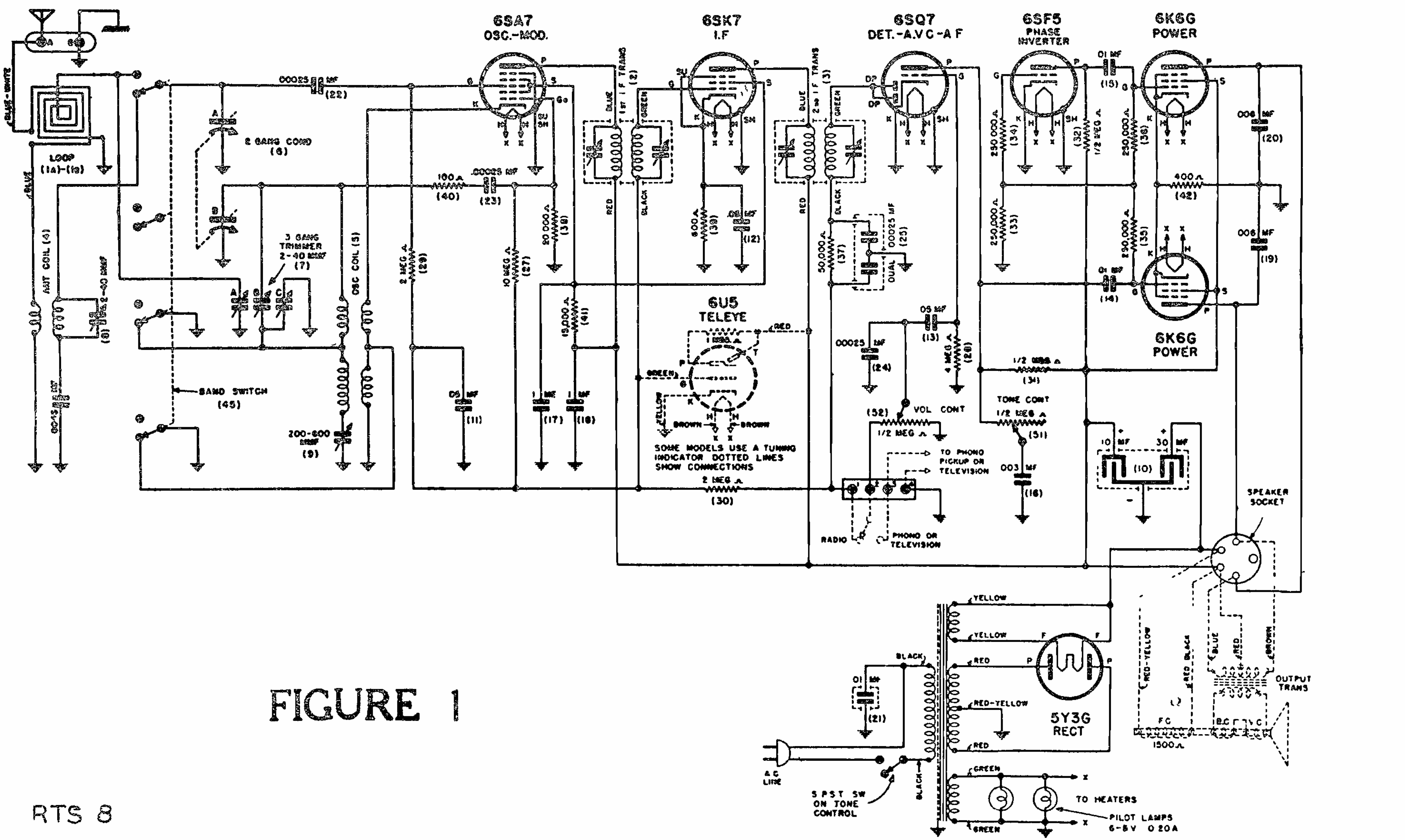


FIGURE 1

RTS 8

QUESTIONS

How many advance Lessons have you now on hand? ____________

Print or use Rubber Stamp.

Name ______________________________ Student No. ____________

Street ______________________________

City ______________ State ______________

1. When checking the operation of a defective Receiver, for what test purpose can the tuning eye be used?

2. With parallel connected heaters, what fairly common tube defect can "short out" the cathode bias resistor?

3. Without the specifications of a Receiver, where can the operating values of plate and screen grid voltages be found?

4. A tube chart lists -50 volts grid bias for an output tube operating with 250 volts on the plate. What value of grid bias is required for operation with 200 volts on the plate?

5. With a normal supply voltage, what circuit defect usually causes low plate and screen grid voltages?

6. With a near normal supply voltage, what two defects generally cause zero plate and screen grid voltages?

7. In high mu triodes, what is the common method of obtaining self bias without a cathode resistor?

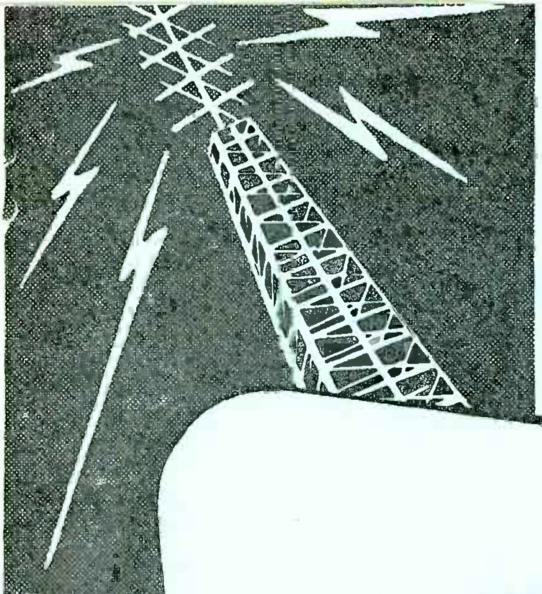
8. With self bias in a balanced push pull output stage, is a cathode bypass condenser necessary? Why?

9. What simple correction may increase the signal output of a Receiver equipped with a "Loop" or "Built In" Antenna?

QUESTIONS (Continued)

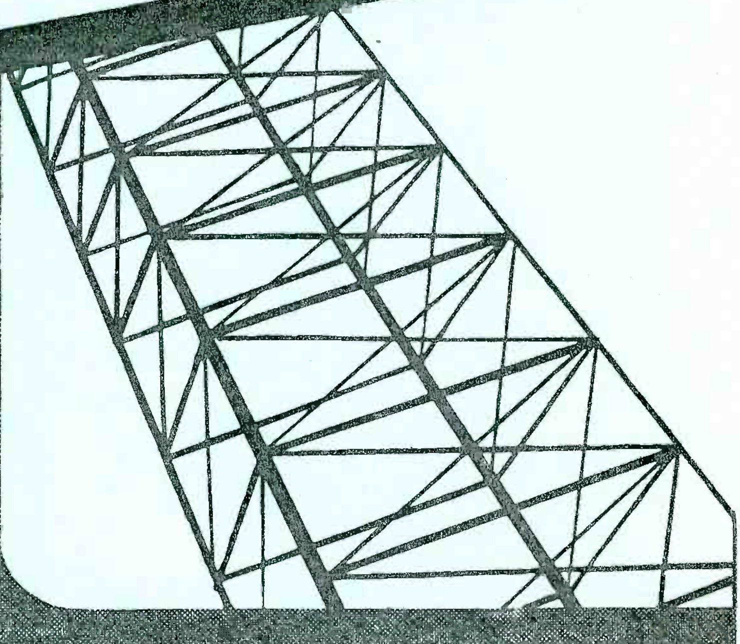
Name ______________________________ Student No. __________

10. Using the antenna, what simple test can be made for defects in the input circuit of a Receiver?



LESSON RTS - 9

TYPICAL FAULTS - BROAD TUNING



DE FOREST'S TRAINING, INC.

2533 N. Ashland Ave., Chicago 14, Illinois

DE FOREST'S TRAINING, INC.

RADIO AND TELEVISION SERVICING

LESSON RTS-9

TYPICAL FAULTS -- BROAD TUNING

Type of Circuit -------------------------- Page 2
Number of Tuned Circuits ----------------- Page 4
Signal Tuning Circuits ------------------- Page 5
Trimmer Tuned Circuits ------------------- Page 8
Number of Stages ------------------------- Page 10
Ganged Tuning Condensers ----------------- Page 10
Signal Strength vs. Selectivity ---------- Page 12
Antennas --------------------------------- Page 13
Summary ---------------------------------- Page 15

△ △ △ △ △

Nothing of worth or weight can be achieved with a half mind, with a faint heart and with a lame endeavor.

-- Bar_ow

BROAD TUNING

As a Radio service man, you must always remember that your customers, with a very few exceptions, are not technical and have no Radio knowledge. They may be quite expert in the manipulation of the various control knobs, may be right up to date on the many Broadcast Programs and Personalities and may have replaced a tube or wire once or twice.

With the simplified controls of the ordinary receiver, this type of person honestly believes he is pretty smart, when it comes to Radio and, when he requires service, is usually inclined to tell the service man how it should be done. He can easily become a nuisance, if not a liability to your business, unless you handle him properly.

Repeating the suggestion of a former Lesson, do not argue, even though he makes a mis-statement, but take him up on his own terms and assume he knows nearly as much as he thinks he does. Then you can say, "of course you know this, that and the other thing", points you want to emphasize and usually, to protect his position, he will have to agree with you.

In this way, you can make him admit what you want him to without argument or contradiction and perhaps make him feel rather proud of your acceptance of his "knowledge". On the other hand, should you corner him in an argument and make him admit he was wrong, you would win your point but perhaps lose your customer.

The average customer makes no claims to Radio knowledge but is easily offended if you question his ability to operate his Radio Receiver properly. This attitude is more pronounced among the "Old Timers" who purchased their Receivers years ago and are accustomed to the low sensitivity and broad tuning of the older models. They have difficulty in tuning the later models, with their greater selectivity, and may complain of noise and distortion which is due only to mis-tuning and a high setting of the volume control.

Theirs is a genuine complaint which the successful service man will handle with the same skill and customer satisfaction as the replacement of a shorted filter condenser. The function of the service man is to provide his customers with satisfactory Radio reception therefore, all troubles, in the Receiver itself or with the operator, are his responsibility.

He must use his technical knowledge, not only to make actual electrical repairs but to instruct or educate his customers so that they may obtain the greatest pleasure and benefit from their Radio equipment.

Most people are anxious to learn provided they can obtain information without being made to appear ignorant. For the type of customer with tuning difficulties, it does not take long to explain the great improvement in the selectivity of the later model Radios as compared to the older ones.

The benefits of this increased selectivity can be emphasized together with the additional tuning care which must be exercised by the listener in order to obtain these benefits. When the customer has a good idea of the actual conditions, he will usually cooperate to the best of his ability because it is to his advantage to do so.

The popularity of the "Push Button" tuners is good evidence of the common difficulty in tuning, usually due to the impatience of the listener, and therefore, for complaints of this nature, you may find that many of the Receivers are in perfect electrical condition.

Perhaps the most common complaint of this general class is that of interfering signals. That is, when the owner tunes in one station he hears a second station also. A more aggravated cause is one in which several stations are heard at all points of the tuning dial.

Then there are other cases in which the interference occurs only at certain points or over certain sections of the tuning range and usually, a careful analysis of the complaint will be of great assistance in diagnosing the trouble.

TYPE OF CIRCUIT

After listening carefully to your customer's complaint, it is well to ask questions to identify the variations mentioned above. Does the trouble occur all over the dial or only at certain points and with certain stations? If so, where are these points and what are the call letters of the stations? Does the trouble occur at all times or only during certain hours of the day or evening? Can the reception be improved by adjusting the volume control?

Depending on the locality, other similar questions may be needed. For example suppose a local or nearby Broadcast station has a frequency close to a distant clear channel station. If the local station is on the air for certain hours, and the interference occurs during those hours only, the cause of the trouble is clear. Other combinations, of relative power and distance from the receiver, of two Broadcast stations will be found which cause difficulties of reception.

Once the details of the cause of the complaint are known, it is much easier to work out the necessary corrective measures. Before this can be done, it is important to determine the type of receiver circuit. This one can be done by following the suggestions made for the "Indentification of Circuit" in the earlier "General Diagnosis" Lesson.

As practically all commercial receivers are either TRF or Superheterodynes, for the Figures of this Lesson we show a representative circuit of each type. For Figure 1, we show a common 4 tube, a-c,d-c receiver of the so called "Midget" or Table type while, for Figure 2, you will find the circuits of a 3 band, 6 tube, a-c super.

The selectivity of any Receiver depends on its ability to discriminate against unwanted signals while its ability to receive desired signals is its "Sensitivity". Do not confuse these two characteristics, although there is a certain amount of interaction between them. In general, the selectivity depends on the "sharpness" of the tuned circuits while the sensitivity depends on the amplification or gain of the complete circuit.

The more sensitive the receiver the greater the gain of the unwanted, as well as the wanted signals and, as the volume control changes the overall gain, it also affects the sensitivity. As high volume, the unwanted signals will be stronger and thus, the setting of the volume control will alter the apparent selectivity.

In our former explanations, we told you that, at resonance, a tuned circuit provided maximum response to the resonant frequency. That is still true but, for cases of interference, it is well to think in reverse as to how weak the off-resonance frequencies are as compared to the resonant frequencies. That is why most values of selectivity are stated as "Down" so much, usually a number of decibels, at so many cycles or kc off resonance.

TRF circuits, on the general plan of Figure 1, use manually tuned stages to amplify the modulated carrier between the antenna and detector. The frequency is not changed and each tuned circuit must resonante at all the frequencies of the tuning range.

Superheterodyne circuits, on the general plan of Figure 2, mix the carrier frequency with that of the local oscillator to produce the intermediate frequency which is amplified before reaching the detector. Here; the input and oscillator circuits must resonante at all frequencies of the tuning

range but the i-f amplifier operates always at one and the same frequency.

We are reviewing these actions because they are important in the diagnosis and care of a "Broad Tuning" complaint.

NUMBER OF TUNED CIRCUITS

Looking at the circuits of Figure 1, you will find but two tuned circuits. The grid circuit of the 6D6 r-f tube and the grid circuit of the 6C6 detector tube. The short wave switch, marked "S.W.", merely shorts out some turns of each of these tuned coils to raise the frequency of the tuning range.

Receivers of this same general type have been made with 3 or more tuned stages but each stage requires its own tuning condenser. For single dial control, all these stages must tune exactly alike thus, the greater the number of stages, the greater the tuning difficulties.

In the circuits of Figure 2, again there is a two gang tuning condenser, one gang for the input circuit and one gang for the oscillator. The signal voltages pass through the tuned input circuit and then through two i-f transformers each of which has a tuned primary and a tuned secondary. Thus, neglecting the oscillator, the signal passes through five tuned circuits between the antenna and detector.

Another point to remember here is that the i-f transformer operating on but one frequency, can be made to give greater efficiency than a similar circuit which must resonate over a band of frequencies. That is why the selectivity of a superheterodyne receiver will be more uniform than that of a TRF receiver over the tuning range.

We mention these facts to help you make a better estimate on the degree of selectivity you can expect for any particular circuit. Often, on strong or local signals, the TRF receiver will sound as well or even better than a superhet because its lack of selectivity will permit a higher degree of fidelity.

As a service man, you are not responsible for the design of a receiver circuit but should be able to adjust the circuit for its maximum performance. The designer has decided the desirable or acceptable balance between selectivity and sensitivity and it is your job to restore and maintain this balance.

As the gain of the various tuned stages has an effect on the selectivity as well as the sensitivity or gain of the circuit, your test routine, for complaints of "Broad Tuning" is about the same as that for "Lack of Volume".

Test the tubes first and test all of them because a weak rectifier tube can lower all of the plate and screen grid voltages while a weak tube in an audio stage may make it necessary to set the volume at too high a level.

After the tubes are known to be good, make sure that all of them, particularly those between the antenna and Detector, are supplied with the proper values of voltage. Tests for these operating voltages are made as explained in the earlier Lessons, therefore we will not repeat.

SIGNAL TUNING CIRCUITS

All of the circuits which carry signal voltages are important but those which are tuned to resonance at the carrier or Intermediate frequencies control the selectivity of a Radio Receiver. In the circuits of Figure 1 of this Lesson there are two circuits of this type. The secondary of the input or antenna coil, or transformer and secondary of the r-f transformer which couples the plate of the 6D6 r-f tube to the grid of the 6C6 detector.

Neglecting the short wave switch, "SW", these are simple arrangements with a variable condenser connected across the coil or inductance. As shown in the diagram, it is common practice to ground one end of the coil and the rotor plates of the variable condenser. Electrically, the coil and condenser are in parallel to the control grid circuit of the tube.

From a service standpoint, there should be a low resistance path through the coil and adjacent turns should not touch to short out any of the windings. The condenser plates should not touch to form a short, a condition we explained in the former "No Signals" Lessons.

For a complaint of Broad Tuning, shorts and opens are not common but cases of high resistance are quite frequent. Any increase of resistance in a tuned circuit causes a broadening of the resonance curve, a reduction of peak response and a loss of selectivity.

For the usual continuity test, a variable condenser should show "infinite" resistance but the resistance between each set of plates and one end of the coil must be as low as possible and should test as a "Short".

To insure a low resistance between the rotor plates and the frame, most variable condensers are equipped with a flat spring which straddles the shaft and presses against the rotor at its center and against the frame at its ends. This arrangement forms a low resistance path between the rotor and the frame, eliminating the shaft with its bearings which may be oily.

Should the shaft and bearings be used as a part of the electrical circuit, variations of resistance, as the rotor turns, would cause "static" in the speaker and the increase of resistance, due to oil between the shaft and frame, would cause broad tuning.

Therefore, it is a good plan to inspect these springs by slipping a knife blade through their points of contact to check their tension. They should be tight enough to keep their points of contact bright and shiny.

Dirt and corrosion can be removed by pulling a piece of sandpaper through the points of contact with the sand side of the paper first one way and then the other. To complete the work, pull a piece of cloth through to remove any loose particles of sand.

Some older models of tuning condensers were not equipped with these springs but a good substitute can be made by attaching a piece of flexible wire to the rotor, making a loose turn around the shaft and fastening the other end to the frame. This is known as a "pig tail" and it must be large enough to permit full movement of the rotor plates.

The connection between the condenser frame and chassis, or other point of the circuit, should be tested for low resistance and should check as a short. To eliminate trouble caused by vibration, some variable condensers are mounted on rubber grommets, but the rubber insulates the frame from the chassis base. Check these types to make sure there is a low resistance path between the condenser frame and the proper point of the circuit.

In much the same way, a resistance test should be made between the variable condenser stator plates and the grid of the tube as well as the grid end of the coil. To complete the work, test from the other end of the winding to ground or other point at which it connects to the circuit.

Similar tests can be made for the tuned grid circuit of the 6C6 detector tube shown in Figure 1 but there is one important difference. The rotor plates of the condenser are grounded directly but the lower end of the coil is grounded

through a one megohm resistor and the 100 ohm resistor in the power supply filter.

In this arrangement, a resistance test from coil to ground would show about one megohm of resistance, a condition which might be interpreted as a defect. However, a visual inspection would locate the .25 MF. condenser connected between the lower end of the coil and ground.

Like the variable condenser, the D.C. resistance of this fixed condenser should be extremely high but, its connections to the coil and ground should test as a short. This circuit carries signal voltages and, at the low Broadcast carrier frequency of 550 K.C., the reactance of a .25 MF. condenser is but a little more than 1 ohm. Thus, as far as the signal voltages are concerned, the coil is effectively grounded.

In general, continuity tests of condensers should show a very high or "Infinite" D.C. resistance for the condenser itself but an extremely low resistance or short for the connecting wires.

To tune a circuit of this type, the fixed condenser is in series with the variable condenser across the coil. To explain the action here, we will remind you that the total capacity of two condensers in series is equal to the product of the separate capacities divided by their sum.

Common types of variable condensers for Broadcast Receivers have a maximum capacity of 365 MMF. and connected in series with a .25 MF. condenser, the total capacity will be about 364½ MMF. Thus, the fixed condenser does not interfere with the capacity values for tuning, provides a low reactance path for signal voltages yet permits a D.C. bias voltage to be maintained on the grid.

In this position, an open condenser would place the D.C. bias voltage resistors in the tuned circuit and thus cause broad tuning. A reduction of capacity could change the resonant frequency of the circuit while a shorted condenser would cause zero grid bias.

A somewhat similar arrangement is shown in the "A" band of the circuit of Figure 2. The control grid of the 6A7 mixer tube is connected to the stator plates of the tuning condenser and, through the switch to the upper end of the antenna coil secondary. The rotor plates of the condenser are grounded direct but the lower end of the coil is grounded through the A.V.C. circuit which consists of a 1 megohm resistor, the volume control and a 4000 ohm resistor.

At the coil end of the 1 megohm resistor there is a .1 mfd condenser to ground and, as far as the tuned circuit is concerned, its action is like that explained for the .25 mfd condenser of Figure 1. Continuity tests can be made here on exactly the same plan explained for the grid circuit of the 6C6 Detector tube of Figure 1.

For the "B" and "C" ranges, the avc circuit is not used and the coils are grounded directly the same as that in the grid circuit of the 6D6 tube of Figure 1. Therefore, the tests for the "B" and "C" ranges can be made as explained for the 6D6 grid circuit of Figure 1.

The tuned circuits of the oscillator of Figure 2 are somewhat different because, as explained in the earlier Lessons, the grid current in the 50 M ohm resistor will cause the proper voltage drop for the negative grid bias. Therefore the tuned secondary of the "A" oscillator coil does not have a conductive or d-c path to ground.

The upper end of the coil connects to the stator plates of the tuning condenser while the lower end connects to ground through the two .0003 mfd parallel connected padder condensers. A continuity test should be made here from the stator of the tuning condenser through the coil to the ungrounded ends of the padder condenser and from each of the other condenser terminals to ground.

Notice here, the .0003 mfd condensers are in series with the tuning condenser across the coil the same as the .25 mfd condenser in the 6C6 detector grid circuit of Figure 1. Here, however, the two .0003 mfd units have a total capacity of .0006 mfd or 600 mmfd which, in series with a 365 mmfd tuning condenser makes an important change of total capacity.

At the positon of maximum tuning condenser capacity of 365 mmfd the .0006 mfd of series capacity will reduce the total to about 225 mmfd. Assuming a 10 to 1 ratio, at the position of minimum tuning condenser capacity of 36.5 mmfd, the .0006 mfd of series capacity will reduce the total to about 34.5 mmfd. Thus, it is evident that the padder condenser has its maximum effect at the maximum capacity position of the tuning condenser which is the low frequency end of the tuning range.

TRIMMER TUNED CIRCUITS

As we mentioned earlier in this Lesson, there are but two tuned circuits in the diagram of Figure 1, each of which is controlled by one gang of the tuning condenser and designed to resonate at all frequencies of the tuning range. Although

not shown in the diagram, each gang of the tuning condenser usually has a small trimmer condenser connected in parallel.

For the common types, the trimmer has a variable capacity of from 3 mmfd to 30 mmfd, adjustment being made by means of a screw with a slotted head. Turning this screw with a small screwdriver, controls the distance between the condenser plates and thus adjusts the capacity.

Thinking of the common 365 mmfd tuning condenser gang, at maximum capacity, the adjustment of the trimmer can cause a reduction of but about 7% while, at minimum capacity, it can cause an increase of about 70%. These values show clearly why, when used in parallel with a tuning condenser, a trimmer condenser should be adjusted with the tuning condenser at a position of minimum capacity.

In the circuits of Figure 2, there is a trimmer condenser connected across each of the three coils A, B and C, in both the input and oscillator circuits. These are adjusted when the receiver is aligned and are in the nature of an adjustment because one setting holds good for all tuning.

Looking at Figure 2 again, there are two i-f transformers, between the 6A7 mixer tube and 75 detector, each of which has a tuned primary and secondary circuit. The tuning condensers here are of the trimmer type designed for adjustment with a screwdriver or socket wrench because, due to the action in the mixer tube, all the modulated i-f carriers are of one and the same frequency. Thus, the trimmer condensers are adjusted or set, usually for maximum response, at this frequency and their circuits provide uniform amplification for frequencies of the tuning range of the input circuits.

When connected in parallel to a larger capacity tuning condenser, the trimmer is used as a compensating device to equalize variations of capacity in the connecting wires but, when connected across a coil, as shown for the i-f transformer of Figure 2, it is the tuning condenser.

A later Lesson will take up the subject of alignment in detail but, at this time we want to point out that, unless all of the tuned circuits resonate at the proper frequency, the selectivity of the receiver will be reduced and Broad Tuning will result. In fact, you may find cases in which the mistuning of these circuits will cause "Lack of Volume" and even "No Signals" complaints.

Trimmer condensers should be tested for shorts on the same plan as explained for tuning condensers, but the trimmers

usually have mica as the dielectric. Adjacent plates may touch the mica but there should be an extremely high resistance between them.

NUMBER OF STAGES

While the characteristics of different receivers will vary over quite a wide range, in general, the overall selectivity depends upon the sharpness of each stage and the number of stages.

The sharpness of a stage can be found by measuring the output with uniform input voltages of different frequencies. For example, suppose an input of one volt at the resonant frequency produced an output of 10 volts, at 5 k-c off resonance, an input of 1 volt produced an output of but 5 volts while at 10 k-c off resonance, an input of 1 volt produced an output of 2 volts.

Working the other way, the input voltage can be varied to produce a constant output voltage and, using the values above, a one volt input at the resonant frequency would produce an output of 10 volts. At 5 k-c off resonance, it would require an input of 2 volts and, at 10 k-c off resonance, an input of 5 volts to produce a 10 volt output.

Thus, you can think of selectivity as a measure of the reduction of off frequency input voltages of the same amplitude or as the required increase of off frequency input voltages to provide equal output voltage.

Using either plan, for this example, the ratio between the voltages at resonance and 10 k-c off resonance is 5 to 1 and for two stages of this kind the ratio would be 5 x 5 or 25 to 1 because each one has the same action. For three such stages, the ratio would be 5 x 5 x 5 or 125 to 1.

This relationship holds true only when all stages are tuned to the same resonant frequency but, after a receiver has been in service for some time, the units in some circuit may change value with age so that its resonant frequency is different.

GANGED TUNING CONDENSERS

To illustrate this action, and thinking in terms of gain, suppose that each of the two tuned stages of Figure 1 had a gain of 10 at resonance. As already explained, the overall gain for both would be 10 x 10 or 100.

Using the values of the former example, we will assume further that, for a voltage 5 kc off resonance the gain of each stage is 5. Also, we will imagine that, due to change of capacity in one tuning condenser gang, there is a difference of 5 kc in the resonant frequencies of the two circuits at some position of the tuning condenser.

Under this condition, an input voltage with a frequency equal to the resonant frequency of the first stage would be 5 kc off resonance for the second stage. The gain would be 10 for the first stage and 5 for the second making a total of 50, reducing the overall gain to 1/2 of its proper value.

At the same time, an input voltage with a frequency of 5 kc off the resonant frequency of the first stage could be equal to the frequency of the second stage. The gain would be 5 for the first stage and 10 for the second, again making a total of 50.

Thus, two carriers, 5 kc apart in frequency, would be amplified to the same degree and produce signals of equal strength. There would be no selectivity, as far as these carriers were concerned, causing a complaint of "Broad Tuning".

With both circuits tuned to the same frequency, a carrier of equal frequency would have a gain of 10 x 10 or 100 while a carrier 5 kc off resonance, would have a gain of 5 x 5 or 25. Assuming equal input voltage, the carrier at the resonsant frequency would have 4 times the voltage of the 5 kc off resonance carrier at the output of the second stage.

Many of the older models of Receivers employed tuning condensers with 3, 4 and sometimes five gangs. Although mounted on the same shaft, the mechanical construction was such that the rotors might shift in position thus changing the resonant frequency of one stage in respect to the others.

Fortunately, the position of maximum gain is also the position of maximum selectivity therefore, by making adjustments for maximum gain, the position of maximum selectivity will be found.

For Superheterodyne Receivers, on the general plan of Figure 2, one gang of the tuning condenser controls the oscillator frequency which usually, should be equal to the signal carrier frequency plus the intermediate frequency. Thus, although it operates at a frequency different from that of the input stages, the tuning of the oscillator is extremely important. Unless it operates at the proper value, the

intermediate frequencies will be incorrect and therefore the i-f stages will not provide the proper gain and selectivity.

SIGNAL STRENGTH VS SELECTIVITY

In explaining the action of tuned circuits, in regard to their gain and selectivity, we assumed conditions of equal input or equal output for voltages of different frequencies. Under actual operating conditions, neither of these assumptions are completely correct because there is a wide range of input voltages in respect to frequency and amplitude, with corresponding variations of output.

Neglecting the effects of variations in Receiving Antennas, carrier frequencies and terrain, for any Receiver, the input signal voltage caused by any transmitting or broadcast station will depend on the power of that station and the distance between it and the Receiver.

Without going into mathematical details, this means simply that a 100 watt, local broadcast station can produce a higher signal input voltage than a distant 50,000 watt station and thereby cause interference.

To show how this works out, we can go back to the circuits of Figure 1 and, using the values of a former example, assume the two tuned stages have a gain of 100 at resonance and a gain of 4 at 10 kc off resonance, for a ratio of 25 to 1. Further, we can consider the low power local station produces an input voltage 25 times as great as that of the distant high power station. To complete the conditions, we will assign carrier frequencies 10 kc apart.

Then, with the receiver tuned to the distant station, its signal will be amplified 100 times while the signal of the local station, with a carrier frequency 10 kc off resonance, will be amplified but 4 times. Thus, although the original signal of the local station was 25 times as great as that of the distant station, they would be equal at the output of the second stage.

Technically, the selectivity of these two stages has caused a 25 to 1 improvement but practically, both signals would be heard with about equal volume and the owner of the Receiver would complain.

Following the same plan of calculations, if the local signal were but 10 times as great as the distant signal, at the output of the second stage, the distant signal would be 2-1/2 times as great as the local. With equal input signals, the distant

signal would be 25 times as great as the local at the output of the second stage.

The figures of these examples have been kept small for simplicity because, in practice, the satisfactory separation of signals requires a voltage ratio of about 100 to 1. Also, to prevent interference of this type, Broadcast stations with but a 10 K.C. difference in their carriers are separated quite widely in location.

Broadcast stations in the same locality usually have carriers at least 50 K.C. apart and, as the response of tuned circuits drops off quite rapidly, at frequencies further off resonance, a receiver having a circuit like Figure 1, usually provides satisfactory reception.

To remedy complaints of "Broad Tuning" the service man can restore the tuned circuits to their original operating conditions, in regard to supply voltages, resistance and capacity and usually, this is sufficient. Should the owner still complain, then the trouble can be considered as outside the Receiver and the operating conditions must be examined.

ANTENNAS

From your earlier studies, you will remember that the antenna of a Receiving System is the part which converts the Radiated Radio Energy into the signal voltages. As this is essentially an application of Electro-Magnetic Induction, the physical dimensions of the antenna have an important bearing on the strength or amplitude of the induced signal voltages.

Thinking of the common type of Broadcast Receiving antenna which consists of a single wire, connected at one end to the Receiver, there are several points to keep in mind. Other things being equal, the signal strength will vary in proportion to its length and height.

In some cases of broad tuning, a cure can be effected by simply shortening the antenna. This can be done by actually cutting the wire or connecting a small capacity in series with it. This will decrease the input signal voltage and, from the examples given earlier in this Lesson, it is easy to understand why the apparent selectivity is increased.

Buildings which contain metal pipe systems for Heating and Water may present some interesting combinations. Customers may tell you their reception is improved by removing the ground connection, connecting the Receiver Antenna to the steam pipe or other similar arrangements. Due to the wide variations in the size and construction of homes and apart-

ments no general rule can be given and usually, the best arrangement must be determined by experiment.

Starting from the earth or ground, buildings of this type have three metallic systems, insulated from each other and elevated above ground. The electric lighting wires usually enclosed in metal conduit, form a metallic path from the receiver to the grounded point of the circuit. Sometimes these lighting circuit wires act as a quite effective antenna and, although not connected to input circuits of the receiver, seem to allow the carrier frequencies to "leak" into the signal circuits.

Also, rusty joints in the pipe systems may be quite effective in insulating the elevated portion of a water or heating system and thus, by connecting the receiver at an elevated point, they may act as an antenna instead of a ground. Good results are sometimes obtained by connecting the Receiver antenna terminal to the heating system pipes and the ground to the water pipe while, in other cases, the reverse may be true.

All commercial lighting circuits are grounded at some point in the building and may form a good ground without any actual connection being made. This is because a comparatively small capacity has a low reactance at Broadcast carrier frequencies and the capacity between the 110 volt supply circuit and the Receiver chassis may be large enough to provide the necessary low reactance path.

With this action in mind, remember that but one wire of the lighting circuit is grounded therefore it is always a good plan to reverse the position of the power cord plug in the lighting circuit outlet. This should always be done when installing an a-c, d-c type of receiver.

With the plug in one position you will usually obtain a very definite "shock" if you touch the metal chassis but, with the plug reversed, the chassis is at ground potential and therefore can be handled without danger of shock.

Normally, the receiver and antenna should be installed for maximum signals because in this condition, there will be the most favorable signal-noise ratio. However, in cases of Interference or Broad Tuning it may be necessary to rearrange the antenna to provide a lower signal input to increase the apparent selectivity.

When interference is caused by one or two stations only, changing the direction of the antenna to provide minimum interfering signals, will often provide the required selec-

tivity. This same action holds for Receivers with built-in loop antennas because the loop, or the entire receiver, can be turned until the interfering signal is at minimum.

SUMMARY

To summarize the total routine for a complaint of "Broad Tuning", the first steps are the same as for "Lack of Volume". A general inspection of the Receiver together with an identification of the circuit will provide enough information to estimate the original selectivity of the circuit.

Next, the tubes should be tested because, any tuned r-f or i-f stage with less than normal gain, will cause a reduction of the apparent selectivity. As explained for "Lack of Volume", the operating voltages are important in producing proper gain and therefore affect the selectivity also.

This means that all plate voltages, screen grid voltages and grid bias voltages must be checked carefully, especially for the tuned stages. Remember here, the avc circuits control the operating grid bias voltages and a defective resistor or condenser in the avc filter may cause broad tuning.

For the tuned circuits, the values of inductance and capacity must be correct in order to produce resonance at the required frequency. Unless replacements have been made, the coils and condensers were originally correct therefore any defects which have changed their original values must be located and remedied.

For the coils, the wire may break to cause an open, a defect which can be located by a continuity test. Adjacent turns may make contact and short out a part of the winding. As most Receivers have two or more coils tuned to the same frequency, a comparison of their total resistance will usually indicate the trouble.

The coupling between the primary and secondary coils of r-f and i-f transformers has a pronounced effect on selectivity. In many common units of this type, both coils are mounted on a single form and the coupling depends on the distance between them. This distance is set carefully when the coils are assembled but, after being in service for a time, the coils may shift in position.

In this connection you need remember only that, the smaller the distance between the coils, the "tighter" the coupling, the higher the gain and the lower the selectivity. The greater the distance between the coils, the "looser" the coupling, the lower the gain and the higher the selectivity.

An examination of the "dope" which covers most coils will usually show if their location has changed and enable a return to their original position. However, in some cases where there is ample signal strength in respect to selectivity, the performance of a receiver can be improved by increasing the distance between the coils.

Tuning condensers, variable and trimmer types, must have no internal circuit between the two groups of plates but each group must have a low resistance connection to the proper points of the circuit. A continuity test is usually sufficient, after one group of plates has been disconnected from the circuit, but the capacity must be varied for its complete range while the test is being made.

A fixed condenser, connected in series with the tuning condenser in some circuits, must have sufficient capacity to prevent detuning and low resistance connections to maintain proper selectivity. An open condenser will cause broad tuning while a shorted condenser will alter the grid bias voltage.

For the input signal voltages, the higher their amplitude or strength, the lower the apparent selectivity thus, a change of antenna to reduce the input will provide more selective reception.

When you feel confident that a Receiver is operating to the full efficiency of its design and interference still persists, it will be necessary to "educate" the owner. That is why we have included many of the details of the explanations of this Lesson. If you have a clear picture of the relationship between Receiver design, Selectivity, Sensitivity and signal strength, it will be much easier for you to "sell" your customer on the conditions and thus enable him to obtain the best possible reception.

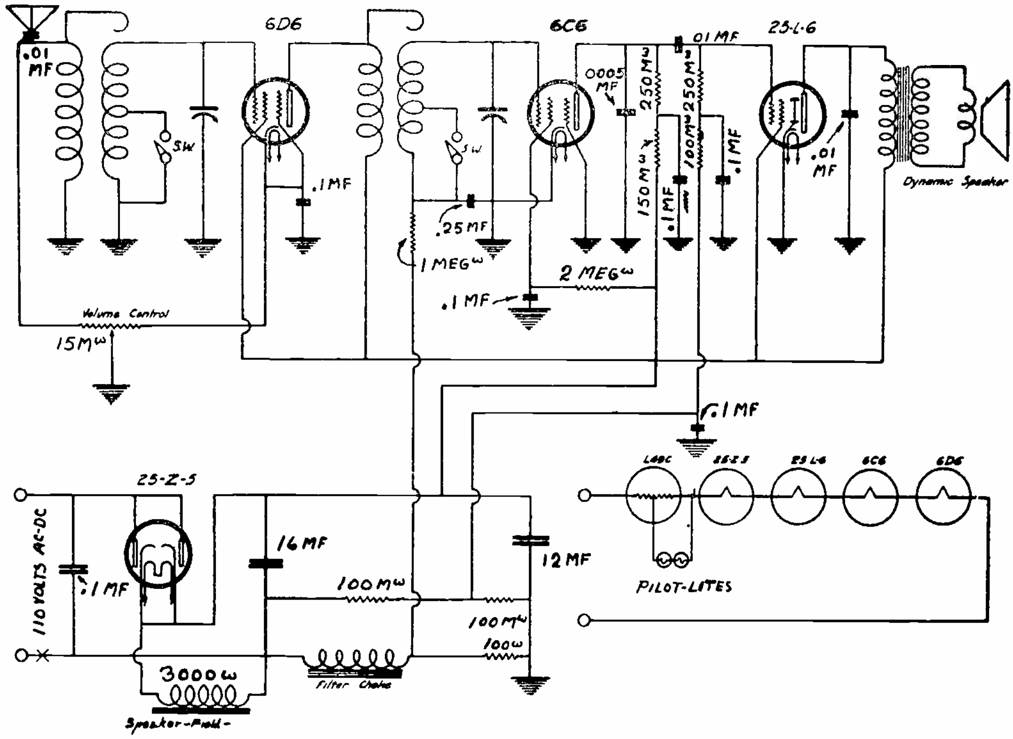


FIGURE 1

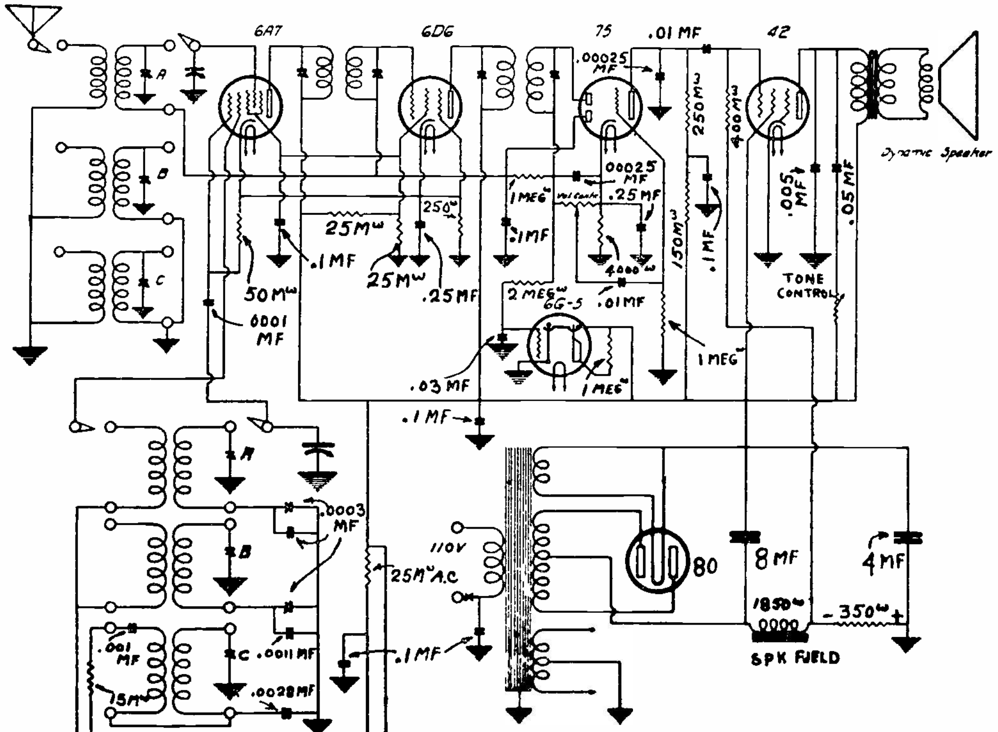


FIGURE 2

QUESTIONS

How many advance Lessons have you now on hand? ______________

Print or use Rubber Stamp.

Name ______________________________ Student No. ______________

Street ____

City ____________________ State ______________________

1. Over the tuning range, why is the selectivity of a Superheterodyne receiver more uniform than that of a T.R.F. receiver?

2. Which circuits control the selectivity of a Radio Receiver?

3. What are the effects of an increase of resistance in a tuned circuit?

4. In most tuning condensers, what is done to insure a low resistance between the rotor plates and frame?

5. In general, what resistance values should be indicated when making continuity tests of condensers?

6. In tuned circuits with a grounded tuning condenser and a coil grounded through the A.V.C. circuit, what is the purpose of the fixed condenser connected between the lower end of the coil and ground?

7. What will be the effect, on the operation of the circuit of Question 6, if the fixed condenser is open?

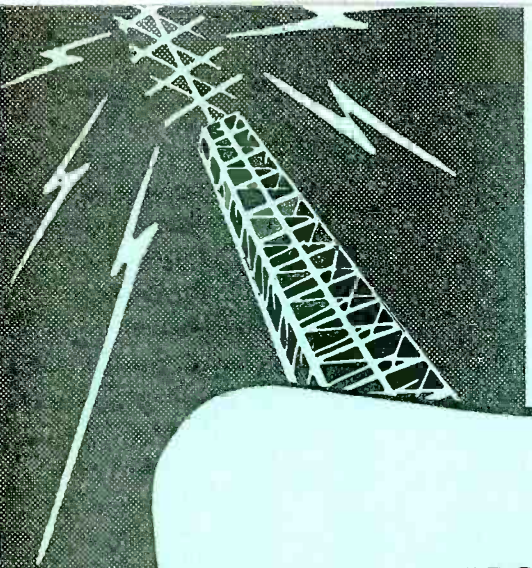
QUESTIONS (Continued)

Name ______________________________ Student No. __________

8. In the circuit of Question 6, what will be the effect if the fixed condenser is shorted?

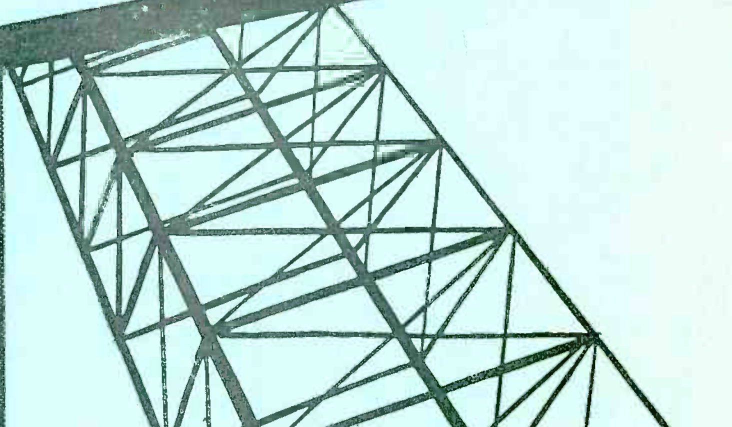
9. In general, upon what does the overall selectivity of a Receiver depend?

10. How does the coupling, between the coils of R.F. and I.F. transformers, affect the selectivity?



LESSON RTS - 10

TYPICAL FAULTS – DISTORTION



DE FOREST'S RADIO ELECTRONICS TRAINING, INC.

DE FOREST'S TRAINING, INC.

2533 N. Ashland Ave., Chicago 14, Illinois

RADIO AND TELEVISION SERVICING

LESSON RTS-10

TYPICAL FAULTS -- DISTORTION

Distortion ------------------------------ Page 1
General Types --------------------------- Page 3
Operating Voltages ---------------------- Page 4
Plate Loads ----------------------------- Page 6
Grid Bias Voltage ----------------------- Page 10
Signal Strength ------------------------- Page 13
Overload -------------------------------- Page 14
Speaker Troubles ------------------------ Page 15
Oscillation ----------------------------- Page 17
Tunable Hum ----------------------------- Page 17

# # # # # #

Do your duty as well as you can do it -- and begin by not hurting others in the effort to please or help yourself. Each can do his duty and he who does that does all that can be asked and all that any man ever did since the world began.

-- Arthur Brisbane

DISTORTION

Used in everyday language, distortion means a twisted or mis-shapen condition and in general, its technical meaning is about the same. As a general definition we can state: Any departure from the initial waveform of a signal, during its complete transmission, is known as Distortion.

Thinking of a Radio Broadcast, a complete transmission includes all steps between the original sound wave, which strikes the diaphragm of the microphone, to the sound waves which reach your ears from the speaker of the Receiver. Thus, all parts of the Transmitter and Receiver are included in a complete transmission.

During a complete transmission, the original sound waves are converted to corresponding changes of electrical energy by the microphone. These changes of electrical energy are then amplified and impressed as modulation frequencies on a Radio Carrier which radiates through space.

The modulated carrier, intercepted by the Receiving Antenna, is converted to corresponding changes of electrical energy which are amplified to some desired level. These amplified signals are then demodulated, leaving the modulation frequencies which are strengthened by the audio amplifier until strong enough to drive the speaker.

The speaker converts these modulation frequencies to corresponding mechanical vibrations of the cone or diaphragm and it converts the mechanical motion to corresponding sound waves which strike the ears of the listener.

Thinking of the definition given earlier in this Lesson, any variation of wave form which occurs during any of these changes will cause Distortion. There can be Acoustical distortion between the origin of the signal and the microphone. There can be mechanical or electrical distortion in the microphone itself. There can be Amplitude and Frequency distortion as the strength of the signal is increased electrically. There can be Modulation distortion as the signal frequencies are impressed on the Radio Carrier. There can be Envelope distortion as the modulated carrier passes from the transmitter to the antenna.

In a reverse order, similar types of distortion can occur as the signal passes through a Receiver from the antenna to the speaker. Technically, these general forms of distortion are subdivided into specific types, the more important of which will be taken up later.

By this time, you may wonder if it is possible to transmit an undistorted signal but, for ordinary programs, it is not necessary to do so. The overall purpose of the usual Radio Receiver is to reproduce speech and music which is pleasing to the ears of the listener and, as the response of human ears varies over quite wide ranges, a certain amount of distortion is sometimes desirable. For example, many Radio Receivers are equipped with a Tone Control yet, according to the general definition, a tone control introduces distortion.

In order to satify your customers, from a Receiver Service standpoint, you must be able to eliminate or reduce undesirable distortion and provide desirable distortion. Here again, the personal tastes of the customer are sometimes of greater importance than the technical performance of a Receiver.

For example, suppose you repaired a complaint of Broad Tuning and returned the Receiver with its original selectivity. The owner, accustomed to "sloppy" tuning, may not tune the stations sharply and complain of distorted signals. Here, you can try to "educate" the customer and sell him on the advantage of good selectivity although a little more care will be required in the operation of the Receiver.

Again, the improved performance of a properly repaired Receiver may cause some confusion in the reception of "Chain Broadcasts". Tuning quickly for the "Program" instead of some particular station, a customer may complain of the noise or "static" and lack of volume. A check up of the Receiver will show that, instead of the local or nearby station he thought he was listening to, actually he had tuned in a distant station of the same chain, operating on a frequency close to that of the local.

The human ear adapts itself quite rapidly to various types of distortion and sometimes, when a repair greatly improves the quality of the signals, the owner may complain because his ears to not react favorably to the change. Complaints of this type are usually temporary because, as soon as the customer becomes accustomed to the change, he will appreciate the improvement.

A little advice or suggestion on the use of a tone control is helpful as many receiver owners do not realize its purpose. A large percentage of them want overemphasized bass for the musical programs and leave the control in this position for news and other voice programs for which the bass response should be reduced.

GENERAL TYPES

The ordinary Radio Service Man is not concerned with the various kinds and types of distortion which may occur in a Broadcast station or Transmitter. Due to competition and technical regulations, most Broadcast signals are of good quality therefore, we are concerned mainly with Distortion which occurs in the Receiver.

According to the general definition, any change in the wave form of the signal is distortion but, as already explained, some changes are considered as an improvement and are therefore desirable. This general type of distortion causes no complaints and therefore seldom concerns the service man.

It is the other general type of distortion, that which impairs the listener's pleasure, which concerns us and which we want to split up into general types according to its description by the customer.

First we want to eliminate the general subject of Noise or Noisy Reception because, while it is distortion in the wording of our definition, usually it originates separately from the signal. In fact, there are so many varieties of Noise that we will spend an entire Lesson on them.

For this Lesson we will consider the complaints of the customer who, not being familiar with technical terms, tells you his Receiver sounds "Tinny", "Raspy" or "Muffled". Or he may say it "Gargles", "Stutters", "Squeals" or "Howls", making it difficult to understand what is being said. There are endless variations of these general complaints but, in every case, they indicate undesirable distortion of some kind.

We have already explained the amplifying action of the tubes for Lack of Volume complaints, the action of tuned circuits for Broad Tuning complaints and now want to review these actions from the standpoint of distortion.

Starting with the simple case of a triode tube used as a Class A amplifier, it should operate on the "straight" portion of its Plate Current - Grid Voltage curve. This means that the Grid Voltage, Plate Voltage and Load Resistance must have the proper relative values. A change in any of these values may allow operation on the lower curved portion of the curve so that, the changes of plate current will not vary exactly in proportion to the changes of signal voltage on the grid and distortion will result.

From a service standpoint therefore, the operating voltages must be measured on the same general plan as explained for "Lack of Volume" complaints. The point to remember here is

that the operating conditions which produce maximum amplification are not always satisfactory from the standpoint of distortion.

Going back to Radio Fundamentals, the reactance of a coil or condenser is controlled to an important extent by frequency and Radio signals cover a band of frequencies. Thus, either a coil or condenser which carries the signal voltages will develop different values of reactance for signals of different frequencies. As the original design of a Receiver Circuit should include details of this kind, the main responsibility of the service man is to restore the circuit components to their original values.

This action should be kept in mind when replacing parts, because the values of some components are critical while others are not. For example, the inductance of a power supply filter choke, of the common untuned type, can vary over quite a wide range without any noticeable effect but, the inductance of a coil, used in a tuned circuit, must be very close to the design value.

OPERATING VOLTAGES

For the illustrations of this Lesson we show the circuits of two Radio Receivers with signal circuits which are almost identical but with different types of Power Supply.

The circuit of Figure 1 is of the common AC-DC type, arranged to operate on any 110 Volt Lighting circuit. It employs tubes with heaters designed for equal current and thus permits the usual series arrangement of the heater circuit. This is shown at the lower center of the diagram and, when the 6N5 eye tube is installed, its heater is connected in series to the others.

The heaters of the six tubes shown in the diagram have a total drop of 120.4 volts and therefore will operate satisfactorily on any 117 volt lighting circuit without a series or dropping resistor. The addition of the 6N5 heater would raise the total to 126.7 volts which is still less than a 10% variation of the 117 volts value of the line.

The manufacturers recommend that all heaters and filaments be operated at their rated values for maximum life and that suggestion is followed closely by most Radio Receiver designers. For AC-DC types however, there is a tendency to operate the heaters at slightly reduced values of voltage for protection against high line voltage.

Should a receiver, with a circuit similar to that of Figure 1, require frequent tube replacements because of burned out

heaters, many men would replace the 35L6GT with a 50L6GT to reduce the current in the heater circuit. This reduction of circuit current would cause a corresponding reduction of voltage, about 8%, across each of the other tube heaters. This reduction has little apparent effect on the operation of the ordinary receiver but does provide some protection against high heater voltages.

The high voltage, or plate supply of Figure 1, consists of a 35Z5GT half wave rectifier, a filter made up of a 40 ohm protective resistor, a 450 ohm speaker field winding, a 30 mfd input condenser and a 20 mfd output condenser.

The input condenser is connected across the supply line, in series with the rectifier, and the peak values of its charging current may exceed the maximum allowable values for tube plate current. The 40 ohm resistor will act to limit the peak values but have a negligible effect on the d-c output voltage.

The filter output voltage is applied directly to the plate loads of all the signal carrying tubes, except the detector, and directly to their screen grids. This is the conventional arrangement and we mention it in order to make a comparison to the similar circuit of Figure 2.

As we mentioned before, Figure 2 is the circuit diagram of a conventional a-c type of receiver employing a power transformer, the primary of which connects across the lighting circuit. This is the original source of supply but, as far as the receiver circuits are concerned, the transformer secondaries supply the operating voltages and current.

Here, the tubes are all of the 6.3 volt type and their heaters are connected in parallel across a transformer secondary. The complete circuit of the 6X5GT heater is drawn and the caption, "To Fils", shown just below the dial lamp, indicates all other heaters are connected in the same manner.

In the circuits of Figure 1, the heaters are connected in series and thus, all operate at the same value of current but may have different values of voltage. In the circuits of Figure 2, the heaters are connected in parallel and thus all operate at the same value of voltage but may have different values of current.

The high voltage, or plate supply of Figure 2 includes the high voltage, center tapped secondary of the power transformer, a 6X5GT full wave rectifier, a filter made up of the 1800 ohm speaker field winding, a 16 mfd input condenser and a 16 mfd output condenser. No protective resistor is needed here because the comparatively high impedance of the secondary winding will prevent excessive peak current surges.

The filter output voltage is applied directly to the plate loads of all the signal carrying tubes, except the detector, directly to the screen grid of the 6K6GT power output tube but through a dropping resistor to the screen grids of the 6SK7, r-f, the 6SA7 modulator and the 6SK7, i-f tubes. Comparing the two circuits further, both employ a type "SK7" r-f tube, an "SA7" modulator tube, an "SK7" i-f tube and an "SQ7" detector and a-f tube. Referring to a tube chart you will find that, with the exception of the heater voltage and current, tubes of these same types are identical.

The filter output voltage of the plate supply, shown in Figure 1, should be approximately 100 volts while that of Figure 2 should be about 250 volts. Neglecting the heaters, that means like tubes must produce comparable signals although operating at widely different values of plate voltage. This situation is often confusing to the service man and makes him wonder as to the value of making voltage tests.

However, the tube chart will be of assistance because, in most cases of this kind, you will find two sets of operating values, one for 100 volts on the plate and another set for 250 volts on the plate.

For example, an "SK7" with 100 volts on the plate requires 100 volts on the screen grid also. Thus, in Figure 1, the plate loads and screen grids connect directly to the power supply filter output. With 250 volts on the plate, an "SK7" requires 100 volts on the screen grid and therefore, in Figure 2, the plate loads connect directly to the power supply filter output but there is a 15,000 ohm dropping resistor in series between the filter output and the screen grids.

PLATE LOADS

The main point to remember is that any type of tube can be made to operate without objectionable distortion over quite a wide range of plate supply voltages provided the other operating voltages and circuit components are proportioned properly. Thinking of a Class A amplifier, which should operate on the straight portion of its plate current-grid voltage curve, in addition to the plate voltage, there are three important factors -- 1. the plate load, 2. the grid bias voltage, and 3. the signal voltage.

From a service standpoint, the plate loads for both r-f and i-f amplifier tubes usually are made up of tuned circuits to provide maximum impedance at resonance which, in the form of an equation, is expressed as:

$$Z = \frac{L}{CR}$$

when L represents the inductance, C the capacity and R the resistance. We have already explained the common methods of tests for these circuits and mention this equation merely to emphasize that, in addition to the effects already explained, an increase of resistance will cause a reduction of impedance at resonance and thus reduce the plate load. A reduction of plate load will permit an increase of plate voltage, other factors remaining the same, and may produce distortion.

Many distortion complaints, due to incorrect plate loads, are found in the power output tube circuits which include the output transformer. This may be due to the fact that the greatest amount of power is carried by these circuits and also the need of matching the plate load to the speaker voice coil.

Speaker troubles, which will be taken up a little later, are quite common and speaker replacements are quite numerous but serious distortion may result, unless there is the proper impedance match between the load impedance of the plate circuit and the speaker voice coil.

Looking in a tube chart, you will find a recommended value of load resistance for all Power Output tubes, also all speakers are listed in respect to their voice coil impedance.

For example, the tube chart recommends a load of 2500 ohms for the 35L6GT output tube of Figure 1, operating with 110 volts on the plate and screen. To present a practical example, suppose that the speaker voice coil has a rated impedance of 4 ohms. By means of the output transformer, this 4 ohms of the voice coil is reflected into the plate circuit as 2500 ohms. The impedance ratio of the transformer is equal to the square of the turns ratio. Thus,

$$\text{Impedance Ratio} = \frac{2500}{4} = 625$$

$$\text{Turns Ratio} = \sqrt{625} = 25$$

Should this speaker be replaced with one having a 2 ohm voice coil, the same output transformer, with an impedance ratio of 625, would reflect a plate load of 625 x 2 or 1250 ohms and distortion would result although the voltage and continuity tests of the circuits could be correct.

Operating at 100 volts on the plate, the 6K6GT output of Figure 2 requires a load resistance of 12000 ohms but, with our assumed value of 250 volts for this circuit, the tube chart recommends a load resistance of 7600 ohms. Assuming a 4 ohm

speaker voice coil here, the impedance ratio is 7600 ÷ 4 = 1900 and the square root of 1900 is approximately 43.5 as the required turn ratio of the output transformer.

Thus, even though the speakers of Figure 1 and 2 were alike, the output transformers could not be interchanged without causing a decided change of load resistance with excessive distortion.

For a practical application of this condition, suppose the receiver of Figure 1 is in your shop for repair because of distortion, apparently in the output circuit, but neither the speaker nor output transformer is marked in respect to electrical values. However, you do have a multimeter for measuring resistance and a-c volts.

First, you can disconnect one end of the voice coil and measure its resistance. This will be the d-c or ohmic resistance of the wire but, the impedance is calculated at a frequency of 400 cycles in most cases. For service work, it is sufficiently accurate to consider the impedance of the voice coil as being 1.5 times its d-c resistance.

Knowing the voice coil impedance and checking in a tube chart for the recommended value of load, you can use these values to calculate the impedance ratio. The square root of this ratio is the required turns ratio of the output transformer.

Going back to electrical principles, the voltages induced in the windings of an unloaded transformer are approximately equal to the turn ratios and thus a simple method of measurement is available.

To measure the resistance of the voice coil, one wire was disconnected and thus the output transformer secondary circuit is open. With the exception of plate bypass condensers or tone controls, the primary circuit is isolated when the power is off or the output tubes are out of their sockets but, can be opened by removing the connection to the plate of the tube or to the power supply filter. All that remains is to supply one winding with a-c and then measure the voltage across each winding. The ratio of these voltages will be the turn ratio.

Remember, these voltage tests must be made with a-c and, for the circuit of Figure 1, you could connect the primary across the supply line. Then, with your a-c voltmeter connected across each winding in turn, read the primary and the secondary voltages.

In a previous explanation of this circuit we found, with a 4 ohm speaker, the turns ratio of the transformer should be 25 to 1. Here then, if the A.C. voltmeter reads 110 when connected across the primary it should read 1/25 as much or nearly 4.5 volts when connected across the secondary.

For the output circuit of Figure 2, we found a turns ratio of 43.5 was needed for a 4 ohm speaker. Here, after the transformer had been disconnected, you could connect the 6.3 volt filament secondary of the power transformer across the secondary of the output transformer. The voltage across the primary should then be 43.5 times 6.3 or about 275 volts.

Of course, you could follow the plan explained for Figure 1 and, with 110 volts across the primary there should be about 2.5 volts across the secondary because 110 divided by 43.5, the turn ratio, is equal to 2.5.

For push pull output circuits, the load for each tube remains the same as for a single tube therefore the impedance of the total primary of the output transformer, or plate to plate load, should be twice that of a single tube. For output tubes connected in parallel, the plate load should be one half the value recommended for a single tube.

Thus, by a few simple tests with ordinary equipment, it is possible to determine the truns ratio of the output transformer as well as the approximate impedance of the voice coil. These values, together with the recommended value of plate load is all that is needed to check up on the actual plate load of the output tube.

One more point to watch is the construction of the output transformer itself. The iron core must be large enough to carry the flux developed by the D.C. plate current of the tube, plus the variations caused by the signals, without becoming saturated magnetically. When the core is saturated, the magnetic flux does not vary exactly as the plate current, the secondary voltage will not follow the variations of signal voltage and distortion will result.

For push pull output stages, the D.C. plate current does not magnetize the core to any great extent because, in the primary of the output transformer, the plate current of one tube is in a direction opposite to that of the other tube. Therefore, there is usually less iron in the core of a push pull output transformer than in one designed for a single tube. That is why an output transformer, designed for a push pull stage of any certain type of output tube may cause distortion if used for a single tube of the same type.

GRID BIAS VOLTAGE

In an earlier explanation of tube action, we stressed the fact that the grid bias voltage is most important in fixing the operating point. For a Class A amplifier, the operating point is located on the straight part of the grid voltage - plate current curve so that equal increases and decreases of negative grid voltage will cause equal decreases and increases of plate current.

With a higher value of negative grid bias, equal changes of grid voltage may cause unequal changes of plate current. Due to the bend in the lower part of the curve, for equal changes of grid voltage, the reduction of plate current will not be as large as the increase and distortion will result.

With a lower value of negative grid bias, the signal voltages may cause the grid to become positive, in respect to the cathode or filament, and allow grid current. This grid current will produce a voltage drop across the grid load and thus, the changes of total grid voltage will not coincide with the changes of signal voltage.

In either case, there will be distortion because the changes of voltage drop across the plate load will not follow the changes of signal voltage.

Checking back over the circuits of this series of Lessons, there are three common methods of obtaining grid bias voltages. One is the cathode or bias resistor arrangement as shown for the 6SK7 and 6K6GT tubes of Figure 2 of this Lesson.

The plate and screen grid currents of the tube are carried by the cathode resistor and the resulting voltage drop is the grid bias voltage. As the variations of current cause variations of voltage drop, a condenser is usually connected across the resistor to provide a more uniform voltage.

As explained in the earlier Lessons, continuity tests can be made to check the resistor and condenser. Also, due to the comparatively low value of most bias resistors, the ordinary 1000 ohms per volt type of test meter will give sufficiently accurate readings of the voltage actually developed.

A second method of obtaining grid bias voltage is to connect the grid return to a voltage divider. In some battery types of circuits, the tube filaments are connected in series and act as the voltage divider. In some a-c types of receivers, the dynamic speaker field, used as a filter choke in the

negative side of the circuit, has a voltage divider connected across it. Both of these methods have been explained in the former Lessons.

The third type, also explained in the earlier Lessons, is the use of a high resistance grid load. This arrangement is popular with high mu triodes and is shown in the triode grid circuits of the "SQ7" tubes of Figures 1 and 2.

Going back to the bias resistors in the cathode circuits, like those shown in the output stages of Figures 1 and 2, the question often arises as to what is the correct value of capacity to use for the bypass condenser. Like all similar conditions, there are many variations but a general conservative rule is that, at the lowest signal frequency, the reactance of the bypass condenser should be one tenth the value of the resistance. As a formula, this rule can be written,

$$X_C = \frac{R}{10} \quad \text{or} \quad 10X_C = R$$

The relationship between Capacity, Capacity Reactance and Frequency can be stated as,

$$X_C = \frac{1}{6.28fC} \quad \text{or} \quad f = \frac{1}{6.28X_CC} \quad \text{or} \quad C = \frac{1}{6.28fX_C}$$

When X_C = Capacity Reactance in Ohms
R = Resistance in Ohms
f = Frequency in Cycles per second
C = Capacity in Farads

Substituting the value of X_C in the formula for the rule:

$$\frac{1}{6.28fC} = \frac{R}{10} \quad \text{or} \quad R = \frac{10}{6.28fC} \quad \text{or} \quad R = \frac{1.6}{fC}$$

Transposing the terms,

$$R = \frac{1.6}{fC} \quad \text{or} \quad C = \frac{1.6}{fR} \quad \text{or} \quad f = \frac{1.6}{CR}$$

but as most capacity values are given in microfarads, the equations can be written as,

$$C_{mfd} = \frac{1,600,000}{fR} \quad \text{or} \quad f = \frac{1,600,000}{C_{mfd}\,R}$$

Applying this rule to the cathode circuit of the 35L6GT tube of Figure 1, which shows a 150 ohm resistor and a 25 mfd con-

denser, we can find the lowest frequency at which the capacity reactance will be equal to one tenth of the resistance.

Substituting in the second form of the equation,

$$f = \frac{1,600,000}{25 \times 150} = \frac{1,600,000}{3750} = 426 \text{ cycles per sec.}$$

For the output circuit of Figure 2, with a 500 ohm resistor and 20 MF. condenser,

$$f = \frac{1,600,000}{20 \times 500} = \frac{1,600,000}{10,000} = 160 \text{ cycles per sec.}$$

Following the same general plan for the 470 ohm resistor in the cathode circuit of the 6SK7 tubes of Figure 2, the lowest frequency is 455 K.C. or 455,000 cycles per second. To find the proper value of capacity, we substitute in the first form of the equation,

$$C = \frac{1,600,000}{455,000 \times 470} = \frac{1,600,000}{213,850,000} = .0074 \text{ MF.}$$

Thus, for the same electrical ratios, the bypass condensers for cathode bias resistors in R.F. and I.F. stages can have a much smaller capacity than those in A.F. stages.

The purpose of these bypass condensers is to maintain a more uniform or steady voltage drop across the bias resistor by charging, during periods of increasing cathode current and discharging during periods of decreasing cathode current. At higher frequencies, a smaller capacity will operate satisfactorily but, at low audio frequencies, a larger capacity is required. Where cost is important, you will find some manufacturers use smaller values of capacity, down to about 1/2 of those indicated by these formulas.

Notice also, other things being equal, the higher the value of bias resistance, the smaller the required capacity. In some cases you may find the cathode bypass condenser omitted entirely to provide inverse feedback because, without it, an increase of cathode current will cause an increase of bias voltage which tends to reduce the current.

Leaky coupling condensers are a quite common source of distortion because they permit some of the plate voltage of the preceding tube to be impressed on the grid. Depending on the amount of leakage, this positive plate voltage will reduce the negative grid voltage or may overcome it entirely.

Looking at the circuit of Figure 1, there is an .006 mfd coupling condenser between the 12SQ7 tube and the 35L6GT control grid and a leak here would complete a circuit from the plate through the condenser and 680,000 ohm grid resistor to ground. Current in this circuit will cause a voltage drop across the resistor to make the grid positive in respect to ground. Note -- the formulas given for bypass condensers of bias resistors apply also to coupling condensers and the following grid resistor.

For proper operation, there should be a 7.5 volt drop across the 150 ohm bias resistor with nothing but signal voltages across the grid resistor. However, by Ohm's Law, a leakage current of but .011 milliampere in the 680,000 ohm resistor would cause a drop of about 7.5 volts, reducing the grid bias to zero.

Going further, and assuming 50 volts on the 12SQ7 plate, a resistance of slightly less than 4 megohms, in the coupling condenser, would allow this amount of current and thus reduce the 35L6GT grid bias to zero. Operating at zero bias, the signal voltages would drive the grid positive, in respect to the cathode, cause grid current and as the changes of voltage across the grid resistor would not follow the changes of signal voltage, distortion would result.

To complete a check of the grid bias voltages, do not overlook the components of the avc circuit. Remember, avc action depends on a change of bias voltage and thus defective resistors or condensers in the avc filter, and the included parts of the detector circuit, can cause distortion.

In modern receivers, the resistors are color coded and the condensers are either color coded or marked so that their actual values can be checked by resistance and capacity tests. When making these tests, be sure that at least one end of each unit is disconnected from its circuit and is entirely open.

SIGNAL STRENGTH

A similar condition can be caused, in circuits which are electrically correct, by the presence of strong signal voltages. Looking at the grid circuit of the output or Power Tube of Figure 1, the total grid voltage will be equal to the sum of the voltage drops across the 150 ohm bias resistor and the 680,000 ohm grid resistor.

With no signal voltage, there should be no current in the 680,000 ohm resistor and therefore, no voltage drop across

it, but the plate and screen currents in the 150 ohm cathode resistor produce the voltage drop which is the grid bias.

Signal voltages, carried over by the .006 coupling condenser, cause alternating current in the 680,000 ohm resistor and these produce alternating voltage drops which, added to the d-c drop across the cathode resistor, provide the total grid voltage. For one alternation, these voltage drops will be series aiding and thus the total voltage will be equal to their arithmetical sum. For the following alternation, the voltage drops will be series opposing and thus the total voltage will be equal to their arithmetical difference.

Should the drop across the 680,000 ohm resistor exceed the drop across the 150 ohm resistor, the grid would be positive, in respect to the cathode, for a part of one alternation of each cycle of signal voltage. As explained for a leaky coupling condenser, a positive grid allows grid current which, in turn, causes a voltage drop across the grid resistor. As a result, the variations of grid voltage do not follow the variations of signal voltage and distortion results.

For Class A amplifiers, the peak or maximum value of signal voltage in the grid circuit should not exceed the d-c bias voltage. Remember here, the peak value of a-c is 1.41 times the effective values indicated on the ordinary a-c meter therefore, as a safe general rule, you can assume the peak a-c values to be 1-1/2 times the effective values.

OVERLOAD

Distortion, caused by excessive signal voltage is commonly known as "Overload" distortion and can be checked readily by means of the volume control. If the signals are satisfactory at low volume but distort as the volume is turned up, the trouble is due usually to overload in some stage. This condition may occur in the plate circuits but is found more commonly in the grid circuits.

In addition to the condition of positive grid voltage, previously explained, excessive signal voltage may cause sufficiently high negative grid voltages to make an amplifier tube act somewhat as a detector and thus cause distortion.

One point to remember is that some designers provide sufficient sensitivity, for the reception of distant stations or weak signals, to cause distortion of strong signals at maximum volume. Therefore; when a receiver provides satisfactory signals of distant stations at full volume, but distorts on strong local signals, the conditions should be

explained to the owner. Should you cut down the sensitivity to prevent distortion on local signals, the distant stations could no longer be heard.

One simple method of checking for overload distortion is to connect a pair of headphones, preferably with a series condenser in each wire, across the detector load, and listen to the signal. In the circuits of Figures 1 and 2, the phones would be connected across the volume control.

Distortion at this point would indicate a defect between the phones and antenna. If no distortion appears here, the phones should be moved to the output circuit of the first audio stage, which is across the 220,000 ohm resistor in the triode plate circuit of the "SQ7" tubes of Figures 1 and 2.

Following this plan, and moving the phones, circuit by circuit toward the speaker, it is possible to hear in which one the distortion occurs. When the faulty circuit is located, the usual voltage and continuity tests can be applied to isolate the defect.

Overload distortion of this type is sometimes called, "Second Harmonic" or "Even Harmonic" distortion because the negative variations of voltage or current have less amplitude than the corresponding positive alternations.

SPEAKER TROUBLES

As you already know, the function of a speaker is to convert variations of electrical energy to corresponding variations of sound energy or to sound waves of corresponding frequency and amplitude. In the common types of speakers, the electrical energy is converted to magnetic energy which, in turn, is converted to mechanical energy or motion. Assuming that electrical tests indicate correct signal voltages or current in the output circuit, distorted sound must be due to magnetic or mechanical defects in the speaker.

In modern types of speakers there are two distinct and separate sources of magnetism. First, the "Field" which sets up a steady or fixed magnetic flux and second, the "Voice Coil" which sets up an alternating magnetic flux proportional to the electrical signals.

The field flux may be produced by an electromagnet, in the "Dynamic" types or by a Permanent Magnet in the P.M. types. The mechanical construction is arranged so that the voice coil is suspended in a small air gap of the magnetic circuit of the field. The mechanical motion of the voice coil is

produced by the attraction and repulsion of the alternating flux, set up by the voice coil, to the steady flux set up by the field.

To prevent distortion, the movement of the voice coil should follow exactly the frequency and amplitude variations of the electrical signals therefore, the magnetic flux of both field and voice coil must be of proper relative strength and mechanically the voice coil must be free to move.

We have described the electrical tests which can be made to check the voice coil but, unfortunately have no similar tests for the field flux. For dynamic speakers, the continuity and resistance of the field winding can be checked as a part of the power supply tests previously explained.

One simple but often effective method of testing field flux, is to place the end of a screw driver or other steel rod on the end of the core inside the voice coil. Then, with the speaker in operating condition, the pull required to remove the screw driver or rod is estimated. A few tests of this kind, on different sizes and types of speakers, will indicate about how much pull to expect and thus form a basis for future tests.

Mechanical troubles are caused mainly by the voice coil shifting off center in the air gap and rubbing on the iron of the field. This can be remedied usually by "Centering" the coil by the methods explained in the earlier Lessons.

The cone is that part of the speaker which converts the mechanical motion of the voice coil into sound waves and therefore, to avoid distortion, it must follow exactly the movements of the voice coil. Cone troubles are mechanical and consist of tears or looseness.

The outer edge of most cones is connected to the speaker frame while the center opening is attached to the voice coil. Any looseness here will permit the movements of the cone to vary, in respect to those of the voice coil, and distortion may result. Every service man should have a supply of "Cone Cement" to repair defects of this type.

Tears or cracks in the cone can also cause distortion because they may allow variations in air waves set up by the movements of the cone. For small cracks and tears, a coating of cement may be sufficient but for larger tears, a piece of toilet or cleansing tissue can be cemented to both sides. However, when good fidelity is desired, the best plan is to replace the entire cone.

OSCILLATION

Distortion may be caused by oscillation in one or more stages of a receiver. Defects of this type will be explained more completely in a following Lesson but should be mentioned here.

When the oscillation is at low audio frequencies it causes a low frequency rumble or "put-put" often called "Motorboating". At higher frequencies, it may produce a squeal or howl while, at still higher frequencies, it will cause a certain amount of "Fuzziness" in the signals.

Most cases of unwanted oscillation are due to feedback caused by loose shielding or insufficient filtering. Many of these defects will be found when making a general inspection, voltage analysis or continuity test and therefore will not be taken up in detail at this time.

TUNABLE HUM

Another form of annoying distortion is known as "Tunable Hum" because it appears as a low frequency hum only as the different stations are tuned in. This defect is found usually in A.C. operated receivers and is due frequently to signal carrier frequencies entering the receiver circuits through the power supply circuit.

The common remedy for this trouble is to connect a paper type condenser, about .05 MF. capacity, from either of both sides of the 110 volt supply circuit to the chassis. At Broadcast carrier frequencies, the reactance of an .05 MF. condenser is about 5 ohms and thus it "shorts out" the carrier frequencies before they reach the receiver circuits. At 60 cycles, the frequency of the common lighting circuits, the reactance of an .05 MF. condenser is about 5000 ohms and thus it makes no appreciable difference to the normal operation of the receiver.

When tunable hum is present in a receiver which has a condenser, between the supply circuit and ground, it should be checked for capacity and a test made by installing a larger capacity. Should this fail to reduce or eliminate the trouble, check the position of the heater circuit wires.

This circuit carries A.C. at the frequency of the supply and sets up an alternating magnetic flux around its wires. In many receivers, you will find these wires are twisted to reduce this flux but it can induce A.C. voltages in the wires of other circuits. The remedy here is to separate other wires, especially those of tube grid circuits, as far as possible from the heater circuit wires.

A heater-cathode leak, inside a tube, can cause tunable hum. Therefore, when the tubes are tested, they should be checked carefully for "Shorts" and "Leakage".

Hum, which is present at all times regardless of the position of the tuning dial, is caused usually by insufficient filtering and should not be confused with the tunable hum mentioned above.

Distortion, extremely annoying to some individuals, may not be noticed by others therefore, it is always advisable, in handling a "Distortion" complaint, to learn the tastes of the customer before deciding on the extent of the service which will be necessary to produce signals, satisfactory to him.

To fulfill the promise made early in this Lesson, the explanations of the following Lesson will cover the subject of "Noise" or "Noisy Reception" which, in a broad sense, can be considered as a special form or type of distortion.

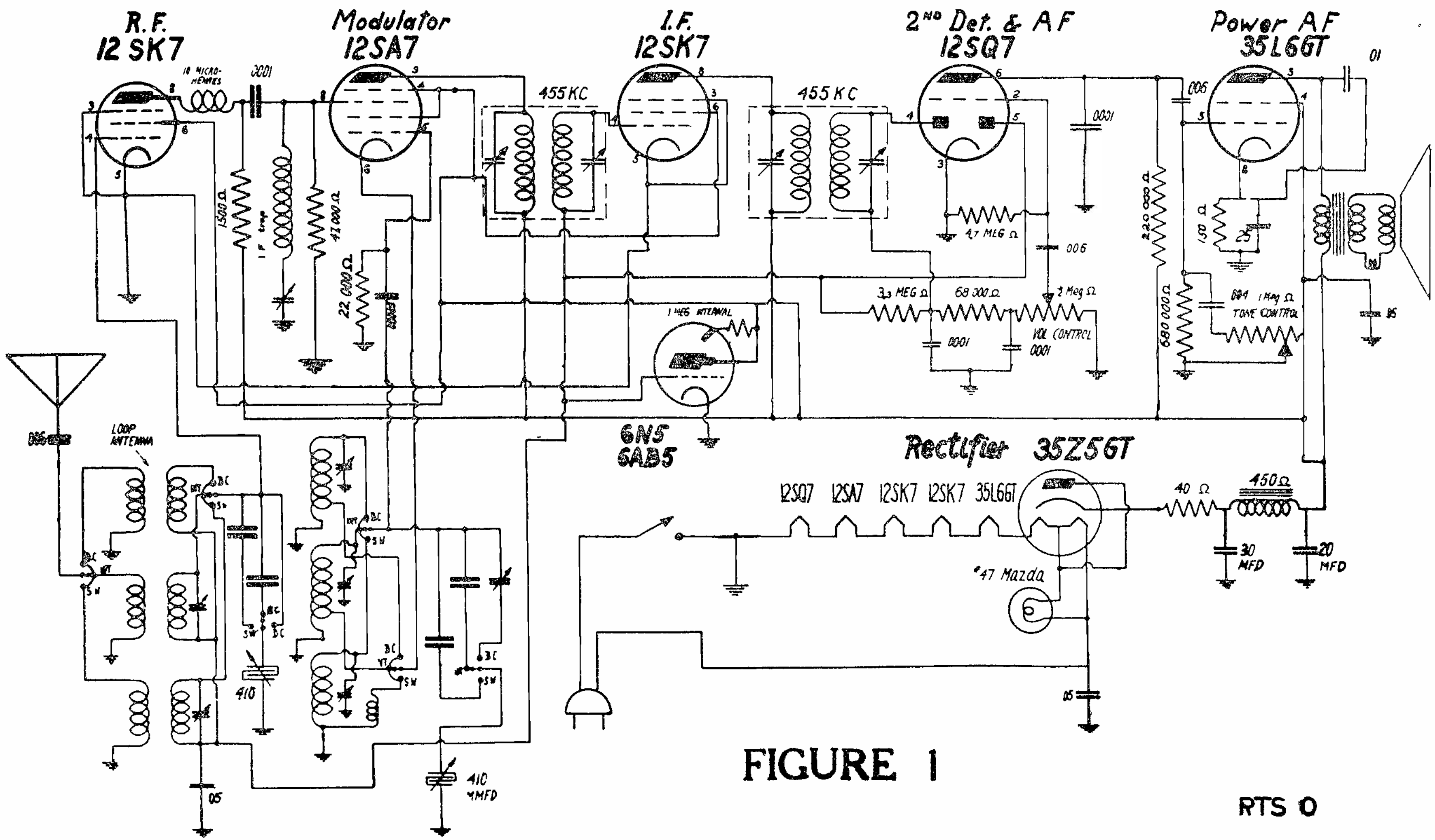


FIGURE 1

RTS 0

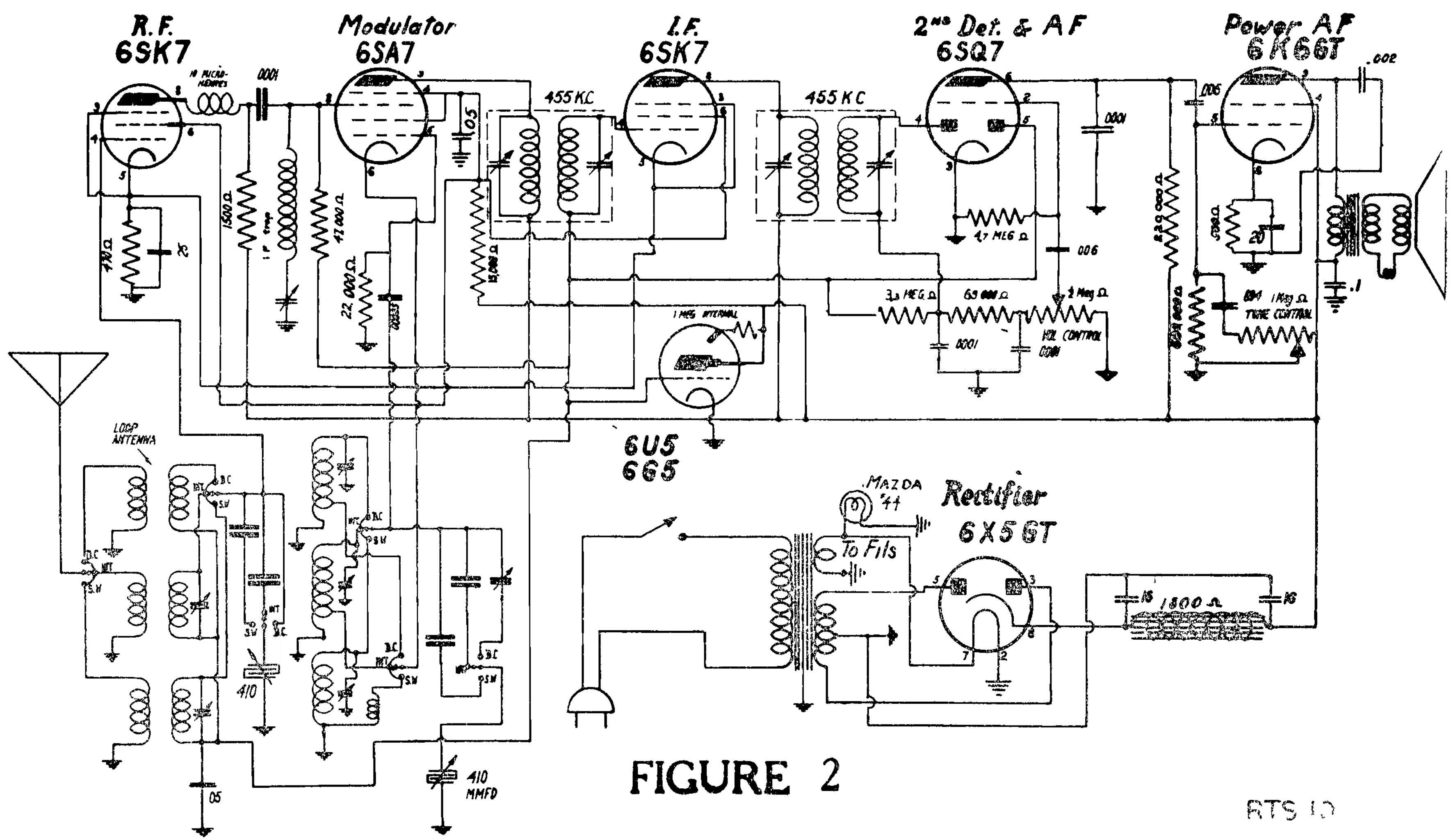


FIGURE 2

RTS 10

QUESTIONS

How many advance Lessons have you now on hand? ______________

Print or use Rubber Stamp:

Name ______________________________ Student No. ____________

Street ____

City ____________________ State ______________________

1. What is the general definition of Distortion?

2. What is the relation between the impedance ratio and turns ratio of a transformer?

3. What simple method can be followed to calculate the approximate impedance of a speaker voice coil?

4. How can a transformer be tested for turns ratio?

5. What are three common methods of obtaining grid bias voltage?

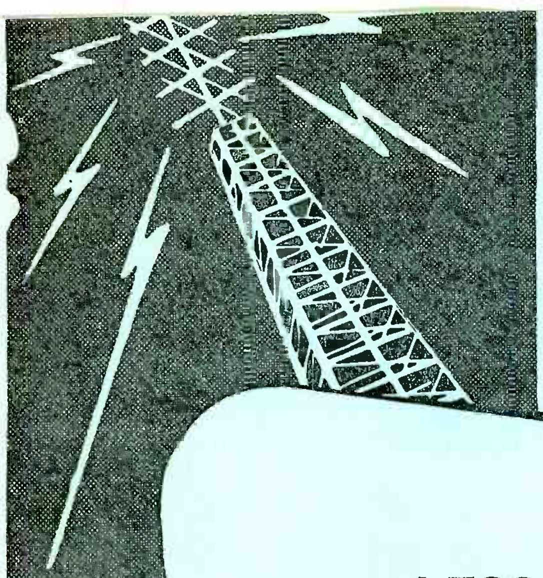
6. What effect does a leaky plate coupling condenser have on the bias voltage of the following grid?

7. Using the volume control, how can overload distortion be checked?

8. How can headphones be used to check distortion?

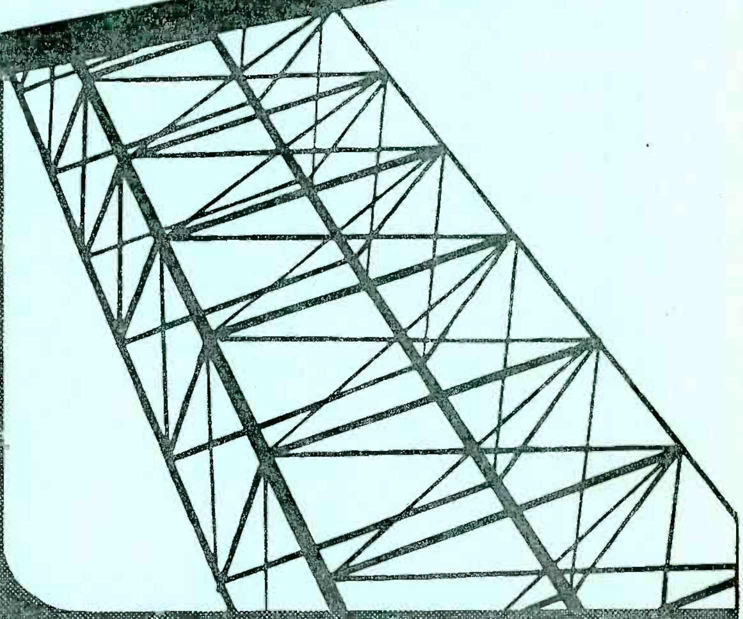
9. What is a simple method of testing speaker field flux?

10. What is a common remedy for tunable hum?



LESSON RTS - 11

TYPICAL FAULTS - NOISY RECEPTION



DE FOREST'S TRAINING, INC.
2533 N. Ashland Ave., Chicago 14, Illinois

RADIO AND TELEVISION SERVICING

LESSON 11

TYPICAL FAULTS - NOISY RECEPTION

Noisy Reception ------------------ Page 1
Natural and Man Made Static ------ Page 2
Signal vs. Noise Ratios ---------- Page 3
Hum ------------------------------ Page 8
Hash ----------------------------- Page 10
Microphonics --------------------- Page 14
Oscillation ---------------------- Page 15
Tone Controls -------------------- Page 16
Cabinet - Resonance -------------- Page 17
Tube Noise ----------------------- Page 18
Noise Reduction Methods ---------- Page 20

To do anything in this world worth doing, we must not stand back shivering and thinking of the cold and danger, but jump in, and scramble through as well as we can.

--- Sydney Smith

NOISY RECEPTION

Ever since the development and construction of the first "Wireless" systems, radio reception has been marred by unwanted sounds, known generally as "Static", "Noise", or "Interference". This condition still exists because much of this "Noise" originates in space or the atmosphere and thus has not been completely eliminated despite the enormous improvements which have been made in receiver performance.

For this Lesson, we want to analyze the various types of noise and discuss the methods by which it can be reduced in some cases and eliminated in others. To begin, we want to examine a few general definitions to determine exactly what your customer means when he makes a complaint of Noisy Reception.

The dictionary states that "Noise is a sound of any sort", and on that basis, all sounds produced by the speaker of a radio receiver are classed as "Noise". Sound is defined as a wave motion or vibration, usually of the air, which stimulates our ears and causes us to hear.

Going further, noise is defined also as:

Sounds which are objectionable to some persons.
Sounds without agreeable musical quality.
Sounds which may or may not have significance.
Sounds that are undesired or that interfere with something to which one is listening.

Then, to distinguish noise from music, noise is defined as irregular or confused impulses, or as sounds which do not exhibit clearly defined frequency components. Musical sounds are due to regularly recurring vibrations or clearly defined frequency components.

Summarizing these various definitions, when your customer complains of noise, he is referring usually to non-musical sounds which are objectionable or which interfere with the sounds he wants to hear. However, perfect reproduction of some programs may sound "Noisy" to some listeners.

As we have mentioned before, complaints of this nature are based on the preferences or tastes of the individual customer and, to be satisfactory, the repair must satisfy him. It is not enough that a repaired receiver sounds "good" to you, it must sound "good" to the customer also.

There is seldom any confusion in regard to a complaint of Noisy Reception because the customer is bothered by signal

voltages which do not carry intelligence, have no constant or fixed frequency but do interfere with the reception of desired signals.

Thinking back to the former Lessons, noisy reception could be caused by a lack of selectivity and could be classed as a form of distortion. However, from a practical standpoint, noisy reception is a distinct type of trouble because it may occur in a selective receiver which is operating properly without noticeable distortion of the signals.

Like all other troubles, there is a definite cause for Noisy Reception and a cure can be made only after the cause has been determined and removed or corrected. Analyzing the complaint in a general way, there are two possible causes of noise. First, random voltages may be generated in space or our atmosphere and, radiating like desired signals, be picked up by the antenna and reproduced by the speaker.

Second, variations of operating voltages, caused by changes in the electrical values of the component parts of a receiver may produce noise in the speaker.

Therefore, when a customer brings in a "Noisy" receiver, your first job is to determine whether the noise originates inside the receiver itself or is picked up by the antenna. For those models which plug into a lighting circuit, it is necessary to consider the supply as a part of the antenna.

As a quick test, the antenna or input circuit can be "shorted" while the receiver is in operation, and if the noise is reduced to a noticeable extent, it is safe to assume it is of external origin. However, if "shorting" the input circuit has no effect on the noise, it is logical to suspect the presence of a defect in the receiver circuits.

Keep this general division in mind as it is the basis for the explanations of this Lesson and details of the various tests will be given later.

NATURAL AND MAN MADE STATIC

As far as radio receivers are concerned, the term "Static" has come into general use to describe many of the unwanted noises which are heard in the speaker. Static is often defined as that form of electricity which is at rest, and it is produced commonly by friction. Most atmospheric electricity is therefore rightly named as static.

A thunderstorm is perhaps the most common and spectacular exhibition of atmospheric electricity and according to a

common theory, the static charges are built up by the friction between the air and the rain drops which cause the drops to break up into smaller particles. When the static charges build up sufficiently, the space between those of opposite polarity is pierced and a discharge takes place. We call these discharges "Lightning" and you may have seen it flash from cloud to cloud or from a cloud to the earth.

It is these discharges which radiate energy, similar to Radio energy and, picked up by the antenna, cause the static in the speaker of the Receiver. Other similar actions occur in the atmosphere and, while not as spectacular as Lightning, cause the same type of noisy reception.

From the standpoint of Service, there is not much which can be done to cure this "Natural" static, because the origin of the complaint is outside the receiver. However, this type of static has broad frequency characteristics therefore, as the selectivity of a receiver is increased, less static will pass the tuned circuits and reception is improved. One of the main advantages of Frequency Modulation is that this type of transmission differs sufficiently from most natural static to permit the receiver to pass the signals and block the static.

As we mentioned previously, it is the static discharges which cause noise and, in much the same way, a spark or an arc along any electric power line will produce similar results. A leaky insulator on a high tension line, tree branches rubbing against a power wire, or loose connections anywhere in a power circuit may produce interference quite similar to natural static.

In cities and industrial districts, Flasher Signs, street cars, elevators in buildings, commutator type motors and other types of electrical equipment which cause sparks or arcs, all cause radiations which can cause "Static" in a Radio Receiver.

Electric Razors, Clippers, Motor Driven Hair Dryers, Violet Ray and Diathermy Machines may radiate energy of high frequency which causes noise in a Radio Receiver. All these are known as "Man Made" static to distinguish them from natural or atmospheric disturbances and, most cases of Man Made static are curable by methods explained later in this Lesson.

SIGNAL vs. NOISE RATIOS

Under ordinary conditions of Radio Reception, there is always a certain amount of atmospheric static which varies with

local as well as general conditions. As far as the listener is concerned, this is the noise he hears in the speaker when the receiver is in operating condition but with no signals tuned in. It can be identified as a "frying" or "crackling" sound, the intensity of which can be varied by adjusting the volume control.

As this noise is not due to any defect in the Receiver and is present all over the tuning dial, the common method of obtaining satisfactory reception is to provide signal voltages of greater strength or amplitude than the static.

The comparative amplitude of the Signal and Noise voltages, induced in the Receiver antenna, is known as the Signal-Noise Ratio. With a high ratio, satisfactory reception of the desired signals can be obtained with the volume control set at a point so low that the Noise is not objectionable.

With lower ratios of Signal to Noise voltages, satisfactory levels of the desired signal may cause Noise levels high enough to cause interference. In general, the weaker the signal voltage the higher the noise level.

In some respects, Noisy Reception is a special type of interference and therefore, when discussing a complaint of this kind, ask the customer for information similar to that suggested in the earlier Lesson on Broad Tuning.

Is the noise present at all times? If not, during what hours is it present?

Is the noise present at all points of the tuning range? If not, at what frequencies is it most pronounced?

Is the noise present when listening to any station? If not, what stations are the noisest?

If the receiver is available, you can turn it on and listen but it is always a good plan to ask the customer to describe the noise. Remember, it is your job to please the customer and the more information he gives you, the easier it will be to learn his individual likes and dislikes.

With the answers to the questions above, it is usually a simple matter to determine the general nature of the noise and make helpful suggestions such as more careful tuning, listening to local or nearby stations instead of distant stations, adjusting the volume control for best reception and so on. Often, a reduction of volume will cause a greater reduction of audible noise and the desired signals will be more satisfactory although at a lower level.

All of these explanations have been made on the assumption that the Receiver is in good order and the noise is due to Natural Static only. However, there are many Receiver defects which cause Noise, defects which require service on the circuits or their component parts.

To make our explanations definite, for the illustrations of this Lesson we have the circuit diagrams of two receivers. Figure 1 shows the circuit of a 2 band, 6 tube, A.C. "super" while Figure 2 shows the circuit of a 6 tube automobile type "Super".

Analyzing the circuits briefly, for Figure 1, there are two input transformers, one for the short wave or "D" band, and another, in the form of a loop aerial, for the broadcast or "B" band. Both primaries are in series between the external antenna terminal and the ground while the "DB" switch connects either secondary across one section of the two gang tuning condenser.

This tuned secondary circuit is coupled to the control grid of the 6SA7 tube through a .0005 MF. condenser and the grid connects to the A.V.C. circuit through a 2 megohm resistor.

For the oscillator, the cathode of the 6SA7 connects to ground through a part of the "D" coil and the primary of the "B" coil, depending on the position of the band switch.

The second section of the two gang tuning condenser tunes the entire "D" coil or the secondary of the "B" coil. The oscillator grid is grounded through the 40,000 resistor and coupled to the tubed circuit through a 50 MMF. condenser.

There is a separate trimmer condenser for each of the input coil secondaries and another trimmer across the oscillator section of the tuning condenser. For the oscillator, there is a variable trimmer condenser across the "D" coil and a fixed trimmer condenser across the "B" coil secondary which also has a variable padder condenser in series between it and ground.

The plate of the 6SA7 tube connects to the high voltage supply through the primary of the 1st I.F. transformer and the screen grid connects to the same supply through a 17,000 ohm resistor. A .04 MF. condenser is connected from the screen grid to ground.

The secondary of the 1st I.F. transformer connects across the grid circuit of the 6SK7, 1st I.F. tube, the grid re-

turn connecting to the avc circuit. The plate circuit of this tube is resistance-capacity coupled to the grid circuit of the 6SK7, 2nd i-f tube by means of a 2500 ohm plate resistor, a 10 mmfd coupling condenser and a 1 megohm grid resistor. The screen grids of both 6SK7 tubes are connected to the high voltage supply through a common 40,000 ohm resistor with an .04 mfd condenser between the screens and ground.

The control grids of both 6SK7 tubes connect back to the avc circuit and the cathodes of both are grounded. In fact, the cathodes of all but the 6SA7 tube are grounded direct and thus there are no cathode resistors for producing grid bias voltages.

The plate of the 6SK7, 2nd i-f tube connects to the high voltage supply through the primary of the 3rd i-f transformer. There is no 2nd i-f transformer because of the resistance-capacity coupling between the 6SK7 tubes.

Checking back to the high voltage supply you will find a filter, made up of a 250 ohm resistor and .02 mfd condenser between the plate circuit of the 6SK7, 2nd i-f tube and the plate circuits of the 6SK7, 1st i-f and 6SA7 tubes.

The secondary of the 3rd i-f transformer connects across one of the 6SQ7 diodes, the complete circuit including a 50,000 ohm resistor and a .5 megohm volume control. The second diode plate is grounded with the cathode and thus is not used. The avc circuit connects through a 2 megohm resistor to the junction between the 50,000 ohm resistor and volume control of the diode, or 2nd detector circuit.

The two 60 mmfd condensers, in conjunction with the resistors, form the 2nd detector filter while the 2 meg resistor and .05 mfd condenser in the avc circuit, filter out the signal frequencies to provide the proper bias voltages.

The triode grid of the 6SQ7 is coupled to the detector circuit through the movable contact of the volume control and the .01 mfd coupling condenser. A 5 meg resistor from grid to ground completes the grid circuit.

The triode plate of the 6SQ7 is resistance-capacity coupled to the grid of the 6V6GT output tube by a .5 meg plate resistor, an .02 mfd coupling condenser and a .25 meg grid resistor.

The 6V6 grid circuit contains a tone control, consisting of an .004 mfd condenser in series with a 3 meg variable resistor. Also, the grid connects to ground through the .25 meg resistor and R_{15}. Resistor R_{15} forms a voltage divider with R_{14} across the speaker field, and the voltage across R_{15} constitutes the grid bias for the 6V6 tube.

Checking the power supply, you will find the high voltage filter includes the 1470 ohm field coil, connected as a choke in the negative side of the circuit, a 20 mfd condenser connected across the filter input and a 40 mfd condenser across the filter output.

As the center tap of the high voltage winding of the power transformer is the most negative point of the high voltage circuit, the grounded end of the speaker field must be positive and thus, the voltage drop across the field will be negative in respect to ground.

The divider is made up of a 90,000 ohm and a .6 meg or 600,000 ohm resistor for a total of 690,000 ohms. The 6V6 grid return connects to a point 90,000 ohms from ground and the bias voltage will be equal to 9/69 of the drop across the field. Assuming a typical value of 100 volts across the field, 9/69 of 100 is equal to approximately 13 volts and the specifications of the 6V6 call for a 12.5 volt bias with 250 volts on the plate.

Looking at the Power Transformer symbol, you will find resistance values for each of the windings but you will notice a 10 ohm difference in the values for each half of the center tapped high voltage secondary. It is natural to assume that each half of a center tapped winding should have the same resistance but, as most of these coils are wound in layers, the outer layers are of larger diameter and thus each turn is longer.

To provide equal voltage, the center tap is made so that the number of turns is equally divided and, as the longer turns of the outer layers contain more wire, the total resistance of one half of the total turns is greater than the resistance of the other half.

To complete the circuits, the screen grid of the 6V6 connects directly to the output of the power supply filter while the plate connects to the same point through the primary of the output transformer. The secondary of the output transformer connects to the speaker voice coil in series with a bucking coil.

HUM

With the details of this circuit in mind, we will assume you have the Receiver which has been brought in with a complaint of noise. You have made the usual routine of inspection, tested the tubes as well as the operating voltages and everything checks correctly, yet there is objectionably loud hum when the receiver is placed in operation.

In a former Lesson, we explained the cause and cure of "Tunable" Hum but, in this case, the hum level remains the same regardless of the position of the tuning dial.

Disconnecting the antenna, shorting the antenna-ground terminals, or loop if one is used, makes no apparent difference to the noise therefore it appears that the defect is in the receiver circuits somewhere. To locate the source of the trouble, the general plan is to start at the speaker and, working back to the antenna, short the output and input circuits of each stage.

A convenient method of "shorting" the noise voltages, without causing large variations of supply voltages, is to temporarily bridge a paper type condenser, of .1 mfd capacity, across the output and input circuits. Usually, this can be done by placing one wire lead of the condenser on the plate or grid connection of the tube, while the other condenser wire is held on the chassis.

At the noise frequencies, the reactance of this test condenser is quite low, compared to the normal plate and grid loads, and thus it provides the desired shorting action with little disturbance of the d-c supply voltages. Some men produce a test short by bridging a screw driver blade from tube plate to ground but this arrangement not only reduces all plate voltages but allows excessive current which may damage some circuit component.

An experienced service man would suspect the components of the filter in the high voltage plate supply. If the hum is present with the volume control turned all the way down the filter condensers have probably decreased in capacity and are not providing sufficient filtering action. For a quick test, a good electrolytic condenser, preferably rated at 450 volts and 8 mfd or more, can be held so that its connecting wires touch the terminals of the installed condensers. A-c/d-c type sets require a 20 mfd or larger condenser for this test but the voltage need not be over 150 or 200 volts.

Electrically, this places the good condenser in parallel to the one installed in the circuit and, if a reduction of hum is noticed when the test connection is made, it is safe to assume the installed condenser is defective and should be

replaced. Looking at Figure 1, the test condenser should be placed first across the 20 mfd filter input condenser and then across the 40 mfd filter output condenser.

Electrolytic condensers are made with connecting wires several inches long and, for the common tubular types, these are both solid wires. When making these tests, first bend these wires so that the ends are approximately the same distance apart as the terminals of the installed condenser. Then, make sure the polarity of the test condenser is correct, that is, its positive wire must be placed on the positive of the circuit. In Figure 1, the positive side of the circuit connects to the rectifer filament. Be sure your fingers do not touch the bare wires of the condenser, while holding it in test position and, after the test has been made, discharge the test condenser by placing both of its wires on the chassis.

As we assumed all the operating voltages were correct, it is safe to assume also that none of the bypass condensers are shorted therefore, bridging a good condenser across those installed is a quick, inexpensive test for open condensers.

With dynamic speakers, like that of Figure 1, the action of the entire filter can be checked by shorting the voice coil circuit. This can be done by connecting a short piece of wire or holding a screwdriver blade across the terminals of the voice coil, on the speaker, or on the terminals of the output transformer secondary.

This short will remove any signal voltage from the voice coil and, if the hum remains it indicates variations of field current due to insufficient filtering. Should the hum be reduced or eliminated, when the voice coil is shorted, it indicates the origin is in some stage and the hum voltages are coming through like signal voltages.

In this case, the next step is to short the input circuit of the output stage and, referring to Figure 1, a short piece of wire could be held across the .25 meg grid resistor. When this short reduces or eliminates the hum, it indicates its origin is in some preceding stage. However, if the hum remains, the trouble is in the output stage and all parts, including the tube, should be rechecked carefully.

Following the same plan, the next stage can be checked but, before making any tests, be sure all shorts, used for the preceding tests, have been removed. In Figure 1, the .5 meg load resistor of the 6SQ7 triode plate could be shorted but it usually saves time to short the input circuit first.

Here, the 5 meg resistor, connected between the 6SQ7 triode grid and ground would be shorted. In practice, the shorting wire could be held with one end on the grid terminal of the socket and the other end on the chassis.

This same plan can be followed, stage by stage, back through the detector, I-F and mixer stages until the shorting of a grid circuit causes no reduction in the hum level, thereby indicating the defective stage.

When the defective stage has been located, pay particular attention to the tube as it may be the source of the hum although it tests "OK" on a tube tester. The trouble, especially in a-c/d-c equipment, is due to faulty insulation between the cathode and heater and requires a replacement.

The detector and audio stages are the most common offenders because they will amplify hum voltages therefore, small hum voltages, introduced in the detector circuit, receive the full amplification of the audio amplifiers before reaching the speaker.

When checking defective stages for hum, it is always a good plan to recheck the supply as additional filtering may be provided. For example, in the circuits of Figure 1, the main filter is made up of the speaker field, a 20 mfd and a 40 mfd condenser. The output of this filter supplies the plate circuits of the 6V6GT, the 6SQ7 and 6SK7, 2nd i-f tubes.

A filter, made up of the 250 ohm resistor and .02 mfd condenser is included in the plate supply circuits of the 6SK7, 1st i-f and 6SA7 tubes. Although the comparatively small values indicate this filter is designed to decouple these two tubes, in respect to high frequencies, in other circuits you will find similar arrangements designed to provide additional filtering for the plate voltage.

HASH

The term "Hash" is usually applied to the noise which, generated by the vibrator of an automobile receiver, is heard in the speaker. As this is a common, yet distinct type of noise, for Figure 2 we show the circuits of a 6 tube superheterodyne auto receiver using a synchronous type of vibrator in the power supply.

Checking the circuit, there is a 6SK7 r-f, a 6SA7 mixer, a 6SK7 i-f, a 6SQ7 Detector, avc and 1st Audio, a 6F6 driver and a 6N7 push pull class B output stage.

The r-f, Mixer Input and Oscillator circuits are "Permeability" tuned by means of adjustable iron cores in the coils. As shown by the broken line of the diagram, all three cores are "ganged" to provide single dial tuning. Trimmer condensers are installed for alignment.

The r-f tube is Resistance-Impedance coupled to the Mixer input by the 15,000 ohm load resistor in the 6SK7 plate circuit, the .001 mfd coupling condenser and the tuned coil in the 6SA7 control grid circuit. Except for the type of tuning, the oscillator circuit of Figure 2 is similar to that of Figure 1 for the Broadcast Band.

The 6SA7 is transformer coupled to the 6SK7 i-f tube which, in turn, is transformer coupled to a diode circuit of the 6SQ7 detector. The detector circuit is about the same as that shown for Figure 1, except for the tone compensated volume control.

The human ear does not respond as readily to the lower and higher frequencies therefore, as the volume of a Radio receiver is reduced, there is an apparent loss of bass and high frequency response. The arrangement shown in Figure 2 is designed to overcome this action, by increasing the relative high and low frequency response as the volume is reduced.

To understand the action you need remember only that the reactance of a condenser varies inversely as the frequency and for the following general explanation we will disregard phase angles by considering the capacity reactance as resistance.

With the movable contact all the way to the left, as drawn in Figure 2, the volume will be at maximum and the full voltage across the control will be impressed on the triode grid of the 6SQ7 through the .01 mfd coupling condenser. The other resistors and condensers have no noticeable affect.

Next, with the movable contact set at the tap, the volume will be reduced because the voltage impressed on the grid will be the voltage between the tap and ground only. According to the values given, the resistance between the tap and ground is but 1/5 of the total resistance.

Thinking of the grid circuit, the .4 meg section of the volume control is in series and any voltage drop across it will be lost. As the 50 mmfd condenser is in parallel to the series part of the volume control resistance, its reactance will cause a reduction of the total resistance, or impedance to be technically correct. The higher the frequency, the lower the re-

actance of the condenser and the lower the total impedance. Therefore, the reduction of the higher frequencies will be less than that of the lower frequencies.

The 7000 ohm resistor, in series with the .06 mfd condenser, form a parallel path to that part of the volume control between the tap and ground. Here again, the reactance of the condenser varies inversely as the frequency and will increase as the frequency is reduced to cause an increase in the total impedance.

This impedance is in parallel to the grid circuit and an increase of its value will cause an increase of voltage on the grid. Thus, the lower frequency signal voltages will be increased.

The movement of the movable contact of the volume control causes a gradual change of resistances in series and parallel to the circuits just explained and therefore, both the high and low frequencies will be increased gradually as the overall volume is reduced. This action is entirely independent of the usual type of tone control which is connected across the triode plate circuit of the 6SQ7.

This plate circuit is resistance-capacity coupled to the grid circuit of the 6F6 second audio or driver tube which, in turn, is transformer coupled to the 6N7 double triode output tube which operates as class B, push-pull.

Tracing the cathode circuit of the 6F6 driver tube, you will find it includes a secondary winding of the output transformer in addition to the bias resistor which is bypassed by a 20 mfd condenser. This arrangement provides inverse feedback as the output voltage is introduced in the cathode circuit of the driver.

Due to the higher background noise in a moving auto, as a rule you will find auto receivers have a higher audio output than corresponding models of Home Radios. In general, the circuit is conventional and, with the exception of the power supply, does not differ greatly from those of Home and Portable receivers.

Looking at the power supply, there is no rectifier tube but, as a vibrator socket is shown, the vibrator must be of the synchronous type. As you already know, the vibrator contacts are rapidly closing and opening their circuits and will therefore cause a certain amount of sparking or arcing in addition to sudden changes of current.

The sparks at the contacts radiate energy which will be picked up by the signal circuits as "Hash", unless sufficient shielding is provided and the sudden changes of current will feed back into the signal circuits unless adequate filters are installed. Thus, for a quiet operation, a vibrator type of Power Supply requires more careful tests than the common a-c or a-c/d-c types.

Going back to Figure 2, the main supply to the automobile storage battery is made through the wire at the lower left, marked "To Ammeter". Tracing from this point, the circuit passes through a fuse and choke coil "L_1" to the "ON-OFF" switch.

When the switch is closed, or "ON", there are three paths to follow but notice, choke L_1 with the 250 mmfd condenser on the supply side and .5 mfd condenser on the switch side form a filter in the main supply. To keep their functions in mind, you can think of this as a filter to keep noise, which originates in the electrical system of the auto, out of the radio circuits.

From the .5 mfd condenser of this filter, one path leads straight up to the "H" arrow which indicates it connects to all of the ungrounded "H" terminals of the tube sockets. Just below this arrow, another path leads to the "Dial Lamp" and includes a choke coil L_2 as well as the 250 mmfd and 200 mmfd condensers.

Looking at the diagram, it appears that these two condensers are directly in parallel but, in the actual installation, the dial lamp may be on the cowl with the remote controls for tuning, tone and volume, an appreciable distance from the receiver chassis. The length of the circuit wire, between these two condensers, makes them both necessary.

Going back to the "ON-OFF" switch, there is another path to the center tap of the transformer primary. This path contains a filter, similar to that in the main supply, but the main function of this filter is to prevent the variation of primary current from feeding back into the heater circuit.

The center tap of the power transformer secondary is the positive of the high voltage supply and the .008 mfd condenser, connected across the entire winding, reduces the arcing of the rectifier contacts. Following the circuit from the center tap there is first a filter made up of choke L5, with an .01 mfd condenser on the input side and a 200 mmfd condenser on the output side. The values of these components indicate that the filter operates to eliminate any high frequencies which may be

present in the rectified output of the transformer. The plate circuits of the driver and output tubes connect to the output of this filter.

The output of this filter connects also to the input of another filter made up of a 1500 ohm resistor and two 40 mfd condensers. This compares quite closely to the filter of Figure 1 and its output connects to the plate and screen grid circuits of the other tubes, including the screen grid of the driver tube.

To check for noise in this type of receiver, assuming it to be installed in an auto, the engine should be idle and the car stopped to eliminate other possible sources of noise. Should the "Hash" continue under these conditions, the trouble is apparently in the power supply, the components of which can be tested on the general plans explained for the signal circuits.

The additional filters are necessary to prevent the vibrator noise from reaching the signal and supply circuits and therefore all components should be checked carefully. In addition, you will find this type of supply is shielded completely because, in addition to circuit paths, the sparks at the vibrator controls radiate noise like a small Radio Transmitter.

Therefore, all shielding must be held tightly in place and make good electrical contact with the chassis. To make sure of this condition, you will often find pieces of flexible wire soldered from one to another part of the shielding, forming what is known as a "Bond". Should you find it necessary to remove any of the shielding, be sure all the bonds are replaced properly when the parts are reassembled.

MICROPHONICS

Sometimes classed as "Distortion" but included here as "Noise", are the howls and hums caused by the mechanical vibration of certain parts or components. The frequencies of this type of noise may vary from high pitched squeals to low pitched rumbles or hums. Regardless of the frequency, they are known as "Microphonics".

Loose elements, inside the tubes, are often the cause of this trouble because, the air waves from the speaker cause the tube to vibrate. When this happens, the slight movement of the loose element causes a change in tube output which is amplified and causes a corresponding sound wave in the speaker. This sound wave strikes the tube and sustains the vibration, resulting in a continuous howl.

The detector tube is usually the worst offender but, in some cases, vibration of the tuning condenser plates will produce

the same effect. That is why, in some models, you will find the detector tube socket, the tuning condenser or the complete chassis mounted on soft rubber grommets.

Loose laminations in the iron core of chokes and transformers will sometimes produce this trouble because, the mechanical motion of the part causes a change in electrical conditions.

Microphonic howls are usually identified quite readily because they start at low volume and build up rather slowly. Often, they will occur only at high volume levels or at some certain signal frequency.

One simple test for microphonic tubes is to place the receiver in operation, preferably with no signal, and then tap each tube sharply with a finger or lead pencil. The intensity of the resulting click in the speaker will indicate the troublesome tube. When the microphonic howl is present, by grasping the tubes firmly, one by one, the defective one may be located because the howl will often die out when it is held.

Microphonic tubes must be replaced but if the receiver contains others of the same type, a satisfactory repair can often be made by reversing the positions of the tubes. Also remember, a tube which causes microphonics in one receiver may operate satisfactorily in another.

To locate loose laminations, some men tune in a signal at fairly high volume and then temporarily short the speaker voice coil. In some cases the signal will still be heard but usually the loose laminations make enough noise to permit the location of the faulty unit.

Loose laminations can often be cured by releasing the coil clamps and inserting thin wedges near the center of the core. Laminations removed from the cores of defective or "junk" parts are ideal for this work. Sometimes, the coil is loose on the core and this can be cured by driving a thin wooden wedge between the core and the coil. When inserting a wedge of this kind be sure it is next to the core and does not injure the insulation around the coil.

OSCILLATION

Every stage in every Receiver has a certain amount of feedback or regeneration which, in most cases, is not enough to cause oscillation. However, circuit conditions often arise which allow the feedback to increase enough to cause oscillation. This condition is necessary for the oscillator cir-

cuits of a Super heterodyne, as shown in the diagrams of this Lesson, but must not occur in the amplifier or detector stages.

Oscillation in these stages will cause howls, whistles or "Birdies" which are similar to microphonic howls. However, the oscillation howls can be identified because they are usually controlled by the operation of the tuning condenser. In general, you can think of this action as being like that of an old type regenerative detector with the regeneration control advanced too far. The incoming carrier frequency will heterodyne with the oscillation frequency to produce the beat notes which cause the squeals and howls as the carrier frequencies are tuned in.

From a service standpoint, assuming the operating voltages have been tested and found correct, oscillation is due mainly to lack of filtering in the plate and screen grid circuits. For complaints of this kind, all plate and screen bypass condensers should be checked for capacity as well as low resistance connections.

High resistance, in tuned grid circuits, may also cause oscillation but as this trouble was explained for "Broad Tuning" complaints the test routines will not be repeated.

In some cases, especially trf circuits, the removal or shortening of the antenna may cause oscillation. This is because the antenna acts as a load on the input or grid circuit and, when this load is reduced or removed, there may be sufficient feedback to cause oscillation.

Also, after a receiver has been serviced, the location of connecting wires, especially those of the grid and plate circuits, may be changed enough to provide the feedback needed to cause oscillation. In these cases, the frequency of the oscillation note can usually be changed by placing a finger on the insulation of the dislocated wire. The remedy is simple; move the wires further apart or at different angles to each other until the oscillation ceases. In the manufacture of Receivers this operation is known as "Dressing" the wires or leads.

TONE CONTROLS

In the typical circuits of this Lesson you will find that each includes a tone control consisting of a fixed condenser in series with a variable resistance. In other models, various values of capacity are connected to the contacts of a rotary switch but, for both types, the action is controlled by a movable contact which is a possible source of noise.

Variable resistors, used as tone and also volume controls, consist of a metallic contact which slides over the surface of a resistance strip, made up of a flat paper or bakelite form which is impregnated with a carbon or graphite solution. After a period of service, the surface of the strip may become rough or worn and the tension on the contact may reduce sufficiently to prevent proper electrical conductivity.

Frequently, noise from this source will occur only as the contact is moved and therefore the source of the trouble is located readily. When there is noise in the speaker, only while the tone or volume control knobs are moved, the control is at fault and, in most cases, should be replaced.

However, with improper contact between the moving arm and resistor strip of a control, mechanical vibration of the receiver or variations of voltage across the control may produce noise in the speaker. Fortunately the volume control which has an irregular or noisy action, when moved, is usually the one which is noisy at other times and therefore is not difficult to locate.

As explained in the earlier Lessons, a continuity test of the control, between one end and the center connection, made while the shaft is turned, will indicate the irregular variations of resistance which can cause noise when the control is in operation.

Various methods have been suggested for the repair of noisy controls of this type, such as using a soft lead pencil to make the surface of the resistor strip more uniform but, from the standpoint of service, a replacement is more economical and satisfactory.

CABINET - RESONANCE

The cabinets of most Radio Receivers, from the largest console to the smallest midget, not only protect and support the chassis but act as a baffle for the speaker. Some larger installations mount the speakers separately but, for the common types, the chassis and speaker are enclosed in the same cabinet.

When the speaker is in operation, the movement of the cone produces sound waves which are projected through the opening or grille, usually on the front of the cabinet. Similar sound waves are projected backward into the cabinet and, at certain frequencies, may produce what is known as "Cabinet Resonance".

At lower frequencies, usually between 100 cycles and 250 cycles, the air in the enclosure formed by the cabinet walls, has what can be thought of as a resonant frequency. When the speaker cone vibrates at or near this frequency, there is a standing wave pattern in the cabinet which causes an increase of sound.

This condition is recognized by most designers and the stiffness of the cone, as well as its suspension is arranged to provide the desired overall frequency response. However, at the frequency of the cabinet resonance, the air pressures are comparatively high and may cause the panels of an old cabinet to rattle.

In other cases, panels or other parts of a cabinet with a natural or resonant vibration frequency may produce an annoying rattle after the cabinet has been in use for some time. Noise of this kind can usually be located by holding your hand firmly against the various parts of the cabinet because the vibrations can be felt and the pressure of your hand will stop them.

The remedy here is mechanical and the loose parts can be tightened with glue, new fastenings or reinforcing strips, depending on the construction. In other cases, strips of sound absorption material, tacked on the vibrating parts, will be sufficient.

While this type of work is not electrical, your customer expects you to do it because he makes no distinction between the various causes of noise. He brought the receiver to you for service therefore, it is your responsibility.

TUBE NOISE

In explaining the action of a simple triode tube, it is always assumed that, with fixed plate and grid voltages, there will be a fixed and uniform value of plate current. For most purposes, this assumption is sufficiently accurate but in highly sensitive receivers, especially those operating on the higher frequency or short wave bands, there are two causes of noise in addition to those mentioned earlier in this Lesson.

Going back to the simple triode tube again, the plate current is said to be a stream of electrons therefore, strictly speaking, it is not continuous but is made up of a series of random pulses as each electron strikes the plate. In a sensitive receiver, these random pulses sound somewaht like machine gun bullets striking a target and therefore the action is known as a "Shot Effect" or "Shotty Effect".

Another similar effect is caused by what is known as "Thermal Agitation", due to the random motion of electrons in a wire or circuit. Noise from this source depends upon the temperature and resistance of the circuit and usually increases with either or both.

For ordinary Broadcast Reception, neither of these effects are of great importance because the Signal-Noise ratios are fairly high. However, for the reception of distant stations or weak signals, especially on the Short Wave Bands of "All Wave" receivers, the noise level may be sufficiently high to cause a customer complaint. In fact, it is these unavoidable noises which limit the amplification or useable sensitivity of a Receiver.

As far as the Receiver is concerned, there is not much to be done in respect to Noise generated by the Shot Effect and Thermal Agitation. However, as the selectivity of a Receiver is increased, this type of noise is reduced and therefore, the suggestions made for Broad Tuning complaints will apply here also.

Microphonics, caused by loose and vibrating tube elements require a tube replacement for correction. In some cases, it may be necessary to try a number of new tubes before a satisfactory replacement is found. Other vibrating parts, such as tuning condenser plates and laminations of iron core components can usually be corrected by mechanical methods.

A similar result may be caused by loose shielding, especially when the shields are riveted to the chassis. When the rivets, or other mounting units are loose, there is a varying resistance between shield and chassis, resulting in noise or oscillation.

Holding the shields tightly, with pressure against the chassis, will frequently locate the troublesome part. Some types of mounting can be tightened but for others, the best remedy is to solder the shield to the chassis, at or near the mounting points.

Noise caused by dirty or imperfect contacts of switches and variable components is also a mechanical defect and may be corrected by cleaning or replacement. Noise may also be produced by rapid changes of resistance in fixed condensers and resistors. Trouble of this type usually causes changes of output at such a slow rate that they are classed as "Intermittents", a subject which will be taken up in the following Lesson.

NOISE REDUCTION METHODS

For checking noisy resistors, condensers and coil windings, a useful test circuit can be made by connecting a battery, of two or three dry cells, in series with a pair of headphones. The suspected part is then connected in series with the test circuit and any slight variation of current, caused by changes of resistance, will cause noise in the phones.

This test circuit is quite sensitive and can be used on the same plan as an ohmmeter. However, to make sure that noise originates in the suspected part, all connections of the test circuit must be good. One click should be heard when the test circuit is completed and another click when it is opened but, as long as the circuit is complete, the phones should be silent. The circuit itself can be tested for noise by connecting the phones to the battery.

As it is commonly used, the expression "Noise Reduction" refers to the reduction or elimination of man made static and, while the receiver itself is not at fault, the cure is often an important part of a complete service job.

There are two main plans for the elimination of this type of noise. First, to locate and eliminate the source and second, to keep the noise out of the receiver. The first of these is a rather large job as it means a check up of all the electrical apparatus within a radius of a mile or more, an undertaking usually impractical for the average service man.

However, due to the popularity of broadcast radio, most Electrical Power Companies have the personnel and equipment to make a check up of this kind and usually are glad to cooperate. Therefore, whenever you receive a number of complaints about a certain type of interference, which occurs in some neighborhood or locality, a report to the Power Company will usually bring assistance.

The second plan, of preventing the noise from entering the Radio, is perhaps the most practical as all the work can be done on the customer's premises. We have already mentioned the test of shorting out the input stage to determine if the noise originates outside or inside the Receiver and now suggest a good commercial type of Line Filter as a useful piece of test equipment.

These filters consist of a combination of condensers and chokes mounted in a metal container with a cord for plugging into a house wiring outlet and a receptacle for the receiver power cord plug. Usually, a terminal is provided which permets the filter housing to be grounded to the conduit of the lighting circuit wires.

Should noise still persist, with the input circuit shorted and the line filter properly installed, it must originate in the receiver circuits or be picked up by direct radiation. In modern receivers, direct pickup is possible usually when the shielding is loose or improperly grounded while, for older type receivers, unshielded coils or connecting wires may act as an antenna.

For a cure here, all shields and ground connections should be inspected carefully for low resistance connections to the chassis and, when necessary, shields should be installed on unshielded parts.

You will find however, that persistent interference of this kind is often generated in the customer's home therefore it is a good plan to check his electrical appliances. With the receiver in operation, go all around his home and turn off everything, refrigerator, fans and so on, including all of the lamps, checking the noise each time a unit is disconnected.

To make this check complete inspect all fuses, to make sure they are in good condition and make good tight contact. A cracked fuse wire may allow operation of the lamps and appliances but produce a small arc which radiates enough noise to spoil the reception of Radio Programs.

After the Lighting circuit has been checked, should the noise still persist, especially when someone walks across the floor or heavy traffic passes, check the lighting circuit for points where the metallic conduit of the wiring system may make contact with water, steam or gas pipes. An intermittent contact at these points can produce a great deal of noise. Friction Tape, wrapped around the pipe to insulate the point of contact, will cure this trouble.

Frequently, a complete check of the house lighting circuit and appliances will locate the source of the noise but, with the Receiver in good condition and a line filter in the circuit, any remaining noise apparently enters through the antenna, along with the desired signals.

For loop antennas, a position may be found which reduces the noise sufficiently to allow acceptable reception and, for outdoor antennas, a noise reducing lead in may be used. The idea here is to locate the antenna proper outside the zone of the noise and make connections to the receiver through a special form of "Lead In".

The simplest form of this arrangement is the "Twisted Pair" made up of two wires wrapped around each other like the old

style "Lamp Cord". One of the wires is attached to the antenna while the other is supported by, but not connected to the antenna.

Signal voltages, induced in the antenna, will be carried to the Receiver through the connected wire but noise voltage, induced in the lead in, will be cancelled by like but opposite voltages induced in the supported wire. Noise reducing antennas can be purchased complete with detailed instructions for connections to common types of Receivers.

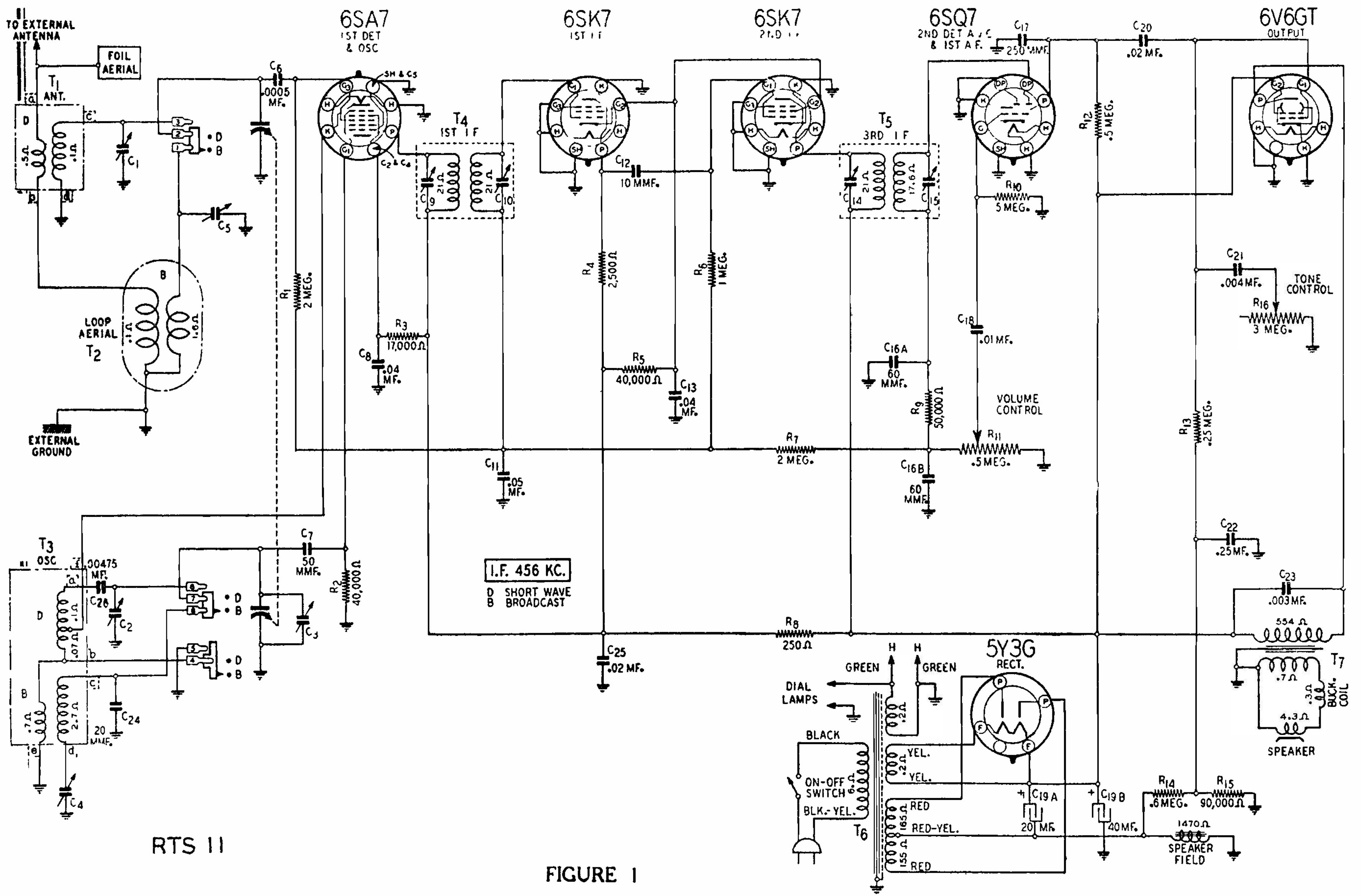

TO EXTERNAL ANTENNA
FOIL AERIAL
T1 ANT.
LOOP AERIAL T2
EXTERNAL GROUND
6SA7 1ST DET & OSC
6SK7 1ST I F
6SK7
6SQ7 2ND DET A V C & 1ST A F.
6V6GT OUTPUT
T4 1ST I F
T5 3RD I F
R1 2 MEG.
R3 17,000Ω
C8 .04 MF.
R4 2,500Ω
R5 40,000Ω
R6 1 MEG.
C12 10 MMF.
C13 .04 MF.
R7 2 MEG.
C11 .05 MF.
C16A 60 MMF.
R9 50,000Ω
C16B 60 MMF.
C18 .01 MF.
VOLUME CONTROL
R11 .5 MEG.
R10 5 MEG.
C17 250 MMF.
C20 .02 MF.
R12 .5 MEG.
C21 .004 MF.
TONE CONTROL
R16 3 MEG.
R13 .25 MEG.
C22 .25 MF.
C23 .003 MF.
T7
BUCK. COIL
SPEAKER
T3 OSC
C7 50 MMF.
R2 40,000Ω
C24 20 MMF.
I.F. 456 KC.
D SHORT WAVE
B BROADCAST
R8 250Ω
C25 .02 MF.
DIAL LAMPS
GREEN
5Y3G RECT.
BLACK
ON-OFF SWITCH
BLK.-YEL.
T6
YEL.
RED
RED-YEL.
C19A 20 MF.
C19B 40 MF.
R14 .6 MEG.
R15 90,000Ω
1470Ω SPEAKER FIELD
RTS 11

FIGURE 1

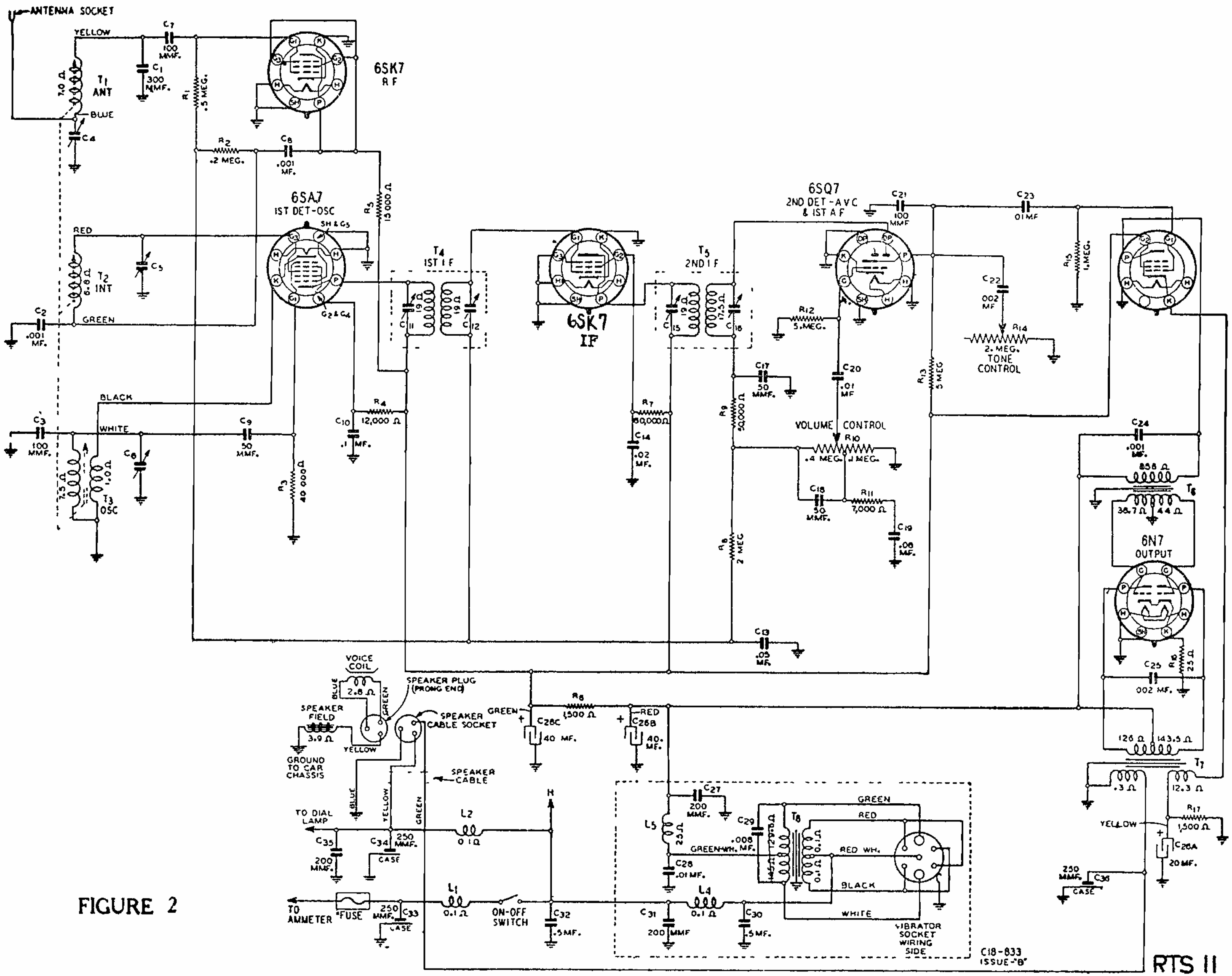


FIGURE 2

RTS 11

QUESTIONS

How many advance Lessons have you now on hand?________

Print or use Rubber Stamp:

Name ______________________ Student No. ________

Street ______________________

City ____________ State ____________

1. In what two places does Radio Receiver "Noise" originate?

2. Referring to Figure 1, what conclusion can be drawn if "noise" in the speaker does not decrease when the antenna and ground terminals are shorted?

3. What is meant by "Signal-Noise" ratio?

4. What would happen to the grid bias on the 6V6 stage of Figure 1 if resistor R_{14} is "open"?

5. What quick test can be made to determine if bypass condenser C_{11} of Figure 1 is open?

6. What is meant by the term "Hash" as applied to Radio Receiver noise?

7. In an operating receiver, how is it possible to determine if the tubes are microphonic?

8. What undesirable condition is likely to exist if screen by-pass condenser C_{13} in the receiver of Figure 1 becomes "open"?

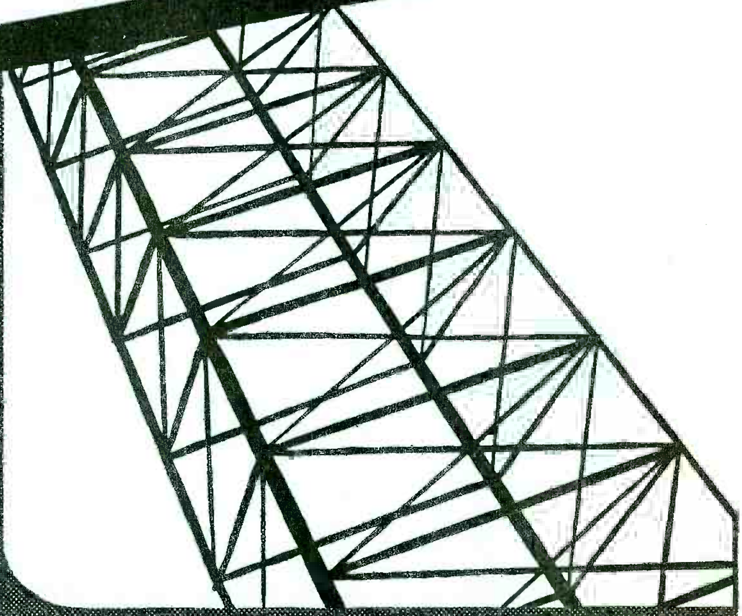
9. Referring to Figure 1, what would be the probable result on the "sound" if the 40 mfd filter condenser, part C19B, reduces in capacitance?

10. What unit is at fault when there is noise in the speaker only while a control knob is moved?

N

LESSON RTS - 12

INTERMITTENT TROUBLES



DE FOREST'S TRAINING, INC.

2533 N. Ashland Ave., Chicago 14, Illinois

RADIO AND TELEVISION SERVICING

LESSON 12

TYPICAL FAULTS - INTERMITTENT TROUBLES

Intermittent Troubles ---------------- Page 1
Signal vs. Circuit Trouble ------------ Page 1
Coupling Condensers ------------------ Page 4
Bypass Condensers -------------------- Page 6
Resistors ---------------------------- Page 7
R.F. Coils --------------------------- Page 7
Iron Core Coils and Transformers ------ Page 13
High Resistance Joints --------------- Page 14
Line Voltage Variations -------------- Page 15

* * * * *

If you wish success in life, make perseverance your bosom friend, experience your wise counselor, caution your elder brother and hope your guardian genius.

— Addison

INTERMITTENT TROUBLES

One of the most common, but perhaps the most troublesome complaint is that of Fading or Intermittent reception. Your customer tells you his Radio works fine for a while and then, either slowly or suddenly, the signals drop to a low level or die out altogether. This may happen for no apparent reason, when some light in the home is turned off or on, when someone walks across the floor or many other seemingly unrelated incidents.

Unfortunately, the cause and effect are not always the same, sometimes the signals will die out when a certain lamp is turned on and the next time, they may die out when the same lamp is turned off. Again, one thing may cause the trouble one time and have no effect the next.

After the signals have died down or out, they may be brought back in a variety of ways such as slapping the cabinet, wiggling the antenna lead-in or power cord and more often, by snapping the OFF-ON switch.

The details of some of these complaints may lead you to believe the customer is just trying to be funny but usually, he is telling you exactly what has happened, as well as he can remember. In any event, find out all the details you can because, as we have mentioned before, the more information you have in respect to the behavior of the Receiver, the better your diagnosis should be.

Another difficulty in analyzing cases of this kind is the irregularity of the trouble. The receiver may operate for hours, days or even weeks without any indication of trouble and then suddenly the signals will die down or out every few minutes. Naturally, you can not test for trouble when it is not present and therefore have to operate the Receiver until the trouble shows up.

Then, after waiting hours for the signal to die down, the instant you make connections with your test meter, the signals may jump to normal volume and remain there.

Complicated as these symptoms may seem, there is a cause for every effect and a careful diagnosis, plus some of the usual types of tests, will usually indicate in a general way at least, what section or stage of the Receiver is at fault.

SIGNAL VS. CIRCUIT TROUBLE

It is a well-established fact that the radiated energy of a Broadcast station, even when held to a constant level at the

transmitting antenna, may not always induce equal signal voltages in the Receiving antenna. This is frequently due to conditions in space and the action is known generally as "Fading".

The variations of received signal strength may vary slowly or rapidly and are more troublesome when the signals are weak, the distance between Transmitter and Receiver is great or the carrier frequencies are high. Fading of this kind is not due to any Receiver defects but the results may sound the same.

Fortunately, it is not difficult to make a check because the conditions which cause Fading of signals from one Transmitter do not affect others. Therefore, if fading occurs on one station, tune in several others and compare results. With trouble inside the receiver, the reception will be similar for most stations but, if the trouble is due to external fading, the changes of reception will vary for each station tuned in.

Like all general rules, there are exceptions to this one and, for short wave reception, an entire band may fade out during certain hours. A check here is to tune in on other bands because, excluding trouble in the input circuits of one band, fading caused by internal troubles will be present on all bands.

Another quite common test is to tune the Receiver to the output frequency of a signal generator and, with fairly loose coupling between them, reduce the output of the signal generator until the avc has little if any control. Under these conditions, the input signal voltage should be reasonably steady and variations of output are due, in most cases, to trouble inside the receiver.

Following these general plans, which require little test equipment, it is usually possible to determine quickly and accurately, whether the fading is due to external or internal causes. For the ordinary customer, little can be done to cure fading of the signals but, once he fully understands the conditions, he will not blame his receiver nor expect you to cure the trouble.

Our interest is in the internal defects which cause fading or intermittent reception because, to many service men, these are the "headache" jobs. Every component in the signal and supply circuits is a possible cause of the trouble, even though the ordinary voltage and continuity tests do not indicate any defect.

As a basis for our explanations of the causes and cures for this type of complaint, Figure 1 of this Lesson shows the circuits of an 8 tube, 3 band superheterodyne Radio Receiver

combined with a Phonograph. Combination models of this type are gaining in popularity because, with a collection of records, the owner can enjoy his favorite music at any time regardless of the programs on the air.

Going further, Figure 2 shows the circuits of an 11 tube combination which includes Frequency Modulation reception as well as 2 bands of a-m radio and provisions for a Phonograph. Un like the combination of Figure 1, Figure 2 does not include the Phonograph turn table and pick up but does have a "Phono Jack" and include a "Phono" position on the band switch.

Looking at Figure 1 you will find the common type of a-c receiver circuit using a full wave 5Z4 rectifier tube and a dynamic speaker, the 1000 ohm field of which is used as a filter choke.

There are three sets of input and oscillator coils, controlled by a four circuit, three position band switch which connects them to a conventional 6SA7 mixer tube. Like pervious circuits we have explained, this arrangement requires a two gang tuning condenser.

The plate circuit of the 6SA7 tube is coupled to the grid of the 6SK7 by the usual double tuned type of i-f transformer. The plate of the 6SK7 is coupled to the diodes of the upper 6SQ7 by a similar transformer, the secondary of which is a part of the diode detector circuit.

Checking this circuit, you will find the cathode of the tube is grounded and a $\frac{1}{2}$ megohm resistor connects from cathode to the lower end of the i-f transformer secondary. Also, there is a parallel path from ground, through the $\frac{1}{2}$ megohm volume control, an .01 m-f coupling condenser, the "Radio-Phono" switch and 50,000 ohm filter resistance to the lower end of the i-f transformer winding. the avc circuit connects to the junction between the "Radio-Phono" switch and the 50,000 ohm resistor.

The Radio-Phone switch is in two parts or sections. The one mentioned above allows either the signals of the detector circuit or those of the crystal pick-up to be impressed across the volume control. The other section of the switch controls the Phonograph Motor, closing its circuit when in the "Phono" position.

The triode grid of the 6SQ7 detector tube is coupled to the moving contact of the volume control by an .01 mfd condenser and the circuit includes a 5 megohm grid resistor. The triode plate is coupled to the upper 6KGT tube by a $\frac{1}{4}$ meg

plate resistor, an .01 mfd coupling condenser and a .5 megohm grid resistor.

The grid resistor connects to ground through a .25 meg resistor and the triode grid of the lower 6SQ7 is coupled to the junction between these resistors by an .01 mfd condenser. This arrangement permits the lower 6SQ7 to operate as a phase inverter and its plate circuit is coupled to the lower 6K6GT by a .25 meg plate resistor, an .01 mfd coupling condenser and a .5 meg grid resistor. Notice here, this grid resistor connects to the junction between the resistors of the other 6K6GT grid circuit to make up what is sometimes known as a balanced phase inverter.

Thus, the two 6K6GT tubes operate as a push-pull output stage and drive the speaker through the usual type of output transformer.

A 6U5 type of tuning eye tube, with its grid connected to the avc circuit, completes the tube complement. A tone control is installed in the triode plate circuit of the first audio 6SQ7 and there is the usual ON-OFF switch in the main supply.

COUPLING CONDENSERS

With the details of this circuit in mind, imagine the receiver has been brought to you with a complaint of Fading or Intermittent reception. Your job is to determine first, whether the trouble is external, due to signal fading, or internal, due to circuit defects. After obtaining all possible information from the owner, you place the receiver in operation, duplicating as nearly as possible the conditions under which the trouble occurs.

Unless the trouble shows up immediately, you tune in some station with a steady signal, set the volume at a comfortable level and allow the receiver to "warm up", while you go ahead with other work. Of course, you keep one ear tuned to the signal so that you can make an immediate check in case the volume changes noticeably.

After operating for 30 minutes or more, the receiver should be heated to its normal operating temperature and be ready for further tests. If the trouble has not shown up, you can tune over its entire range and check on the reception of various stations, comparing the results with the information given by the owner.

Should the operation still appear to be normal, remove the chassis from the cabinet so that all of the parts are accessible. Then, with a station tuned in, tap each of the

tubes, as previously explained for microphonics, listening closely for variations of signal. Using a small rod, preferably of insulating material, the resistors, bypass condensers and connecting wires, underneath the chassis, can be tapped and also pushed slightly from side to side.

This is done to discover any loose connections which may test correctly, as far as continuity is concerned, but which may change because of vibration or expansion due to the increased temperatures of operation. The source of many intermittent troubles can be found by this plan because, when the defective part is tapped or moved, either the signal will change in volume or clicks will be heard in the speaker.

Coupling condensers are quite common offenders in this respect and, in the circuits of Figure 1, you will find eight of them. Two in the oscillator coil assembly, one in the 6SA7 oscillator grid and five between the detector and speaker. Of these, there is one between the Radio-Phono switch arm and volume control, one between the moving contact of the volume control and the triode grid of the upper 6SQ7 and one between the triode grid of the lower 6SQ7 and the junction between the grid resistors of the output stage.

These circuits carry signal voltages only and thus the condensers do not have to withstand the higher voltages of the plate supply. However, they must be checked carefully because, every time the receiver is operating, their temperature is raised, causing some expansion of the metal foil and connections. When the receiver is off, the parts cool and contract to their original size. In time, this repeated expansion and contraction may produce a high resistance or intermittent open and cause a customer complaint.

The coupling condensers between the 6SQ7 plates and 6K6GT grids are subject to the same conditions but, in addition, have to withstand the plate voltage. We have already explained the symptoms and tests for shorted coupling condenser but, an intermittent open will not show up on the ordinary voltage or continuity tests.

As many of these troubles are caused by the heating of the parts when the receiver is in operation, some men exaggerate this condition by exposing the underside of the chassis to a reflector type of electric heater. This treatment raises the temperature in a very short time and often causes the intermittent effect to appear.

When the intermittent does appear there are usually certain indications which permit quick tests. For the circuits of Figure 1, the cause of a drop in volume can be localized in

the rf-if section or a-f section by means of the tuning eye. With trouble between the detector and antenna, a drop in volume will be accompanied by an increase of shadow angle in the 6U5 tuning eye. If the defect is between the detector and speaker, a drop in volume can occur with no change in the shadow angle of the tuning eye.

With a combination like that of Figure 1, the audio amplifier can be tested separately by playing a record and comparing the signals with those of Radio Programs. When the trouble is present for both, it is located in the audio amplifier but, if it occurs only for Radio signals, it must be located between the detector and antenna.

Because the cost of new parts may be less than the cost of the time spent in testing, some men replace all the coupling condensers when the intermittent symptoms indicate that one of them may be defective.

BYPASS CONDENSERS

By-pass condensers are subject to conditions like those mentioned for coupling condensers and therefore develop the same defects. In this case, the complaints may be due to intermittent hum, howling or other forms of distortion depending on the location of the defective unit.

Checking the circuit of Figure 1 you will find an .05 mfd from the 6SA7 grid return to ground as part of the avc filter or tuned input circuit, a .25 mfd across the 300 ohm bias resistor of the 6SK7 tube, and an .05 mfd between the 6SA7 and 6SK7 screen grid and ground. Another .05 mfd is connected between the supply end of the 21,000 ohm screen dropping resistor and ground while, in a similar arrangement in the diode detector circuit, there is a 100 mmfd condenser between each end of the 50,000 ohm resistor and ground.

For the triode section of the 6SQ7 detector there is a 100 mmfd between plate and ground with an .006 mfd in the tone control. Each of the 6K6GT tube plates have an .002 mfd to ground and there are two 16 mfd condensers in the power supply filter, to make a total of twelve bypass or filter condensers.

While intermittent condenser shorts are possible, they are not as common as intermittent opens because the current, resulting from the short, usually makes the defect permanent to cause a No Signal, Low Volume or other similar complaint. Intermittent opens do not allow excess current and therefore cause no change in the condition of the defect.

A check of the symptoms will usually indicate the general location or purpose of the defective condenser. For example,

suppose for the circuit of Figure 1 that, after playing normally for a time the signals suddenly sounded "Tinny" with an increase of high notes or frequencies. Naturally you would suspect the tone control condenser because its purpose is to reduce high frequency response and an open condenser would make the circuit inoperative. However, each of the output tubes has an .002 mfd bypass condenser connected from plate to ground which, with the exception of the variable resistance, is the same arrangement as used in the tone control. Thus, anyone of these condensers could cause the trouble taken for this example.

A similar diagnosis can be made for most troubles and, if the screen bypass condenser should open, it might permit the i-f tube to oscillate and cause squeals or howls but would have little effect on the frequency response of the signals.

RESISTORS

Similar troubles occur in resistors, especially those of the carbon type, because they carry current and are therefore subject to internal heating. In addition to the possibility of intermittent opens between the resistor and its connecting wires, the repeated expansion and contraction may cause the body of the resistor to crack or partially crumble.

Any resistor, which has been overheated sufficiently to blister or burn its outer surface, should be suspected and given a careful continuity test. First, the indicated value of resistance should be checked against the color coding on the body and, if the variation is over 20%, a replacement is advisable. In case the color coding is blistered so badly it can not be read, it is a good plan to replace the resistor as it may cause future trouble.

With the continuity tester or Ohmmeter connected across the resistor, strain the connecting wires and tap the body, watching for chages in the test reading. Be sure the test connections are tight and then, if the test reading varies, replace the resistor.

R. F. COILS

To continue these explanations, we will refer to Figure 2 of this Lesson which contains the circuits of an eleven tube General Electric receiver with provisions for two a-m bands, one f-m band and also a "Phono" position on the band switch.

The band switch consists of four sections, marked "S1", "S2", "S3" and "S4" and, as the arm is shown in the f-m position, we will trace the signals for this band.

The input circuit, connected to a special f-m antenna, consists of transformer T5 which, tuned by condenser C3, covers the band of 42-50 megacycles. The 7Q7 oscillator uses part of coil T-7 which, tuned by condenser C5, covers a band of 18.85-22.85 megacycles.

These outputs are coupled through condensers C6 and C7 to the grid of the 6SG7 r-f tube through contacts 6 and 7 of switch S2 and condenser C13. Under this condition, the tube acts as a mixer and its plate circuit will carry the two original frequencies as well as beat frequencies equal to their sum and difference.

The plate circuit of this tube includes part of one coil of transformer T6 which is tuned by condenser C29 to cover the band of 23.15-27.15 megacycles. Checking the frequencies of the input and oscillator circuits, you will find the plate circuit is tuned to the beat frequency equal to their difference but this value is fairly close to that of the oscillator.

As a result, both the oscillator and beat frequencies will appear in the plate circuit and be carried over to the grid of the 6SG7 converter tube by coupling condenser C16. Here again there is a mixer action and i-f transformer T1 is tuned to 4.3 mc, the frequency equal to the difference of the beat and oscillator frequencies.

For example, when the inout circuit is tuned to 46 mc, the oscillator tunes to 20.85 mc for a beat of 46 - 20.85 mc or 25.15 mc. The 25.15 mc beat and the 20.85 oscillator frequency are impressed on the grid of the 6SG7 converter to produce a beat of 25.15 - 20.85 or 4.3 mc.

The i-f transformer T1 consists of two pairs of coils. As shown in the diagram, the upper pair are tuned to 4.3 mc for f-m reception as explained above while the lower pair are tuned to 455 kc for the usual Broadcast and Short Wave bands. Switch S4 shorts out the low frequency i-f primary and thus the f-m signal voltages appear across the high frequency primary with 4.3 megacycles as the mean frequency.

The two secondaries are in series at all times but operate one at a time. For f-m, the intermediate frequency is 4.3 mc or 4300 kc, while for the a-m bands, the intermediate frequency is 455 kc, a ratio of about 9-1/2 to 1. Both secondaries have a parallel connected tuning condenser but, for the higher frequency, the values of inductance and capacity are much smaller than for the lower frequency.

With the band switch in the f-m position as shown, the 4.3 mc i-f will resonate the upper secondary circuit but, at

this frequency, the reactance of the other condenser is so low that, in effect, it shorts out the other unit.

With the band switch in the a-m position, the 455 kc, i-f will resonate the upper secondary but, at this frequency, the reactance of the upper coil is so low that, in effect, it shorts its circuit.

Thus, the signal is impressed on the grid of the 6SG7 i-f amplifier which, by means of a similar i-f transformer, is coupled to the grid of the 6SH7, 1st limiter. The purpose of this tube is to remove variations of signal amplitude and therefore it operates at values of plate and grid voltages which permit normal signal voltages to drive it from plate current saturation to plate current cut-off. Under these conditions, any voltages above normal level are prevented from passing through and do not appear in the plate circuit, thus eliminating much of the "Noise".

To eliminate the noise more completely the 6SH7, 1st limiter is coupled to a 6SH7, 2nd limiter by a modified form of resistance-capacitance. Instead of the usual arrangement, the plate load consists of a coil and resistor in parallel to limit the impedance at high frequencies.

The 2nd limiter operates on the same plan as the 1st, removes any remaining variations of amplitude and is coupled to the diodes of the 7K7 by the conventional type of discriminator transformer. The discriminator is really the detector as it converts the frequency variations of the carrier into corresponding variations of rectified signal voltage.

The output of the discriminator is like that of other detectors and, in Figure 2, it is impressed on the volume control, R27, through resistance R36, a section of switch S4 and coupling condenser C45. This signal voltage is impressed on the triode grid of the 6SQ7, 1st audio tube, by coupling condenser C46 and grid resistor R26.

The audio amplifier is of a conventional type but uses the triode section of the 7K7 tube as a phase inverter which, with the triode section of the 6SQ7, drives the push-pull 6V6GT output stage. Notice here, the plate of the 6SQ7 couples to the grid of the 7K7 through C67 while C68 and C69 couple the inverter to the output tube.

The plate circuit of the 6SQ7 includes a simple type of tone control, made up of condenser C66 and variable resistance R44, connected in series between plate and ground. The volume control is tone compensated with switch S5, arranged to provide three positions of apparent bass boost, and inverse feed

back resistor R29, connected to the voice coil circuit through R3.

The power supply is conventional but you will find additional filtering in the plate supply circuit. Starting at the 5U4G rectifier filament, the speaker field with a condenser to ground at each end, is used in the first filter and its output connects to the plates and screens of the 6V6GT output tubes.

From this same point, there is a circuit to the plate of the 6SG7 i-f amplifier, with R16 and C40 as a filter, also a path to the plate of the 6SG7 converter and, with the switch S4 in the position shown, R11 and C32 act as a filter.

Going back to the speaker field, there is another path containing R46 and C73C as a filter, the output of which connects to other plates and screen grids. Following this circuit you will find a voltage divider, made up of R34 and R23 with a condenser from each end of R34 to ground. The screen grid of the 6SH7, 2nd Limiter connects to the junction between the resistors.

Also, there is a circuit to the screen grid of the 6SG7 i-f amplifier through R15 with C38 to ground. From this screen there is a voltage divider made up of R20 and R56 with the screen grid of the 6SH7 1st Limiter connected to the junction between the resistors. Condenser C54, from screen to ground, completes the circuit.

In much the same way, R15 and C38, R5 and C20, R6 and C21, R2 and C14 make up isolating filters for the various tube circuits.

One other interesting feature here is the f-m squelch circuit to reduce the noise in the speaker when no f-m carrier is tuned in. Under these conditions, noise voltages will appear across resistor R35 in the plate circuit of the 6SH7, 2nd Limiter and be carried over to one diode of the 6SQ7, 1st audio tube through coupling condenser C63, causing a rectified voltage to be developed across R32.

With switch S6 open, R32 is in the triode grid circuit of this 1st audio tube and the rectified noise voltages, across R32, increase the grid bias to plate current cut-off. With no current in the triode plate circuit of the 6SQ7, no signals, or noise, reach the speaker.

With the f-m carrier on the grid of the limiter tube, the average plate current remains constant, eliminating any voltage changes to be carried over by coupling condenser C63. Therefore, the voltage across R32 dies out, restoring the

grid bias to normal and allowing the triode section of the 6SQ7 to operate as an amplifier. Switch S6 is installed to short out R32 and permit the reception of weak signals which are noisy.

For a-m reception, the inpit circuit consists of transformer T4 tuned by condenser C12. For the short wave band, the external antenna is used but, for Broadcast, the loop "13" acts as the antenna. There are two oscillator coils in Transformer T7, one used for short wave and one for Broadcast but both tuned by condenser C22.

The first 6SG7 tube acts as an r-f amplifier on the a-m bands and is coupled to the 6SG7 converter through T6, the circuits of which are tuned by condenser G18. For these bands, the oscillator is coupled to the converter through its cathode circuit which is completed to ground through 12-R55 and part of one oscillator coil.

The signal is carried by the low frequency coils of the i-f transformers, the secondary of T2 being connected to a diode of the 6SQ7 a-m detector. As the cathode of this tube is grounded, the circuit is completed through R18 to the lower end of the secondary.

The signal voltages across R18 are carried to switch S4 through the filter made up of R24, C49 and C4. From the switch, the signals are fed to the triode grid of the 6SQ7 tube and follow the path to the speaker as explained for f-m signals.

Looking at this switch, "S4, you will find its fourth position connects the "Phono-Jack" to the input circuit of the 6SQ7 and thus, the audio amplifier of the receiver is available for the reproduction of phonograph records. All switches, shown as S1, S2, S3 and S4 are ganged to operate by a single control and, when in the "Phono" position, the input, oscillator and detector output circuits are opened to prevent Radio signals from causing interference while the phonograph is in use.

We have included these details of the circuit of Figure 2 to try and show you that individually, the components of a more complicated circuit are no different from those of a simpler circuit. Their construction and functions are the same therefore the same test routines and checks apply in all cases. The only difference is one of quantity. The more tubes and stages, the greater the total number of components and therefore a larger number of tests may have to be made.

For example, in the circuits of Figure 1, the three band receiver has 3 pairs of input coil windings, three oscillator coils and two i-f transformers, each of which contains one primary and one secondary winding. Thus, there are a total of 13, r-f and i-f coils to test.

In comparison, for the circuits of Figure 2, input transformer T4 includes 3 coils and loop, input transformer T5 has 2 coils, oscillator T7 has 2 coils, interstage transformer T6 has 3 coils, i-f transformer T1 has 4 coils, i-f transformer T2 has four coils and discriminator transformer T3 has 3 coils for a total of 22.

To continue the comparison, the band switch of Figure 1 has a total of 12 contact points while the band switch of Figure 2 has a total of 39 active contacts in its four sections. Individual continuity tests for each contact are the same for all switches but the circuits of Figure 2 have more than three times the number of contacts shown in the circuits of Figure 1.

Many intermittent troubles in r-f and i-f coils are due to open circuits and frequently, these occur at or near the lug to which the end of the coil wire is soldered. In commercial coils, the wire is wound tightly on the form and usually, the ends are wrapped around a lug and soldered. As we explained for condensers, expansion of the parts, due to the increased temperature of operation, may strain the wire sufficiently to cause a crack or complete break.

When the coil is cool, the sides of the break may touch enough to pass the usual continuity test and the insulation on the wire or the dope on the winding may make the break invisible to the eye. Thus, it is a good plan to bare the ends of the coil wires of a suspected unit.

In some similar units, the coil wire is joined to a heavier flexible wire which is used for making connections to the circuit. For this arrangement, examine the joint carefully for defects due to slight breaks of the smaller coil wire, poor soldering or corrosion. The application of a hot, well tinned soldering iron will usually restore the proper conductivity of the joint.

In other types of coils, especially shielded i-f transformers, the connecting wires are carried from the trimmer condensers, at the top, to the bottom of the shield. In addition to the intermittent opens just explained, these wires may shift sufficiently to touch each other, or the shield and form intermittent shorts.

IRON CORE COILS AND TRANSFORMERS

Intermittent troubles which develop in iron core coils and transformers are similar to those explained for r-f and i-f coils. However, the windings are usually made up of insulated layers of closely wound enamel wire which, for audio and ourput transformers, is of small size. Also, the iron core which passes through the coil is at ground potential.

Looking at Figures 1 and 2 of this Lesson you will find the primary of the output transformer is connected to the output of the high voltage filter in series with the plates of the output tubes. Thus, this winding will not only carry the plate current but must be insulated for the high plate voltage because it is supported by the grounded core. Because of this condition, there are more possibilities of shorts than in the r-f and i-f coils.

You will not find much trouble in modern transformers, due to the improved methods of construction but shorts, opens and grounds are possible, either singly or in combinations which are often confusing. Usually, the coils and core are mounted inside a closed metal shield and the entire assembly is filled with an impregnating compound which makes repairs rather impractical.

Older models of audio transformers and chokes sometimes caused intermittent or noisy operation because of corrosion in the windings or internal connections. A temporary, or sometimes permanent repair could be made by connecting the winding momentarily across a fairly high d-c voltage source to allow excessive current. This condition caused the corroded points to weld together or burn completely apart to provide a sort of "Kill or Cure" treatment.

Some modern audio transformers and chokes bring the internal connections out of the compound to lugs on the bottom or sides of the outer shield. For these types, it is a good plan to make a close check of the connection between the internal wire and the lug, resoldering if necessary.

Although the wires of the windings are somewhat larger, a similar plan is used on many power transformers, the ends of the coil wires being wrapped around and soldered to lugs which also carry the external circuit wires. Sometimes, when soldering the circuit wire to the lug, the joint between it and the coil wire is weakened and develops trouble later on.

When a continuity test on this type of power transformer indicates a complete or intermittent open, always resolder each lug making sure of every wire attached to it. Them make

another continuity test before deciding the trouble is internal and requires a replacement.

You may find several circuit wires wrapped around one transformer lug and therefore the joint must be heated thoroughly to make sure the solder runs in and tins all of the wires equally. Unless this is done, the inner wires may not be soldered properly, if at all, although the external appearance of the joint is perfect.

HIGH RESISTANCE JOINTS

Looking at the power transformer of Figure 2, you will see nine external connections to the Receiver circuits, each indicated by a single line. However, you will find one end of the heater secondary and the center tap of the high voltage plate winding connect to ground together with one end of filter condenser C73C and one terminal of each of the three dial lamps, P1, P2, and P3.

In the actual construction of the unit, these grounded terminals of the transformer may form a convenient point for making additional grounds and thus several wires may be supported by them. Sometimes, the enamel insulation on the ends of the coil wires is not completely removed so that, although completely covered with solder, there is a "High Resistance Joint" as far as electrical conductivity is concerned. The value of this resistance may vary, due to the expansion and contraction caused by changes of temperature, and thus become the cause of intermittent trouble.

For troublesone joints of this kind, you may find it necessary to remove all of the wires, carefully and completely tin each one separately and then solder all of them after they have been twisted around the lug.

Similar conditions can occur in any soldered joint and, in most cases, a momentary touch with a hot, well tinned soldering iron will "rerun" the solder and restore the connection to its proper electrical condition. This is another reason why, when making continuity tests, at least one connecting wire of the unit should be removed from the circuit. Also, it explains some cases where, after a unit has been removed from the circuit, tested and replaced, the trouble disappears although the tests did not indicate any defect.

In this connection, all continuity tests should be made first, with the test prods directly on the connecting wires and second, with the test prods on the lug or terminal so that the joint is a part of the test circuit. If the unit is moved around slightly, as this second test is made, many high resistance joints can be located.

Similar troubles are caused by what are known as "Cold Soldered Joints". These are joints made in a hurry, made with parts not properly cleaned or made with an iron that is not hot enough. Externally, the joint looks perfect but the solder, although holding the parts mechanically, has not run in and tinned them sufficiently to form the necessary low electrical resistance.

LINE VOLTAGE VARIATIONS

Another cause of intermittent reception, and one that is commonly overlooked, is the variation of Line Voltage. While most Power Companies make every effort to maintain a uniform voltage, local conditions may cause sufficient change to cause troublesome variations of Radio Reception.

These changes may be gradual, sudden or intermittent, depending on their cause. In some localities, the heavy power load of the large number of lights used during the early evening hours may cause a gradual reduction of line voltage. If this is sufficient to affect the Radio Receiver, usually it causes a correspondingly gradual decrease of volume.

Sudden changes of line voltage are caused by the operation of some electrical devices connected to the circuit. For example, the common types of Electric Refrigerators momentarily draw a heavy current when the motor is turned on. Ordinarily this will cause a click in the Radio Receiver and may also cause a visible dimming of the house lights. However, this action seldom causes complaints because it does not happen too frequently and the cause is obvious.

However, if a similar motor is installed on the lighting circuit, either in the Receiver owner's home or some neighboring building, and is started and stopped more frequently, it may cause complaints. There may be a nearby store with motor driven cash registers, coffee grinders and so on or a neighbor may have motor driven tools in his basement workshop.

The starting and stopping of these motors frequently cause complaints of noisy reception but, under certain conditions may cause intermittent reception.

The main difficulty in locating intermittent troubles is to have the receiver and test instruments available when the defect occurs. As suggested earlier in this Lesson, the receiver can be turned on and left in operation while other work is being done, until the defect appears.. Sometimes this will not happen for hours, or even days, making it difficult to promise a definite time for the completion of the repair.

Again, the defect may appear only to disappear the instant the test meter prods are touched on exposed points of the circuit. In this connection, it is well to remember that a voltmeter is essentially a resistance and, with its test prods placed on two points of a circuit, it can act as a substitute resistance between those points.

For example, the common type of Radio voltmeter has a sensitivity of 1000 ohms per volt with 500,000 ohms as the total resistance of the 500 volt range. Connected across an open 500,000 ohm resistance, the voltmeter circuit will restore normal circuit conditions and thus may provide normal operating conditions.

As long as the voltage across the test meter prods does not exceed the meter range, a multiscale voltmeter can be used as a handy resistor for test replacements.

No matter what the complaint, or method of testing, after a defective part has been located, it must be repaired or replaced. Although this part of Radio Service is mechanical, rather than electrical, it is important and therefore the next Lesson will contain explanations on the removal and replacement of component parts and their connecting wires.

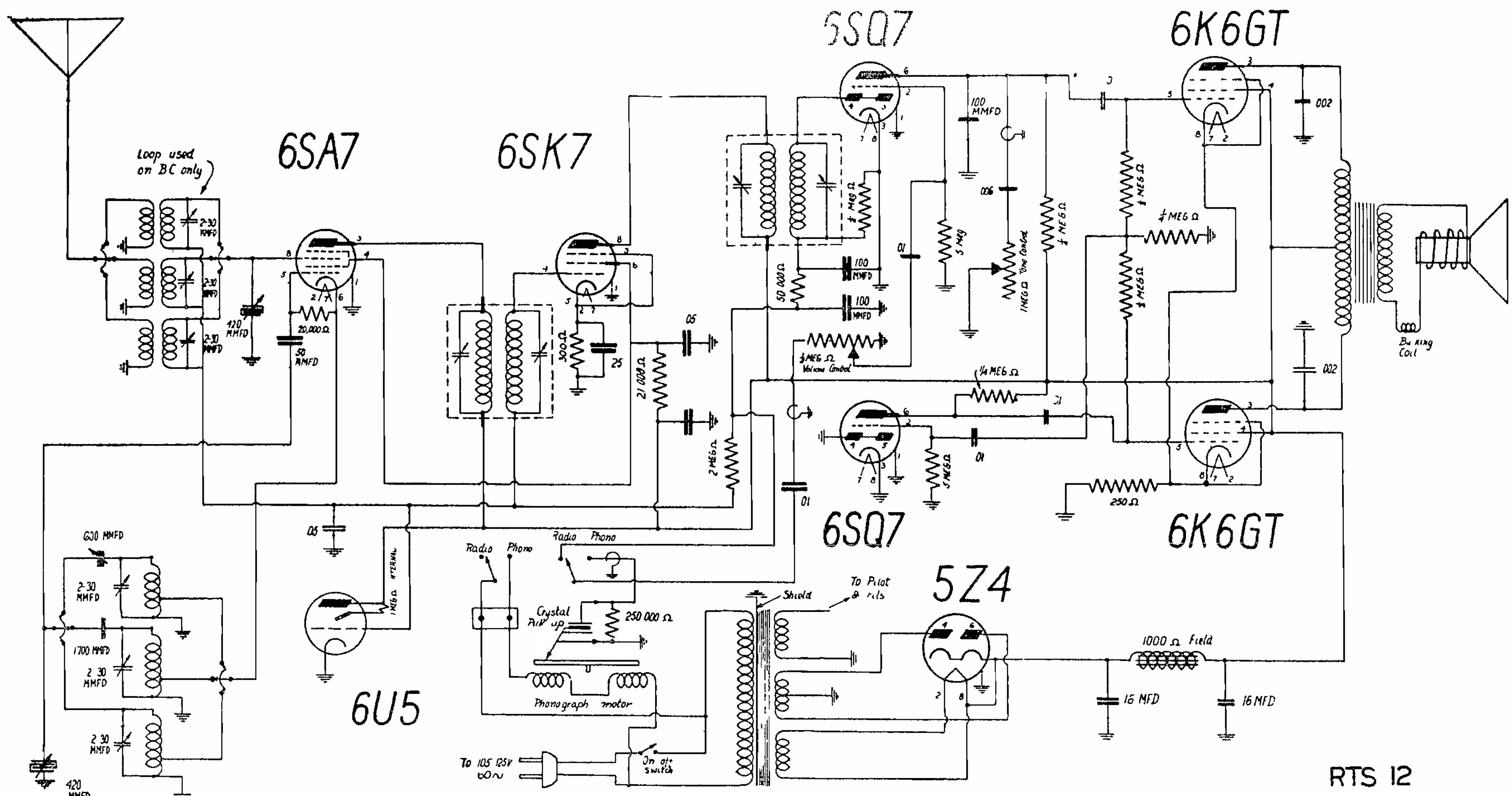
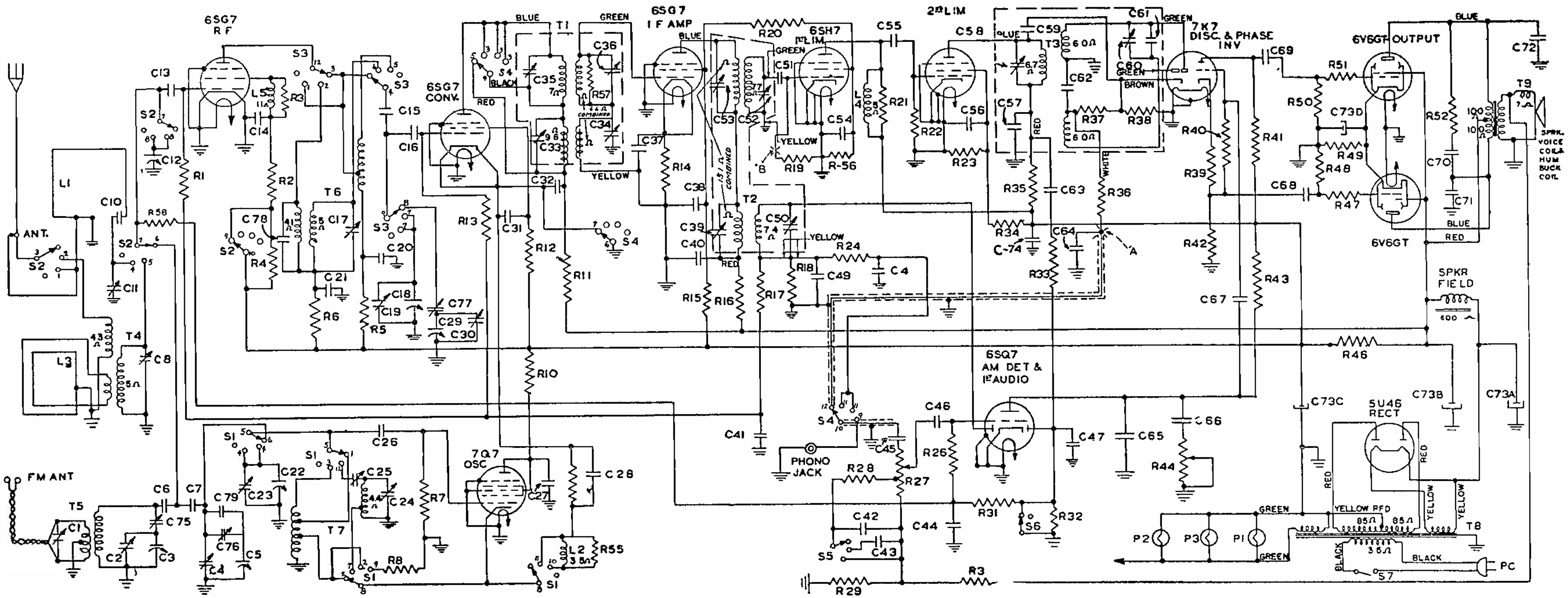


FIGURE 1

RTS 12

GENERAL ELECTRIC



RTS 12

FIGURE 2

QUESTIONS

How many advance Lessons have you now on hand?

Print of use Rubber Stamp:

Name ______________________________ Student No. __________

Street ____

City ____________________ State ______________________

1. How can the operation of a Receiver be used to make a check on Fading signals?

2. What simple plan can be followed to test for loose connections which test correctly as far as continuity is concerned?

3. How does the action of a tuning eye tube localize the cause of a drop in volume?

4. How can an ohmmeter be used to test a resistor for intermittent trouble?

5. In r-f and i-f coils, where do intermittent opens frequently occur?

6. What condition may cause intermittent shorts especially in shielded i-f transformers?

7. What should be done when a continuity test indicates a complete or intermittent open in a power transformer with lug type terminals?

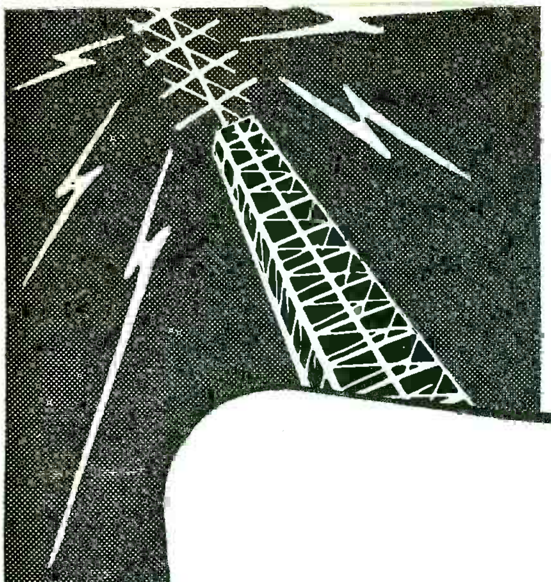
8. What two checks should be made for all continuity tests?

QUESTIONS (Continued)

Name_______________________________ Student No. __________

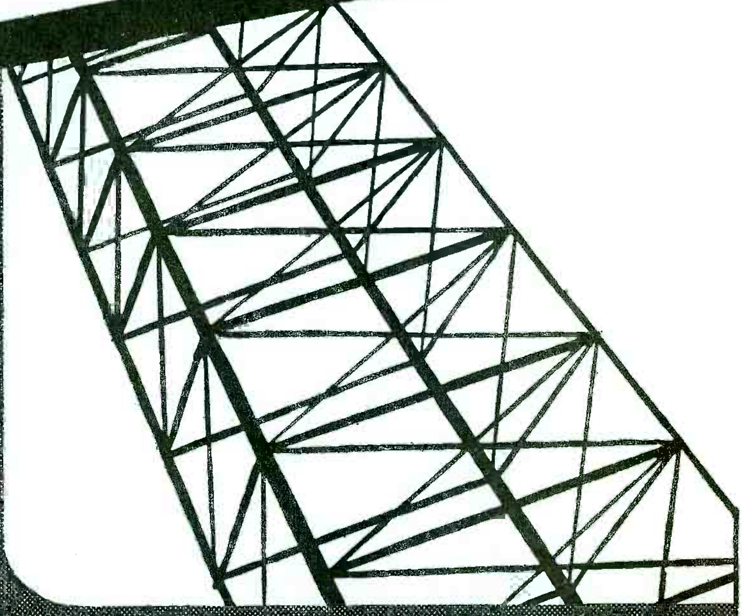
9. In addition to its normal use, what handy test replacement does a multiscale voltmeter provide?

10. What two complaints are caused frequently by motors operating on home lighting circuits?



LESSON RTS - 13

REPLACEMENT OF PARTS



DE FOREST'S RADIO ELECTRONICS TRAINING, INC.

DE FOREST'S TRAINING, INC.

2533 N. Ashland Ave., Chicago 14, Illinois

RADIO AND TELEVISION SERVICING

LESSON 13

REPLACEMENT OF PARTS

Identification ---------------------------- Page 2
Specifications ---------------------------- Page 3
Methods of Mounting ----------------------- Page 5
Removal ----------------------------------- Page 7
Identification of Connecting Wires -------- Page 8
Diagnosis of Failure ---------------------- Page 9
Need of New Specifications ---------------- Page 10
Installation Methods ---------------------- Page 12
Rewiring Procedure ------------------------ Page 13
Check of Interrelated Components ---------- Page 14
Circuit Tests ----------------------------- Page 15
Operating Tests --------------------------- Page 15

# # # #

If you succeed in life, you must do it in spite of the efforts of others to pull you down. People are willing to help a man who can't help himself, but as soon as a man is able to help himself, and does it, they join in making his life as uncomfortable as possible.

-- E. W. Howe

REPLACEMENT OF PARTS

In the former Lessons of this series, we have given a great many details in respect to the various methods and applications of electrical tests. By comparing the symptoms of the general types of customer complaints with the functions of the circuits and their components, we have tried to bring out the principles of diagnosis.

As far as radio equipment is concerned, it is generally agreed that the important and difficult part of service work is in the location of the defect. However, after this has been done, the defective part must be repaired or replaced and, while this part of the job is mainly mechanical, electrical conditions must be carefully preserved to provide the desired operation.

For this Lesson therefore, we want to explain some of the proven methods which will complete the mechanical operations of a complete service job in the shortest time possible to provide for satisfactory future operation. From time to time, many "Short Cut", "Slap Stick" ideas have been presented for emergency repairs and, while some of them have merit, it is a good idea to analyze them carefully. Any Radio Service Man who has, or is establishing, a reputation for good work cannot afford to turn out even one makeshift job. If a customer refuses to accept your estimate for a good job, don't try to meet him on his own terms and do a "cheap" job. In case of a disagreement, follow the suggestion of an earlier Lesson and give him two estimates on the repair. One, to place the Receiver in operation only and another to service it properly, a job you can stand back of.

Even when this is done, many customers still assume the proper operation of the Receiver is the responsibility of the last service man who worked on it and, if dissatisfied, will go out of their way to tell your other customers, as well as prospective customers, what they think about you.

You cannot completely please everyone, no matter how hard you try but, by refusing to do slip-shod or makeshift work, you can keep dissatisfied customers at a minimum. As far as your reputation is concerned, complaints of high prices are not detrimental but, complaints of poor work are.

You will receive requests to "Just patch it up any way so I can hear the fight tonight", or "Just keep it working until after the football game tomorrow". Many of these requests are made in all sincerity but, after the fight is over and the game is won or lost, should the receiver go bad, the customer begins to wonder if you could not have done a better job, no matter what you charged him.

Then, especially if the outcome of the program was disappointing, his recollection of the transaction may be completely negative, as far as you are concerned. He may bring the receiver back and make demands that will surprise you, placing you completely on the defensive. As we have said before, the best solution for situations of this kind is to avoid them entirely therefore, regardless of the details, do not undertake these "special" jobs.

Fortunately, many of your customers will be reasonable and cooperative, have confidence in your judgment as well as your ability and cause no trouble. We mention these rather extreme cases because they are the ones which can harm your business.

A satisfied customer does not brag about your ability or boost your business at every opportunity. You gave him service, which he bought and paid for and "that's that". In answer to a direct question, he may say a good word about you but he has no more reason to boost your business than that of his barber, grocer or garage man.

In contrast, a dissatisfied customer may feel it his duty to warn his friends, acquaintances or anyone else who will listen, in regard to your lack of ability, inefficient service or exhorbitant prices. Each time he tells the story he may add a few imaginary details until finally, what began as a minor disagreement is built up into an all important issue.

It is often said that "Bad News Travels Fast" and because this seems to be the natural tendency of human nature, it may take a hundred satisfied customers to offset the effect of one that is dissatisfied. That is why we have emphasized conditions of this kind because, although but few in number, dissatisfied customers can do much to harm your reputation.

IDENTIFICATION

While making a general inspection, continuity test or voltage analysis of a defective receiver, the defective part, component or circuit usually provides some indication of its condition. This may be a visible indication, which locates the position of the part, or an electrical indication which identifies the circuit in which it is connected. In either case, both the physical or mechanical location of the part, as well as its electrical position, should be determined accurately before any repairs or replacements are begun.

This may seem like an unnecessary precaution, especially in those cases where the defective part can be located by inspection but, as we will explain a little later, it often saves time to obtain full information before starting a job

You may see a broken or burnt resistor, with its color coding still readable and your first inclination is to replace it immediately before making any tests. However, in order to remove the defective part, in most cases, it is necessary to remove other connecting wires also and, for a simple job like this, few men will take the time to label or tag these other wires.

Then, before you find the proper replacement, the phone may ring and another customer may come in so that thirty minutes or more slip by before you get back to the job. By that time, you will find yourself wondering just which wire went to which terminal and, not knowing their circuit locations, the simple job becomes complicated.

Of course, you can cut and try because, with but a few wires there are not a great many combinations possible but, if you happen to misplace two wires in your first try, changing them one by one will not be of much help.

Working on general averages, you will save time by checking the circuit first and making a pencil sketch of the parts if there are more than three connecting wires. Then, regardless of the number or duration of interruptions, you can pick up the work at any stage of the job and go ahead with little chance of error.

Even if you feel a sketch is not necessary, it is well to identify the defective part electrically. Think of it as, "The plate resistor of the 1st a-f", "The screen bypass of the second i-f", "The cathode resistor of the output" or in similar terms which make its electrical location definite. You will find this a much easier and better method than one which depends entirely on mechanical location.

For example, to identify a resistor by location you may have to remember, "It is the third one to the left of the second socket to the right when the chassis is upside down and the power transformer is at the lower left as I face the bench".

SPECIFICATIONS

Knowing the circuit location of a defective part gives you a definite idea of its purpose and an approximate idea of its required values. For resistors, there are two important specifications, the ohms and the watts. For condensers, there are two important specifications, the capacity and the voltage.

For iron core chokes, the specified values of inductance, current and resistance are important while for power transformers the values of voltage and current of each winding should be known.

For audio transformers, the turn ratio is usually considered of greatest importance although the primary winding should provide sufficient inductance to load the plate circuit of the tube properly. For output transformers the turn or impedance ratio and the power capacity, in watts, are the essential specifications.

For i-f transformers, the principle specification is the resonant frequency of the circuits but there are variations for those units installed in the input, interstage and output positions in the i-f amplifier.

For the r-f, Mixer and Oscillator coils of the signal tuning circuits, the values of inductance are most important. However, most of these coils are sold commercially to cover a certain band when tuned by a variable condenser of some stated capacity.

As far as the actual units are concerned, resistors are usually color coded to show their ohmic value but are seldom marked in respect to their "Wattage". However, with a little experience you can estimate the wattage of the common types of carbon resistors by noticing their size. While dimensions vary somewhat, the average 1 Watt resistor is a little over one inch in length with a diameter of about $\frac{1}{4}$ inch. The half watt size is from $\frac{5}{8}$ inch to 1 inch in length with a diameter from $\frac{3}{16}$" to $\frac{1}{4}$".

You will find a number of $\frac{1}{3}$ watt and $\frac{1}{4}$ watt carbon resistors in use with dimensions proportionately smaller than those given above. Some 2 watt carbon resistors are installed but, for higher values of wattage, it is customary to employ wire wound types.

Most condensers are marked with their capacity value, either by color coded dots or by printed numbers. The paper and electrolytic types also are marked with a value of test or peak voltage as well as a lower value of "Working Volts". For safety, the value of the "working volts" should be about twice the normal circuit voltage and, because the difference in cost is small, many service men install 600 volt condensers for all paper type replacements. For most bypass and filter circuits, both the capacity and voltage rating of a replacement condenser can be higher than the values of the original unit but should not be lower.

Exceptions to the statement above are found in the signal circuits where an increase of capacity could cause a change in frequency response. For example, a plate bypass condenser has the same circuit location as many common tone controls and an increase of its capacity would cause a reduction of high frequency signals.

METHODS OF MOUNTING

From a mechanical standpoint, the assembly of a Radio chassis and its component parts is quite simple. The sheet metal chassis, or "can", is used as a base and most of the larger parts, partly or completely shielded, are mounted on top with connections made from below through holes in the base.

To illustrate this arrangement, for Figure 1 we show a cut away section of a chassis with a "Half shell" type of Power Transformer in place. The core is on top, covered by a shield or shell while the lower half of the coil, with the connecting lugs, projects below through an opening or "cut-out". Mounting bolts extend from the top shield down through the laminations of the core, through holes in the chassis and are held in place by nuts on the lower end. The larger types have four mounting bolts, one in each corner, while smaller types may have but two bolts, one in the center of opposite sides.

A similar method for mounting the fully shielded types of Power Transformers, Audio Transformers and Iron Core chokes is shown in Figure 2. Here, the core as well as the complete coils are above the chassis while the sides of the shield are flanged out at the bottom to provide a space for the mounting bolts. As the core is clamped securely by the shield, many commercial Receivers mount units of this type with rivets instead of the small bolts shown in Figure 2. Holes are provided in the chassis, below the shield, to permit connections to be made to the windings of the unit.

An unshielded or open type of iron core unit is shown in Figure 3. The core is held by a metal strap, the ends of which are bent out to form brackets and provide what is known as a "strap type" mounting. Here again, the actual mounting may be made with bolts or rivets as explained for Figure 2. The connecting wires are brought out from the top or bottom of the coil and therefore, units of this type are mounted below as well as on top of the chassis.

For unshielded R.F. and I.F. coils, the same general plan of mounting is used by means of a small metal bracket attached to the coil form. As shown in Figure 4, a simple bracket may be bolted or riveted to the chassis. You will find variations in regard to the method of attaching the bracket to the coil form and the chassis but a visual inspection will reveal all the details.

A somewhat different arrangement is employed for shielded types of R.F. and I.F. coils which have the general appearance of Figure 5. Here, the coil is mounted mechanically inside the shield which, in turn, is mounted on the chassis. Spade lugs are riveted to the lower edge of the shield with their lower

threaded ends extending through holes in the chassis. A nut and lock washer on the threads complete the mounting.

A somewhat similar arrangement is used for electrolytic condensers as well as shielded r-f, i-f transformers and r-f chokes. As shown in Figure 6, the lugs are riveted to the lower end of the shield or cover while their lower end extends through a narrow slot in the chassis. The lower end of the lug is given a slight twist to make a firm fastening. In some cases, the lower, twisted end of the lug is soldered to the chassis to provide a low resistance electrical connection.

As shown in Figure 7, other types of electrolytic condensers are mounted by means of a large nut on a threaded sleeve of insulation. The metal can of the condenser acts as one of the terminals while the other is brought out to a lug mounted on the end of the threaded sleeve.

In many circuits, the condenser can is grounded directly to the chassis while, in others, the assembly of Figure 7 is mounted on a fibre or bakelite washer which, although mounted on the chassis, provides electrical insulation between the chassis and condenser can.

There are two common methods of mounting tube sockets. As shown in Figure 8, wafer type sockets are mounted below the chassis, with bolts or rivets, directly below an opening large enough to permit the pins on the tube base to be inserted in the socket from the top.

The chassis type of socket, shown in Figure 9, is placed through a hole in the chassis and held in position by a spring washer which fits in a groove in that part of the socket below the chassis.

In some cases, where the tube is to be shielded, you will find a metal flange mounted on the upper side of the chassis around the wafer socket of Figure 8. After the tube is in place, the shield is slipped down over it and pressed firmly on the metal flange.

Small units, such as trimmer and padder condensers, are often installed by the "Single Hole" plan of Figure 10. A threaded sleeve, mounted rigidly on the body of the unit, extends up through a hole in the chassis and a nut, screwed down on the threads, holds the part in place. A variable shaft, mounted inside the sleeve, permits adjustments to be made without disturbing the mounting.

Checking back over the illustrations of the Lesson, the units of Figures 1, 7, 8 and 9 carry lugs which are strong enough to support the connecting wires of their circuits. For the other

units shown, flexible wire leads are provided for connection to the proper points of the circuits. As most of these wires must be supported mechanically and insulated electrically, the mounting strips of Figure 11 are in common use.

These mountings, sometimes called "airplanes", consist of a strip of bakelite or fibre on which a number of solder lugs are riveted. As shown, one or two of these lugs extend below the strip to provide a means of mechanical mounting.

You will find these strips made up in a variety of combinations with two or more lugs and one or more mounts. The upper ends of the lugs provide convenient points of connection for insulated, as well as grounded circuit wires because the short lugs are insulated while those which extend to the chassis are grounded. All of them are mechanically secure and, in an actual installation, each may carry a number of wires.

As shown in Figure 12, practically all variable resistance controls, as well as rotary switches, are installed by the single hole plan of Figure 10. Other units, such as the "Jack" of Figure 14, follow the same general plan and are held in position by means of nuts which fit the threaded sleeve.

To accommodate a variety of installations, the threaded sleeves are sometimes longer than needed but, with two nuts, installed on the plan of Figure 12, the position of the sleeve can be adjusted in respect to the panel or chassis wall.

Smaller units, such as resistors and bypass condensers, are provided with wire leads which are soldered to the lugs of the sockets, mounting strips or other units. This is known as "Point to Point" assembly because the leads of the units are connected directly to the proper electrical points of their circuits.

REMOVAL

In the explanations of the earlier Lessons, we mentioned some of the troubles caused by loose mounting of parts and shields and naturally, when a defect of this kind is found, it should be corrected. However, when a defective part has been located, it must be removed for repair or replacement.

Looking at Figures 1, 2, 3, 4, 5, 8 and 11, you can see that a screwdriver and small socket wrench are the only tools needed to remove the mounting bolts. For Figures 7, 10, 12 and 14, the removal of one nut will disconnect the parts mechanically while, for the arrangement of Figure 6, the lower part of the lug can be straightened with a pair of pliers and unsoldered if necessary.

When the parts are riveted to the chassis, the safest plan of removal is to "drill" them out. This is done by using a metal type of twist drill, with a diameter slightly smaller than that of the body of the rivet, held in the chuck of a Hand or Breast Drill.

For hollow rivets, the drill will follow the opening and, to prevent the rivet from turning, the drill should be operated at a fairly high speed but with light pressure. For solid rivets, it may be necessary to center punch the center of the head in order to keep the drill in proper position. The idea is to drill out the rivet without injury to the mounting hole in the unit or the chassis.

Other types of mounting are usually modifications of those illustrated and a visual inspection of their arrangement will be sufficient to indicate a method of removal.

IDENTIFICATION OF CONNECTING WIRES

In most cases, you will find it a better plan to remove or disconnect all the circuit wires before dismounting a part mechanically. If this is not done, the part will be "hanging" by the wires and, if the chassis is turned up or over, the weight of the unit will shift and may break some of the connections.

To insure their rapid and correct replacement, all the connecting wires should be identified before they are removed from a defective unit. Some men trust their memory because many of the wires have color coded insulation or the circuit arrangement may be quite obvious. However, as mentioned earlier in this Lesson, the work may be interrupted and make it difficult to remember all the details when the job is resumed.

Other men tag each wire, as it is removed, using their colors or positions as a method of identification. This method is not extremely popular because, to a customer, it appears to indicate a lack of familiarity with the circuits.

Repeating our former suggestion, whenever a replacement job involves three or more wires, make a circuit diagram which includes all of the connections. With a diagram of this kind available, you can go back to an unfinished job after a delay of a week or a month and pick up where you left off.

When complete schematic diagrams are available, you can refer to them in case of doubt but often a partial circuit diagram, with the parts arranged according to their actual location will save time in the identification of connecting wires.

For the actual connections, most of them are made by hooking the end of the wire through a hole in a lug and covering both the hook and the end of the lug with solder. To open a joint of this kind, a hot soldering iron is held on the solder until it melts sufficiently to expose the wire hook and then, with a small screw driver or long nose pliers, the hook is opened by bending the end of the wire.

When all parts are thoroughly tinned, it may be necessary to keep the soldering iron in contact with the joint but, after the hook has been opened, and the solder is hot enough to be soft, the wire can be pulled through the lug.

With several wires mounted on one lug, each can be removed on the same plan. Any excess solder can be removed from the wire ends, or the lug, by heating with an iron. Should solder run to the inner end of the lug, the chassis can be turned so that when heated, the solder will run out or off.

It may seem faster to cut off the connecting wires of a defective unit but, quite often, the cut ends interfere with the replacement wires and must be removed before proper connections can be made. It will also speed the replacement of the wires if all excess solder is removed when the wires are taken off. With open holes in the lugs, the wires can be replaced quickly and properly.

Regardless of the actual number of wires which may be removed, always make certain of some means for identifying each one. For a simple job, such as the replacement of a plate supply filter input condenser, don't assume its negative connects to the chassis, make sure before you remove it. Unless you are certain the replacement of the new unit will be completed without interruption, make some sort of a record which will insure its proper installation.

DIAGNOSIS OF FAILURE

In the earlier Lessons of this series we explained the general method of making a diagnosis to determine the nature of a defect and to help locate its source. After this has been done and the defective part has been removed, the diagnosis should be continued to determine, if possible, the cause of the trouble.

For example, when you remove a defective resistor which has been overheated, the replacement of a duplicate unit will restore that part of the circuit to its original condition. However, to insure the life of the new part, the operating conditions of the complete circuit as well as the condition of the other components, should be checked carefully.

Thinking of the dropping resistor in a screen grid circuit, a leaky by-pass condenser could cause an increase of current, sufficient to overheat the resistor but not enough to seriously affect the operation of the receiver. Unless the circuit is checked and the leaky condenser is replaced, the new resistor will develop trouble in a short time.

Again, when testing the tubes or a Receiver for complaints of Low Volume or No Signals, if all but the rectifier tube test "O.K.," always check the condensers of the high voltage filter because, a defect in them could allow excessive rectifier current and shorten the life of the tube.

The defect of a part is usually the cause of the symptoms of the customer's complaint but it, in turn, may be caused by a defect in some other unit. That is why a diagnosis should be continued until the original cuase of the trouble has been determined.

NEED OF NEW SPECIFICATIONS

A complete diagnosis of this kind may indicate circuit conditions which overload the original parts and thus, to insure a permanent repair, new specifications may be needed for replacements. For example, the full load current of a 1 watt, 50,000 resistor is approximately 4.5 milliamperes. This value is calculated by using the equation which states that watts and equal to the current squared times the resistance. As a formula,

$$W = I^2R \quad \text{or} \quad I = \sqrt{\frac{W}{R}} \quad \text{or} \quad R = \frac{W}{I^2}$$

For the example above, the second form of the formula was used and, substituting the given values,

$$I = \sqrt{\frac{W}{R}} = \sqrt{\frac{1}{50,000}} = \sqrt{.00002} = .00447$$

$$I = .00447 \text{ Amp.} = 4.47 \text{ Milliamperes.}$$

For a 1/2 Watt, 50,000 Ohm resistor,

$$I = \sqrt{\frac{W}{R}} = \sqrt{\frac{.5}{50,000}} = \sqrt{.00001} = .00316$$

$$I = .00316 \text{ Amp.} = 3.16 \text{ Milliamperes.}$$

Thus, if you found a burnt out, 1/2 watt, 50,000 ohm resistor in a circuit with a normal current of 4 M.A., for a permanent repair it would be advisable to replace it with a 1 watt unit of the same resistance value.

Along similar lines, you will find some a-c/d-c receivers equipped with filter input condensers rated at 150 volts. For a-c, the peak values are 1.41 times the effective or stated values and thus a supply line rated at 117 volts has a peak of approximately 165 volts. Allowing for a drop across the rectifier tube, the filter input condenser will operate at almost its rated voltage value. A surge of line voltage or drop of load current could cause a voltage above the rated value.

When a condenser of this type causes trouble, for a permanent repair it is a good plan to replace it with a unit of equal capacity but higher voltage rating. For the line voltage of this example, a rating of 200 volts or 250 volts would be an improvement.

The same conditions hold for bypass and coupling condensers and it is a good conservative policy to install replacement condensers of a higher voltage rating. As mentioned before, some servicemen use only 600 Volt paper condensers for replacement in circuits normally operating at 250 volts or less.

The point to remember here is that the capacity of a condenser is most important, as far as the electrical operation of a circuit is concerned. The voltage rating indicates only the strength of the insulation between the condenser plates and it must be able to withstand the operating voltage without breakdown. Condensers of equal capacity are made with various voltage ratings and while they are alike electrically, those with higher voltage ratings provide greater safety in service.

A .1 mfd, 200 Volt paper condenser can be replaced by any .1 mfd condenser with a voltage rating of 200 Volts or more. Therefore a .1 mfd, 400 Volt or .1 mfd, 600 Volt could be used as a replacement and the higher voltage rating would provide an additional factor of safety against breakdown.

In contrast, a .1 mfd, 400 Volt condenser should not be replaced by a .1 mfd, 200 Volt although the capacities are equal. The defect of the 400 Volt type would indicate the need for a higher voltage rating rather than a lower one.

When cost is a factor, some manufacturers install minimum values of capacity and, as explained in the former Lessons, an increase of capacity will remedy certain troubles due to insufficient bypass or filtering. However, as a general rule, it is well to replace defective condensers with new ones of equal capacity.

Larger components, such as Power Transformers, Filter chokes, Output and Audio Transformers can be considered as having the correct specifications but, in case of trouble, the defective

part should be checked to make sure it is an original component and not a replacement. A careful inspection of the chassis and its wiring will usually reveal the components which have been replaced because they will differ slightly in make or model from other similar components. Also, the arrangement and type of hook-up wire will indicate which parts have been serviced previously.

A voltage analysis of the circuits will reveal the operating conditions and these can be checked against the recommended specifications for the various tubes. With this information, the required specifications of the various components can be compared with those of the installed parts so that any needed changes can be made.

In most Engineering work, definite allowances made for unexpected or unforeseen overloads are known as the "Factor of Safety". This same principle is important in Radio Service work especially when repairs are guaranteed for some definite period of time. As a good conservative plan, make it a rule to install replacement parts of the next higher rating.

For example, when a resistor must dissipate a 1/2 watt load, install a 1 watt unit. When a condenser is connected across a 200 volt circuit, install a replacement with a 400 volt rating. The increased cost of these components with higher ratings is usually very small when compared to the cost of replacing any one of them.

INSTALLATION METHODS

When installing replacement parts, always complete the mechanical mounting first because that will provide a solid and permanent support for the electrical connections. Of course, there are a few exceptions where the mechanical arrangement does not provide space to make electrical connections after the part has been mounted mechanically but, in general, you will find it saves time to complete the mechanical work first.

For point to point wiring, the electrical connections are also the mechanical supports but the above plan still holds because all joints should be made secure mechanically before applying solder. Making joints so that the solder provides both mechanical support and electrical conductivity is a rapid method satisfactory for temporary work only.

When components like those shown in Figures 2, 3, 4 and 5 of this Lesson have been removed by drilling out the original mounting rivets, it is usually more convenient to mount the replacement part with small machine screws, held by a nut and lock washer.

Round head, 6-32 machine screws are in most common use for this work because they fit the ordinary rivet hole and, with a 1/4" x 6-32 nut require about the same space as the original rivet. These screws are available in various lengths up to 1-1/2 inches and can be fitted with #6 lock washers which are made in several types.

Some larger components are mounted with 8-32 or 10-32 machine screws and, as mentioned for the more common 6-32 size, nuts and lock washers are available. For replacement work, machine screws and nuts have the advantage of easy installation without disturbing any other parts and can be tightened with a screwdriver and pliers or socket wrench. In contrast, rivets present somewhat of a replacement problem as special tools are often required to clinch them properly. Even when the tools are available, a complete chassis seldom has sufficient space for their proper positioning and the required hammering may disturb other components.

When the replacement part is not an exact duplicate of the original, other problems may arise. For example, all of the windings of the Power Transformer of Figure 1 are brought out to terminal lugs which are used to support the circuit wires. The replacement unit may have flexible wire leads, instead of lugs, thus eliminating the mechanical supports for the connections between the transformer windings and the circuits.

As it is poor practice to simply splice the wires and allow the joints to hang loosely, some men install mounting strips like those shown in Figure 11. Strips of this kind, mounted along each side of the replacement transformer, can restore the original arrangement and thus simplify the work.

The original circuit wires can be mounted on the lugs of the strip, together with the proper lead wires of the transformer, thus maintaining both the electrical and mechanical arrangement of the original parts. To simplify future service work, by yourself or someone else, always make replacements to retain the original circuit arrangement as closely as possible.

REWIRING PROCEDURE

After a replacement part has been properly mounted, the wiring is replaced in the reverse order to which it was removed. Here again it pays to be careful and the wires should be replaced, one by one, only after their electrical location has been checked against a diagram or other means of identification. Then, after the mechanical mounting has been completed, it is good insurance to make a continuity test of the wire to make sure the removal and replacement has not caused it to break.

Precautions of this kind may seem to cause a needless delay in the work but, there is nothing more aggravating than to find a completed replacement job which will not work because one of the connecting wires has broken. Usually, this broken wire is the most difficult to replace and makes it necessary to remove other wires also. A simple continuity test of each wire, as it is replaced, insures the proper operation of the completed job.

However, to make sure of the replacement part, as well as the connections, the continuity tests should be extended to include a complete part of each circuit. For example, when a new output transformer is installed, all of the circuit between the output of the supply filter and the plate of the tube should be included in the test. Thus, not only the connecting wires but the circuit of the unit will be checked.

In most cases, the original circuit or "hook-up" wires can be used for replacements but, wires with brittle or damaged insulation should be replaced. This is also a good time to inspect all of the wiring and replace any which has defective insulation.

While it is used quite often, the ordinary electricians tape does not work out well for Radio repairs. It is bulky and the increased temperatures of operation cause it to dry out rapidly. When it is necessary to make a joint which requires insulation, slip a short length of insulated tubing, "spaghett", over one of the wire ends and then, after the work is done, slide the tubing back over the wire joint.

Careful attention to the mechanical details of a wiring job will insure the best electrical conditions. All radio receivers, especially those with speakers attached, are subject to vibration which may cause loose wires or components to shift in position. These changes of position may cause noise, introduce feed back to cause oscillation or degenerative feed back to reduce volume. Continued vibration of a connecting wire will cause it to break eventually, a condition which may provide an intermittent trouble. A little extra time, spent in doing a good mechanical job of wiring, will usually prove a good investment.

CHECK OF INTERRELATED COMPONENTS

The need of a complete diagnosis, to determine the original source of trouble, has been mentioned earlier in this Lesson therefore, after a replacement part has been installed, rewired and its circuits checked, the job is not quite complete. All other components, which could affect the voltage or current values of the replacement unit, should be given a final test.

We have mentioned the effect of leaky bypass condensers in the plate and screen grid circuits but, a shorted bias resistor or bypass condenser can cause excessive plate and screen grid current. A leaky coupling condenser can cause a reduction of grid bias and thus produce the same effect as a shorted bias resistor.

Following the routine suggested in these lessons, all of the components will be checked by continuity or voltage tests. However, when a general inspection of the chassis reveals the defective part, many men neglect the overall tests. That is why we want to emphasize the importance of making tests on all component parts, the condition of which could affect the replacement parts.

CIRCUIT TESTS

No matter how difficult a service job, or how clever your method of repair, the customer bases his opinion of your work on performance only. Unless the customer understands completely and agrees to a temporary job, the cost of the work has no appreciable effect on his complaint when a breakdown occurs. Therefore, it is a matter of good common sense to do everything possible to insure continued uninterrupted operation of every job you deliver.

For that reason, you will find it a good investment of time to make a fairly complete circuit test of every completed job. While some defects occur suddenly, others take place more gradually and can be detected before the receiver becomes inoperative. While there are exceptions, the safest plan is to consider that any defect, no matter how slight, will become more pronounced with age and eventually cause a complete breakdown.

Coupling condensers with slight leakage, filter condensers with reduced capacity and resistors with increased or decreased values are good examples of this condition. Although the customer may not agree to a replacement until he has cause for complaint, the recommendation should be made and placed on record to avoid future dissatisfaction.

OPERATING TESTS

After a repair job has been completed, the receiver should be placed in operation for a reasonable length of time. Many Manufacturers guarantee their products against defective material and workmanship for a period of 90 days on the assumption that any defects, in the original assembly, will show up in that time. Some Radio servicemen follow the same policy and, with the same general thought in mind, operate all

reparied Receivers for an hour or two before making delivery to the customer. Most hidden defects, which may be present in replaced components, will show up during this test run and can be corrected before the job leaves the shop.

Another point which has an exaggerated importance in the customer's mind, is the "feel" of the control knobs. As shown in Figure 12, practically all controls hava an extended shaft for mounting the knobs which should be secure but not rub against the panel. Therefore, make sure that every knob is tight on its shaft.

You will find a number of mounting methods in common use with several types of shafts. As shown in Figure 13A, the standard shaft is a round rod, usually $\frac{1}{4}$" in diameter. The grooved shaft of Figure 13B has the same general size and shape but is provided with a number of grooves which act as "markers" for cutting the shaft of a replacement part to the desired length.

For mounting on shafts of this type, the knobs have a $\frac{1}{4}$" hole, to fit over the shaft and a small set screw, threaded in the body of the knob, is tightened to secure the mounting. This arrangement permits the knob to be shifted, in respect to the panel, and turned to align any mark or pointer with dial scales, before the set screw is tightened.

There are other arrangements, such as the slotted shaft of Figure 13-C which permits the knobs to be mounted securely without the use of a set screw. Other types have a flat side on the shaft to hold a spring placed inside the opening of the knob.

No matter what the mechanical arrangement, make sure the knobs are tight on the shaft and turn freely without rubbing against the panel. If the original assembly included felt washers, between the knob and panel, be sure they are all replaced.

Small details of this kind, while not of great importance from an electrical or mechanical standpoint, do impress the customer and, when properly done, make him feel his receiver has been repaired carefully, not just "fixed"

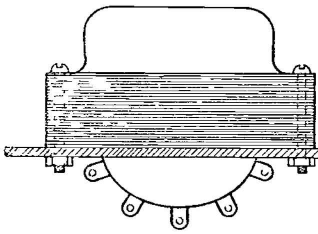


FIGURE 1

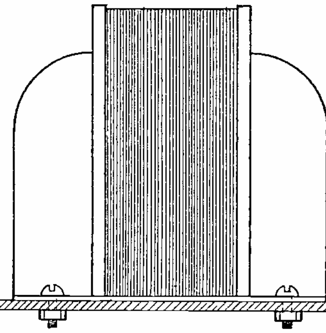


FIGURE 2

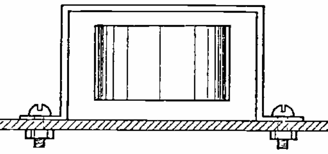


FIGURE 3

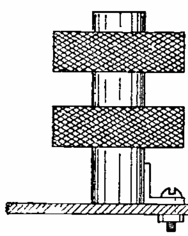


FIGURE 4

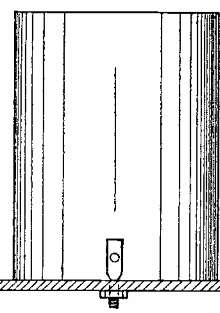


FIGURE 5

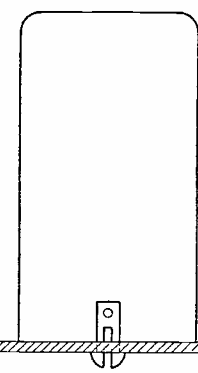


FIGURE 6

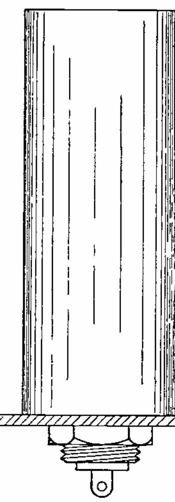


FIGURE 7

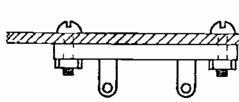


FIGURE 8

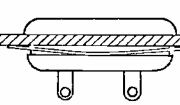


FIGURE 9

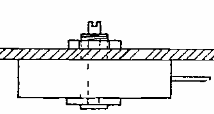


FIGURE 10

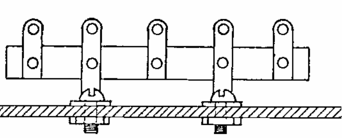


FIGURE 11

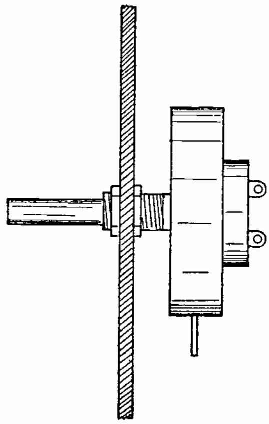


FIGURE 12

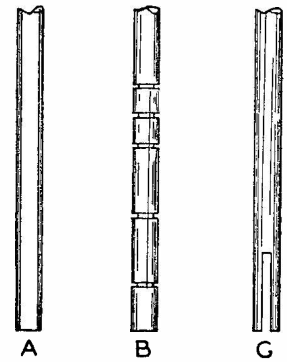


FIGURE 13

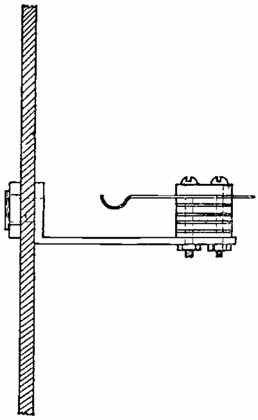


FIGURE 14

RTS 13

QUESTIONS

How many advance Lessons have you now on hand?________________

Print or use Rubber Stamp.

Name________________________________ Student No.____________

Street____

City__________________________State_________________________

1. What are two important specifications for Resistors?

2. What are two important specifications for Condensers?

3. What are three important specifications for iron core chokes?

4. What are the important specifications for Power Transformers?

5. Why should all connecting wires be identified before they are removed from a defective unit?

6. When excess solder runs to the inner end of a lug, how can it be removed?

7. Why should a diagnosis be continued until the original cause of a trouble has been determined?

8. What specifications are necessary for a unit to replace a .1 mfd, 200 volt paper condenser?

9. When installing replacement parts, should the mechanical mounting or the electrical connections be completed first?

10. Should repaired receivers be operated for an hour or two before delivery to the customer? Why?

LESSON RTS - 14

SUBSTITUTION OF PARTS

DE FOREST'S TRAINING, INC.

2533 N. Ashland Ave., Chicago 14, Illinois

RADIO AND TELEVISION SERVICING

LESSON 14

SUBSTITUTION OF PARTS

Location of Defect ---------------------------- Page 1
Diagnosis of Failure -------------------------- Page 2
Analysis of Circuit --------------------------- Page 3
Sèlection of Substitute Circuit -------------- Page 4
R.F. Coil Requirements ------------------------ Page 5
Tuning Condenser Capacities ------------------- Page 6
Resistance vs. Transformer Coupling ---------- Page 7
Dynamic Speaker Fields ------------------------ Page 8
Dynamic vs. P.M. Speakers --------------------- Page 11
Output Transformer Impedances ----------------- Page 12
Power Transformer Voltages and Wattage ------- Page 14
Mounting Methods ------------------------------ Page 16

* * * * *

In all things, success depends upon previous preparation, and without such preparation, there is sure to be failure.

— Confucius

SUBSTITUTION OF PARTS

Strictly speaking, the duties of a Radio Service man should include only the location of defects and, when necessary, the replacement of duplicate parts and components to restore the proper operation of a Radio Receiver. However, to make a success of his business, the modern service man must be able to do this work without undue delay although duplicate replacements are not available.

In effect, he must be a designer as well as a Service man, in order to adapt the circuits of any receiver to conform to the specifications of replacements which are available. For this type of work, the operation of the various circuits must be known quite completely, a fact which is frequently overlooked or ignored.

Some Service men, especially among the "Old Timers", rely almost entirely on their mechanical ability plus their experience in handling previous complaints. They are inclined to ridicule modern methods especially if some "pencil" work is required. Men of this type are quite successful on older models but usually have to give up when a repair includes some circuit which is new to them.

That is why these Lessons include detailed explanations of a variety of Receiver circuits, analyzed in respect to their electrical operation, because this knowledge makes possible a proper choice of repair methods or substitution of parts when needed. In any service work, especially Radio with its wide variation of makes and models, the more complete your knowledge of the operation of the various circuits and the purpose of the various parts, the better your ability to restore the proper conditions.

LOCATION OF DEFECT

For every service job, the first part of the work is the location of the defect which is the cause of the complaint. As explained in the earlier Lessons, this can be done by following the suggested routine of general diagnosis, continuity testing, circuit tracing or voltage analysis. When the equipment is available, Dynamic Testing can be employed.

Reviewing briefly, there are but three electrical quantities in any circuit, Resistance, Inductance and Capacity therefore, all methods of testing are designed to check one or more of them. The importance of tube testing has been emphasized in the earlier Lessons and, with the universal use of "Tube Testers", can be considered as a special or separate test of any general routine.

Continuity or Resistance tests are perhaps the most common in general work as they apply directly to all resistors and connecting wire. They are also useful when testing inductances for continuity, especially when the resistance of the coil is known. Resistance tests are also useful for checking the leakage, as well as shorts of condensers.

Because of the definite relationship between Voltage, Current and Resistance, as defined by Ohm's Law, Voltage tests are simply another method of checking conditions in a circuit. In some cases, they are preferable because the tests are made under conditions which approximate those of actual operation, but they do not include those circuits which carry signal voltages only.

Both Voltage and Continuity Tests are classed as "Static" because they are made without the presence of signal voltages. As Radio Receivers are made for the purpose of reproducing signals, they are not in operation unless the signals are present. With the power turned on, a Receiver can be in an operating condition but it is not actually in operation until signals are received.

We mention this fact to bring out the distinction between Static and Dynamic Tests. Static tests, such as Voltage Analysis, can be made with all operating voltages applied to the circuits to place them in operating condition. Dynamic Tests, based on the signal voltage, are made only when the receiver is in actual operation.

Regardless of the method, the sole purpose of all testing methods or routines is to isolate any defects to some certain stage or circuit. After this has been done, all the component parts of each indicated stage are tested separately to locate the exact point of trouble. Usually, this is the major part of any service job because, once the defect is located, the cure is comparatively simple.

DIAGNOSIS OF FAILURE

Again referring to the earlier Lessons, locating and correcting a defect does not always complete a repair. When a fuse "blows", in your home lighting circiut, it indicates trouble which ordinarily, a new fuse will not cure and a larger fuse may make worse. The usual procedure is to locate the trouble and then replace the fuse.

The same general idea holds for radio service and the defective unit, located by tests, may compare to the fuse of the home lighting circuit. Therefore, after the defect has been repaired, always analyze the conditions before turning on the power.

For example: Did the defective resistor simply break down from age or was it subject to overload due to some other defect? Did the shorted bypass condenser absorb enough moisture to weaken the dielectric or was it operating at excessive voltage? Did the resistance strip of the volume control just wear out or did some other defect permit it to carry excessive current.

All of these possibliities have been explained in the earlier Lessons and we repeat them now because of their importance. Knowing the nature and location of a defect, a rapid analysis of the circuit will indicate which other components could have caused the trouble, in case they were defective. A careful test of these components is good insurance against "come back" repairs.

In the home lighting circuit, new fuses will continue to "blow" until the cause of the overload has been located and corrected. In Radio Service, the replacement condenser, resistor or other part will break down quickly unless the cause of the trouble is located and corrected.

Every Radio or other Electronic unit is nothing but a combination of circuits, each of which is comparatively simple therefore, for your service work, keep the circuit in mind. Any defective part must be replaced but do not consider the work complete until the circuit, which contains the defective part, has been checked completely.

ANALYSIS OF CIRCUIT

Carrying the circuit idea still further, you will find it is the basis for practically all design and maintenance work. The great variety of component parts, a few of which are shown in the illustrations of this Lesson, can be considered as nothing but different physical forms of the three electrical quantities together with arrangements to complete or change the circuits.

The units of Figure 1 are representative of iron core components which include power transformers, chokes, audio transformer and output transformers. All the units of Figure 1 could be identical, in respect to their electrical specifications and their substitution, one for another, would depend on the available chassis space and mechanical arrangement. Thus, while the size and shape must be considered, the electrical specifications are of first importance.

The analysis of ordinary radio circuits is not difficult if their purpose is understood and the function of each component is kept in mind. For example, a common screen grid circuit,

connected to the output of the power supply filter, contains a dropping resistor and bypass condenser, either or both of which may be defective.

We have already explained the action by which a short in the bypass condenser would allow excessive current in the resistor and, along similar lines, a short in the resistor would allow higher voltage across the condenser. However, the complete circuit includes the tube, between screen grid and cathode as well as the path between cathode and ground or high voltage negative.

With the complete circuit in mind, it is evident that high values of screen current can be caused by conditions in the control grid and cathode circuits of the tube. The grid bias could be reduced by a leaky coupling condenser, a reduced value of bias resistance or a shorted bias bypass condenser. Thus, an analysis of the complete circuit includes the tube and other components, in addition to the resistor and condenser connected between the positive of the power supply and the tube.

A complete circuit includes all of the components connected in any path across the source of voltage. This fact has been explained before and, in the case of signal circuits, the source is the coil, resistor or condenser across which the signal voltage is produced.

Keeping each complete circuit in mind will not only be of assistance in locating defects but will permit a more complete analysis to help in the diagnosis of the failure and thus insure a more permanent repair.

SELECTION OF SUBSTITUTE CIRCUIT

A review of the typical circuits, given earlier in this series of Lessons, will show a variety of arrangements to produce like results. To name a few, there are volume controls in the antenna, cathode bias and detector circuits, tone controls in grid and plate circuits of different audio amplifier stages, cathode resistors for self bias and voltage dividers for semi-fixed bias, stages coupled by transformers and by resistance-capacity networks.

Thus, when exact replacement parts are not available, many Receivers can be placed in operation by the use of substitute circuits made up of parts which are different from those of the original circuit. Most Radio Servicemen do not hesitate to substitute a replacement part with similar electrical specifications but of different size or shape than the original, yet some are reluctant to alter the electrical arrangement of a complete circuit.

That is the important distinction between a "Repairman" and a "Service Man". The repairman depends entirely on duplicate parts to restore a circuit to its original condition while a service man employs his Radio knowledge to restore operating conditions with substitute parts or substitute circuits if necessary. During World War II, the scarcity of Radio Tubes and parts made it necessary to substitute both in order to keep some receivers in operation. Even in normal times, the percentage of obsolete and "Orphan" models is quite high so that substitution must be considered as a regular part of successful Radio Service.

Another application of this same service is in modernizing old receivers for customers who want to retain expensive console cabinets. Work of this kind should be accepted only on the basis of a complete rebuilding as the installation of newer tube types or other components is seldom satisfactory. Also, much of the actual work may not be of an electrical nature as the purpose of the job is to retain the beauty of the original console and the modernizing may require new panels, speaker grilles and so on.

When making any circuit substitution, there are several main points to keep in mind in order to prevent any loss in performance. First, the new circuit must not disturb the operation of existing circuits; Second, each stage must retain its original gain, Power output or both; Third, the selectivity and frequency response can be improved but must not be reduced and Fourth, all controls should retain their original "authority".

These specifications may not always be met completely but should be held as a standard and approached as nearly as possible. As we have said before, your customers are not technical and therefore judge your work by its results, not by the amount of effort or ingenuity necessary to complete it.

R-F COIL REQUIREMENTS

Thinking of the points mentioned above, suppose you have a job which requires a new r-f coil and no exact replacement is available. Analyzing the circuits, you find the secondary of this winding is tuned by one gang of the tuning condenser and therefore its inductance must be of proper value to match or track with the other tuned circuits.

In most parts catalogues, the inductance value of Antenna and r-f coils is seldom stated but instead, the specifications state, "Secondary covers 545 to 1580 kc with 365 mmfd tuning condenser", or whatever the particular values of frequency and capacity may be. Thus you have the information

necessary to select a substitute coil with specifications close to those of the original. As most tuning condensers have a trimmer for each gang, it is possible to compensate for a certain amount of variation in the inductance of the coil.

The primary of the coil is also important as it usually forms the load in the plate circuit of an amplifier tube. Here again, exact specifications are seldom stated but the primary windings are listed as "High" impedance or "Low" impedance. For older model Receivers, using triode tubes as r-f amplifiers, a low impedance primary might be satisfactory but for modern types of r-f pentodes, a high impedance primary is needed to obtain proper gain. This is one reason why the installation of modern high gain tubes in an old model Receiver may not provide the expected improvement.

The same general requirements apply to i-f transformers and Oscillator coils, the resonant frequencies of which must match those of the other components. In a parts catalogue, you will find i-f transformers listed as "Input", "Interstage" and "Output" to describe their locations in the circuit. The coils may be "Air Core" or "Iron Core" with single or double tuning by mica or air type trimmer condensers.

While these specifications should be matched as closely as possible, the substitute unit must resonate at the proper frequency and the standards available are 175 kc, 262 kc, 370 kc and 456 kc. The adjustment of the trimmer condensers will permit operation over a fairly wide band and thus a 456 unit can be used for receivers with an i-f of any value between 445 kc and 465 kc.

In general, all tuned coils must resonate at frequencies to match those of similar units in other parts of the complete Receiver circuit while untuned windings must provide the proper load for their circuits.

TUNING CONDENSER CAPACITIES

The variable capacities, used to tune the coils, are made in two general styles or types. First, the trimmers and padders, shown in Figure 7, are adjusted with a screwdriver and their specifications usually list the maximum and minimum capacity values.

Second, variable condensers with rotatable plates are used generally for manual tuning of signal carriers. The specifications for these units include the number of gangs, the maximum capacity of each gang and whether the capacity increases by clockwise or counter-clockwise rotation of the shaft.

For Broadcast Reception, the common capacities are about 365 mmfd or 450 mmfd maximum and, if the minimum value is not stated, it is safe to assume it to be 10% of the maximum. For smaller capacities, used in short wave Receivers, both the maximum and minimum capacity values are given for most models. However, when a substitute unit is installed, some allowance must be made for the capacity of the connecting wires and the actual minimum capacity will be greater than that given for the condenser itself.

Superheterodyne type tuning condensers with specially shaped plates in the oscillator section are seldom available as substitute replacements because the oscillator coil must be designed to "match" the condenser. When a condenser of this type require replacement, the common trf type can sometimes be used by rearranging the oscillator tuning circuit to include a padder condenser. However, it may be necessary to substitute a "standard" oscillator coil also, in order to obtain proper tracking.

Like the r-f and Antenna coils, these replacement oscillator coils are designed to cover the Broadcast Band when tuned with a variable condenser of stated maximum capacity, usually 365 mmfd, in conjunction with a padder condenser. Also, their specifications state the intermediate frequency which will be produced.

RESISTANCE VS. TRANSFORMER COUPLING

From your study of audio amplifiers, you will remember the three general forms of coupling, Transformer, Impedance and Resistance, a coupling condenser being required for the two latter types. Most of the early Radio Receiver Models employed transformer coupling but the trend has been toward the resistance-capacity method. In fact, with the exception of the output transformer, the audio amplifier stages of the typical circuits shown in this series of Lessons are all resistance-capacity coupled.

As we mentioned before, the older types of audio transformers are subject to many defects, some of which make their replacement necessary. However, when but one transformer winding is at fault, it is often possible to install a substitute circuit. Thinking of an interstage transformer, the defective winding is disconnected at both ends to remove it from the circuit and a coupling condenser, .05 mfd to .1 mfd is installed between the plate and grid of the tubes originally connected to the transformer windings. The defective winding is then replaced with a resistor, connected to complete the original plate or grid circuit, to provide a "Resistance-Impedance" coupling. The substitute resistance provides

resistance load, for the plate or grid, while the remaining transformer winding provides an impedance load.

When both windings of the transformer are defective, a complete resistance-capacity coupling circuit can be substituted. In general, the resistance coupling will provide less gain than the transformer but, in many cases, it will improve the frequency response of the amplifier. However, the substitution can be made for single tube voltage amplifier stages only because one resistor can not replace a center tapped winding and a transformer is needed for the transfer of power.

For example, the power in the plate circuit of the output stage is transferred to the speaker voice coil circuit by the output transformer which, at the same time, provides the proper impedance match. The driver stage of a Class B amplifier supplies power to the grids of the output stage and therefore a transformer is required.

When resistors are used as substitutes for defective transformer windings, their proper value will depend on the types of tubes used as well as other details of the individual circuits. However, as a general rule, a resistance of from 50,000 to 100,000 ohms will usually be satisfactory as a substitute for a transformer primary while a resistance of from 250,000 ohms to 500,000 ohms will make a similar substitution for a transformer secondary. The common type of coupling condenser has a capacity of .05 mfd and should be rated at 600 volts.

When it is desirable or economical to substitute a new transformer for one that is defective, the turns ratio is perhaps the most important specification. Most modern audio transformer windings have sufficient impedance to provide satisfactory performance and the common turns ratios are 2 to 1 and 3 to 1.

They are made as push-pull input with a single primary and center tapped secondary and as push-pull interstage with center tapped or separated windings for both primary and secondary. The substitute transformer should be designed for the same circuit arrangement as the original because, as mentioned before, the core of a push-pull type may become magnetically saturated if used with a single tube.

DYNAMIC SPEAKER FIELDS

A review of the typical circuits, shown in the earlier Lessons, will indicate the popularity of the Dynamic speaker for most models of Radio Receivers. This is due, in part, to the economy of using the speaker field as a choke in the high voltage supply filter, connected in either the positive or

negative side of the circuit. In some a-c/d-c equipment, the speaker field is connected across the rectifier tube output circuit therefore, when substitute speakers are installed, there are several points to keep in mind.

Looking in a parts catalogue, you will find speaker specifications given somewhat as follows.

> 12" Dynamic Speaker, Normal Rating 16 Watts, Peak 24 Watts, 8 ohm voice coil -- 1500 ohm, 9 Watt field.
>
> 5" Field Coil Dynamic -- Normal Rating 3 Watts, 4 ohm voice coil -- 3 Watt, 1800 ohm field tapped at 300 ohms.

Checking these values, you will find the diameter of the cone, the power the voice coil will handle, the voice coil impedance as well as the resistance and power of the field winding. Right now we are interested in the field and want to investigate the importance of the specifications -- given in terms of ohms and watts.

Going back to fundamentals, Watts equal Volts times Amperes and by transposing terms, the following equations can be derived:-

$$W = EI \quad \text{or} \quad I = \frac{W}{E} \quad \text{or} \quad E = \frac{W}{I}$$

To include resistance, we make use of Ohm's Law which states,

$$E = IR \quad \text{or} \quad I = \frac{E}{R} \quad \text{or} \quad R = \frac{E}{I}$$

Then, as things equal to the same thing are equal to each other, we can substitute the value of "E" or "I", as given by Ohm's Law, into the power equation to find,

$$W = EI \quad \text{or} \quad W = (IR)I \quad \text{or} \quad W = I^2R$$

$$W = EI \quad \text{or} \quad W = E\frac{E}{R} \quad \text{or} \quad W = \frac{E^2}{R}$$

However, as the values of watts and resistance are given, we can transpose further to find

$$W = I^2R \quad \text{or} \quad I^2 = \frac{W}{R} \quad \text{or} \quad I = \sqrt{\frac{W}{R}}$$

$$W = \frac{E^2}{R} \quad \text{or} \quad E^2 = WR \quad \text{or} \quad E = \sqrt{WR}$$

By using the last form of these two equations, we can find the values of voltage and current which are required for any stated value of watts in any given resistance.

Substituting the specifications above for the 12" speaker field,

$$I = \sqrt{\frac{W}{R}} = \sqrt{\frac{9}{1500}} = \sqrt{.006} = .077 \text{ Amp.}$$

$$E = \sqrt{WR} = \sqrt{9 \times 1500} = \sqrt{13500} = 117 \text{ Volts}$$

Thus we know that, for proper excitation, this field must carry a current of .077 amp. or 77 milliamperes which will produce a drop of 117 volts.

Following the same plan for the 5 inch speaker field,

$$I = \sqrt{\frac{W}{R}} = \sqrt{\frac{3}{1800}} = \sqrt{.00167} = .041 \text{ Amp.}$$

$$E = \sqrt{WR} = \sqrt{3 \times 1800} = \sqrt{5400} = 73 \text{ Volts}$$

Here we see that, for proper excitation, this field must carry a current of .041 ampere or 41 milliamperes which will produce a drop of 73 volts. With this information, the specifications of the speaker can be expanded to include the current and voltage values of the field.

To install a substitute speaker, the first step is to check its normal power rating against the power of the output stage of the receiver. This can be done quite easily by reference to a tube chart which lists the power output of the various types of tubes, singly and in push pull.

As home receivers are seldom operated at full volume, the peak power rating of the speaker should equal the maximum output of the tubes. For Public Address and other commercial sound systems, operated at higher volume levels, it is better that the normal power rating of the speaker equal the power output of the tubes.

A check of the power supply circuit is necessary to locate the electrical position of the field to determine the amount of current it will carry and the effect of the voltage drop across it. Remember here, while excess current may overheat and damage the field winding, insufficient current will not cause proper excitation and both the quality and volume of the signals may suffer.

To emphasize these variations, suppose the 1500 ohm, 9 watt field of the 12" speaker was used to replace the 1800 ohm,

3 watt field of the 5" speaker. This might be done on the idea that the larger speaker would provide better tone and greater volume. However, the 41 milliampere field current of the smaller speaker would provide but 2.52 watts of excitation, instead of the specified 9 watts, and thus the reproduction of signals would be poor.

Some variations of field current can be made by circuit alteration such as tapping the output plate circuit off the rectifier, ahead of the field, to reduce the current or installing a bleeder circuit, across the filter output to increase the current. However, before making changes of this kind, be sure that decreased current will not allow high plate voltages and that the power transformer has sufficient capacity to supply additional current.

When analyzing a receiver circuit of an earlier Lesson, we explained the production of grid bias voltages by the use of a voltage divider across a speaker field connected in the negative return of the high voltage circuit. In the specifications of the 5" speaker of this Lesson, the 1800 ohm field was tapped at 300 ohms making it possible to obtain a grid bias voltage without installing resistors to form a voltage divider. With a normal drop of 73 volts across the entire field, there will be a 12 volt drop across the 300 ohm section, a voltage value suitable for the negative grid bias for severaltypes of output tubes.

For a-c/d-c receivers there are two general types of dynamic speaker fields, both of which require about 3 watts excitation. Connected as a series filter choke, the fields have a resistance of about 400 ohms but, when connected across the rectifier tube output circuit, the fields require a resistance of 2500 ohms to 3000 ohms.

DYNAMIC VS. P.M. SPEAKERS

As a general definition, any speaker, activated by means of current in a coil suspended in the air gap of a magnet, is "Dynamic". In practice, a distinction is made according to the source of the magnetic energy and when an electromagnet is used, the result is a "Dynamic" speaker. With the same general construction, but using a permanent magnet, the result is a p-m speaker.

With recent improvements in permanent magnet materials, p-m speakers are the equal of Dynamic speakers, as far as the reproduction of signals is concerned, without the need of an external source of d-c voltage to supply the field. This is an advantage for nulti speaker installations as the p-m speakers require but a two wire circuit for their voice coil, a circuit which need carry signal voltages only.

For single speaker units, such as the common types of Radio Receivers in which the speaker is mounted on or close to the chassis, the dynamic or field coil type of speaker is still popular. As we mentioned earlier in this Lesson, the speaker field serves as the choke of the power supply filter, a unit which is necessary, regardless of the type of speaker.

Therefore, in order to substitute a P-M for a Dynamic speaker, in most cases the speaker field must be replaced by a choke with similar resistance and reactance. When the speaker field connects across the high voltage circuit, it can be replaced with a resistor of equal value. In either case, the substitute unit must have a power rating equal to that of the field.

As shown in Figure 10-A, both Dynamic and P-M speakers are similar in appearance and often are classed generally as "Moving Coil" speakers. This is because both types use the same cone and voice coil assembly of Figure 10-B.

OUTPUT TRANSFORMER IMPEDANCES

The output transformer is an important component of the complete speaker circuit and, as their voice coils are alike, the requirements are the same for both P-M and Dynamic types of speakers. The two important functions of the output transformer are first, to couple the voice coil and plate circuits of the output tubes and second, to match the impedances of the voice coil and plate load of the output tubes.

Reviewing the explanations of an earlier Lesson, the impedance ratio of a transformer is equal to the square of its turns ratio and, as the voltage ratios of the windings are approximately equal to the turns ratios, voltage tests can be made to determine turns-ratios. As the details of these tests have been given, we will not repeat at this time.

Universal output transformers are available for substitution work in sizes from 2 watt "Midgets" up through 5 watt, 10 watt and 12 watt to 20 watt. The power specification is of first importance because, the primary winding must carry the plate current of the output stage including the variations caused by the signals.

Electrically, the universal output transformer usually includes a center tapped primary and secondary with several taps to provide a variety of turns ratios. The catalogue specifications may read somewhat as follows:-

Universal Output Transformer
Primary -- 2000, 4000, 7000, 8000, 10,000, 14,000 and 18,000 ohms.
Secondary -- .11 to 54.5 ohms.
Strap Mounting -- 5 watt.

The wide variation of both primary and secondary values may be confusing but, for impedance matching, the actual impedance of the transformer windings themselves are disregarded. The turns ratio of the windings is the factor which determines the reflected impedance, the values of which are given in the specifications.

For example, if we assume an output transformer with a turns ratio of 20 to 1, the impedance ratio will be 20 squared or 400 to 1. Connected to a 4 ohm voice coil, the reflected impednace of the primary will be 400 times 4 or 1600 ohms. However, with the same transformer connected to an 8 ohm voice coil, the reflected impedance of the primary will be 400 times 8 or 3200 ohms.

Thus, by tapping the secondary winding so that different numbers of turns can be included in the circuit, it is possible to obtain a variety of turns ratios which, in effect, vary the primary impedance although the number of its turns is not changed.

For another example, we can assume an output transformer which has a secondary winding of 100 turns with taps at the points shown in the following table.

TERMINAL	TURNS	DIFFERENCE
1	0	0
2	46	46
3	68	22
4	77	9
5	83	6
6	100	17

The first column identifies the terminals by number, the second column shows the number of turns between each terminal and No. 1 while the third column lists the number of turns between adjacent terminals. As the voice coil can be connected across any two terminals, in addition to the complete winding, quite a number of combinations are possible as shown in the following table.

TERMINALS	TURNS	TERMINALS	TURNS
4 - 5	6	3 - 6	32
3 - 4	9	2 - 5	37
3 - 5	15	1 - 2	46
5 - 6	17	2 - 6	54
2 - 3	22	1 - 3	68
4 - 6	23	1 - 4	77
2 - 4	31	1 - 5	83

To complete this example we will assume a 2000 turn primary with a center tap and thus, for the entire secondary, the turns ratio is 2000/100 or 20 to 1 for the full primary and 1000/100 or 10 to 1 for either half of the primary. In terms of impedance, these ratios become 400 to 1 and 100 to 1.

In contrast, by making connections to secondary terminals 3 and 5, there are but 15 active turns and the turns ratios become 2000/15 or 133 to 1 and 1000/15 or 67 to 1. In terms of impedance, these ratios become 17,689 to 1 and 4489 to 1.

For substitute units, the exact ratios are not always available for every combination of output tube and voice coil but variations up to 10% will seldom cause any appreciable difference in the reproduced signal. However, when a change is necessary, always select the next higher value of reflected impedance as the increase of distortion is more pronounced at reduced values of plate load.

The "strap Mounting" item of the specifications refers to the tyoe of transformer shown in Figures 1-D and 1-E. Thinking of circuits, the type of mounting is often important as the substitute output transformer may have to be mounted on the speaker, instead of the chassis, or vice versa.

POWER TRANSFORMER VOLTAGES AND WATTAGE

The replacement of Power Transformers is a quite common part of Radio Service and here again, when exact replacements are not available, there are several important points to check in the selection of a substitute. Usually the largest single component of a Radio chassis, the physical size and shape of a substitute power transformer is important. The units shown at "A", "B" and "C" of Figure 1 illustrate the common types of power transformers and, while those shown at A and C project part way through an opening or cut out, the one shown at B mounts on top of the chassis with openings for the connecting wires.

To substitute a tyoe "B" unit for either the "A" or "C" of Figure 1 can usually be done with a minimum of mechanical work as the original cut out provides amole space for the connecting wires. However, depending on the dimensions, new holes may have to be drilled for the mounting bolts.

In contrast, to substitute either tyoe A or C for type B of Figure 1, the chassis will have to be cut out to accommodate the lower part of the winding. Here again, new holes may have to be drilled for the mounting bolts. A careful comparison of the original and substitute units will usually indicate the solution of any mounting problems.

Electrically, the catalogue specifications of a Power Transformer read somewhat as follows:

Plate - 675 volts, C.T. - 50 ma
Fil. 1 - 5 volts - 2 amps.
Fil. 2 - 6.3 volts - 2 amps.
110-120 volt - 50-60 cycle operation

Checking here, the center tapped plate secondary develops a total of 675 volts or 337-1/2 volts for each half, with wire large enough to carry a current of 50 milliamperes. Connected in the supply for a full wave rectifier, this winding will provide about 350 volts d-c at the rectifier output, and with a 100 volt drop across the filter will supply 250 volts to the plate and screen grid circuits.

With this information and a list of the tubes in the Receiver, a tube chart will permit the plate and screen circuits to be added to find the required current. The circuit should be checked for bleeder currents as they must be added to those of the tubes to find the total. This total should not exceed the current rating of the plate secondary and, if it does, a substitute with a higher plate current rating should be selected.

A similar check should be made of the filament circuits in respect to their required voltage and current. In the specifications given above, the secondary "Fil. 1" is evidently designed for the rectifier tube filament only and will handle the common types.

Referring again to a tube chart, the specifications for the heater of any particular tube can be found and while the voltage rating of the winding should equal that of the heater, the winding must be able to supply an equal or greater amount of current. With specifications of 5 volts, 2 amps., this winding is too small for a 5U4G rectifier with heater specifications of 5 volts, 3 amps.

The heaters of all but the rectifier tube of the common a-c type of Receivers, are connected in parallel and therefore operate at equal voltage, the value of which should be the same as the rated voltage of the transformer secondary. In the specifications given above, secondary winding "Fil. 2" is rated at 6.3 volts, 2 amps.

As the common 6.3 volt tube heaters operate at .3 amp. this secondary will supply six of them with an allowance for an output tube with a heater which requires a higher current.

In general, a check of a Receiver circuit, together with the tubes which are used, makes it possible to total the tube

chart values and determine the required amount of current for the low and high voltage circuits. The transformer specifications should equal or exceed these requirements for trouble free operation. When a transformer is overloaded, its output voltages are reduced and it will overheat. The reduced voltages may impair the sensitivity of the receiver while the overheating will reduce, not only the life of the transformer, but other components located close to it.

The specifications we have been explaining are for a small type of Power Transformer suitable for the common 6 or 7 tube Receiver. Many other substitute units are available with a variety of voltage and current values and with three, four or more secondaries. However, the power requirements of the Receiver must be checked carefully before a suitable substitute unit can be selected.

Although listed as Power Transformers, the specifications of these units seldom include any values of watts but, if needed, they can be calculated from the given values of voltage and current. Referring to the specifications of this explanation, the high voltage output was estimated as 350 volts at 50 ma which is equal to 350 x .05 or 17.5 watts. Fil. 1 at 5 volts, 2 amp. rates at 5 x 2 or 10 watts while Fil. 2, at 6.3 volts, 2 amps. rates at 6.3 x 2 or 12.6 watts. Adding these three values, the total is 40.1 watts.

When fully loaded, the power transformer of an average Radio Receiver operates at about 80% Power Factor which, together with the losses in the transformer, may cause the product of the primary volts and amperes to be as much as 1-1/2 times the calculated wattage. Keep this fact in mind when checking supply line power with a voltmeter and ammeter.

Some testing methods use the power in the supply line as a check on the condition of the Receiver circuits because the power in the transformer primary will vary with the secondary load. That is why a short across a secondary will blow a fuse in series with the primary.

MOUNTING METHODS

In the former Lesson on the Replacement of Parts, we described the common forms of mounting but, when substitute parts must be installed the method of mounting may be changed.

As explained earlier in this Lesson, if the transformer of Figure 1-B is replaced by a unit like Figure 1-C, it may be necessary to cut an opening in the chassis to accommodate the lower part of the winding, as well as drill new holes for the mounting bolts. For strap type units, like those of "D" and

"E", Figure 1, the size of the substitute unit may differ from that of the original. However, it is usually possible to use one of the original mounting holes and drill but one additional hole to line up with the substitute part.

The R.F. and I.F. coils of Figure 2 are equipped with two spade lugs and require two mounting holes like the strap mounted type of Figure 1. The opening provided for the connecting wires of the original unit will, in most cases, accommodate the wires of the substitute unit but, if the substitute shield is of different size, one mounting hole must be drilled to accommodate the different spacing of its spade lugs.

Figure 3-A shows the common wafer type of socket in comparison to the chassis type of Figure 3-C. For general substitution, the socket of Figure 3-B is convenient because it is made up of a chassis type mounted on a metal flange with mounting holes spaced the same as those of wafer type sockets.

As shown in Figure 3, this type can be used to replace the wafer type sockets at A but, with the flange removed, it will replace the chassis type shown at C.

The "Standard" size of wafer sockets have mounting holes spaced with 1-27/32" centers while the more common "Midget" size has 1½" mounting centers. Some sockets, of the type shown in Figure 3-B, have slotted openings to replace either of the above sizes. These are made in 4, 5, 6, 7 large, 7 small, octal and loctal types to accommodate the bases of standard tubes. The later types of smaller tubes require miniature and bantam type sockets made especially for them.

Practically all controls, such as the switches of Figure 4 and Potentiometers of Figure 5 are designed for single hole mounting and, in addition to their electrical specifications, substitute units must be checked for size to make sure the chassis contains sufficient mounting space.

The resistors of Figures 6-A and 6-B are supported usually by their connecting wires and thus a substitution can be made as a replacement. However, when conditions indicate the need for a resistor of higher wattage, the type shown in Figure 6-C may have to be substituted.

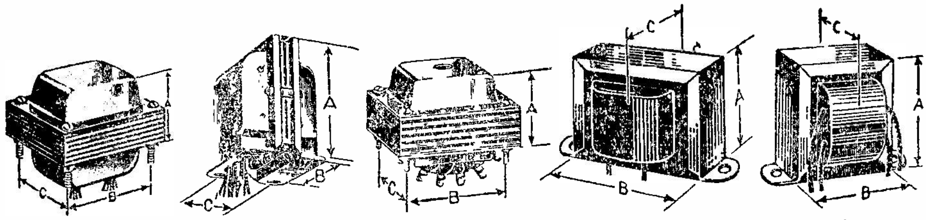
Because of their greater weight, this type of resistor require mechanical mounting and, as shown, many of them are supplied complete with brackets. The actual mounting of these brackets is the same as explained for Figures 1-D and 1-E but, as these larger resistors dissipate an appreciable amount of heat, they should be located where the heat will not damage other components.

The trimmer condensers of Figure 7-A and the small fixed, mica type condensers of Figure 8 are mounted on the same general plan as the resistors of Figures 6-A and 6-B. For types like Figures 8-A and 8-B, short lengths of hook up wire can be soldered to the terminal lugs to simplify substitution for the type shown at Figure 8-C.

Electrolytic condensers are made in the three general forms shown in Figures 9-A, 9-B and 9-C. The type shown at "A" mounts through a hole in the chassis which makes substitute parts, like B and C rather difficult to mount. However, there is usually enough space, somewhere in the chassis, to mount the brackets of type B, or suspend type C by its connecting wires.

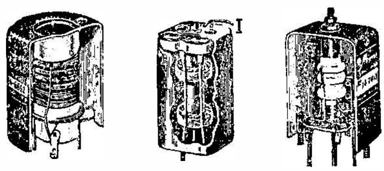
The condenser shown in Figure 9-D is often called a "Bathtub" type, because of its metal case. Extensions of this case are shaped to form mounting lugs which, when bolted to the chassis, provide solid support. Substitute parts of different size can be mounted by following the plan explained for the units of Figures 1-D and 1-E.

When substituting any component parts, both the mechanical and electrical specifications must be acceptable. As far as the mechanical specifications are concerned, the substitute component must be of a size and shape that will fit the available space. Electrically, the substitute part must have specifications which will permit all circuits to operate at, or very close to, their original values.



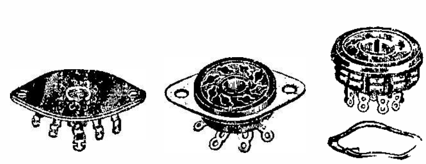
A B C D E

FIGURE 1



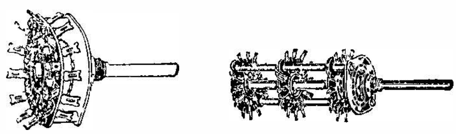
A B C

FIGURE 2



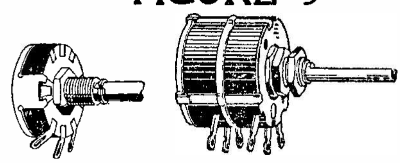
A B C

FIGURE 3



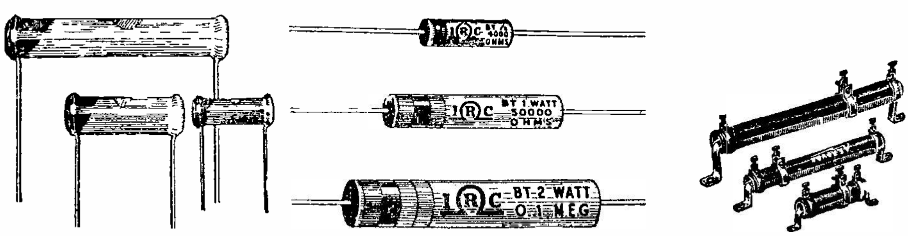
A B

FIGURE 4



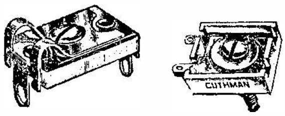
A B

FIGURE 5



A B C

FIGURE 6

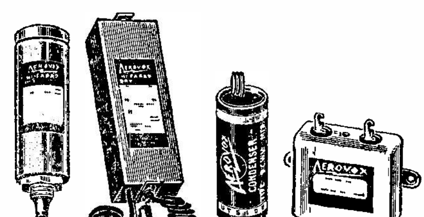


A B

FIGURE 7

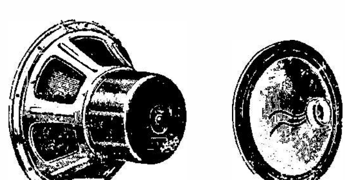
A B C

FIGURE 8



A B C D

FIGURE 9



A B

FIGURE 10

QUESTIONS

How many advance Lessons have you now on hand? ______________

Print or use Rubber Stamp:

Name ______________________________ Student No. ______________

Address ____

City __________________ State __________________________

1. What is the sole purpose of all testing methods or routines?

2. When a defective part is located and replaced, why should its complete circuit be checked?

3. In general, what components does a complete circuit include?

4. What are two important specifications of r-f coils?

5. What value of current is required to excite properly a 2500 ohm, 3 watt dynamic speaker field coil?

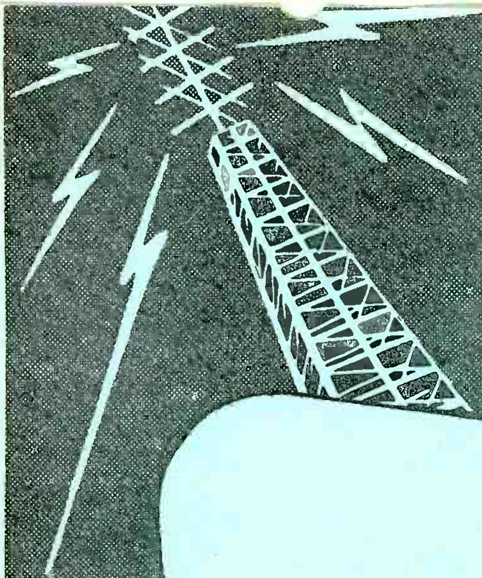
6. When properly excited, what is the voltage drop across a 10 watt, 1000 ohm dynamic speaker field?

7. In most cases, what must be done in order to substitute a p-m speaker for a field coil type of dynamic speaker?

8. What are the two important functions of an output transformer?

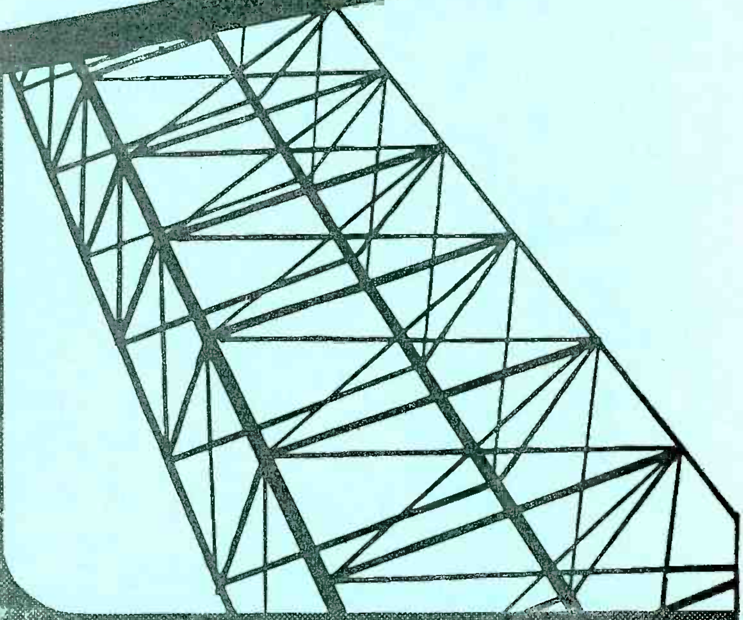
9. What turns ratio is necessary in an output transformer to match an 8 ohm voice coil to a 9800 ohm plate load?

10. When substituting a power transformer, how can the voltage and current requirements of a receiver be determined?



LESSON RTS - 15

ALIGNMENT OUTPUT METER



DE FOREST'S RADIO ELECTRONICS TRAINING, INC.

DE FOREST'S TRAINING, INC.

2533 N. Ashland Ave., Chicago 14, Illinois

RADIO AND TELEVISION SERVICING

LESSON RTS-15

ALIGNMENT - OUTPUT METER

Output Meter Connections ---------------- Page 1
TRF Receivers ------------------------ - Page 2
Alignment -------------------------------- Page 3
Adjusting Slotted Rotor Plates ----------- Page 5
Neutrodyne Receivers -------------------- Page 6
Superheterodyne Receivers --------------- Page 7
Oscillator Circuits --------------------- Page 8
I-F Alignment --------------------------- Page 9
R-F and Oscillator Adjustments ----------- Page 10
Calibration ----------------------------- Page 12
Wave Traps ------------------------------ Page 12
Image Frequency ------------------------- Page 13
Superhet Alignment ---------------------- Page 14

# # # # #

READINESS

BE READY. The way to be ready is to be at work. Opportunity comes to the worker, not to the idler who is waiting for opportunity to come.

ALIGNMENT

Following the routine of the preceding Lessons, which include Inspection, Diagnosis, Testing and Replacement or Substitution of Parts, every defect in the components of a Radio Receiver should be located and corrected. However, the performance of the Receiver may be far from satisfactory until all of the tuned circuits have been adjusted to resonate at the proper frequency.

As tuning adjustments are provided, this important part of Radio Service is considered as a separate subject known commonly as "Phasing" or "Alignment". In the earlier explanations on the causes for "Lack of Volume" and "Broad Tuning", the need of correct tuning was emphasized and now, to fulfill the promise made at that time, the details of this work will be explained in this Lesson.

In a Radio Receiver, the purpose of all tuned circuits is to provide maximum or minimum response at some definite frequency or over a band of frequencies. As far as the desired signals are concerned, the tuned circuits are arranged to provide the maximum response. Thus, the tuning can be checked with any type of indicator which will register the relative response of the circuit and, when used for this purpose, the indicator is known as an "Output Meter".

Because all ordinary Radio Signals are a-c, any a-c Voltmeter can be used as an output meter, provided it has sufficient sensitivity and is connected properly. When no a-c meter is available, some men connect a d-c meter in the detector circuit because the average value of the rectified current will vary with the strength of carrier frequency.

OUTPUT METER CONNECTIONS

As the a-c Voltmeter type of Output Meter is in most common use, for Figure 1 we show the usual methods of connection to the output stage of a Receiver. At position "A", the meter is connected across the voice coil and output transformer secondary to indicate the voltage across this circuit. Due to the comparatively low impedance of the voice coil, the voltage across it is also comparatively low.

For example, a 4 ohm voice coil, with 5 or 6 volts across it would carry from 6 to 9 watts of signal, a fairly high value for the ordinary home type of Receiver. Therefore, for use in this position, the voltmeter requires a fairly low scale. Similar measurements can be made by connecting the voltmeter across the output transformer primary as shown at Figure 1-B

for a push-pull stage and at Figure 1-C for a single tube. Because of the d-c present in this circuit, blocking condensers must be connected in series with the meter, not only to protect it from the high d-c plate voltage but to insure readings proportional to a-c signal voltages only. In many commercial types of multimeters, these condensers are placed in the circuit when the selector is in the "output" position.

Compared to the secondary, the voltage across the output transformer primary is quite high and therefore, a meter, connected in position "B" or "C" of Figure 1, must operate on a higher scale. Here, if we assume a reflected impedance of 5000 ohms for the primary, there will be about 200 volts across it for the 9 watt signal explained for the secondary.

For routine work, the meter reading need not be calibrated accurately in volts as most adjustments are made to obtain maximum deflection of the meter hand. In position "A" of Figure 1, the meter reads the voltage across the voice coil circuit but, as many a-c voltmeters are calibrated at 60 cycles and the common types of Signal Generators provide an audio signal of 400 cycles, the reading may not be accurate. In positions "B" and "C" of Figure 1, the blocking condensers are in series with the meter and, due to their reactance, the reading may not be accurate.

Connected across the output transformer primary or secondary, the a-c voltmeter becomes an output indicator to show when adjustments produce maximum response or output. For this work, the actual output voltage is of secondary importance but, for greatest sensitivity, the lowest possible output meter scale should be used.

For example, the 200 volts mentioned above could vary 5 or 10 volts with a comparatively small variation of meter hand deflection. However, by reducing the test signal input to produce an output of .1 watt, there would be but 22 or 23 volts across the primary and, using the 25 volt scale of the output meter, any slight variation of output would cause a more noticeable change of meter hand deflection.

TRF RECEIVERS

As explained in the Lesson on Broad Tuning, to align a trf receiver, it is necessary to "Balance" the gang condenser., For Figure 2, we show a typical gang condenser, made up of three variable condensers mounted on a single shaft with metal shield plates between them. Because of the mechanical construction, it is known as a "Three Gang Condenser".

To be properly matched, all sections of this condenser must have equal maximum capacity, equal minimum capacity and equal

capacity for any other position of the rotor plates. No matter how carefully the parts are made and assembled, there will be slight differences and the connecting wires usually add unequal amounts of capacity. To take care of these differences, and match or "Balance" the sections, small "Trimmer Condensers" are employed.

As shown in Figure 2, each section of the gang condenser has a trimmer made of two small metal plates, one of which is fastened to the main stator plates, and the other to the rotor. A piece of insulating material separates the plates and an ordinary machine screw is used to adjust the distance between them.

All condenser plates are made as nearly alike as possible and, when assembled, the rotors are all lined up and fastened to the main shaft. While the maximum capacity of the various sections is usually almost equal, the minimum capacity varies and the trimmers are used to bring the minimum capacity of all the sections to the same value.

Looking at Figure 2 again, you will notice the outside rotor plates of each section are slotted. By bending the segments, formed by the slots, the total capacity of each section can be changed for different rotor positions.

ALIGNMENT

When the sections of a gang condenser are out of alignment, the receiver will tune broadly, or tune one station at two or more points on the dial. To properly align the the gang, it is necessary to employ a signal generator, or test oscillator, and an output meter.

To show you how this is accomplished, we will assume that we have a trf Receiver in which the condenser gang, like that of Figure 2, is out of alignment. First, we closely inspect the gang, watching to see that all the rotors are tightly fastened to the shaft and all in about the same position. In some of the older types, when one rotor does not turn with the others, it can be lined up by eye and its set screw tightened.

With the rotors turning in the same relative positions, the test oscillator is connected across the antenna and ground terminals of the receiver and the output meter is properly connected across the output stage in one of the positions shown in Figure 1.

To secure proper alignment of the antenna stage however, and simulate the conditions of normal operation with an antenna,

the signal generator is connected to the antenna post through what is known as a "Dummy Load" or "Dummy Antenna".

While there are various recommended values for this dummy load, perhaps the simplest is to use a series condenser of .00025 mfd for frequencies from 600 kc to 1800 kc and, for frequencies above 1800 kc to connect a 400 ohm resistor in series with the condenser mentioned above.

With the signal generator and output meter properly connected, the generator is set at a frequency of about 1400 kc and the receiver volume control turned on all the way. Next, the condenser gang is tuned to the frequency of the generator, a condition which will be indicated by maximum deflection of the pointer of the output meter. Should the pointer go off scale, the output of the generator should be decreased. Do not turn down the volume control of the receiver.

As mentioned in the explanation of output meter connections, maximum sensitivity of output readings is obtained at minimum signal levels. Therefore, as a general rule, with the Receiver Volume all the way on, the signal generator output should be held at the lowest possible value which will produce a readable deflection of the output meter hand.

With the receiver tuned to the frequency of the signal generator, the trimmers are then adjusted for maximum meter reading.

In this connection, we want to remind you that the trimmer condenser adjusting screws should never be turned down tight. In this position, the full capacity of the trimmer is added to the variable condenser and may prevent the receiver from tuning to the higher frequencies.

As a general rule, the trimmer should be adjusted for the lowest possible capacity. If the gang is badly out of balance, it is a good plan to turn the adjusting screws all the way down and then back them off one full turn before starting to make adjustments. Then the receiver is carefully tuned to the generator frequency and the trimmers adjusted, one by one, for maximum reading of the output meter.

When this adjustment is made properly, the trimmers will be "peaked" which means the output meter reading will decrease when the adjusting screw is moved in <u>either</u> direction.

In modern receivers, the tuning dial is marked in Kilocycles, or Megacycles for the high frequency bands, and frequently, the indication on the dial does not coincide with the frequency of signal generator, when the receiver circuits are tuned for maximum output meter reading.

When the variation is small, it is customary to turn the receiver dial until it reads the frequency at which the signal generator is set and then adjust the trimmers for maximum output. When the variation is great, it is usually more practical to first tune the receiver circuit to resonance, as explained above and then, without changing the position of the tuning condenser, mechanically adjust the dial until the reading is correct.

ADJUSTING SLOTTED ROTOR PLATES

After all the trimmers have been properly adjusted, the signal generator is set at about 1000 kc and the receiver is tuned for maximum output at this frequency. With a condenser like that of Figure 2, the rotor will be in approximately the position shown and the segments of the end rotor plates, which are partly in mesh with the stator plates, can be bent in or out for maximum output meter reading.

For this type of condenser, you will have to read the output meter, bend the sections in or out slightly with a screwdriver and then read the meter again after the screwdriver is removed. If the second reading is higher, bend the segments a little further in the same direction and take another reading.

After the segments are bent, always retune the receiver for maximum output before starting to adjust the next section. All sections are adjusted in the same way and the segments of each section should be bent in or out about the same amount as each adjustment is made.

After these adjustments have been completed, the signal generator is set at about 800 kc and again, the receiver is tuned for maximum output reading. This will bring the next segment of the slotted end plates partly in mesh with the stator and adjustments are made as explained for 1000 kc.

For the final adjustment, the signal generator is set at about 600 kc and the receiver is tuned again for maximum output. This will bring the last segment of the slotted end plates in position and the adjustments are made as explained for 1000 kc.

By this plan, the tuned circuits have been balanced at four different points of the receiver range and thus its tuning should be approximately correct at all points of the dial.

You will find many variations of this method, but the general plan remains the same for all. Some manufacturers balance at different frequencies, others use a different number of segments, some have an adjusting screw for each segment and so

on. If you have no detailed instructions, the method we have explained will, if carefully followed, give a good job on almost any trf receiver.

In order to cut down on the capacity effect of metal screw-drivers and wrenches, regular aligning tools should be used when doing any type of balancing. Even then, it is a good plan to entirely remove the tool and your hands from the chassis before reading the output meter.

NEUTRODYNE RECEIVERS

In many of the earlier models of trf Receivers, it was necessary to balance out the grid-plate capacity of the r-f amplifier tubes in order to prevent oscillation. While several types of neutralizing circuits were developed, the receivers in which they were installed were known generally as "Neutrodynes". From a service standpoint, their important feature was a trimmer type of balancing or neutralizing condenser connected so as to parallel the grid-plate capacity of the tube.

To prevent unwanted oscillation, each r-f stage of a Neutrodyne Receiver was neutralized by adjusting the neutralizing condenser until its capacity was of a value to offset exactly the effect of the grid-plate capacity of the tube. To make this adjustment, the tube had to be in place but not in operation and, to obtain this condition, it was customary to open the heater or filament circuit.

One popular method of opening the filament circuit was to slip a short length of thin wall spaghetti, or even a soda fountain straw, over one of the filament prongs of the tube before placing it in its socket. To make the adjustment, a signal generator and output meter were employed, as explained for a trf Receiver, the signal generator set at a frequency of about 1000 kc and the receiver tuned for maximum output.

The neutralizing condenser, for the stage of the open circuited tube, was then adjusted for MINIMUM output. The tube was then restored to operation and the same plan followed for each stage in turn. When all of the stages were neutralized, the gang condenser had to be balanced by the procedure explained for a trf Receiver.

The neutrodyne receiver was very popular when only triode tubes were available. Since the advent of pentodes, the popularity of this receiver had decreased considerably and today, very few are in use. However, if you are called upon to phase or align one, the above procedure should be followed.

SUPERHETERODYNE RECEIVERS

The alignment of the superheterodyne receiver, which has replaced practically all other types for Broadcast reception, entails the tuning of each I.F. stage to the intermediate frequency and the tuning of the oscillator stage to track with the Mixer and R.F. stages.

The tuning condensers, usually mounted on a single shaft, control the frequency of the R.F. and Oscillator stages but, to provide adjustment for proper tracking, these tuned circuits also contain semi-fixed or adjustable units which are known as Trimmer and Padder Condensers. Similar types of condensers are used to tune the I.F. transformers and you may find one, two or three of them in each unit, depending on its design.

For Figure 3-A, we show the circuits of a "Single Tuned" I.F. transformer with the tuned primary in the plate circuit of one tube and the secondary in the grid circuit of the following tube. You may find this single tuning condenser in either the primary or secondary circuit but its purpose is always the same, to tune its circuit to the intermediate frequency.

For Figure 3-B, we show the circuits of the more common "Double Tuned" I.F. transformer which has a condenser in both primary and secondary circuits. Remember, all I.F. circuits are tuned to, and operate at, one definite frequency and therefore, these condensers are of the adjustable, or semi-fixed type.

Mechanically, their capacity is varied by turning a threaded screw which usually has a slotted or hexagon head. Thus, some types require the use of a screwdriver while others need a socket wrench. To conserve space, other types are made so that the slotted screw, for adjusting one trimmer condenser, is placed inside a hollow hexagon head screw which adjusts the other trimmer.

We mention this arrangement because it is quite common and at first glance, appears to be only a single adjustment made up of a slotted screw with a lock nut. To align a unit of this type however, both the slotted and hexagon head screws must be handled as separate adjustments.

The circuits of Figure 3-C, represent a "Triple Tuned" I.F. transformer which has three condensers and three coils. The primary and secondary are connected as shown in Figure 3-B but are more loosely coupled. When tuned to the same frequency as the secondary, the third winding, sometimes called a "TERTIARY" winding, will absorb a certain amount of energy and thus "Flat-top" and broaden the frequency response curve of the unit.

In some receivers, you will find a variable resistance connected between the tertiary winding and ground. By changing

the value of this resistance, the action of the circuit can be controlled to provide variable selectivity. For the usual alignment procedure, all three windings are tuned to resonance at the same frequency.

OSCILLATOR CIRCUITS

In order that the i-f frequency will be present at all positions of the main tuning condenser, arrangements must be made to maintain a constant difference between the frequencics of the oscillator and the resonant frequencies of the Mixer and Radio Frequency stages.

The oscillator is usually tuned to a frequency higher than that of the r-f stages because this arrangement requires a smaller percentage of oscillator frequency change to cover the tuning range. Because of this small percentage change, it is practical to use tuning condensers with the common "maximum to minimum" capacity ratio.

Two general types of oscillator circuits are in use.

1. The oscillator and Radio Frequency sections of the main ganged tuning condenser are all alike with a combination of shunt and series condensers, in the oscillator circuits, to maintain the constant frequency difference.

The simplified circuit is shown in Figure 4 where "A" represents the oscillator gang of the main tuning condenser and "B" a small "Trimmer" condenser of the adjustable type. "C" represents the fixed series or "Padder" condenser and "D", like "B", is a trimmer.

In practice, trimmer "B" is adjusted for proper tracking at the low capacity or high frequency end of the tuning range while trimmer "D" is adjusted for the low frequency end of the tuning range.

2. The main ganged tuning condenser contains plates of a special shape for the oscillator section. Because of their special shape, these plates produce the same effect as the padder condenser and provide a lower capacity to maintain the proper frequency difference between the oscillator and r-f stages. However, to compensate for variations due to stray capacities, the oscillator section of the tuning condenser is usually equipped with a high frequency trimmer.

There are many minor variations of the circuit of Figure 4 and in some receivers, one or both of the trimmers are omitted. The purpose of the various condensers however, remains the same as explained above.

I-F ALIGNMENT

To properly align a superheterodyne receiver, it is necessary to use a signal generator and an output meter. The signal generator must have a frequency range which includes the tuning range of the receiver as well as its intermediate frequency.

With the output meter in place, it is good practice to short the antenna and ground connections of the receiver and also stop the operation of its oscillator. This can be done by connecting a .1 mfd paper condenser between the stator and rotor plates of the oscillator gang of the main tuning condenser or by connecting it from the control grid to ground. When a separate oscillator tube is employed, it may be removed from its socket.

The signal generator is then placed in operation, adjusted to produce a modulated signal at the i-f frequency and connected to the grid of the last i-f tube. Practically all commercial signal generators are equipped with a shielded cable which carries the signal frequency to the grid of the receiver tube. The signal generator output circuit is completed through the cable shield which is generally provided with a clip that attaches to the receiver chassis.

To prevent any change in the operation of the stage, the regular grid connection should be left in place and the generator output connected to it through a series condenser of .001 mfd to .01 mfd capacity.

The volume control of the receiver is turned on all the way and the output of the signal generator increased only until an indication can be seen on the output meter. In some cases, it may be necessary to increase the generator output to maximum and even then, the output meter will indicate zero.

When this happens, the signal generator frequency is adjusted slowly to values above and below the original and proper setting until there is a reading on the output meter. The generator frequency is then adjusted, 1 or 2 kc at a time, to the desired frequency. Each time the frequency is changed, the trimmers are adjusted for maximum output reading.

With the generator adjusted to the proper frequency, the trimmer condensers of the i-f transformer in the plate circuit of the tube, are then adjusted carefully for maximum deflection of the output meter hand. Should the meter reading increase to the end of the scale, the signal input should be reduced because, as previously explained, the purpose of this job is to obtain maximum deflection of the meter hand.

This point is not difficult to locate because, turning the trimmer adjusting screw in one direction will cause an increase of meter reading but, when turned too far, the reading

will decrease. The screw is then "backed up" until maximum deflection occurs again in order to "peak" the adjustment.

The actual amount of output meter hand deflection can be varied by adjusting either the volume control of the receiver or the output of the signal generator. However, as practically all modern receivers incorporate automatic volume control, the operation of which will prevent the output readings from varying exactly with the input, it is necessary to follow the former instructions and turn the receiver volume on full with the signal generator output as low as possible. In this way, the avc action is reduced sufficiently to permit more accurate output readings.

After both trimmers of the last i-f transformer have been adjusted for maximum output, the signal generator is connected to the grid of the preceding i-f tube and the above procedure is repeated.

Starting at the second detector and working back toward the mixer tube, each i-f transformer is adjusted in the same manner, the trimmers being peaked for maximum response or maximum reading of the output meter.

For the common i-f transformer, with more than one trimmer condenser, it is customary to adjust first one and then the other but, after the last adjustment is made, the former ones should be gone over to take care of any variations caused by tuning the circuits.

In much the same way, after all the i-f transformers have been aligned, the signal generator is connected to the grid of the mixer tube and all adjustments given a final check. This final adjustment of all stages will compensate for any changes in impedance of the tubes, caused by shunting the signal generator across their grid circuits.

R-F AND OSCILLATOR ADJUSTMENTS

After the i-f amplifier has been properly aligned, the r-f amplifier and oscillator must be adjusted for maximum deflection of the output meter.

The receiver oscillator is restored to operation and the tuning dial is set near the high frequency end of the Broadcast Band. The signal generator frequency is then set, usually at 1400 kc and, with its "Dummy Load", connected across the antenna and ground terminals of the receiver.

The general procedure here is the same as explained for the i-f stages and the trimmer condensers, usually mounted on the main tuning condenser, are adjusted for maximum response.

Due to errors of dial calibration, there may be no response in the output meter when the signal generator and receiver dials are tuned to the same frequency. Under these conditions, the receiver dial is adjusted slowly until a position of maximum response is found.

Then, completely disregarding the Receiver dial readings, the tuning condenser is rocked back and forth, as the trimmers are adjusted for maximum response, usually higher than that obtained by adjusting the tuning condenser only.

As the tuning condenser is moved, in either direction, the deflection of the output meter hand will increase, reach a peak and then decrease. It is these peak readings which are important therefore, the tuning condenser is rocked only far enough to pass the peak deflections. The adjustment of the trimmers will vary the peaks and the job is not complete until the maximum peak is located.

Here again, the trimmer should be "peaked" and, turning its adjusting screw in a direction to increase the peaks caused by rocking the tuning condenser, you will find they increase to a certain point and then start to decrease. When this happens, the trimmer adjusting screw is turned in the reverse direction until the maximum peak is located.

Once the trimmers are adjusted for the high frequency end of the band, they must not be disturbed to provide an improved response at any other frequency.

The next step is to align the low frequency end of the band and, for this part of the job, the signal generator is set at about 600 kc. The tuning dial is turned to approximately the same frequency reading and then moved only enough to tune the signal.

Following the plan explained for the high frequency end of the band, the tuning condenser is "rocked" across the signal as the padder condenser is adjusted for maximum response.

When the tuning condenser contains specially shaped plates in the oscillator section, this adjustment can not be made because the circuit does not contain an adjustable padder condenser.

After the low frequency end of the band has been adjusted, it is a good plan to go back and recheck the high frequency end as there may be some interaction between them.

For all wave receivers, the same general procedure is followed for each band, but the i-f, trimmer and padder adjustments

of the Broadcast Band, must not be disturbed. It is common practice to install separate r-f, mixer and oscillator coils for each band and equip each with trimmers or padders as explained for the Broadcast Band.

CALIBRATION

After the alignment has been completed, the tuning dial should be checked for accuracy and calibrated if necessary. For this work, the signal generator is set at about 1400 kc and the receiver tuned for maximum response. The reading of the tuning dial is then checked against the frequency of the signal generator, a notation being made of any variation between them. The same plan is followed for other frequency settings of the signal generator, such as 1000 kc and 600 kc, with the dial read carefully for each.

A comparison of signal generator frequencies against the corresponding dial readings will usually indicate in which direction and about how far the dial or pointer must be moved, in respect to the position of the tuning condenser, to provide accurate calibration of the dial. This adjustment is entirely mechanical and must be made in accordance with the mechanical construction of the tuning indicator.

Whenever the manufacturer's alignment procedure is available, it should be followed exactly as the stated values of test frequencies, coupling circuits and points of connection have been worked out carefully to permit a better job in a shorter time.

WAVE TRAPS

To reduce interference, due to the heterodyne action of two carrier frequencies with a difference equal to the Intermediate frequency, some receivers incorporate a wave trap between the antenna and mixer input circuit.

As shown in Figure 5-A, the trap may consist of a simple series resonant "ACCEPTOR" circuit shunted across the antenna circuit. The other arrangement, shown in Figure 5-B, is a parallel resonant, "REJECTOR" circuit connected in series with the antenna circuit. When a receiver circuit includes an r-f stage, similar circuits may be found in the mixer input circuits.

To adjust either type of wavetrap, the signal generator, adjusted to produce a modulated signal at the intermediate frequency, is connected across the antenna or input circuit. The wave trap condenser is then adjusted until the output meter has minimum deflection. Notice carefully, in our for-

mer explanations, adjustments were made for maximum deflection of the output meter but the wave trap is adjusted for minimum deflection.

IMAGE FREQUENCY

On high frequencies, or short waves, an image frequency can easily be mistaken for the true frequency and therefore, a check should be made on the received signal.

One method of making this check is to first tune the receiver to the signal generator frequency and then detune the receiver to a frequency equal to twice the i-f less than the signal frequency. If the signal is heard again, the first setting was correct.

For example, we will assume a receiver with an i-f of 456 kc, and a short wave band extending up to 18.75 mc. In most cases, better tracking is obtained by selecting alignment frequencies near, rather than at the extreme ends of a band therefore, the signal generator has been set at 15 mc and the trimmer adjusted for maximum response.

Under these conditions, the oscillator is operating at 15 mc plus 456 kc for a value of 15.456 mc to produce the 456 kc i-f. Twice the i-f is 2 x 456 or 912 kc which, subtracted from the 15 mc gives 14.088 mc as the check frequency to which the receiver is tuned. At this setting, the oscillator will be operating at 14.088 mc plus 456 kc for a value of 14.544 mc.

The signal generator, still operating at 15 mc will heterodyne with the oscillator frequency of 14.544 to produce a beat note of 15.000 mc minus 14.544 mc for a difference of .456 mc which is equal to the i-f of 456 kc. Thus, the generator signal may be heard at the lower frequency setting of the tuning dial although the original tuning was correct.

If no signal is heard at the lower frequency setting it may be that the first setting was the image frequency and to check on this condition, tune the receiver to a frequency equal to twice the i-f plus the signal frequency. If the signal is heard again at this point, this is the true frequency. However, if no signal is heard, the first signal was the correct one and you can assume the receiver has good image frequency suppression.

A second method, to determine whether the receiver signal is correct, is to first tune the receiver to the signal and then increase the capacity of the trimmer in the oscillator tank

circuit until the signal is heard again. This second signal will be the image frequency and the trimmer capacity is then decreased until the original signal is heard again.

SUPERHET ALIGNMENT

Due to the extreme popularity of the superheterodyne receiver and the fact that its alignment is more difficult than other types, we are going to show you the step by step alignment procedure of the circuit shown in Figure 6. This circuit appeared in an earlier series of Lessons and we are repeating it to avoid duplicate explanations.

Checking through the circuit, you will notice that with the exception of the push button tuner, there are 20 tuned circuits, all of which must be accurately adjusted in order to allow the receiver to operate at maximum efficiency. For this work, we will assume the Broadcast Band covers the frequencies from 540 to 1720 kc, the Police Band from 1.7 to 5.6 mc and the Short Wave Band from 5.5 to 18 Megacycles. Also, we will assume the i-f frequency to be 465 kilocycles.

To go ahead with the alignment, the output meter should be connected as shown in either Figures 1-A or B. The signal generator is then set to 465 kc and its output fed into the control grid of T4, Figure 6, through an .01 condenser. Then, with the output of the generator set as low as possible to give a readable deflection on the meter and the oscillator tube T12 removed, the trimmers across the primary and secondary of the i-f transformer, between T4 and T5, are adjusted for maximum output.

With these trimmers properly adjusted, the output of the signal generator is connected to the control grid of T3 and the second i-f transformer peaked. To complete the i-f alignment, the signal generator output is applied to the input grid of T2 and all the i-f transformers are readjusted for maximum output.

The next step in this circuit is the alignment of the afc system which will necessitate a little additional explanation. From an earlier Lesson, you will remember that the discriminator transformer operates at the i-f frequency and, when the i-f frequency is exactly that to which the i-f transformers are peaked, there should be no difference of potential between the cathodes of the discriminator rectifier. Thus, for proper alignment, the primary and secondary of the discriminator transformer must be adjusted to exactly the same frequency as that to which the i-f transformers are peaked.

To do this for the circuit of Figure 6, the signal generator is set at 465 kc and its output fed into the input grid of

T2, the same as for the final adjustments of the i-f's. The regular output meter cannot be used here but instead, a more sensitive instrument, such as a 200 microampere meter or vacuum tube voltmeter, is connected across the cathodes of the discriminator rectifier, T10.

With the connections properly made and the afc switch turned "ON", the output of the signal generator is increased until an indication is observed on the meter. Should it be impossible to obtain a reading, it indicates the secondary is correctly adjusted and its trimmer should be turned slightly, in either direction, until a reading is obtained. Then, the trimmer across the primary of the discriminator transformer is adjusted for maximum meter reading.

After this is done, and without changing any connections. the trimmer across the secondary is adjusted for zero deflection of the indicator. The accuracy of this adjustment can be checked by disconnecting one side of the indicator and noting whether there is any deflection of the pointer. If there is, then further adjustment of the secondary trimmer should be made until there is no motion of the indicator needle.

This secondary adjustment is very critical and, in general, there will be three positions which give zero voltage output. One of these adjustments occurs when the trimmer capacity is at minimum, the second occurs at maximum capacity, while the third occurs for a position approximately half way between the first two. The minimum and maximum capacity settings of the trimmer are incorrect adjustments and should be avoided. The correct adjustment can be easily recognized because of the fact that the indicator reading changes rapidly from plus to minus for a slight change in the trimmer setting.

When the secondary trimmer is properly adjusted, the afc alignment is completed and the indicator should be removed from the discriminator rectifier.

The r-f, mixer and oscillator coils of the Broadcast Band are ready for alignment next, therefore the signal generator is connected to the antenna and ground terminals of the receiver, and the oscillator tube, T12, is put back in its socket. The signal generator is set at a frequency near the "high" end of the band, preferably between 1300 kc and 1500 kc, and the receiver is tuned to the generator signal.

The exact value of this test frequency is not important as long as it is high enough to tune in on the receiver when the tuning condenser is close to its position of minimum capacity. Should Broadcast station signals be received also, slightly

raise or lower the signal generator frequency until its signal can be tuned in without interference.

Then referring to the output meter, connected in the output circuit for the i-f amplifier alignment, the trimmers, connected across the coil secondaries of the broadcast band, are adjusted for maximum output. As explained earlier, the tuning condenser may be rocked across the signal as the trimmers are adjusted.

One common procedure, in aligning at this point, is to adjust the oscillator trimmer first after which antenna and mixer coils trimmers are adjusted for maximum response. Should either of these adjustments fail to "peak", the oscillator trimmer is readjusted and the entire routine is repeated.

Without changing any connections, the signal generator and receiver are both tuned to about 600 kc and the series oscillator padder is adjusted. When making this adjustment, it is necessary to "rock" the condenser gang until maximum meter deflection occurs. When this is completed, both the receiver and test oscillator are returned to 1400 kc and the procedure outlined for this frequency is repeated.

This completes the alignment for the broadcast band and for the police band, the same procedure, as outlined above, is followed, however, the high frequency adjustments for this band should be made at about 5.4 megacycles and the low frequency adjustments at about 1800 kc. For the short wave band, follow the same procedure but make adjustment at frequencies of about 5.6 mc and 16 mc.

When aligning at these higher frequencies, be sure that you are working on the true frequency. It is always a good plan to make a check by the method explained earlier in this Lesson under the heading "Image Frequencies". Also, remember the i-f frequency remains constant, regardless of the band, and once the circuits operating at this frequency are adjusted, they should not be disturbed when aligning the separate bands.

After the alignment has been completed the dial should be checked for calibration as it may read high or low when tuned to the known frequencies of the signal generator. In most cases, you will find the dial reading is either high or low for all frequencies and therefore it can be calibrated mechanically by changing the relative positions of the dial pointer and tuning condenser rotor.

The push button tuner of Figure 6 can also be adjusted by the use of a signal generator and output meter. To do this,

The output meter is connected as before and the signal generator connected to the antenna and ground posts of the receiver. The generator is then set to the frequency of the desired station and a push button is depressed. The oscillator trimmer for this push button is first tuned for maximum indication on the output meter. Then, the other trimmers for this same push button are tuned for maximum output. The same procedure should be followed for each button, the signal generator operating at the frequency of the desired station.

Unless otherwise stated, the output of the signal generator should always be kept at the lowest value which will give a satisfactory reading on the output meter. As previously explained, this is to prevent the avc action of the receiver from giving inaccurate output readings.

Whenever possible, always follow the manufacturers alignment procedure. However, when this data is not available, the explanations of this Lesson, if properly followed, will result in good alignment jobs. Remember, the performance of a modern superheterodyne receiver depends to such a great extent upon proper alignment that a little extra care in making the adjustments will more than repay you for the time spent.

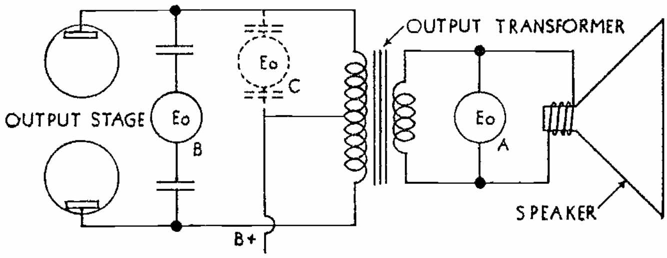


FIGURE 1

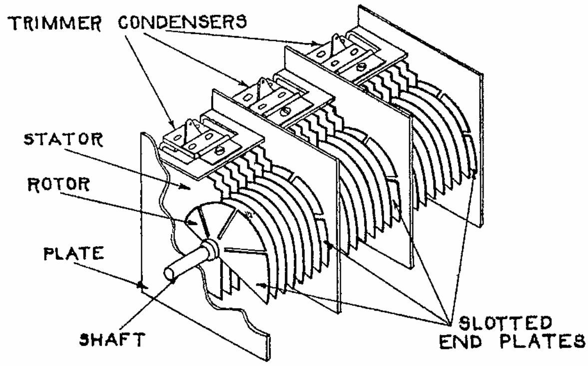


FIGURE 2

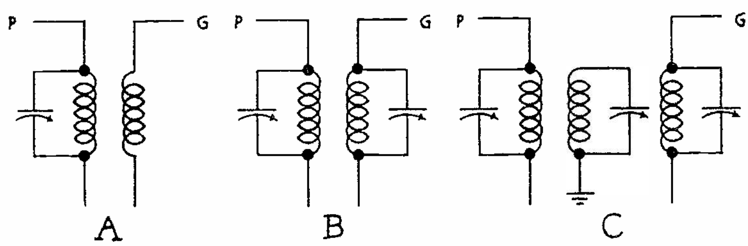


FIGURE 3

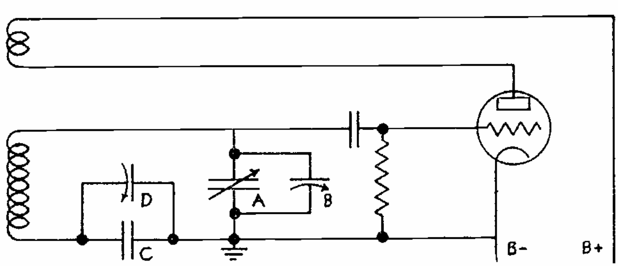


FIGURE 4

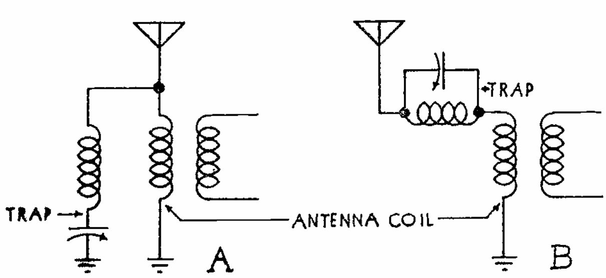


FIGURE 5

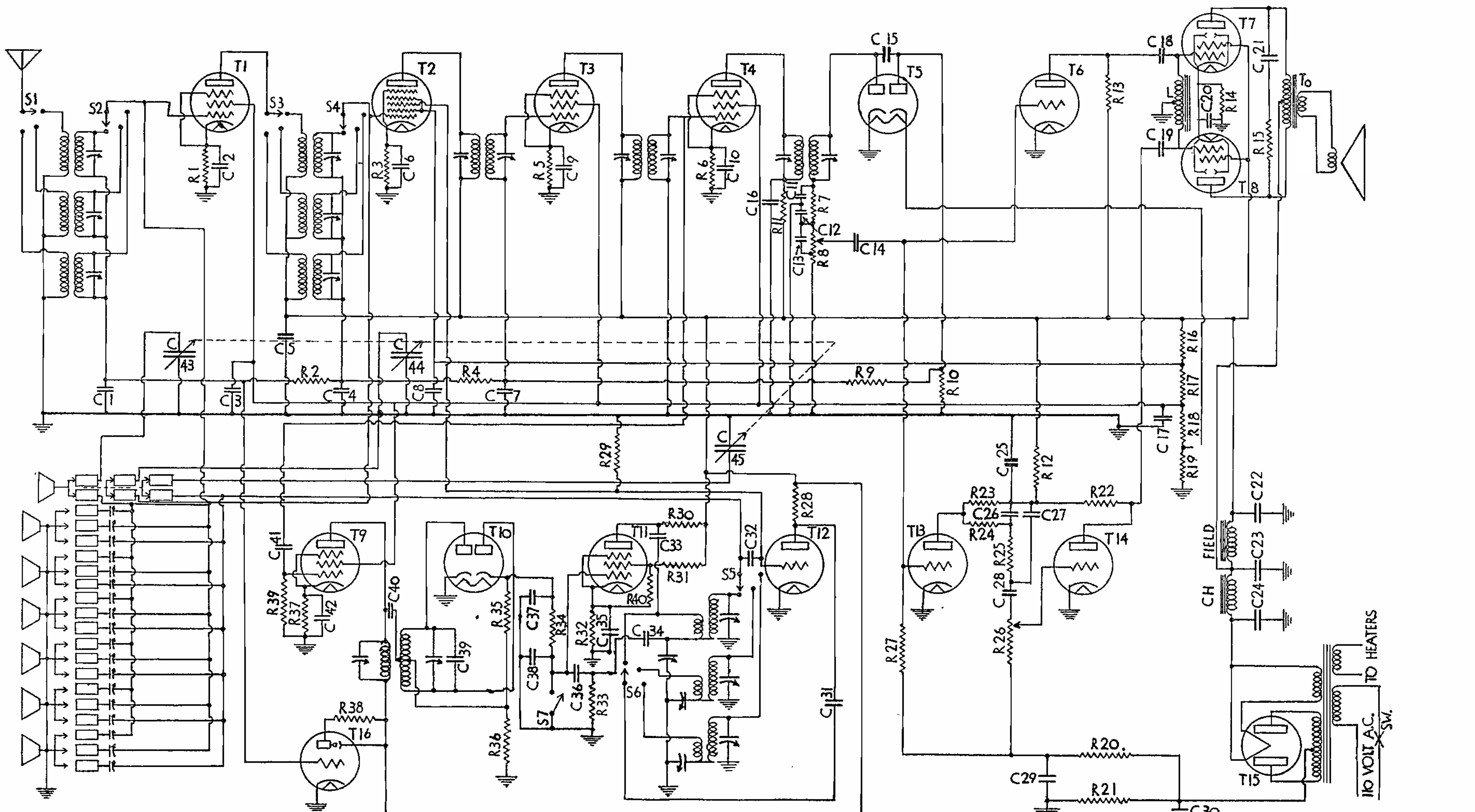


FIGURE 6

SWITCHES SHOWN IN BROADCAST POSITION

QUESTIONS

How many advance Lessons have you now on hand?________________

Print or use Rubber Stamp.

Name ______________________________ Student No. ______________

Street ____

City ____________________ State ______________________

1. When using a voltmeter as an output indicator for the receiver of Figure 6, where should the test leads be placed to secure the highest readings?

2. Are the trimmer condensers adjusted at the maximum or minimum capacity setting of a gang condenser?

3. What is the purpose ofthe slotted outside rotor plates in each section of a gang condenser?

4. When a condenser gang is out of alignment, what effect will it have on the tuning of the receiver?

5. An output meter and signal generator are properly connected to the receiver shown in Figure 6. As the tuned circuits are adjusted, how is resonance determined?

6. When aligning a receiver is the oscillator padder adjusted at the high or low frequency end of the band?

7. When aligning the receiver of Figure 6, which circuits should be adjusted first and at what frequency?

8. Why should the test oscillator output be as low as possible when aligning receivers with avc?

9. What is the purpose of "rocking" the tuning condenser as the trimmers or padder is adjusted?

10. At what circuit frequency are wave traps adjusted and for what reading at the output?