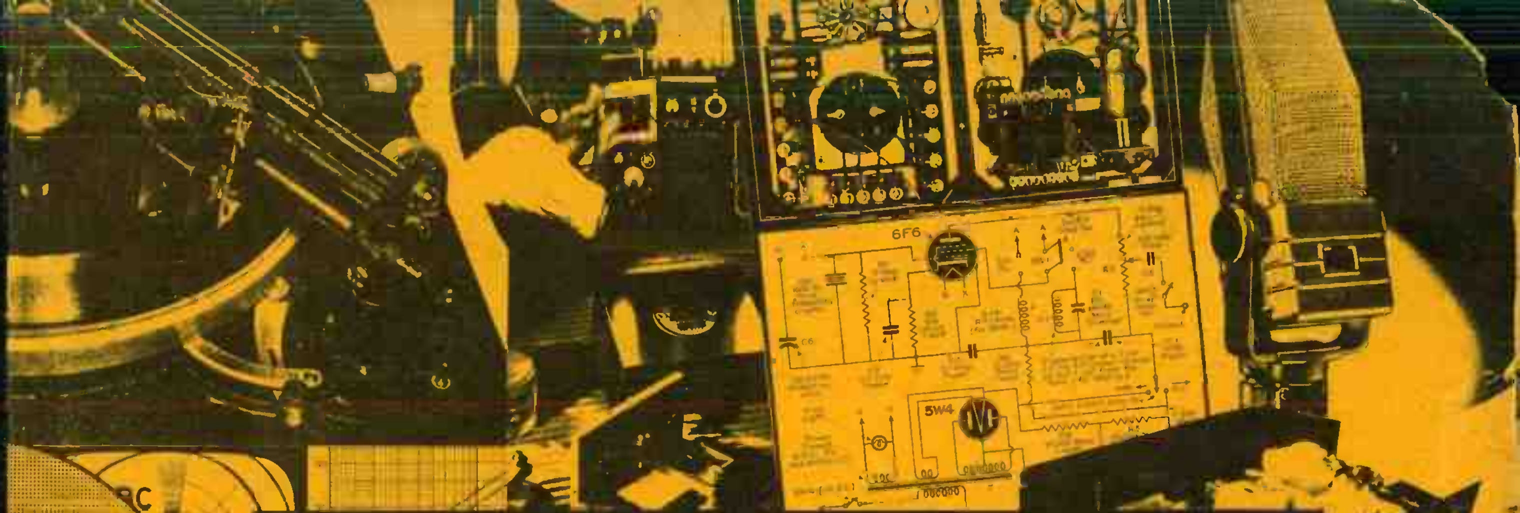


RADIO SERVICING COURSE

REPRINTED FROM

RADIO TECHNICAL INSTITUTE COURSE

SUPREME PUBLICATIONS

RADIO BOOKS, MANUALS, AND DIAGRAMS
3727 WEST 13th STREET
CHICAGO, ILLINOIS

An open letter --
To all new Students

Dear Friend:

You have taken the right step in deciding to improve your knowledge of radio. The Radio Technical Institute Course is ideally well suited to give you the essential background for success in radio work.

The reprint of the R.T.I. course has been purchased by you at a real saving. While the lessons have been combined in book form, the contents are exactly the same as the original material.

What is more the reprinted edition has been checked and corrected by M. N. Beitman. As you probably know, Mr. Beitman was connected with the original Institute. He has also been an active radio serviceman during the early part of his career.

Mr. Beitman holds a B. S. degree from Lewis Institute, and has written many books and numerous articles in magazines on all phases of radio. He was connected in engineering capacity with several radio factories and large jobbers in the Chicago area. At present he is teaching National Defense Radio Classes at Englewood High School. His supervision of this reprinting is your assurance of the course's accuracy and adaptability to act as your "teacher" and guide.

We wish you good luck in your study and complete success in Radio. Thank you.

Cordially yours,

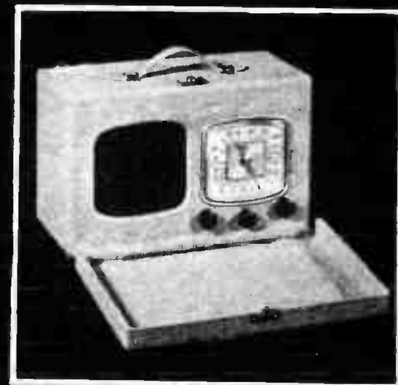
SUPREME PUBLICATIONS

JL:ms

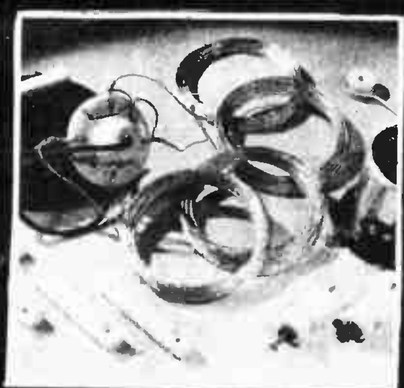


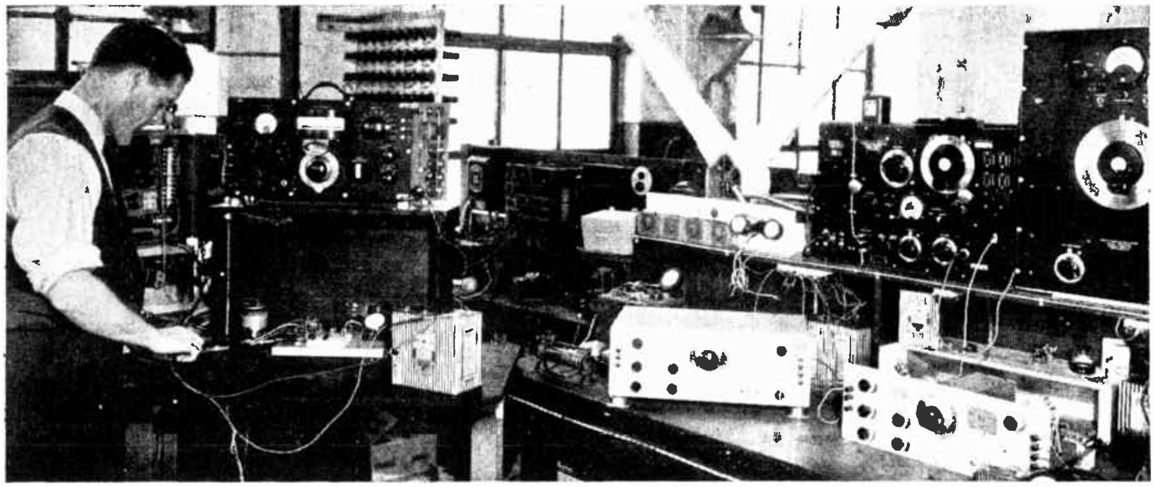
37,000,000 RADIOS TO BE REPAIRED






ANTENNAS, P. A. & ACCESSORIES





RADIO is today's opportunity field. More and more radio receivers are sold every year, Public Address is finding extensive use, Television is almost here commercially. Study this course willingly, slowly, with plenty other reading. Be sure to keep up with the latest developments by reading good radio magazines. And for practice build radio sets, get repair work, study real radio equipment. Success is yours in radio.

PRINTED IN THE UNITED STATES

RADIO SERVICING COURSE

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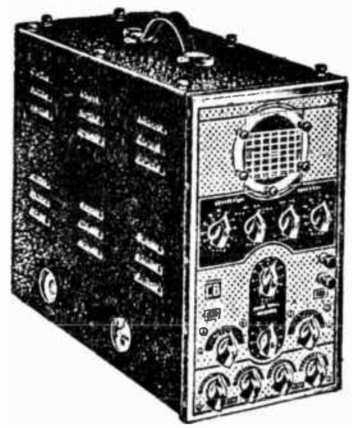


THIS Text material has been carefully prepared by the staff of consulting engineers and instructors of the Radio Technical Institute. The subject material has been selected from the latest sources and is up to date. The presentation is made in the simplest manner without the sacrifice of correctness.

RADIO TECHNICAL INSTITUTE
CHICAGO, ILLINOIS

LESSON 1

A WELCOME AND INTRODUCTION TO YOU

There was a time when any jack-of-all trades could have successfully serviced a radio set. Modern radios, however, are complicated machines employing many circuits and requiring exacting adjustments. And yet the entire science of radio is based on surprisingly few simple principles that can be easily mastered. The complete material of this carefully prepared course will enable any one of average intelligence and ambition to grasp the principles of radio theory and practice. With the data given in these pages mastered, and the commercial practices and equipment described clearly understood, you will possess the knowledge essential to be a first class radio serviceman. But you need not wait until you finish the course to begin to earn extra money servicing sets. When you study Lesson 11 and are ready to purchase your first radio tester, you are ready to do simple service work.

The entire course is written in a simple, straight from the shoulder manner. Study carefully, reading the hard to understand parts three or four times until these facts are clear to you. If you have any questions write to us and we will help you. When you enroll at the Radio Technical Institute you become a life member and it is our business to serve you. Your success is our responsibility.

Now let us begin the interesting study of Radio.

Although we are primarily interested in learning how to service radio receivers, that is how to correct any faults that develop in radio sets, in order to do so well and quickly a clear understanding of radio theory and practice as well as a knowledge of many related subjects is essential. The main need for radio servicing is due to people's desires to listen to broadcasting stations. Radio frequency waves are merely instrumental in radio transmission; sound waves in the form of speech or music are the waves that must be transmitted. Therefore, sound is a subject of importance to radio servicemen and must be studied. All words underlined are to be looked up in the dictionary.

MEANING OF SOUND - MEDIUM - VELOCITY - AMPLITUDE - PITCH

Sound must be conducted through some medium. In general solids are very good conductors of sound, but porous materials such as cotton, sawdust, etc. are poor conductors. Liquids are better media for sound than gases. For us the air is the most useful medium for sound conduction.

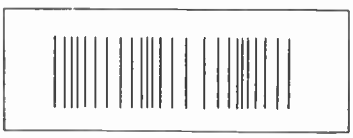
The physiological meaning of sound is entirely within us. It is the actual experience of sensation that we undergo. The physical meaning of sound is the existence of a disturbance in the air or other media consisting of a succession of alternate waves of compression and rarefaction that tend to travel outwardly in all directions away from a vibrating body.

The velocity of sound in air has been carefully determined. In air at 0°C. the velocity of sound is 1,090 feet per second. As the temperature rises the velocity also increases. This rate of increase is about two feet per second per degree C.

The velocity of sound in many other media has also been determined. In water it is approximately four times as great as in air. The table below gives the velocity of sound in some common materials. The velocity in any medium is inversely proportional to the square root of the density. A solid having greater weight per unit volume, all other factors being equal, will have lower velocity. The velocity is also directly related to the elasticity of the material. The elastic constant of any substance is the degree that the substance resists deformation. Soft rubber has a very low elastic constant.

VELOCITY OF SOUND IN SOME COMMON MATERIALS (In feet per second)			
Aluminum	16,700	Silver	8,770
Beeswax	2,820	Steel	16,220
Brick	11,000	Tin	8,160
Glass	17,000	Wood:	
Iron	16,800	Ash	15,300
Lead	4,020	Elm	13,500
Marble	12,480	Fir	17,220
Platinum	8,800	Pine	10,880

Vibrations are transverse or longitudinal. Water waves are transverse to the line of motion. There is no forward movement of the water itself, but there is a rising and falling motion as the water wave advances. Any particle of water on the surface will rise and fall, but will move neither forward nor backwards. If the motion of the particle was plotted against time, it would describe a curve similar to the wave. The wave itself, of course, results because a great many such particles move up and down in the correct order.



Crowded lines represent condensations, the other lines rarefactions, in this analogy of the effect of sound on a medium.

When a body vibrates the air immediately in front is first compressed and then released. In this way a series of condensations and rarefactions is produced. This train of waves is longitudinal, since it takes place in the direction of motion. There is but little movement of the air forward since each pulse communicates its energy to the air directly in front.

A single cycle is completed when the vibrating point completes two vibrations and returns to the original position. The period is the time required for the completion of one cycle. It is also the time it takes the vibrating body to pass a point while traveling in the same direction. The number of cycles per second is the frequency.

Any sound wave, no matter how complex, may be shown to be made up of a number of simple sine waves. One of these is the original wave and the others the harmonics or overtones of this wave. The character of sound depends only on three things: (1) pitch, (2) loudness, and (3) quality.

The pitch is the characteristic which enables us to distinguish between notes of various frequencies, the high, medium, low-frequency notes for instance. Pitch is a direct function of the frequency of the vibrations. In simple and complex tones the pitch is usually determined by the fundamental frequency. In some complex tones, however, this is not the case as shown by recent research work.

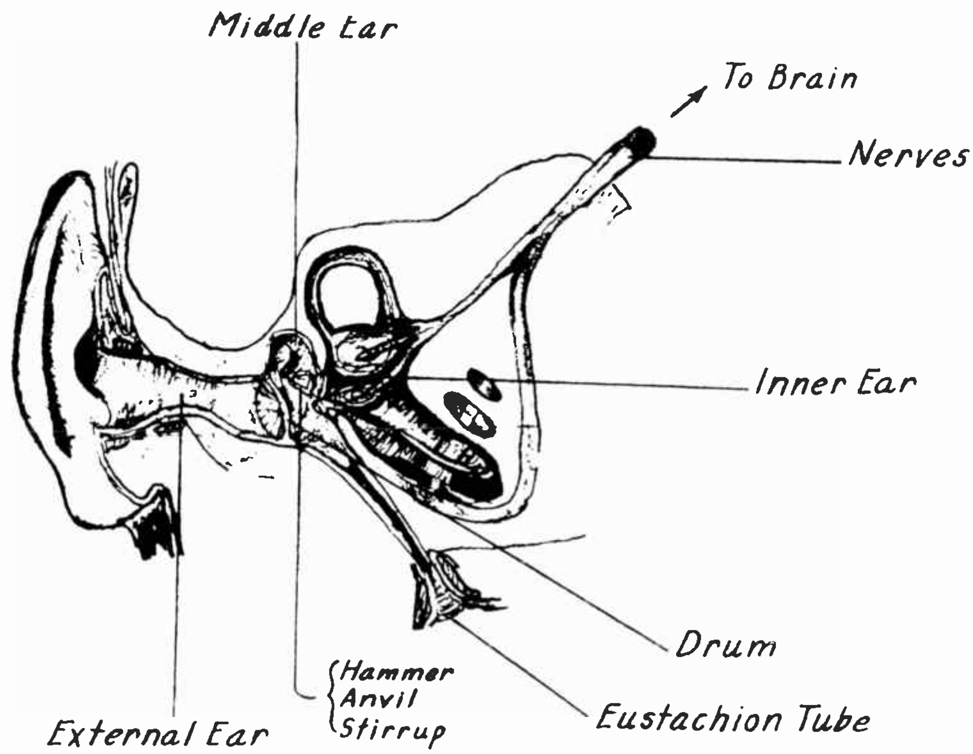
The second characteristic, loudness, depends on the energy of the vibration. Our ears respond to loudness in logarithmic proportion and not in direct ratio. A ten-fold increase of loudness would appear to the average listener only as twice as loud. Signals of equal intensity but of different frequencies usually appear to be of different loudness.

Quality or timber of sound is the characteristic that enables us to distinguish sounds of identical pitch and loudness but produced by different people or instruments. Every one knows that the same notes played on a violin and piano equally loud will sound entirely different. This is because while both, being of the same pitch, have the same fundamental frequency, the harmonics present in each greatly differ in number and their relative intensities.

To the future radio servicemen, in view of greater everyday application of sound amplification, it is important to understand the behavior of sound in enclosed rooms. The actual selection of the equipment and the placement are directly related to the way sound will be directed and acted upon in the particular location. Acoustics is that branch of science that deals with the action of sound. All sounds created proceed outwards in spherical waves until they strike the boundaries of the room. Upon striking the walls, sounds are absorbed, reflected, and transmitted in varying amounts depending upon the character of the walls. Sound energy is diminished with each reflection because of the absorption, and this finally results in the sound dying out. Continues reflection has the advantage of loudness, but always introduces prolonged existance of each sound. This prolongation, or reverberation, is the most common acoustic fault found in auditoriums.

A person talking in an auditorium having a high reverberation time can be understood only with difficulty. Each sound instead of dying out quickly persists for some time, so that spoken words blend with their predecessors and set up a mixture that produces confusion. This acoustic difficulty may be corrected by the introduction of sound-absorbing materials to reduce the reverberation time.

In the case of music similar, but less objectionable, effects are produced because of prolonged reverberation. Good acoustic conditions are obtained when sound rises to a suitable intensity, with no echoes or other types of distortion, and then dies out quickly enough not to interfere with the succeeding sounds. This is a very hard condition to fulfill, but considerable departure from the ideal is not very objectionable to an average listener.



Relative positions of the components of the human ear. When the word "ear" is used in this sense it means all shown, not only the lobe that is signified in everyday speech by the word "ear."

No discussion of sound would be complete without due consideration of the human ear. The ear is an organ especially adapted to receive sound vibrations and to transform them into nervous impulses.

Anatomically the ear is divided into three separate and distinct parts. These parts are so interconnected that sound waves are transmitted from one part to the next. These parts will now be briefly analyzed.

EXTERNAL EAR. This consists of the external parts, including the part we commonly call the ear. There is also a short tube about one inch long along which sounds pass inwards to a sort of a drum.

MIDDLE EAR. This small cavity lies on the other side of the membrane of this drum. By means of the Eustachian tube this cavity is connected with the throat and, thereby, the air within is under the same pressure as the air in the external ear. This arrangement cleverly releases extreme strains on the membrane between these two sections. Stretching directly across the cavity of the middle ear is a chain of three very small bones, called the hammer, anvil, and stirrup. These bones are bound together and transmit vibrations from the tympanic membrane between the external and middle ear, to the portion of the inner ear known as the cochlea.

INNER EAR. The inner ear receives the ultimate terminations of the auditory nerves and is the essential part of the organ of hearing. Without going into detailed anatomy, the inner ear may be said to consist of a system of small bony spaces and tubes within which lies a membranous labyrinth. Forming part of the lining of the membranous labyrinth are sensitive cells between which are the endings of the nerve fibers. These nerve fibers conduct the impulses to the brain.

The vibrations that can be perceived by the ear lie within certain limits. These limits, of course, are subject to considerable individual differences. Usually the lowest frequency is placed at 30 cycles per second, although some people respond to vibrations as low as 16 cycles. Below this limit, if any reaction occurs at all, it is due either to pressure sensation or the presence of harmonics.

The high limit of audibility is about 40,000 cycles. Very great variations in this connection exist in different individuals. The ability to hear high-pitched sounds also decreases with age. However, sounds of frequencies higher than about 10,000 cycles are usually overtones and are not missed except by a trained critical listener.

Considerable variation in loudness must occur before the change is noticed. In general the ear is not a critical apparatus. It does not discriminate well between different degrees of loudness, fails to notice small percentage of distortion, fills in missing gaps, and possesses tonal gaps and tonal islands.

REVIEW QUESTIONS

1. Can sounds be conducted by a vacuum?
2. If 0° C. corresponds to 32° F., at 70° F. is the velocity of sound greater than 1,090 feet per second?
3. What is a cycle? How is frequency of sound determined?
4. How would you overcome prolonged reverberation in a hall?
5. Looking at the cut-away view of the human ear, explain how sounds are heard.
6. What frequencies are audible to human beings?
7. What makes a middle C note of a piano and a violin sound differently?

DO NOT RUSH YOUR PROGRESS, KNOW EVERYTHING IN THIS LESSON.

LESSON 2

ELEMENTARY ELECTRICITY

For comparative purposes of the quantities that are encountered in electrical circuits, selected units are employed. These units are inter-related and are based on absolute basic reactions. Because of the nature of electricity and the associated force magnetism, we cannot measure or note these forces directly with our senses, but must resort to indirect indicators (meters, lights, etc.) operated by these forces.

Electrical current in a circuit consists of a large number of electrons flowing in a complex manner through the conductor such as a wire cord. Since electrons are negatively charged particles, the current actually consists of a motion of negative electrical charges. The measurement of quantity of current, therefore, is the measure of the sum of all the charges. An electrical or magnetical charge may be measured by the force of attraction or repulsion which exists between this charge and some other charge. It is important to remember that unlike charges attract, and like charges repel.

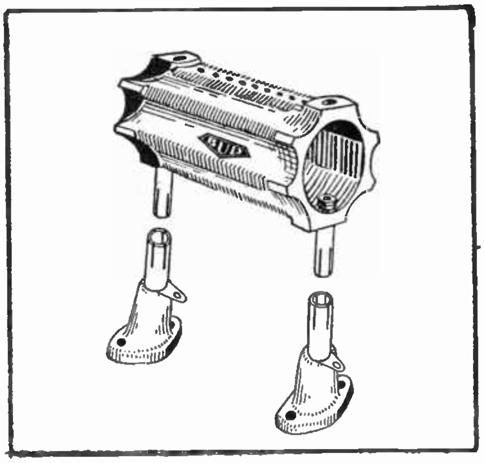
If we connect two bodies that have different charges (one positive and one negative) a current will flow. The positive body lacks electrons, and the negative body has an excess of electrons; the current is the passage of these electrons from the negative body to the positive one.

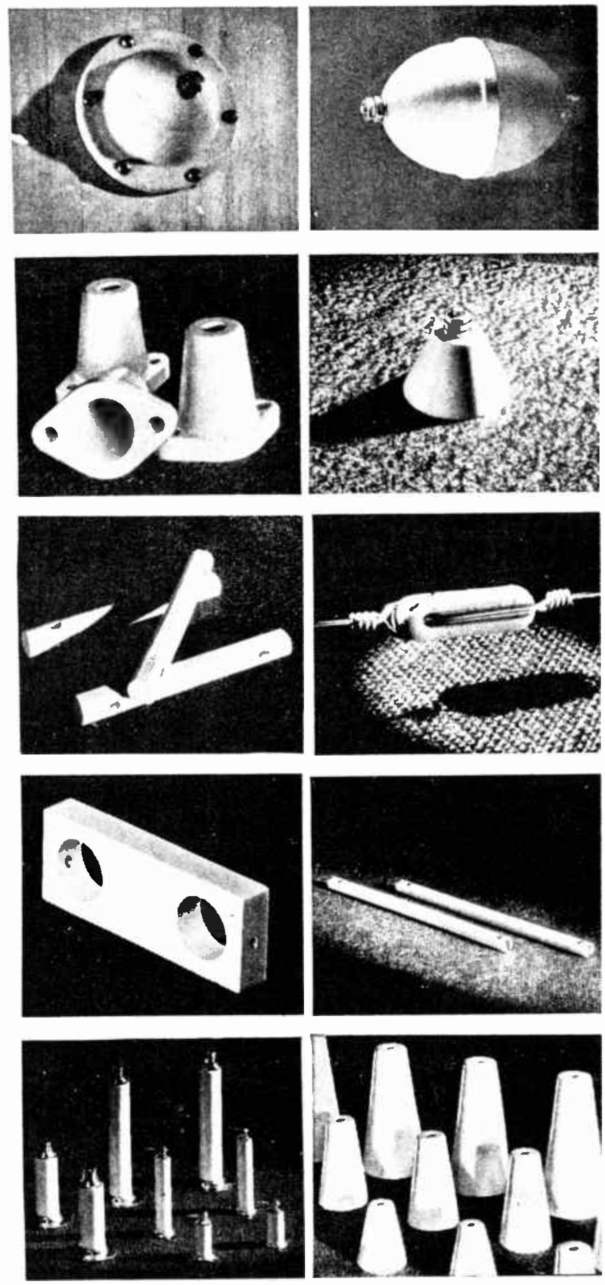
Electro-motive force, E.M.F., which will force electrons to flow through a conductor can be generated in a number of different ways. Friction was the earliest known method, but is not used commercially today. In dynamos a conductor is moved in a nagnetic field. Chemical changes generate an electrical current in batteries.

The flow of electricity is the passage of electrons between the heavier atoms of the conductor. The solid substances which conduct electricity best are the metals. Copper is the best conductor of the materials practical to employ for this purpose. Other metals, iron, alloys of nickel, have greater opposition (resistance) to the flow of electric current and find certain special applications.

It is evident that some substances are very good electrical conductors, others have greater resistance, while still others have almost no conducting properties and are called insulators. Hard rubber, bakelite, glass, porcelain are used extensively as radio insulators to separate parts that should not have electrical current flowing between them.

For the beginner student we have included a number of illustrations of radio parts that are excellent examples of conductors and insulators. Note the coil form which is made of special insulating material, Isotex; while the terminal jacks are of good conducting metal. The application of many parts may not be clear at this time, but will be explained later.



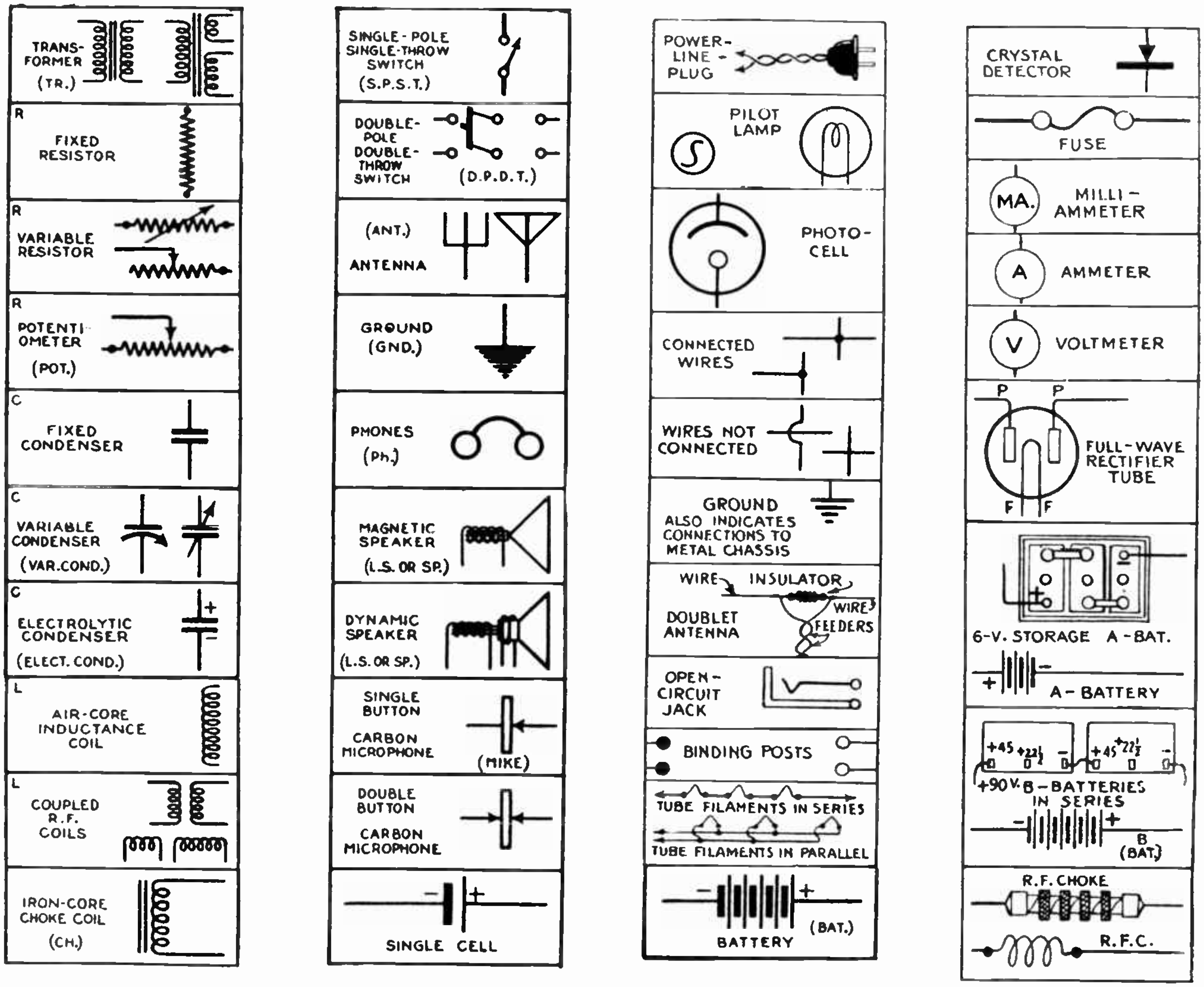


Many different insulators of the National make are shown on the right. These are employed for various applications in antenna systems, transmitters, and receivers. Special ceramic materials are used to reduce the electrical losses and make the units better insulators.

Every radio part, naturally, must have some conducting material. In coils we have the wire, in condensers the metal plates -- and every circuit has the many parts wired and interconnected with copper hook-up wire.

In radio work it is important to have good insulators and good conductors. There is no need for half-way measures.

The radio serviceman has his own language of radio symbols. Circuits are always shown in these symbols and the radio manuals use them. There are only a few used and once these are mastered, the understanding of radio becomes a simpler problem.



Much information of late character is presented in many technical radio magazines. You, as a future radio serviceman, should begin reading these magazines at an early stage of your career.

REVIEW QUESTIONS

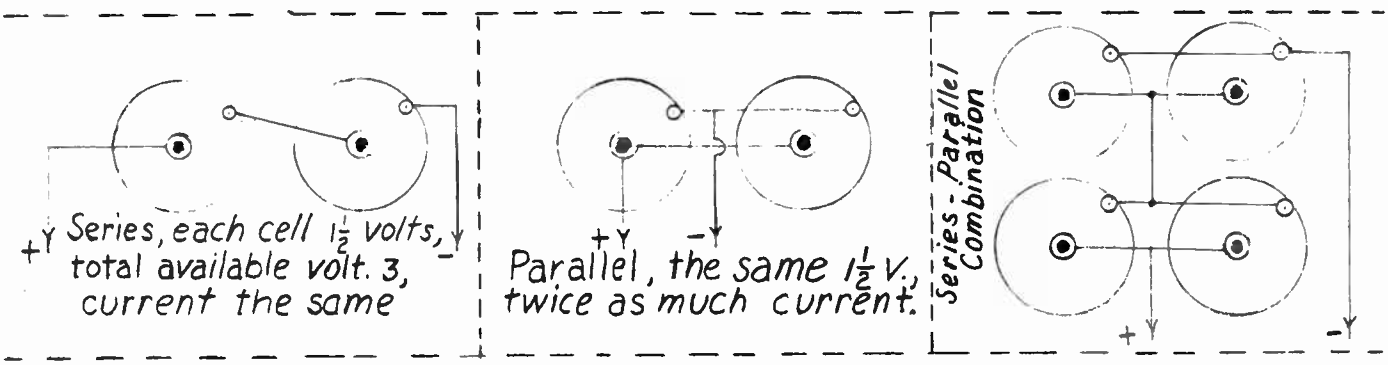
1. Of what potential are electrons?
2. Name two ways an electric current can be generated.
3. Name several good conductors of electricity?
4. Make a sketch showing the connection of a fixed condenser and a fixed resistor connected to a meter.
5. Examine several circuits in radio magazines and name each part used.

LESSON 3

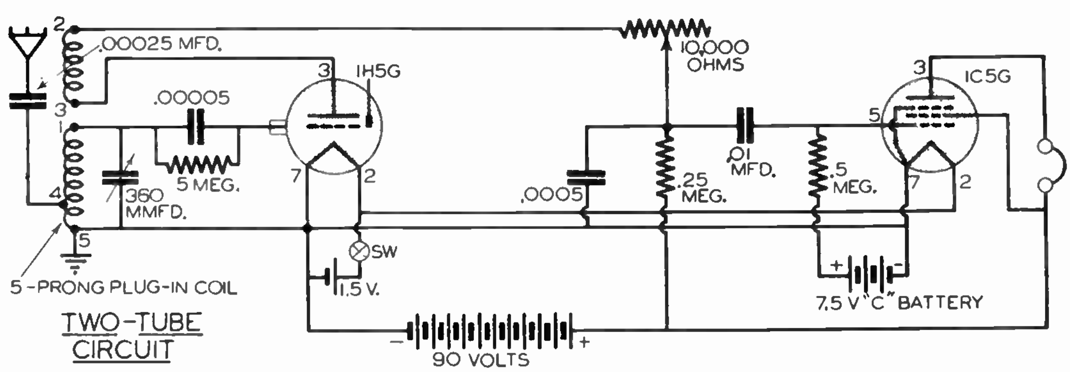
RADIO BATTERIES

A cell is a unit that produces electrical energy by means of chemical action. A battery is a combination of two or more cells connected in series or parallel. A primary cell is a unit that produces an electrical current because of a chemical reaction. Once the acting material is used up or an equalibrium is reached, no further appreciable current can be produced.

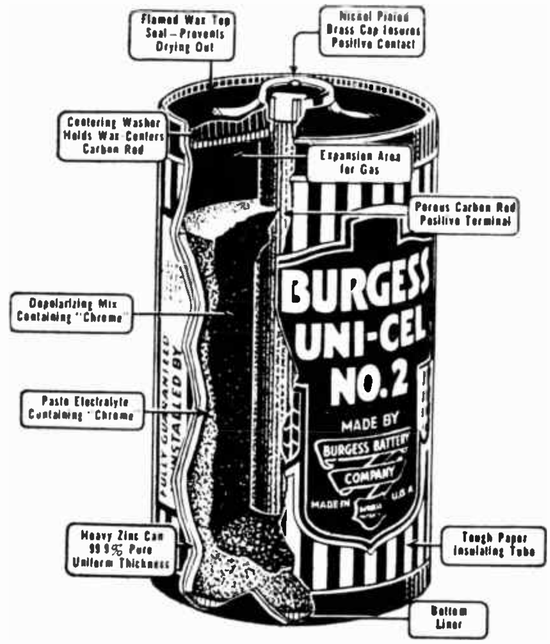
The ordinary flash-light battery is of this type. This "dry" cell has an outside foil of zinc that acts as the negative electrode and a center positive electrode of carbon (copper could be used instead). There is also a chemical solution $N\ H_4\ Cl$ in paste form. The common type B batteries are made up of a great number of these cells connected in series and thereby furnishing relatively high voltages. Different methods of connecting cells are illustrated below.



While A.C. operated receivers are used in the majority of homes, battery type radio sets are still finding widespread use in rural communities that as yet have not been electrified. Some house sets and all the modern auto sets obtain all their operating power from a single 6 volt storage battery. Means are incorporated in the set to change the available low D.C. voltage to high voltage for plate supply requirements. Some battery sets still use B batteries and we refer the student to the circuit below. This is a simple set using a detector and a single audio stage.



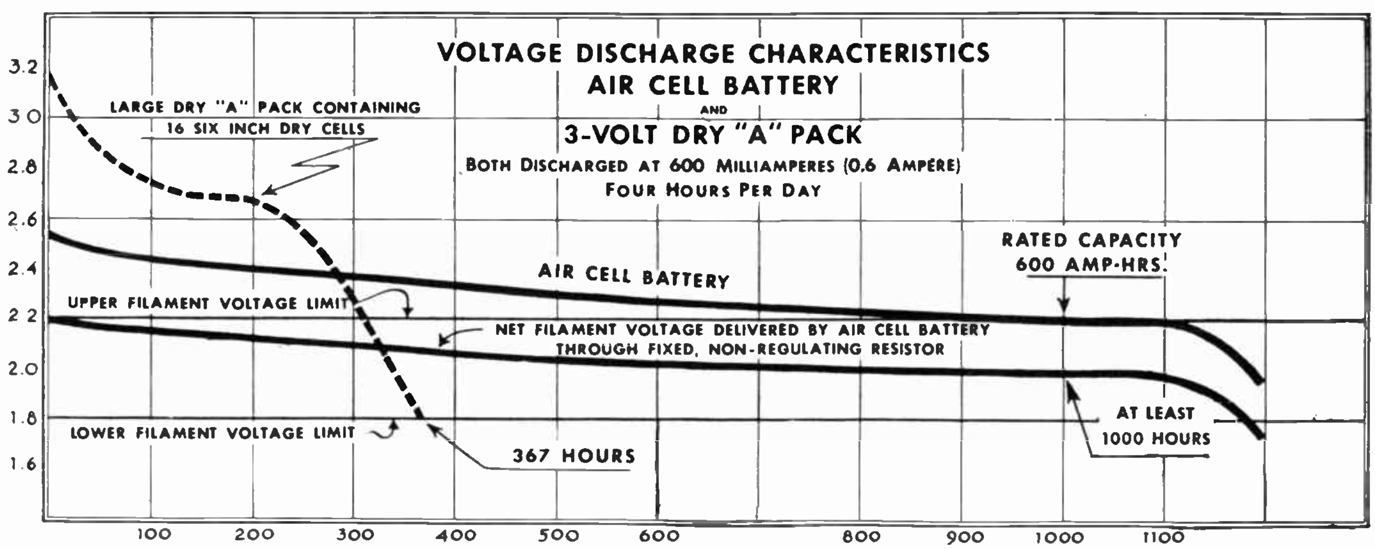
TWO-TUBE CIRCUIT



The storage battery is a secondary battery because it cannot produce an electrical current of itself, but must at first be charged. The current used for charging is stored and may be obtained when needed. The battery actually does not store electricity, it stores chemical energy created by the charging current. When the current is used during the discharge period, chemical energy is used up. Radio storage batteries are tested with a gydrometer since the specific gravity of the solution changes with the "charge" condition of the battery. The acid level should be at 1.275 when the battery is fully charged, and the battery should be recharged when the level reaches the 1.150 point.

The storage battery may be recharged by means of a charger from a 110 volt line, or a generator rotated by the wind may be used in conjuction with the battery to keep it always in operating condition. There are now also available inexpensive gasoline driven generators for quickly charging batteries.

Operating on a new principle, the Air Cell Battery's voltage is different from that of other batteries. Consequently, a line of tubes had to be developed to match it before set makers could produce a practical rural receiver.



LESSON 4

CIRCUITS - MAGNETISM - ELECTROMAGNETS

A coulomb is a definite quantity of electricity just like a gallon of oil is a quantity of oil. An ampere is the rate of current flow and is the passage of one coulomb per second. For measuring small electric currents a unit, milliampere, equal to 1/1000 of an ampere is used. 1,000 milliamperes are equal to one ampere. Meters used to measure electrical current are called ammeters or milliameters depending upon the currents they are designed to measure.

A current passes along a conductor because of an electromotive force (e.m.f.) or a potential difference. The volt is commonly used to measure potential difference and e.m.f. is often referred to as voltage.

The e.m.f. developed by a single standard dry cell, such as a flash light cell, is 1½ volts. A single storage battery cell fully charged has a potential (voltage) slightly over 2 volts.

All conductors of electricity oppose the flow of current through them. They have electrical resistance. The unit of resistance is the ohm. In radio circuits very high resistances are sometimes encountered and the term megohm is used for 1,000,000 ohms. The student should memorize all the terms underlined as they are of prime importance in radio work. If an Encyclopedia is available at the library, the history of each term should be looked up.

NUMBERS, FRACTIONS, DECIMALS, SIMPLE FORMULAS EXPLAINED AS A TOOL.

Mathematics is a symbolic way of explaining and analyzing physical occurances. Arithmetical numbers represent quantity. Ten volts is ten times the standard measure -- the volt. Numbers tell how many, is it larger or smaller, is it too small ... all these are measures of quantity. Algebraic symbols (usually letters of the English and Greek alphabet) represent specific measureable quantities. For example E usually stands for voltage in electrical work. This is really another way of writing "voltage", i. e. we write E instead of the word voltage. In a like manner we usually write I for current, and R for resistance. Using letters saves time and greatly simplifies the writing of formulas. The Ohm's Law may be written in words as:

Voltage = Current (multiplied by) Resistance

or in symbols as $E = I \times R$

Of course, the algebraic way of writing is much simpler.

Sometimes in the same problem there are two different voltages, such as the grid and plate voltages in a vacuum tube. Here again we may use some letter, as "E", to represent voltage and use small letters after E and a little below it, to stand for grid and plate voltages respectively. As:

E_g ⟶ grid voltage

E_p ⟶ plate voltage

Many times in radio work quantities are parts of a whole unit and are called fractions. $\frac{1}{2}$ volt is a fraction of a volt. $5\frac{1}{4}$ is a whole number and a fraction. The number above the line is called the numerator, and the one below the denominator. The denominator tells what part of the whole, the numerator tells how many parts.

Decimals are more convenient than fractions and, therefore, find greater application. Multiplication and division by ten or some multiple of ten simply shifts the decimal point. Fractions, of course, may be expressed as decimals, and vice versa. For example, 5 2/5 may be written as 5.4. The number 5. representing the whole part of the fraction, and 2/5 changed to tenths becoming 4/10 and written .4 . In radio work decimals are almost exclusively employed.

A number multiplied by itself is said to be squared.

$$A \times A = A^2$$

The small raised ^{2} indicates that "A" has been multiplied by A, that is by itself.

The square root sign $\sqrt{\ }$ means that it is required to find a number that multiplied by itself will give the number under the $\sqrt{\ }$ sign. For example find $\sqrt{9}$. A number that multiplied by itself will give 9, is 3, so that:

$$\sqrt{9} = 3 \qquad\qquad 3^2 = 9$$

OHM'S LAW

We now come to an important relation between voltage, current and resistance. It is easily seen that the greater the voltage, the large is the number of electrons flowing or the larger is the equivalent current. But the larger the resistance the smaller is the current. In mathematical words, the current in amperes equals the voltage in volts divided by the resistance in ohms.

$$I = \frac{V}{R}$$

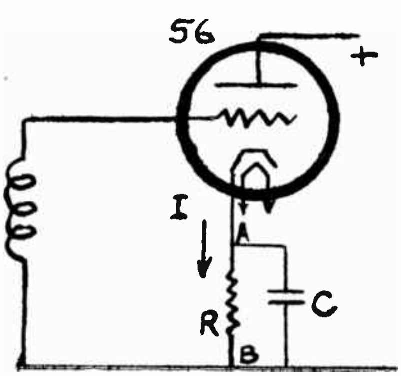
where I stands for current, V for voltage, R for resistance. This equation enables us to calculate the current when the voltage and the resistance of the circuit are known. For example, in a 110 volt circuit the resistance is 10 ohms. Dividing 110 by 10, we obtain 11 amperes which is the current.

Ohm's Law may also be written as $V = I \times R$

The voltage is equal to the product of the current by the resistance. If a current of 2 amperes flows through a resistor of 6 ohms, the voltage drop is (2 x 6) or 12 volts. In some devices the voltage drop produced in a resistance is used to reduce the over all high voltage. In some other cases the current is made to flow through a resistor purposely to create a voltage drop for some special need. This latter application is used for "C" bias in vacuum tube circuits.

By means of Ohm's Law if the voltage and current are known the circuit resistance may be found. For this purpose the formula below is used.

$$R = \frac{V}{I}$$



In the circuit to the left a resistor R is used to create a negative bias on the grid of the vacuum tube. There is a constant D. C. current I passing through the tube and, of course, through R. The A.C. component of the tube is by-passed by the condenser C. The voltage difference between points A and B, will be equal to the IR drop. Point B will be more negative since current passes from plate to cathode and then across the resistor "R", so that the drop occurs from A to B. Since the grid is connected to point B, it will be at a IR lower potential than the cathode connected to A.

A formula represents a relation between a number of related factors. Usually a formula is applied to find one unknown factor when the others are known. The Ohm's Law is a simple formula:

$$E = I \times R$$

Suppose in a certain circuit we know that I = 2, and R = 50, substituting these values in the formula above, we are able to find the unknown E.

$$E = 2 \times 50$$

$$E = 100 \text{ volts}$$

In this case by knowing the current and the associated resistance and by applying the Ohm's Law formula, we were able to find the value of the voltage.

WATTAGE OR ELECTRICAL POWER

Electricity can do work or create heat and is therefore a source of power. The unit of electrical power is the watt. The watt is the power produced by one ampere flowing under the pressure of one volt. Numerically the power in watts equals the product of volts by amperes of current.

$$W = E \times I$$

where W stands for watts, E stands for the voltage (we used V before), and I stands for the current. The filament of a common type 56 vacuum tube operates on 2½ volts and requires 1 ampere of current. The filament wattage is, therefore, 2½ x 1 or 2½ watts. If current and voltage are known, wattage can be calculated.

By recalling from Ohm's Law that E = IR and substituting in the equation above, another important formula for wattage in terms of current and resistance is obtained.

$$W = I^2R$$

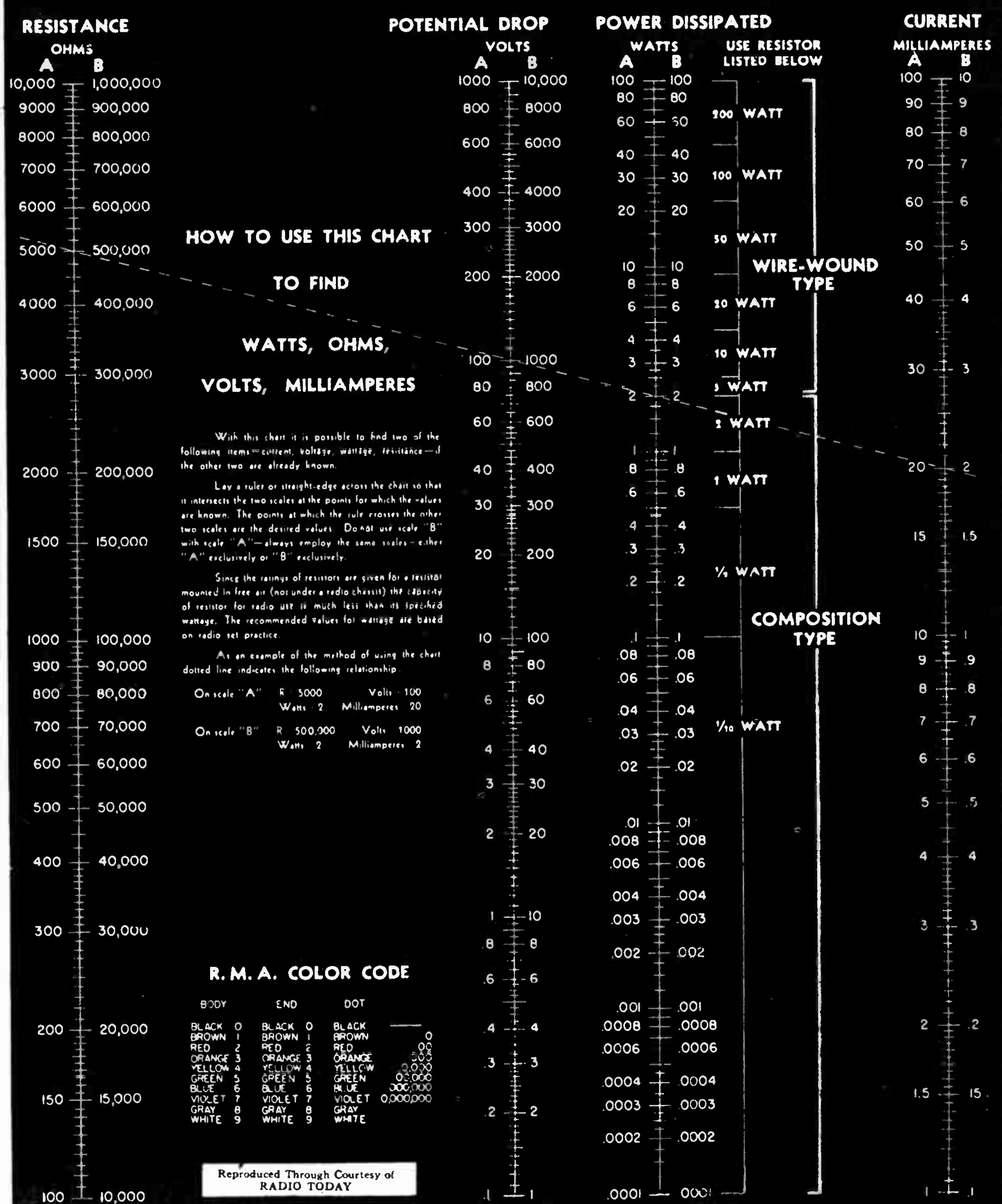
This means that the wattage is equal to the current multiplied by itself, and multiplied by the resistance. This formula is useful in finding the wattage dissipated (handled) by a resistor. For example, a current of 1.5 amperes passing through a resistor of 2 ohms, dissipates (1.5 x 1.5 x 2) or 4.5 watts. This power is actually lost as heat.

It is important in working on a radio circuit to have clearly in mind the relation existing between the different electrical factors. The Ohm's Law applies only to Direct Current, but is also applicable with certain modification to Alternating Current.

The resistance of any wire is directly proportional to its length. A piece of wire 10 feet long has twice the resistance of a similar piece 5 feet long. On the other hand, the larger the cross sectional area of the conductor the smaller is the resistance. The wire sizes are rated according to a number of different systems, but in the United States the B. & S. gauge is usually used. The larger the gauge number, the thinner is the wire. In radio work wire sizes from # 12 to # 38 are commonly employed. Wire is obtainable with different insulation such as enamel, cotton, silk, or the combination of these materials.

Carbon composition resistors are commonly employed in radio circuits. For conveniency in determining the size of a resistor in repair work, resistors are color coded according to a standard code adopted by the R.M.A. Three indications are employed: the body, the end, and the middle dot. Ten colors are used, one for each number from 1 to 9, and 0. The table below gives color figure code.

HOW TO TELL WHAT RESISTOR TO USE



HOW TO USE THIS CHART

TO FIND

WATTS, OHMS, VOLTS, MILLIAMPERES

With this chart it is possible to find two of the following items—current, voltage, wattage, resistance—if the other two are already known.

Lay a ruler or straight-edge across the chart so that it intersects the two scales at the points for which the values are known. The points at which the rule crosses the other two scales are the desired values. Do not use scale "B" with scale "A"—always employ the same scales—either "A" exclusively or "B" exclusively.

Since the ratings of resistors are given for a resistor mounted in free air (not under a radio chassis) the capacity of resistor for radio use is much less than its specified wattage. The recommended values for wattage are based on radio set practice.

As an example of the method of using the chart dotted line indicates the following relationship.

On scale "A"	R = 5000	Volts = 100
	Watts = 2	Milliamperes = 20
On scale "B"	R = 500,000	Volts = 1000
	Watts = 2	Milliamperes = 2

R. M. A. COLOR CODE

BODY		END		DOT	
BLACK	0	BLACK	0	BLACK	—
BROWN	1	BROWN	1	BROWN	0
RED	2	RED	2	RED	00
ORANGE	3	ORANGE	3	ORANGE	000
YELLOW	4	YELLOW	4	YELLOW	0,000
GREEN	5	GREEN	5	GREEN	00,000
BLUE	6	BLUE	6	BLUE	000,000
VIOLET	7	VIOLET	7	VIOLET	0,000,000
GRAY	8	GRAY	8	GRAY	
WHITE	9	WHITE	9	WHITE	

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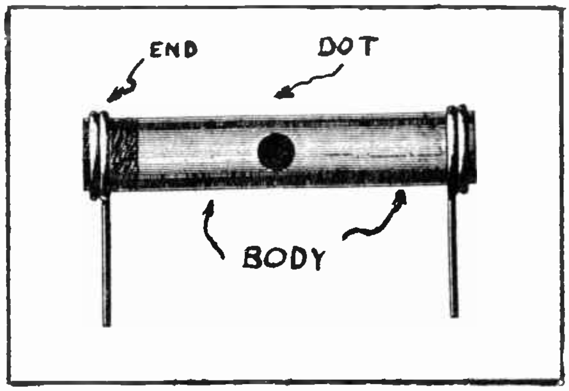
Figure	Color
0	Black
1	Brown
2	Red
3	Orange
4	Yellow
5	Green
6	Blue
7	Violet
8	Gray
9	White

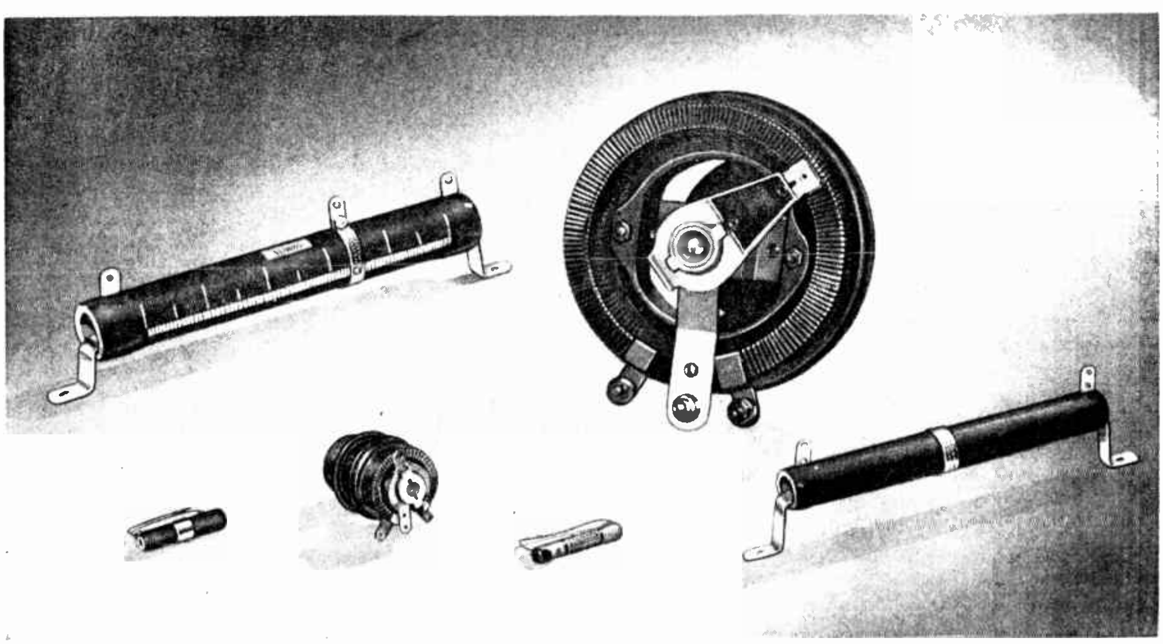


The body of the resistor represents the first figure, the end the second figure, and the dot the number of ciphers. For example, a 300,000 ohm resistor will have an orange body, black end, and an yellow dot to represent the remaining four ciphers.

Color codes have also been developed for other radio parts, such as condensers, but so far their application has been limited.

Besides being rated in ohms, every resistance possesses another electrical rating corresponding to its power handling ability or wattage. Composition-type carbon resistors are rated from $\frac{1}{4}$ to 2 watts depending on their size. Wire-wound resistors begin with about 5 watt size and go up to larger sizes.

The power dissipated by the resistor is changed to heat; if the heat is excessive due to overloading the resistor by more than just the normal current flow, the heat so developed may injure the resistor element. The rating commonly given is for open air mounting and where there are no close parts that may be injured by the heat. In mounting resistors in a closed chassis adjacent to other easily harmed parts, it is best not to load the resistors more than 50% of their rated wattage.



If a resistor of 3 ohms, carries a current of 2 amperes, what is the wattage dissipated?

$W = I^2R = 2^2 \times 3 = 2 \times 2 \times 3 = 12$ watts

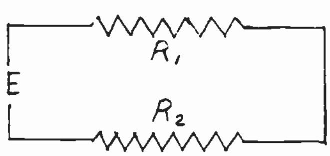
A biasing resistor causes a drop of 30 volts, with a current of 15 milliamperes (.015 amperes). What is the wattage of the resistor ?

$W = I \times V = .015 \times 30 = .45$ watts

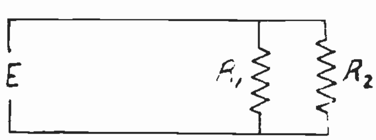
Rheostats have a single end terminal and a connection to the movable contact. Potentiometers have two end terminals and a movable arm. Volume controls are a form of variable resistors.

Resistances are used not only individually, but are combined in series, in parallel, and sometimes in more complex networks. The total resistance of two resistors R_1 and R_2 connected in series is the sum total of the individual resistances. In a like manner if more than just two resistors are connected in series, the total resistance is the sum total of all individual resistances. If we let R_s stand for the total resistance of a circuit having series resistances, than:

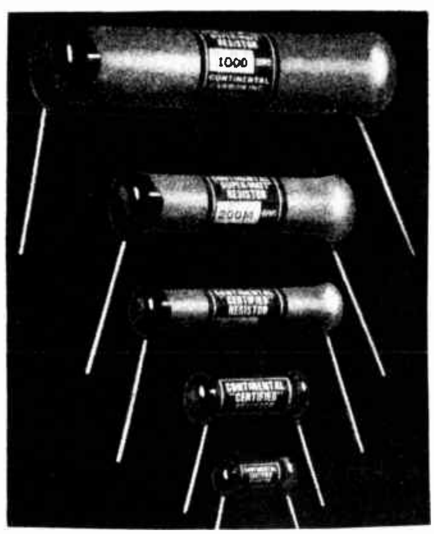
$R_s = R_1 + R_2 + \cdots$ (all the other resistors present)

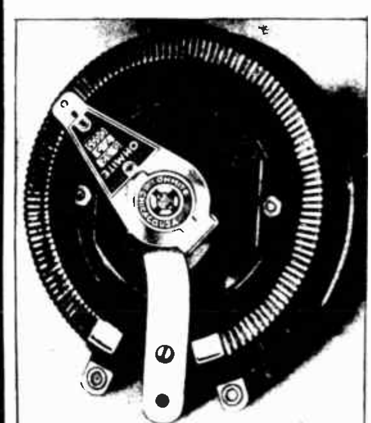


SERIES



PARALLEL





If in the series circuit above voltage E is impressed across the two resistors, the voltage drop across each resistor will be equal to IR_1, and IR_2, where I is the current. These two voltage drops together will equal to E.

$E = IR_1 + IR_2$

The larger voltage drop will be across the larger resistance, and by selecting proper sizes for R_1, and R_2, E may be subdivided in any way required. Care must be taken that neither of the resistors is overloaded. The wattage formula should be applied as a test.

In a four tube midget radio set, three tubes are of the type that require 6.3 volts each, and one requires 25 volts. All these tubes are connected in series and use a current of 0.3 amperes. The total voltage required to operate all these tubes in series is the sum of the individual voltages, or 43.9 volts. We can round this figure into 44 volts. If the set is to be used on a 110 volt line (110 - 44) or 66 volts must be lost in a series resistor. Recalling Ohm's Law and solving:

$E = I \times R_1$ $\quad$ $66 = 0.3 \times R_1$ $\quad$ $R_1 = 220$ ohms

What wattage will this resistor dissipate?

Using the formula $W = I^2R$

$$W = (.3)^2 \times 220 = .09 \times 220 = 19.8 \text{ watts}$$

A twenty watt resistor could be used, but a slightly larger size would be better. Sometimes line cords are built with the proper resistor already incorporated.

What is the total resistance of the four tubes in series?

$$R_2 = \frac{E}{I} = \frac{3(6.3)+25}{0.3} = \frac{44}{.3} = 146.7 \text{ ohms}$$

The table on the next page and the explanation below have been prepared by the Aerovox Corporation and is reprinted from the "Research Worker."

It is of course impossible to give the figure for all possible cases in a table. The nearest approach one can make to such an ideal is to provide a chart and even then it is difficult enough to cover the complete range and to obtain sufficient accuracy to be of any use.

Logarithmic divisions are the only ones which permit the coverage of a wide range keeping the accuracy the same percentage throughout the range. The given problem could be solved either by a chart of the "alignment" type (also called "abac" and "nomograph"), or by the one shown. Both have their advantages. The first one does not have the page so full of lines but it requires a straight-edge to get a solution. The second one does not require this: when two of the quantities: volts, milliamps, ohms or watts, are known the other two can be found immediately.

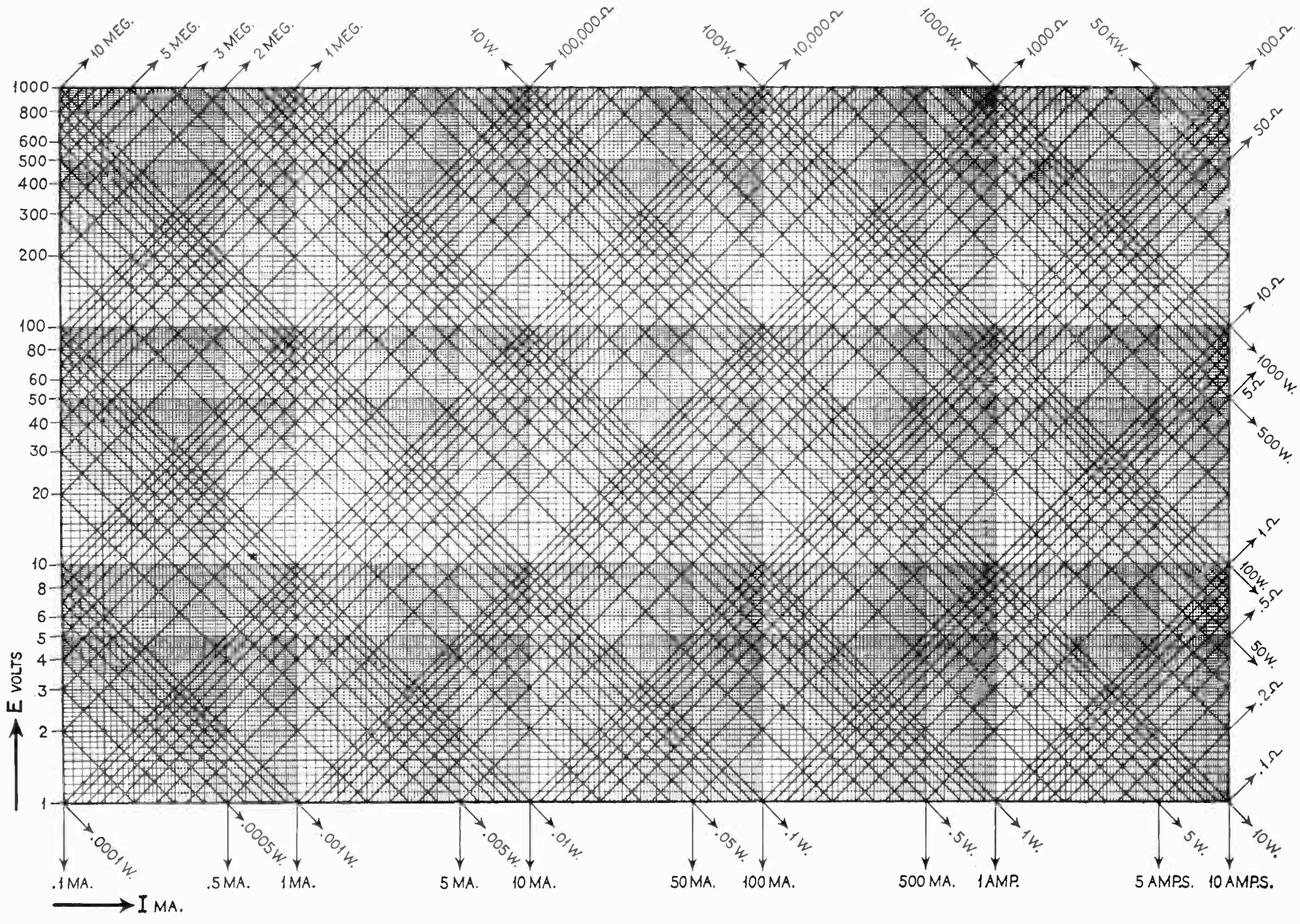
The chart covers a range which should be large enough for all radio work involving receivers and amplifiers. The ranges are from 1 to 1000 volts, from .1 ma to 10 amperes, from .1 ohm to 10 megohms and from .1 milliwatt to 10 kilowatts.

The lines are plotted on regular full logarithmic coordinate paper. Current is measured along the horizontal axis (X-axis) and volts along the vertical (Y- axis). When this is done, the locus of all points representing a given resistance will form a line making an angle of 45 degrees with the X-axis. All these lines are parallel, sloping upwards to the right. All points representing the same power are situated on a straight line which makes an angle of 135 degrees with the horizontal, sloping upwards towards the left.

USE OF THE CHART

A few examples will best illustrate the use of the chart. Suppose the e.m.f. in a circuit is 100 volts and the current is 100 ma.; what is the resistance and the power? Beginning with the 100 ma. mark on the horizontal axis, follow the vertical line to the intersection with the horizontal 100 volt line. This is also an intersection of the slanting lines. Following the one going upwards to the left read 10 watts; following the other, towards the right, read 1000 ohms.

A 5000 ohm resistor has a rating of 20 watts; what is the maximum current and corresponding voltage? Following the 5000 ohm line until the 20 watt line is reached. Follow the vertical lines down, and interpolating by estimation read 63 ma. Then follow the horizontal lines towards the left and read 316 volts.



10 MEG.
5 MEG.
3 MEG.
2 MEG.
1 MEG.
10 W.
100,000 Ω
100 W.
10,000 Ω
1000 W.
1000 Ω
50 KW.
100 Ω
50 Ω
10 Ω
1000 W.
5 Ω
500 W.
1 Ω
100 W.
.5 Ω
50 W.
.2 Ω
.1 Ω
1000
800
600
500
400
300
200
100
80
60
50
40
30
20
10
8
6
5
4
3
2
1
E VOLTS
.0001 W.
.0005 W.
.001 W.
.005 W.
.01 W.
.05 W.
.1 W.
.5 W.
1 W.
5 W.
10 W.
.1 MA.
.5 MA.
1 MA.
5 MA.
10 MA.
50 MA.
100 MA.
500 MA.
1 AMP.
5 AMPS.
10 AMPS.
I MA.

The total resistance of two resistors connected in parallel is less than the resistance of either resistor. For many resistors connected in parallel the total resistance

$$R_p = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots}$$

for only two resistors this formula simplifies to:

$$R_p = \frac{R_1 \times R_2}{R_1 + R_2}$$

In the preceeding diagram if we let $R_1 = 3$, and $R_2 = 5$ ohms,

$$R_p = \frac{3 \times 5}{3 + 5} = \frac{15}{8} = 1.875 \text{ ohms}$$

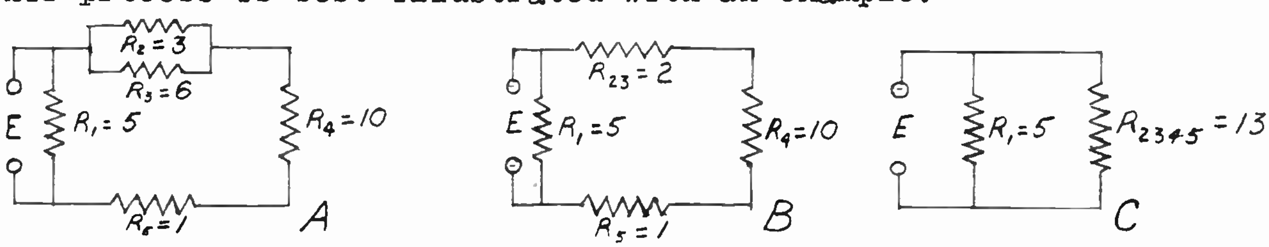
If a total current I_t flows in the circuit, only a fraction of this current will be in each resistor. However, the full voltage E will be across each resistor. The current in the resistors may be found from the formulas:

$$I_1 = \frac{E}{R_1} \qquad I_2 = \frac{E}{R_2}$$

and, of course, ... $I_t = I_1 + I_2$

The power handled by each resistor may be found easiest by applying the formula: $W = \frac{E^2}{R}$

In circuits where more complex combinations of resistances are present individual parts are solved separately and combined. This process is best illustrated with an example.



In circuit A, we may consider R_2 and R_3 as parallel resistors.

$$R_{23} = \frac{R_2 R_3}{R_2 + R_3} = \frac{3 \times 6}{3 + 6} = \frac{18}{9} = 2 \text{ ohms}$$

Now we can replace circuit A by B, placing a single resistor R_{23} in place of R_2 and R_3. Consider now R_{23}, R_4, and R_5 as a single series circuit.

$$R_{2345} = R_{23} + R_4 + R_5 = 2 + 10 + 1 = 13 \text{ ohms}$$

We now can replace B, with circuit C. This circuit is a simple parallel circuit having two resistances of 5 and 13 ohms.

$$\text{Total resistance } R_t = \frac{5 \times 13}{5 + 13} = \frac{65}{18} = 3.6 \text{ ohms}$$

This method of solving complex circuits is always used. While the steps may appear a little difficult the actual work is quite simple. The student should draw some circuits having resistors in series and parallel combinations, and solve these circuits for practice. The student may also examine the circuit diagrams in later lessons for actual examples of similar use of resistors.

MAGNETISM

Magnetic force plays a very important role in the operation of many radio components. Transformers of all types, phonograph pickups, loud speakers operate on the principle of magnetism. In other fields of electricity magnetism also is of a great importance. Being similar to electricity we cannot actually see or feel magnetism, but the effects of this force can be noticed and accurately measured.

There are certain natural magnets found already magnetized. If a piece of hard steel is stroked continuously in the same direction with a piece of natural magnet, the stell will become nagnetized. For practical use small percentage of nickel, chromium, cobalt, or tungsten are added to steel for making permanent magnets that have greater magnetic strength and other desirable properties.

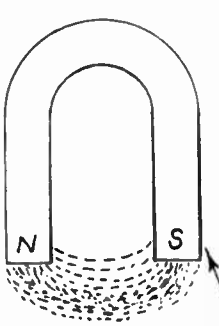
Just as in the case of electrical charges,

UNLIKE MAGNETIC POLES ATTRACT EACH OTHER

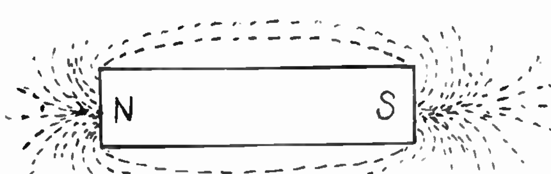
LIKE MAGNETIC POLES REPEL EACH OTHER.

Also it is important to remember that the force of attraction or repulsion between two magnets is inversely proportional to the square of the distance. A north and south magnetic poles will attract each other four times as much at 1 inch distance, as at 2 inch distance. This is why the space between the field and the armature in a generator is made as small as practical.

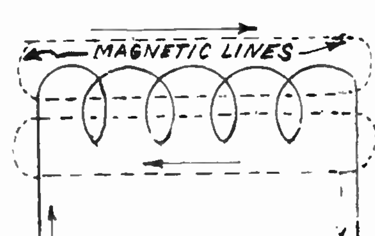
If either end of a bar magnet is dipped in iron filings, most of the filings stick to the pole indicating that the attractive force is the greatest at the poles. This magnetic effect is noticable for a considerable distance around the magnet. This force constitutes the magnetic field and is made up of lines of force. The filings around the magnet follow the lines of force.



HORSE SHOE MAGNET



BAR MAGNET



ELECTRIC CURRENT

If a strong magnet is dipped in a barrel of nails made of soft iron, many nails will be picked up. Some nails in turn will hold other nails becoming themselves temporary magnets. However, once these nails are removed from the magnet, their magnetism will be lost. Hardened steel substances on the other hand will retain some magnetism once they are brought into contact with a magnet.

ELECTROMAGNETISM

Although many devices employed in radio circuits depend on permanent magnets for their operation, magnetism produced by the flow of electric current through a conductor finds even greater application. Every wire carrying electric current has an associated magnetic field proportional to the current strength and the arrangement of the wire.

The fact that an electric current in a conductor has an associated magnetic field may be easily proven. If a compass is held near the wire the needle of the compass (actually a small magnet on a pivot) will take a position at right angles to the wire. If no current is present in the wire, the needle will assume its natural N - S position.

An electromagnet is made by winding a number of turns of wire in the form of a coil, a much stronger magnetic field can be created since the fields of all the individual turns will add up. Since the magnetic field of force of each turn adds to that of the next turn, the greater the number of turns of wire the coil has, the stronger will be the magnetic field.

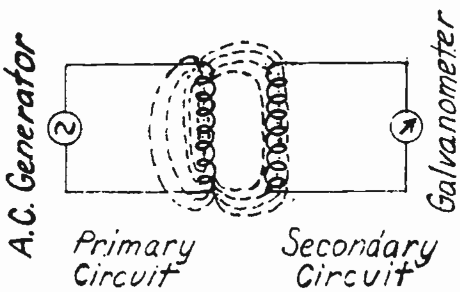
The total magnetic flux (lines of force) depends on the number of turns and the current strength. If the current is strong, relatively few turns of thick wire will be needed to produce a given magnetic field. On the other hands, if the current is very minute a great many turns of fine wire will be needed.

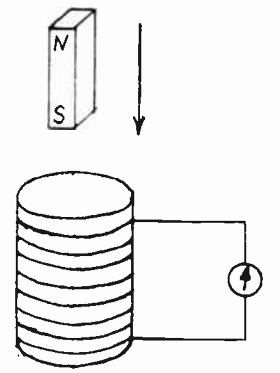
If a bar of iron is placed in the center of the coil, the iron will become magnetized when the current will flow through the coil, but will loose its magnetism once the current is stopped. This principle is used to operate relays, door bells, and other devices.

After a certain value, the effect of the applied electro-magnetizing force will be diminished and, if the force is increased beyond definite limit, no further effect will be noticed. The substance is then said to be <u>saturated</u>. For example, Wrought Iron will have a very strong flux when inserted in a coil of 10 ampere-turns. Increasing this to 20 ampere-turns only increases the lines of force per square inch from 89,000 to 97,000. At 40 ampere-turns this figure is only 106,000 lines per square inch. Saturation is reached when a further increase in <u>ampere-turns</u> has no effect on the flux.

ELECTROMAGNETIC INDUCTION

We have learned that an electrical current in a conductor sets up an associated magnetic field. If a conductor, connected to some indicating instrument such as a sensitive galvanometer, is moved across the magnetic field of a permanent magnet a current will be noticed to exist in the circuit. The current will only be present while the motion continues and will be proportional to the rate of motion, the number of turns of wire being swept across, and the total flux or the number of lines of force. This principle of current generation is employed in all electrical dynamos.

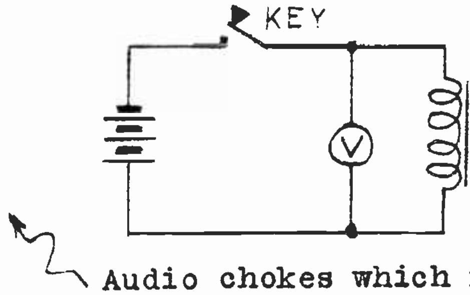




It is also possible to induce a current in one conducting circuit by means of the magnetism produced by the current flowing in another associated, but not electrically connected circuit. The flux set up by the first circuit induces a current in the second circuit. This action takes place only while the current in the first circuit is changing (increasing or decreasing: as in the case when the first circuit is connected to a source of Alternating Current (A.C.) that is periodically rising and falling. The circuits must be located closely together, that is coupled. A device used to transform electrical energy by induction is called a transformer. A transformer does not create energy, it simply separates two circuits, or steps up or down voltage. When any voltage is stepped up by means of a transformer, the current correspondingly in the same ratio is stepped down.

The coil receiving the original current is called the primary, and the coil in which the current is induced by electromagnetic induction is called the secondary. In the illustration it is evident that since only a part of the lines of force set up by the primary link the secondary coil, the current induced is not as great as would be in case all the lines of force linked the secondary. The lines of force not linking the secondary and, therefore, not being useful are termed the leakage flux. To keep the lines of force in the desired path soft steel material is used for the core. Usually thin sheet laminations are employed to reduce losses.

Transformers and inductors having air cores are used in radio receiving circuits where the frequencies encountered are very high and would create heavy losses due to eddy currents and hysteresis if iron cores were used. Where the frequencies are relatively low as in the case of audio frequencies (commonly employed 30 to 12,000 cycles per second) and power frequency of 60 cycles, iron laminated cores are used.



Audio chokes which may be used in this test.

SELF INDUCTION

An electric current flowing through a conductor sets up a magnetic field around the wire. If the current is varied, the magnetic field also varies correspondingly. This varying field sets up in the wire itself, a counter or self-induced e.m.f. which opposes any changes. A voltmeter connected in the battery circuit illustrated above to the right, will indicate the battery voltage when the key is closed. Upon again opening the key, the voltmeter will momentarily indicate a large diflection (voltage) in the opposite direction. This action indicates that the magnetic lines of force around the coil have broken down to refrain the current of the coil from changing. This effect is similar to that of inertia found in mechanical devices. Inertia tends to oppose any changes in the speed or direction of motion. The effect of self-induction is especially noticeable in a solenoid (coil) since the inductance is consentrated in a small space. The unit of inductance is the Henry. The symbol for inductance is L.

The Henry is a relatively large unit and while some audio coils having special iron cores have an inductance of several hundred henries, the inductance encountered in coils used in radio frequency work and having air cores is only a small fraction of a henry. One/thousand of a henry is a millihenry, and one/million part of a henry is called a microhenry. Coils used for tuning the broadcast frequencies are in the order of 250 microhenries.

Inductive coils may be connected in series, in parallel, and in other combinations without the magnetic fields interlinking to any degree. When inductors are connected in series, the total effective inductance is the sum total of the individual inductances.

P E R M E A B I L I T Y

If a coil having an air core has a given current passing, a magnetic flux of a certain value will be produced. If an iron core is slipped in, replacing the air core, the electromagnet so formed will have a flux 200 times as strong. By using special nickel-iron material for the core, the strength can be made even greater. The ratio of the strength of the magnetic field with a given substance to the strength of the field when air is used as the core is the permeability. The permeability of air is taken as 1, all magnetic substances have a permeability greater than one.

REVIEW QUESTIONS

1. What does the prefix "milli" mean?

2. Since each cell in a "B" battery generates $1\frac{1}{2}$ volts, how many cells are connected in series to produce the full voltage of 45 volts? Do you understand why a "C" battery has $4\frac{1}{2}$ volts and not 5 volts?

3. Rewrite the following decimals as fractions: 0.5 , 4.25 , .05 , 2.3 , and 0.1 .

4. Rewrite the following fractions as decimals: 1/10 , 3/100 , 3/50 , 3/2 , and 1/3 .

5. What is the square root of 81? Of 49? Of 2.25?

6. In a 110 volt D.C. circuit an electric bulb takes 1/2 ampere of current. What is the resistance of the bulb? (Use the Ohm's Law relation.)

7. A 100 ohm resistor is connected across a 10 volt battery. What current is being taken from the battery?

8. In Question 7, what power is being used?

9. Examining a radio circuit, estimate the current in the various resistors and calculate the voltage drops and power dissipated. You may use the chart for this purpose.

10. If a 12 ohm and a 6 ohm resistors are connected in series, what is the equivalent resistance?

11. If a 4 ohm and a 8 ohm resistors are connected in parallel, what is the equivalent resistance?

12. Make up your own complex circuit of resistors and solve it following the example given in the text.

13. On what two factors does the magnetic flux depends?

14. Make a sketch of a buzzer and battery and explain how this unit operates?

15. How are power transformers made? What materials are used and how does the transformer operate?

16. What effect does a choke coil have upon the changing current in a circuit?

17. If two inductive coils are connected in series and also have their magnetic fields linked, what is the equivalent inductance? Remember that besides the self inductance of each coil, the mutual inductance may add or subtract.

LESSON 5

RADIO FREQUENCY INDUCTANCES

MUTUAL INDUCTANCE

In the section on Self-Inductance, above, the definition of "Self-Inductance," and the properties thereof were briefly explained. If, in the example of the bunched winding, half of the turns formed one circuit and the remaining half formed another circuit, a change in magnetic flux occasioned by a change in current in one winding, would induce two voltages, one in its own winding opposing the change in current, and the other in the second coil. This phenomenon of a voltage induced in the turns of one coil by a change in current in another coil is known as "Mutual Inductance."

The unit of Mutual Inductance is the "henry" defined as that value of mutual inductance in which one volt is generated across the terminals of one coil when the current in the other coil is changing at the rate of one ampere per second.

The practical units for Mutual Inductance are the same as those for self inductance, namely the Henry, Millihenry and Microhenry.

A very convenient property of mutual inductance is that the mutual inductance existing between two dissimilar coils is the same, whether the current change is in the large coil and the voltage is measured in the small one or vice versa, regardless of how dissimilar the coils may be.

This phenomenon called mutual inductance makes the formulae for inductances in series or in parallel much different from the formulae for resistances. In the latter case, the equivalent resistance of two resistances in series is the sum of the individual resistances; but in the case of two inductances in series, there may be a mutual inductance between the coils that may seriously disturb that simple relationship. If the two coils are placed so that the wires of one coil and those of the other coil occupy practically the same space, as in the case of winding the second coil as a single layer directly over the first single layer coil, or between the turns of the first coil, the overall inductance of two equal coils wound as above, will be twice the sum of the inductances of the two individual coils, if the coils are connected "Aiding" and will be practically zero if connected "Opposing." This is a special case which seldom occurs, but shows one of the extremes of mutual inductance which can influence the equivalent inductance of two coils connected in series.

The general expression for any case involving only two coils in series is: overall inductance equals the sum of the individual inductances plus or minus twice the mutual inductance. The reason for this relationship is given in the following explanation.

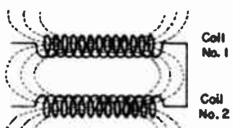


Figure 1

A current change in coil No. 1 induces in itself a voltage proportional to its inductance, and similarly in coil No. 2 a voltage proportional to the inductance of coil No. 2. The current change in coil No. 1 induces a voltage in coil No. 2 proportional to the mutual inductance between the two coils, and similarly the current change in coil No. 2 induces a voltage in coil No. 1 of the same magnitude because the mutual inductance is the same whether measured from the first to the second coil, or in the reverse direction. The overall inductance is proportional to the total voltage induced, and is consequently equal to the sum of the individual inductances plus or minus twice the mutual inductance. The "plus or minus" provision is made because the voltage induced in one coil by a current change in the other does not necessarily aid the self-induced voltage in the coil. Inductances themselves are positive, there being no negative inductances; nor, strictly speaking, are there any negative mutual inductances; but a mutual inductance may be connected into a circuit so that its effect may oppose some other effect and can be considered as a negative mutual inductance *when so connected.*

The maximum value of mutual inductance that can exist between two coils is equal to the square-root of the product of the two individual inductances. In practice it is very difficult to obtain sufficiently close coupling to produce this limiting value unless the two coils are wound together, the wires from both circuits being wound on the coil simultaneously.

COUPLING COEFFICIENT

When two coils are arranged so that some definite mutual inductance exists, the coils are said to be magnetically coupled.

In many calculations, it is frequently convenient to express the amount of coupling as a percentage of the maximum that could possibly exist, rather than a numerical value of mutual inductance. In such a case, the term applied to this percentage is "coupling coefficient" which, for inductance, is defined as the quotient resulting from dividing the existing mutual inductance by the maximum possible mutual inductance (square-root of the product of the two separate inductances).

DESIGN OF RADIO COILS

Since almost all radio-frequency coils operate in resonant circuits, the coils must be designed for three important characteristics — inductance, distributed capacity, and losses.

For simple geometric forms such as the solenoids, formulae are available in many text books for calculating the above mentioned characteristics, but for universal wound coils no satisfactory formulae exist for any one of the three quantities. Within limits, the inductance and distributed capacity are practically constant with frequency, but the losses change with frequency, requiring different designs for minimum losses in coils of the same inductance but operating at different frequencies. This is the reason for the great amount of design work required on radio-frequency coils.

The losses in a coil may be divided into the following classes:

1 — Ohmic or D.C. losses in the wire
2 — Eddy-current losses in the conductor
3 — Eddy-current losses in the shield
4 — Eddy-current losses in the core material
5 — Skin effect
6 — Dielectric loss in the wire insulation
7 — Dielectric loss in the terminal strip

None of these items is independent of the others, and a change to improve one usually changes one or more of the remaining factors.

Considering the sources of loss in the order named above, the D.C. or ohmic resistance of a coil can be reduced by increasing wire size, in which case the coil becomes larger, and, in the case of shielded coils, brings the coil closer to the shield, which consequently increases the shield losses. In addition, because the copper cross section increases, permitting higher eddy-voltages to be generated, the eddy-current losses in the conductor increase.

The eddy-current losses in the conductor are minimized by subdividing the conductor as finely as is economical, insulating each of the subdivided parts from all other parts. Commercially, this is done by the use of so-called Litz (Litzendraht) wire, which consists of many strands of fine wire, each strand individually insulated with enamel, and the group of wires covered with some insulation, usually fabric, although sometimes enamel, paper, or other covering is used over the group.

Eddy-current losses in the shield are minimized by using a shield as large as possible, or large enough so that further increase in diameter produces no improvement, and by the choice of shield material of the lowest economical specific resistance. The shield materials in common use are copper, aluminum and zinc, named in the order of their merit. Magnetic alloys, such as sheet iron or silicon steel, are very high in R F losses.

A peculiar phenomenon with regard to composite shields is that whenever a shield is made of two closely bonded materials, the characteristics of the shield approach the characteristics of the poorer material. For example, a copper plated steel shield is almost as bad as an all steel shield of equal dimensions even though the plating is commercially heavy.

Iron cores are frequently used in coils to increase the effectiveness of the turns of wire, thereby permitting a given inductance to be obtained with fewer turns, and consequently with lower D.C. resistance. The core itself introduces some eddy-current losses which partially offset the improvement made by reducing the number of turns. In some cases (usually above 6 megacycles) the introduction of even the highest grade of powdered iron cores results in an increase in losses rather than a decrease.

A very important and frequently unsuspected contributor to coil losses is the insulation of the wire. Analyzing a coil, it will readily be apparent that the fabric insulation on the wire is the dielectric of the distributed capacity of the coil. The losses in the insulation influence the coil just as surely as would an external condenser of the same capacity connected across the coil, having the same fabric for a dielectric. With this in mind, many coil designs have been improved by increasing the thickness of fabric insulation, thereby reducing the distributed capacity and consequently its detrimental effect. In many cases, this effect was so important that increasing the insulation thickness resulted in improvement in the coil even though smaller wire was used to give space for the insulation!

In considering the distributed capacity of a coil it must be remembered that, in many instances, the terminals on the coil contribute an important part to the distributed capacity, and that the losses in the terminal strip should not be neglected. On some coils of high quality, hard rubber terminal strips are used to minimize the losses occasioned by the terminal strip.

Since all of the losses in a coil taken together make up the radio frequency resistance of the coil, a single number can be used to express this quantity, but the resistance alone does not give sufficient information to judge the electrical excellence of the coil. Resistance is usually the undesired quantity in a coil, and practically all coil designs attempt to make it as low as possible. Reactance is the desired characteristic of the coil and is the product of frequency, inductance and the usual multiplier, 2π. A special term has been given to the ratio of the desired to the undesired characteristic of the coil. This term is "Q" which is defined as the reactance divided by the resistance.

ANTENNA COILS

The basic types of antenna coils have high-impedance inductive, high-impedance capacitive, low-impedance inductive and low-impedance capacitive couplings. Typical values of capacity, self inductance and mutual inductance for these four types of broadcast coils are shown in Fig. 3.

HIGH-IMPEDANCE PRIMARY

High-impedance magnetic coupling, usually spoken of as "High-Impedance Primary" is the most universal type of coupling on the broadcast range of household receivers. It has good image ratio, reasonable gain, and, when properly designed, almost negligible misaligning of the first tuned circuit as the size of antennas is changed. With the usual design of coil, this type of coupling results in higher gain at the low-frequency than at the high-frequency end of the tuning range. Sometimes, to compensate for this deficiency at the high frequency end, a small amount of high-impedance capacity coupling is used. This capacity is connected from the antenna to the grid terminals of the coil. Its size is from 3 to 10 MMF.

It is to be noted that capacity coupling can reduce as well as raise the gain of a high-impedance magnetically coupled transformer, depending upon the polarity of the windings. **If capacity coupling is to aid the magnetic coupling, a current entering the antenna terminal of the primary and the grid terminal of the secondary must go around the coil form in opposite directions, and the coupling capacity must be connected between these two points.**

LOW-IMPEDANCE PRIMARY

Antenna coils with low-impedance primaries, although cheaper to manufacture than high-impedance primaries, are rare on the broadcast band of modern home radio receivers.

This type of coupling, when used with any of the conventional household antennas, gives a great deal more gain at the high-frequency end than at the low-frequency end of the tuning range. This gives rise to very poor image-ratio when used in a superheterodyne receiver.

The closely coupled low-impedance primary reflects the antenna capacity across the tuned circuit in an amount depending upon its inductance and coupling coefficient. Without attempting to derive an expression for the actual magnitude of this effect, suffice it to say that if the primary is large enough to give reasonable gain at the low-frequency end of the frequency range, the reflected antenna capacity will be so high that the secondary tuning condenser will not be able to tune to the high-frequency end of the band, and every different antenna capacity would change the amount of mistracking. Because of this sensitivity to changes in antenna capacity, and because of poor image ratio, the low-impedance primary is seldom used on broadcast-band antenna coils.

On short-wave coils, the low-impedance primary is used almost exclusively because the antenna gain is usually higher than with a high-impedance primary, and the antenna is usually resonant in or below the broadcast band. For this reason, the image-ratio does not suffer nearly as much as in the case of using low-impedance broadcast coils in place of coils with high-impedance primaries.

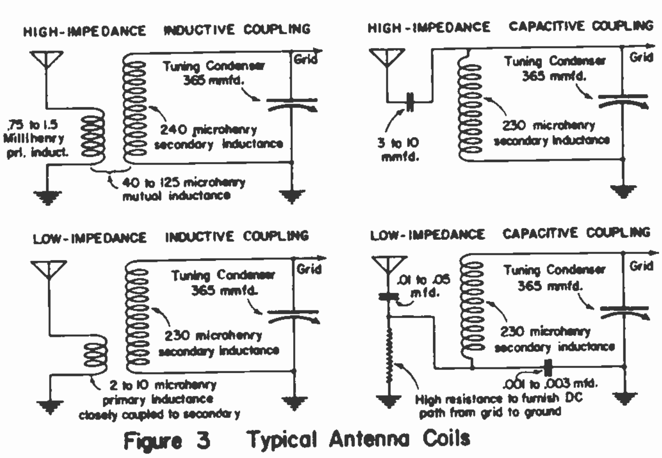


Figure 3 Typical Antenna Coils

HIGH-IMPEDANCE CAPACITY COUPLING

The high-impedance capacity coupling scheme consists essentially of connecting the antenna directly to the grid end of the first tuned circuit through a capacity, usually from 1 to 10 mmf. This method of coupling has been popularly used on amateur receivers of simple design, where simplicity of coil construction was imperative, but is not used in broadcast receivers by recognized manufacturers because of the very poor image-ratio that results.

Practically speaking, the only use for high-impedance capacity coupling in a broadcast receiver is as reinforcement to a high-impedance primary, as discussed in the paragraph on "High-Impedance Primaries."

LOW-IMPEDANCE CAPACITY COUPLING

Low-impedance capacity coupling, familiarly known among radio engineers as the Hazeltine coupling system, consists of coupling the antenna directly to the junction of the low side of the tuning inductance with the high side of a high-capacity coupling condenser which is connected to ground. (See Fig. 3.) The voltage across this coupling condenser is multiplied by the resonance phenomena of the tuned circuit to give appreciable voltage at the grid.

This circuit is particularly adapted to receivers that must use a high-capacity shielded lead-in such as an automobile radio receiver. In such a circuit, the shielded lead-in is made part of the coupling capacity because of the circuit arrangement and, practically speaking, causes no loss in voltage as would be occasioned if this capacity would be connected across a high-impedance primary. For this statement to be strictly true, it is necessary that the shielded lead-in have a good power factor or else the losses in the lead will slightly reduce the effective circuit "Q," thereby bringing down the gain in the antenna coil by a corresponding amount.

This type of coil has high gain and excellent image-ratio. The drawbacks to its use are that the R.F. amplifier circuit, if used, must have a value of capacity included in its tuned circuit equal to the antenna coupling capacity in order that proper tracking may result.

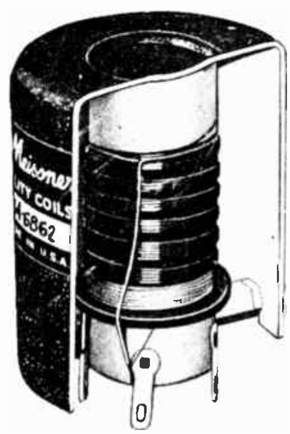
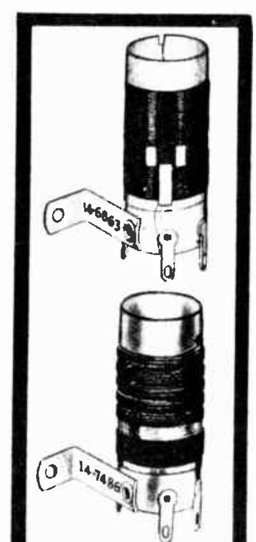
An alternative is to use a tuning condenser whose antenna section is different than its R.F. section, but this can only be done where a heavy production schedule justifies the additional tool cost.

When this coupling scheme is used in household radio receivers, precautions must be taken to prevent 60-cycle hum modulation from being introduced into the first tuned circuit by low-frequency voltages picked up on the antenna circuit. In the best of receivers employing this circuit, an R.F. choke is connected from antenna to ground to provide a low impedance path for power frequencies in order to keep hum modulation off of the grid of the first tube.

R. F. COILS

R.F. coils may be divided essentially into four types: high-impedance magnetic, low-impedance magnetic, high-impedance magnetic with high-impedance capacity coupling, and choke-coupled circuits.

The high-impedance magnetically coupled R.F. coil has characteristics very similar to the high-impedance antenna coil and therefore needs little discussion.

Antenna Coils
Meissner make.

The low-impedance magnetically coupled R.F. coil has the same deficiency as the similar antenna coil and is consequently seldom used in the broadcast range of a superheterodyne receiver. Like the antenna coil, it has possibilities for higher gain than the high-impedance type, but usually the selectivity is enough worse to rule out this type of coupling on modern receivers.

In the shortwave range, this is the most popular type of circuit, because it is the one giving the highest gain and since, with a fixed capacity of gang condenser, it becomes increasingly more difficult to obtain high gain as the frequency is increased, this circuit with its high gain is the almost universal choice in spite of its deficiencies in image-ratio.

The R.F. coil employing a high-impedance primary in combination with high-impedance capacity coupling is the most flexible design, and is popularly used for that reason. By shifting the primary resonant frequency and by changing the amount of capacity coupling together with changes in "Q" of the secondary circuit, the overall gain of an amplifier stage can be made to have almost any desired shape with respect to frequency; that is, it may give high gain in the middle, at the high-frequency end, at the low-frequency end, or almost any shape desired, to compensate for the frequency characteristics of the other stages employed in the receiver.

The choke-coupled R.F. circuit is very similar to the high-impedance primary with high-impedance capacity coupling, except that, in choke coupling, the magnetic coupling has been made zero, but design still requires that the choke have as much inductance as a primary would have, in order that the resonance of the primary circuit may fall outside of the tuning range of the secondary.

OSCILLATOR COILS

Oscillator coils in modern receivers exhibit less variation in types than any other R.F. component. They either do or do not have a "tickler."

Those oscillators that do not have a tickler coil, oscillate by virtue of the feedback across the padding condenser. A typical circuit of such an oscillator is shown in Fig. 4. Using a 456 KC IF system requiring relatively small padding condensers makes this type of operation possible. The only bands that have padding condensers small enough to sustain oscillation are the long wave and broadcast bands. In some instances the range 1500 to 4000 KC can be made to oscillate if a very high Q coil is used with a tube of high mutual-conductance, but much more reliable results will be obtained on this band with the conventional tickler feedback, shown in Fig. 5.

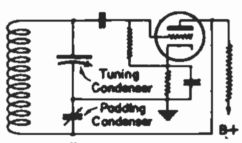


Figure 4

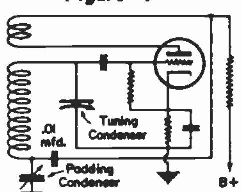


Figure 5

IF TRANSFORMERS

Intermediate-frequency transformers used in radio receivers have taken a variety of forms and have operated at many different frequencies. They may be divided into several classes according to the number of selective circuits: untuned or self-tuned, single-tuned, double-tuned, and triple-tuned. Receivers have employed IF transformers with more than three tuned circuits per transformer but such cases are very rare.

The untuned IF transformer usually added practically no selectivity to a receiver. Its principal purpose was to give a high amplification at very little cost. It was always used in conjunction with one or more tuned IF transformers which supplied the required selectivity.

SINGLE-TUNED IF TRANSFORMERS

The single-tuned IF transformer has taken two important forms, the bi-filar coil and the double coil types.

In the former case, the two wires constituting primary and secondary are wound simultaneously, forming a coil that is a single physical unit yet having two independent circuits. The start of the primary was usually the plus "B" connection and the start of the secondary was ground. The outside of the primary was the plate connection and the outside of the secondary was the grid connection. These transformers were characterized by very high gain and comparatively little selectivity. They were used on receivers that had no A.V.C. and the secondary low-potential end usually connected directly to chassis. Such a transformer could not be used satisfactorily in a receiver employing the conventional diode type A.V.C. circuit for the reason that on damp days there is enough leakage between primary and secondary to produce a decidedly positive bias on the grids of the automatically controlled tubes.

In addition, such a structure possesses such a high capacity between windings that the ripple in the "B" supply would be transferred to the diode load resistance which would produce a bad audio hum in the output of the receiver. A third reason why this type of transformer would not now be acceptable, even if there were no diode load resistance to pick up hum or to be incorrectly biased, is the frequent failure of windings due to electrolytic corrosion. Where two conductors are run so intimately parallel for so many turns, with opposite D.C. potentials applied to the two wires, ideal conditions are set up for rapid failure due to electrolytic corrosion in the presence of moisture.

With this transformer redesigned to have two physically separate coils wound side by side, the objectionable features of leakage, corrosion and hum transfer are reduced to a very small per cent of their original importance, and transformers acceptable in today's critical market can be produced. The largest remaining objection to the single-tuned transformer is selectivity. In a low-frequency amplifier operating at 125 KC or 175 KC, the transformers are too sharp for good audio fidelity, and at the higher intermediate frequencies such as 456 KC, the transformers do not add sufficient adjacent-channel selectivity.

Single-tuned transformers may be divided into two classes according to the circuit tuned; some have their primaries tuned while the remainder have their secondaries tuned. As far as secondary voltage is concerned, there is not a great deal of difference regardless of which winding is tuned, but if there is a question of single-stage oscillation in the tube driving the single-tuned transformer, greater stability is had by tuning the secondary than by tuning the primary.

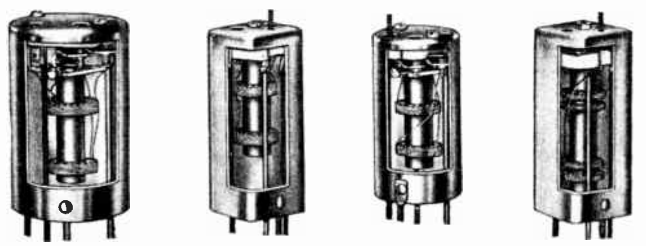
DOUBLE-TUNED IF TRANSFORMERS

The double-tuned IF transformer is, by far, the most popular type. It is simple in construction, has negligible leakage, no measurable hum transfer into diode circuits and can have its selectivity curve made as sharp as two single-tuned transformers in cascade, or can be considerably broader at the "Nose" of the selectivity curve than two cascaded single-tuned transformers, yet on the broader part of the selectivity curves maintain practically the same width as the cascaded single-tuned transformers.

If the coupling on a double-tuned transformer is made sufficiently loose, the transformer is quite selective and has a resonance curve of the same general shape as a single circuit, except sharper. As the coupling is increased, the gain will go up until the point of "critical coupling" is approached where the gain of the transformer is practically constant but the selectivity curve is changing, particularly at the "nose" of the curve. As the coupling continues to increase, first there is a decided flattening on the nose of the selectivity curve, after which continued increase in coupling produces an actual hollow in the nose of the curve. Still greater increase in coupling can spread the two "humps" and deepen the "hollow" in the nose of the response curve until a station can be tuned in at two places on the dial very close together.

Variations in magnetic coupling cause variations in the gain and selectivity of IF transformers as described above, but this is not the only source of variation. Variations in capacity coupling can be equally important in transformers operating above 400 KC. This variation is so important that it is discussed separately in the section "Capacity Coupling in IF Transformers."

The complete selectivity characteristics of any circuit can be shown only by a curve from which it is possible to determine the performance at any point, but nearly as much useful information can be given in a few figures where the selectivity of IF transformers is concerned.



TRIPLE-TUNED IF TRANSFORMERS

Triple-tuned IF transformers have been used for two general purposes: greater adjacent-channel selectivity without increasing the number of tubes and transformers, or a better shape on the nose of the selectivity curve to produce better audio fidelity than is produced by double-tuned transformers.

CAPACITY-COUPLING IN IF TRANSFORMERS

The ordinary circuit diagram of a double-tuned IF transformer is as shown in Fig. 6, but actually the circuit in Fig. 7 is more representative of true conditions.

The capacity coupling, shown in dotted lines, is a very important part of the coupling in practically all transformers operating at frequencies above 400 KC. This statement applies with even greater emphasis as the frequency, or the "Q," of the coils is raised.

The capacity that is effective in the above mentioned "capacity coupling" is that which exists between any part of the plate end of the primary circuit and any part of the grid end of the secondary circuit; to be more specific, the capacity between the plate and grid sides of the trimmer condensers, the plate and grid ends of the coils, the plate and grid leads, the grid lead and the plate end of

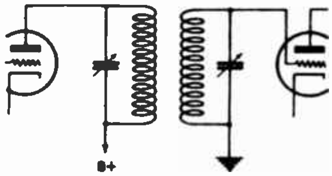


Figure 6

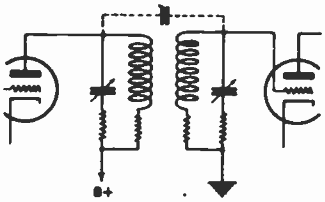


Figure 7

the primary coil, and between the plate lead and the grid end of the secondary coil.

The capacity between the two high-potential plates of a trimmer condenser such as the Meissner unit shown in Fig. 8 is 0.35 mmfd. if both trimmers have an even number of plates and the bottom plate of each trimmer (on the same base) is a high-potential (either grid or plate) electrode. If an odd number of plates is used on both trimmers, the capacity drops to 0.07 MMF. The difference between these two coupling capacities, amounting to only 0.28 MMF. is sufficient to make quite a difference in the gain of transformers operating above 400 KC.

Figure 8

Double-tuned IF transformers may be built with the magnetic coupling either aiding or opposing the capacity coupling. For reasons of production economy, both coils on one dowel are usually wound simultaneously, which means they must be wound in the same direction. For reasons of production uniformity, the insides of both windings are usually chosen as the high-potential ends of the coil so that the outside (low-potential) ends of the coils will automatically act as spacers to keep the high-potential hook-up wires from approaching the high-potential ends of the coils.

Triple-tuned IF transformers, particularly output transformers where diode and plate leads both pass through the open end of the shield can, are particularly subject to gain and selectivity variations as a function of variation in capacity coupling.

As an example, in a particular triple-tuned output transformer where the plate and diode leads ran close together, it was found that in attempting to align the transformer, the middle circuit was effective as long as either the input circuit or the output circuit was out of tune, but as soon as both input and output circuits were aligned, the center circuit had a very peculiar action. If the gain of the transformer is plotted against the capacity of the middle circuit, a curve similar to Fig. 11 was obtained. From this it is seen that there is one adjustment (A) that produces an increase in the overall amplification of the transformer. At this point the center circuit is contributing to the selectivity of the transformer. At another point (B) the amplification through the center circuit opposes the capacity coupling from the input to the output winding and results in a considerable decrease in amplification. At all other settings of its tuning condenser, the center circuit is so far out of resonance that it has no effect upon the gain of the transformer, which for all practical considerations, may be assumed to be a double-tuned capacity-coupled transformer. When the capacity between the high-potential input and output leads was reduced to a very low value by keeping the leads in opposite corners of the shield can, the transformer behaved as a triple-tuned transformer should, with all three circuits effective.

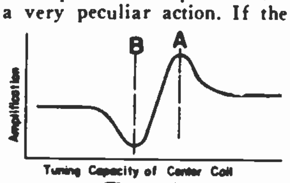


Figure 11

TRACKING

Early models of radio receivers usually used only one tuned circuit per receiver, but as the number of circuits was increased to provide better selectivity, tuning a radio set became a problem beyond the grasp of the average citizen, and confined the sale of receivers to the "DX" hunter who spent innumerable midnight hours listening for new stations.

To make the receivers commercially more acceptable, simplifications in tuning were imperative. To this end, designs were produced that had a nominal single-dial control with an "antenna compensator" to produce maximum results. Such receivers were essentially single-dial control over a limited frequency range, but required an adjustment of the antenna compensator when passing from one end of the tuning range to the other. This simplification in tuning permitted general merchandising of radio receivers to the average citizen.

In order to make such receivers possible, it was necessary for the condenser manufacturer to produce tuning condensers with several individual condenser-sections on one shaft, in which, at any point in its rotation, the several sections of the condenser were practically identical in capacity, and the radio manufacturer was required to produce coils that had practically identical characteristics.

Given identical condenser sections and identical coils, it is obvious that the resonant frequencies of the several identical combinations of coils and condensers would be the same. In other words, such circuits would be self-adjusted to the same station and it would no longer be necessary to tune each circuit separately. In the language of the radio man, the circuits are said to "Track." These conditions made the single-dial control receivers possible.

As long as low-impedance magnetically coupled antenna circuits were employed, it was not possible to eliminate the "Antenna Compensator" since the size of antenna had considerable effect upon the tracking of the first circuit, but when high-impedance primaries were adopted on the antenna coil, true single-dial control with all circuits tracking became possible.

It is not to be understood from this that a high-impedance primary on the antenna coil automatically makes the coils track properly, for there are designs of high-impedance antenna coils that mistrack seriously. Neither is it to be inferred that a properly designed high-impedance antenna coil gave perfect tracking independent of antenna constants. A properly designed high-impedance antenna coil gives reasonable gain and tracks well enough that when trimmed to accurate tracking, the increase in sensitivity in the receiver is not greater than 30%.

In setting up the conditions for perfect tracking, the first requirement is identical circuits, the second is simplicity of circuit, the third is identical circuit inductance and capacity.

It is much simpler to track two RF stages of similar circuits and constants than it is to track an antenna and RF stage, and it is simpler to track two high-impedance circuits than it is one high-impedance and one low-impedance circuit.

The circuits which track most easily are those having the smallest number of circuit elements. The simplest possible circuit of an RF amplifier is shown in Fig. 12-A, which, for purposes of tracking, is equivalent to Fig. 12-B. In this circuit there is one inductance tuned by one variable condenser, which condenser is assumed to include the grid and plate capacities. This circuit, in the broadcast band with the conventional capacity gang condenser, has entirely too much amplification, too much gain variation from one end of the tuning range to the other, and too little selectivity. Where the lack of selectivity and lack of uniform gain is not a serious problem, the gain of the amplifier can be reduced by tapping the coil to connect the plate somewhere near the middle of the coil as in Fig. 13-A. In order not to have the plate voltage on the tuned circuit, a primary is usually wound on the coil, spaced between or exactly over the secondary turns, so that for all RF purposes, the plate is a tap on the secondary, but for DC is isolated. The RF coil now has a secondary tuned by the tuning condenser and is tightly coupled to the primary which has a very small capacity (plate and wiring capacity) across it. This arrangement permits the simple circuit of 13-B to be used. Such a circuit has two resonant frequencies, but for practical purposes the second resonant frequency is so high that it seldom causes any trouble, except in the case of certain high-frequency coils where the inductance of leads is comparable to the coil inductance.

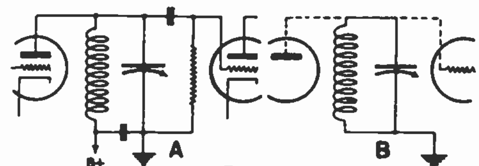


Figure 12

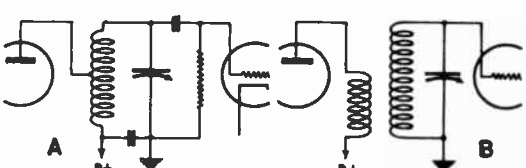


Figure 13

The high-impedance primary type of RF coil has an inductance in the plate circuit many times higher than the inductance of the tuning coil. Such a circuit has two resonant frequencies, both of which are important. One is the frequency determined almost entirely by the secondary inductance and tuning capacity, and the other by the plate inductance and the plate capacity.

In Superheterodyne receivers, which almost universally employ an intermediate frequency lower than the broadcast frequencies, it is important to see that the primary-circuit resonance does not occur at the intermediate frequency, or the RF amplifier circuits will pass unwanted signals of intermediate frequency directly into the intermediate amplifier, even though the grid circuit of the RF amplifier is tuned to a frequency far removed from the intermediate frequency. This is particularly true of receivers employing an intermediate frequency just below the broadcast band, such as the 456 KC now so popular. On such receivers, the primary resonance should be placed either midway between the IF and the low end of the broadcast band, which gives high gain but leads to considerable production difficulties, or the primary resonance should be placed well below the intermediate frequency. The latter arrangement is highly recommended over the former because it is more uniform, causes less trouble from oscillation, and produces better tracking.

The presence of the primary circuit resonant below the low end of the tuning band has the effect of lowering the secondary inductance as the low end of the tuning range is approached. Fig. 14 shows the tuning curve for a high-impedance and a low-impedance RF circuit adjusted to have the same low-frequency inductance and the same maximum frequency. The low-impedance circuit is seen to follow the frequency curve calculated from the secondary inductance and total tuning capacity, but the high-impedance circuit does not follow this curve, departing from the calculated values at the low-frequency end. This point is brought out to show that two circuits may track perfectly over part of their tuning range and yet badly mis-track over another part due to resonances from some circuit not a part of the tuned circuit. From this it is easy to see that similarity of circuit is an aid in tracking.

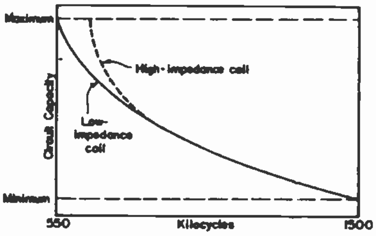


Figure 14

The amount the actual tuning curve of a high-impedance stage departs from the ideal curve depends upon two factors: the proximity of the primary resonance to the low end of the secondary tuning range, and the degree of coupling between primary and secondary. In the design of high-impedance coils, a reasonable limit on both of these factors may be assumed as follows: first, primary resonant frequency less than 80% of the lowest tuning frequency, but must not occur at the frequency of the IF amplifier in a superheterodyne receiver; second, magnetic coupling between primary and secondary should not exceed 15% coupling coefficient.

If the two circuits whose tuning curves are shown in Fig. 14 are to be tracked together, a series of compromises must be made. The tuning curves shown may be accepted as satisfactory, or a compromise may be made in the gain of the stage by moving the primary resonance farther away, with consequent reduction in gain, but resulting in a straighter tuning curve, or the inductance may be changed to make the low end mis-track less and the previously perfect tracking of the remainder of the tuning curve be less perfect. Such tuning curves are shown in Fig. 15.

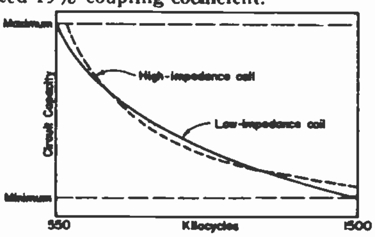


Figure 15

With the advent of superheterodyne reception, the problem of tracking became more complicated. The problem then became one of tracking one or more circuits to cover a given frequency range while another circuit (the oscillator) of different arrangement must maintain not the same frequency but a constant *frequency difference* in Kilocycles. Since the oscillator frequency is almost always above the signal frequency, and since the oscillator must cover the same number of Kilocycles from maximum to minimum, but cover them at a higher frequency than the antenna circuit, it is obvious that the oscillator covers a smaller frequency ratio than the antenna circuit.

In order to accomplish a restricted oscillator frequency-range compared to antenna frequency-range if no other restrictions were imposed, two methods are available; (1) Connect a fixed condenser across the oscillator. This reduces the capacity ratio by adding to the minimum capacity a much greater percentage than it adds to the maximum; (2) Connect a fixed condenser in series with the tuning condenser to reduce its maximum capacity without materially changing its minimum capacity. In actual receiver design, a combination of both types of compression is used, producing better average tracking than could be accomplished by either method alone. Formulas have been developed for calculating the values of inductance, padding and aligning capacities to be used to track an oscillator coil with a given antenna or RF coil, but unless there is access to a considerable amount of complicated test equipment, oscillator tracking must be accomplished experimentally with simple equipment.

TRACKING REPLACEMENT COILS

Radio servicemen are frequently called upon to replace Antenna, RF or Oscillator coils that have failed either through corrosion, or because of the failure of some other component in the receiver, or because damaged by some outside agency such as lightning.

Usually the damage is confined to the primary of the coil, in which case very frequently a new primary can be installed in place of the old one.

If the primary is replaceable, the winding direction of the old primary should be noted before removing it so that the new one may be installed with its winding direction the same.

If the damaged coil is beyond salvaging by installing a new primary, or if the secondary has been damaged, it will be necessary to install a new coil and check its tracking with the remainder of the tuning circuits.

In order to permit replacement coils to be tracked rapidly and to eliminate the possibility of having removed too much inductance and thereby ruined the replacement coil, to say nothing of the hours of labor installing, checking, removing and altering the coil, etc., Meissner has developed "Universal Adjustable" replacement antenna, RF and oscillator coils which are provided with a screw-driver adjustment of inductance by means of a movable core of finest quality powdered iron. By means of this adjustment, it is as easy to add inductance as to remove it, and to quickly obtain the optimum value of inductance. A coil of this type is shown in Fig. 16.


Figure 16

When a replacement antenna or RF coil is installed in a TRF receiver, the process of aligning is very simple. The dial is set to 600 KC, a dummy antenna of 200 mmfd. connected between the high side of the service oscillator and the antenna connection of the receiver, an output indicator of some type is connected to the output of the receiver, the service oscillator tuned to the receiver and the screw adjustor in the top of the can rotated until maximum sensitivity is obtained. The receiver and signal generator are next tuned to 1400 KC and the circuits aligned in the usual manner by adjusting the trimmers on the gang condenser. The process should then be repeated in order to obtain the best possible alignment at both checking points. It is best to seal the inductance adjustment on the coil by the application of a satisfactory cement, such as Duco Household Cement or equivalent.

When replacing an antenna or RF coil on a superheterodyne, essentially the same practice is followed as above with the exception that, since the oscillator determines the dial calibration, if the adjustments thereon have been disturbed, it is necessary to readjust the oscillator circuit to agree with the dial calibration at the checking points before adjusting the inductance of the new coil or aligning it.

If a new oscillator coil is being installed, the greatest aid to rapid adjustment of the new coil to proper inductance is an *undisturbed padding condenser adjustment.* There are innumerable combinations of oscillator inductance, padding capacity, and trimmer capacity that will track an oscillator circuit at two places in the broadcast band, but these various combinations give varying degrees of mis-tracking throughout the remainder of the band. If the padding condenser has not been disturbed, one of these variables is eliminated, and, with only inductance to adjust for proper alignment at the low-frequency end of the band, and capacity to adjust at the high-frequency end of the band, the adjustment is practically as easy and rapid as installing and adjusting an antenna or RF coil.

ALIGNMENT OF RECEIVERS

Modern radio receivers employ from two up to eight, ten or even more circuits to achieve the selectivity desired. These circuits, however, are of little benefit unless all of them are working at their proper frequencies simultaneously. Only someone acquainted with the alignment of receivers in a radio production department, or someone engaged in radio service work who has adjusted a receiver on which someone has tightened all of the adjusting screws, can realize how dead a receiver can sound when all of its tuned circuits are out of adjustment any considerable amount.

The purpose of "Aligning" a radio receiver is two-fold — to adjust it for maximum performance, and to make the dial indicate within two or three percent the frequency of the station being received.

NOTE

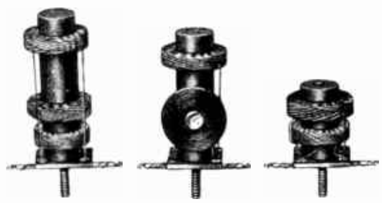
Detailed alignment information is given in later lessons. Much of the information in Lesson 5 has been prepared with the assistance of the Meissner Manufacturing Company.

RADIO COILS

Examples of the type of coils commonly used in radio receivers and requiring service work are illustrated. Examples have been taken from the Miller line, but other manufacturers have similar units. Please read the descriptions carefully and be able to identify any of the types. Notice the advantages of each type. Selector switches are used in multi-band receivers. The loop antenna has replaced the antenna coil in many portable and midget radio sets.

TRF AND SUPERHETERODYNE COILS

DUO-LATERAL WOUND

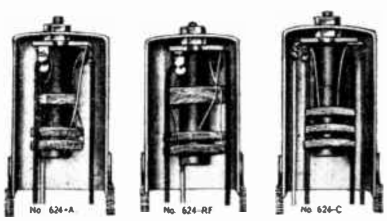


Single-section, Litz-wire-wound duo-lateral secondary. High-impedance primaries. Wound on treated hard-wood dowel with bakelite terminal plate. Use with .000365 mfd. variable condenser.

HIGH GAIN SERIES

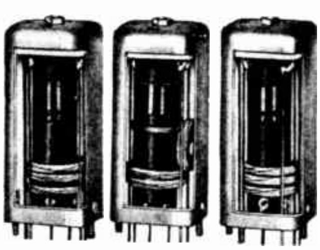
Sectional wound duo-lateral secondary, using No. 15/41. Litz-wire High-impedance primaries for uniform gain with any screen grid tubes. Wound on XXX bakelite tubing. Use with .000365 mfd. variable condenser. Excellent for improving performance of sets using coils similar to our Economy Series.

IRON CORE COILS



Sectional-Duo-lateral-wound on Armite sleeves. Special iron-core provides extremely high "Q" in minimum space. Especially adapted to auto and aircraft receivers. Use with .000365 mfd. variable condenser. Antenna coil has a low-impedance primary for operation on mobile antenna equipment. R.F. Coil has high-impedance primary for maximum gain.

TWO BAND COILS



Especially designed for the constructor who wishes to build an inexpensive 2-band receiver covering standard broadcast band and either of two short-wave bands. Adaptable to Marine receivers. Wound on high-grade bakelite tubing. Assembled in aluminum shields with trimmer condensers. For use with .000365 mfd. variable condenser and 455 KC I.F. Amplifier.

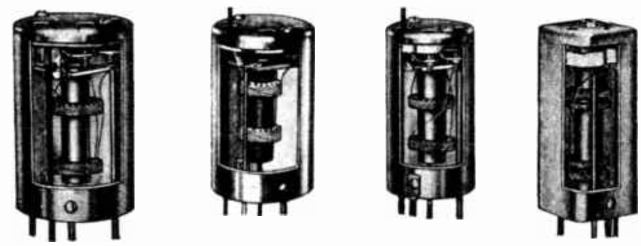
AIR CORE UNSHIELDED CHOKES

Miller Duo-Lateral-Wound, single-section, Radio Frequency Chokes are ideally suited for receiver applications wherein a moderately priced unit is required. These chokes are wound with silk-covered wire, on impregnated hard-wood dowels. A bakelite terminal plate, 1⅛" in diameter, is fastened to the dowel with a tubular brass eyelet, providing for single-hole mounting with a #6/32 machine screw. The winding on these chokes is impregnated to prevent any moisture absorption. Inductance values accurate to within three per-cent.

MICA COMPRESSION TYPE

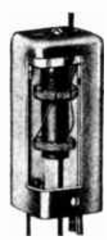
DOUBLE TUNED AIR CORE

Mica-Compression trimmers used in Miller I. F. Transformers are treated with our exclusive automatic cycling heat treatment consisting in alternately heating to 200°F and cooling to 90°F through 5 complete cycles. This heat treatment results in a much higher degree of capacity-stability, which insures perfect alignment of the I. F. Transformer under conditions of varying temperatures encountered in modern Radio receivers. **All Shields Aluminum.**



REPLACEMENT I.F. TRANSFORMERS

DOUBLE TUNED



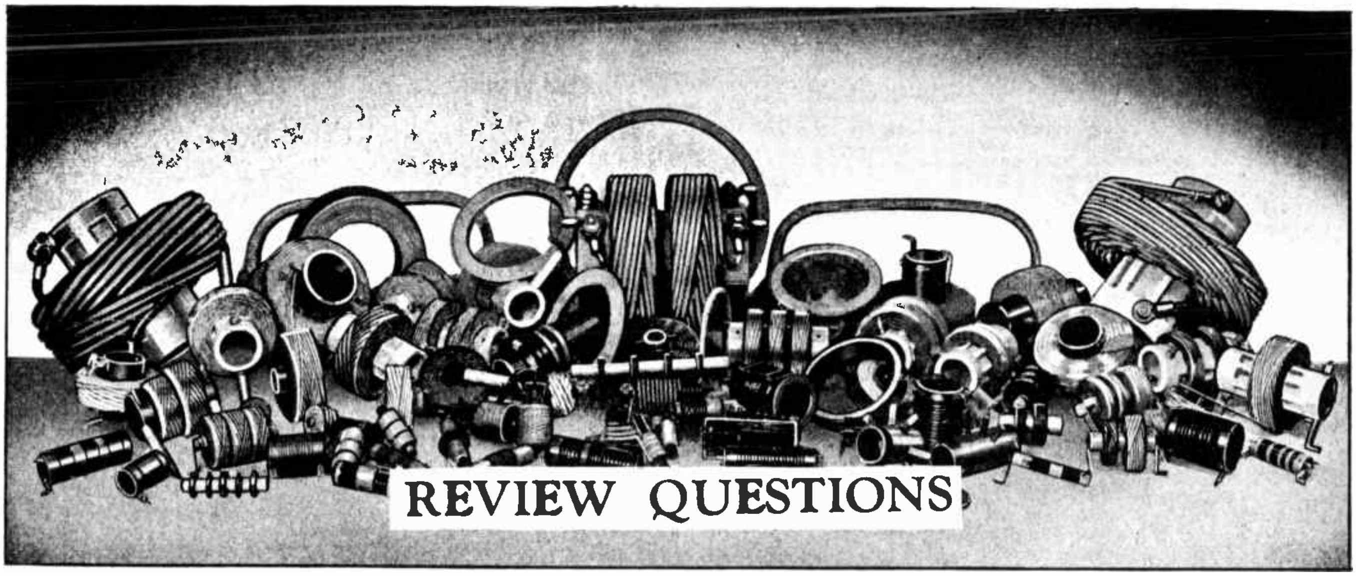
These Transformers are an essential part of the stock of every service man and dealer. In many cases they give better performance than the original unit. Only the finest materials are used. Every precaution is taken to insure a long and trouble-free life. Coils have Duo-lateral windings on treated hardwood dowels. Double tuned with Miller Heat-Cycled, Low-Drift, Mica-Compression Trimmers. Impregnated in special moisture-resistant wax. Pre-tuned to nominal frequency. Easily identified, color-coded leads. Assembled in "Okite" finished Aluminum shields. Spade-bolt mounting.

BAND SELECTOR SWITCHES

The successful operation of a multi-band receiver depends to no little degree upon the excellence of the switch used. These switches are of a positive self-cleaning type with silver plated contacts. All switches are provided with an adjustable stop

LOOP ANTENNA

The Miller Loop Antenna is primarily designed for use with the popular Miller Portable Battery-Receiver Kit, but is applicable to most portable-receiver assemblies. The inductance of the loop is high to permit removal of turns to match different sets. The loops are wound from low-distributed capacity wire and are of the flat, pancake type of winding.



REVIEW QUESTIONS

1. What is the unit of mutual inductance?

2. What three factors must be considered in designing R.F. coils?

3. Name several losses that may be present in a coil?

4. Is there any advantage in copper-plating a steel shield?

5. What is the advantage of high-impedance primaries in antenna coils?

6. Is it true that feedback tickler winding permits more reliable results from oscillator coils? Why?

7. What type of IF transformers are most commonly used?

8. Why is the bi-filar type IF transformer not used very much?

9. Name some advantages of a double-tuned IF transformer?

10. Were the early "single-dial control" receivers really such? Why not? How about present day sets?

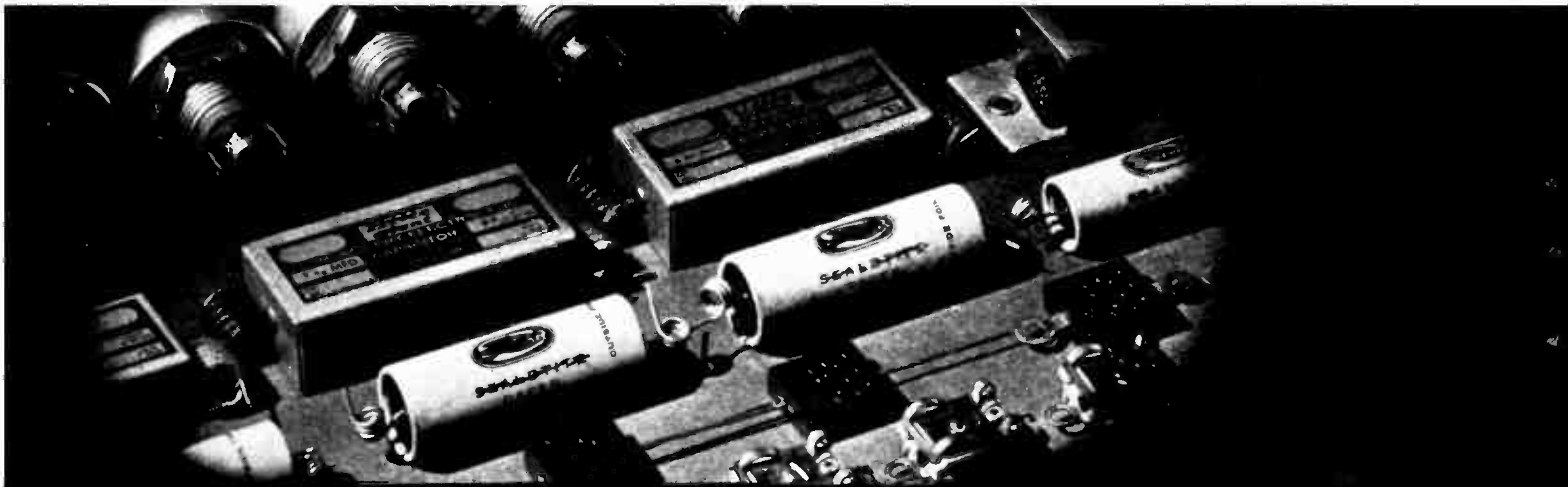
11. What new design in antenna coils eliminated the "Antenna Compensator"?

12. Why are trimmers used in gang condensers?

13. What effect will poor alignment have on the operating efficiency of a four tube receiver?

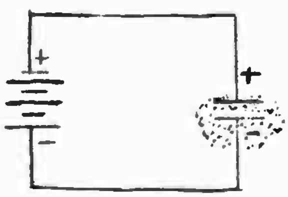
14. Explain how you would re-align a small radio set in which the R.F. coil has been replaced.

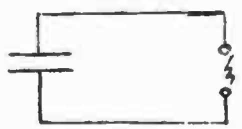
15. Make a pictorial sketch of an antenna coil. If you did not have the connecting instructions, how would you know which terminals to use for the different connections. Review the chapter on winding methods of coils.



RADIO CAPACITORS

LESSON 6

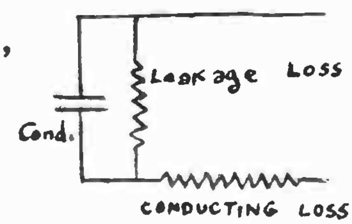




If a condenser is connected to a source of D.C. potential such as a battery, the negative side will become charged with electrons. If the battery connections are removed and the condenser shorted, a spark will jump across the point of contact, and the two plates will again be in electrical equilibrium or will be neutral. The strength of the charge will depend on a number of factors as we shall see later.

A condenser must have two plates made of conducting material, and a separation of a non-conducting material or vacuum. The material between the plates is called the dielectric. Any insulator will serve as the dielectric, but only a limited number of insulators have characteristics that make them especially well suited for this application. Every condenser has certain losses which are almost neglible in a high quality unit.

For one thing, there is an actual resistance loss in the conducting plates of the condenser. The dielectric, while having very high insulating value, does permit a certain leakage. A practical condenser, therefore.may be assumed to be a perfect condenser with no losses with a resistor connected in series to represent the loss in the conducting plates, and a resistor in parallel to represent the leakage. Because of the leakage loss a charged condenser will soon loose its charge. There are also other losses, but they are not of importance from the practical point of view.



The degree of ability of a condenser to store electrical charges is known as the capacity of the unit. Since the quantity of the electrical charge depends directly upon the

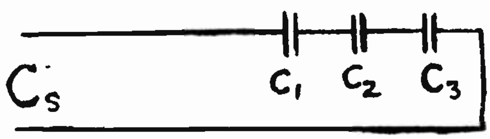
E.M.F. of the current source, capacity is defined in terms of not only how much charge is stored, but also on how much voltage is applied. The unit of capacity is the Farad. The farad is equal to the capacity of a condenser that will store one coulomb of electricity at the pressure of one volt.

The Farad is much too large for radio applications, the microfarad or mfd. equal to one-millionth of a farad is commonly used. Condensers of very small capacity are also rated in still smaller units of micro-microfarads or mmfd. being equal to one/millionth of a microfarad.

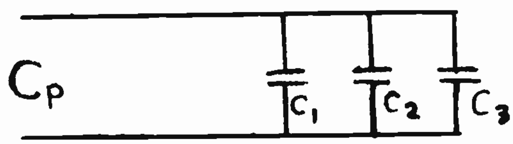
Condensers similarly to resistors may be connected in series and in parallel. When condensers are connected in parallel, the final capacity is greater than that of any condenser used in the combination. The total capacity is equal to the sum of all the individual condensers connected in parallel.

$$C_p = C_1 + C_2 + C_3 + \ldots\ldots$$

Where C_p is the total capacity of units in parallel. This formula suggests a means of obtaining larger capacity from a number of smaller units. Each condenser used, however, must be able to withstand the applied voltage of the circuit. Should 15 mfd. be required and only 5 mfd. units be on hand, three of these may be employed connected in parallel with equally satisfactory results as might be obtained from a single 15 mfd. condenser.



Condensers in Series



Condensers in Parallel

When condensers are connected in series, the final capacity of the combination is always less than that of the smallest used in the combination. It is very rarely that condensers are used in series, except when all are of the same capacity. In such cases the total capacity

$$C_t = \frac{C}{n}$$

where n = number of condensers of capacity C connected in series.

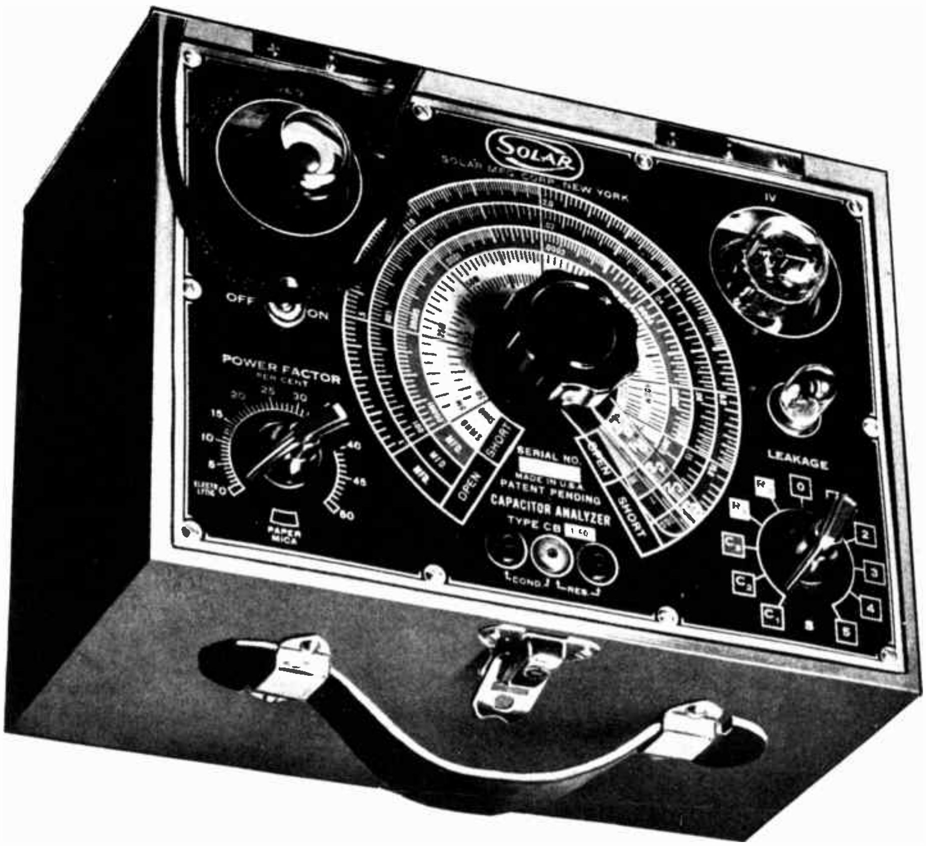
There are three factors affecting the capacity of a condenser.

(1) The type of dielectric used

(2) The area of the plates in contact with the dielectric

(3) The actual thickness of the dielectric, or what is the same thing the separation between the plates.

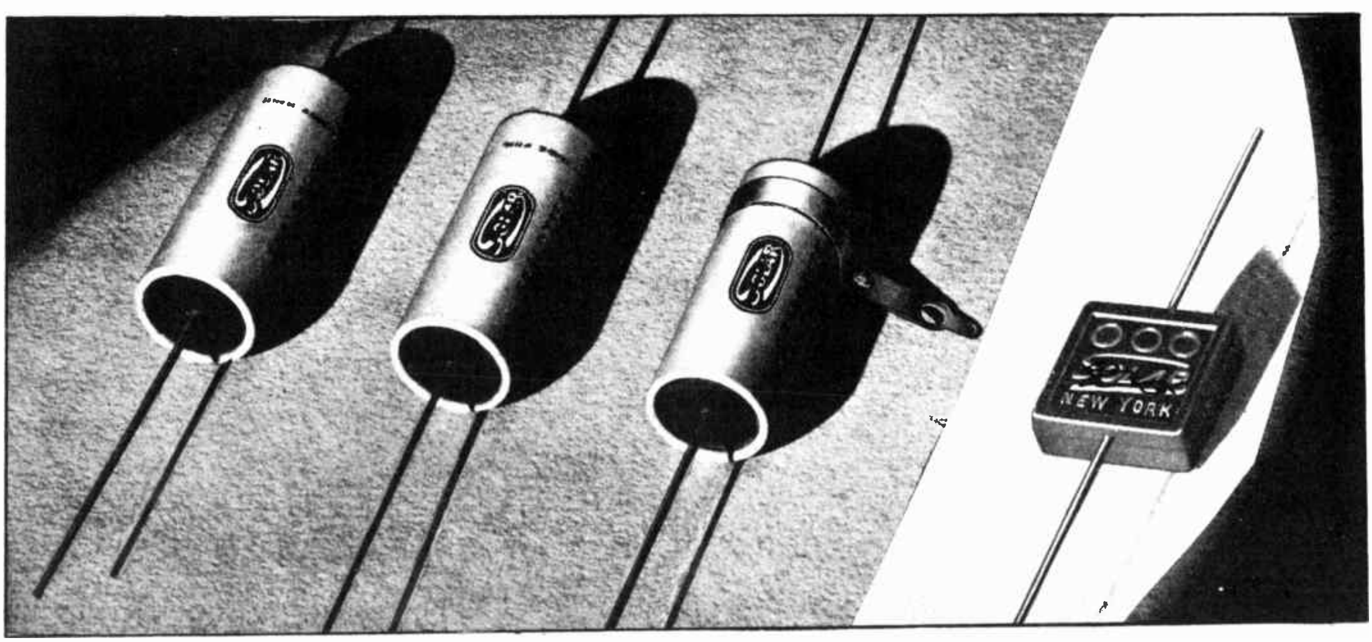
It has been found that the capacity of a condenser using air and other substances for the dielectric changed for each definite substance used. For example certain wax employed for the dielectric made a condenser have twice the capacity as when this same condenser had an air dielectric. Bakelite gave a value 6½ times as large as air, etc. This property of different materials used for the dielectric of condensers is known as the dielectric constant. Air is taken as standard and its dielectric constant is assumed to be 1.



The actual capacity of different condensers may be calculated from formulas, but the serviceman uses commercial units already supplied with the capacity indicated and for the serviceman there will be little need for such calculations. Certain test analyzers have provisions for indicating the capacity of paper and electrolytic condensers directly.

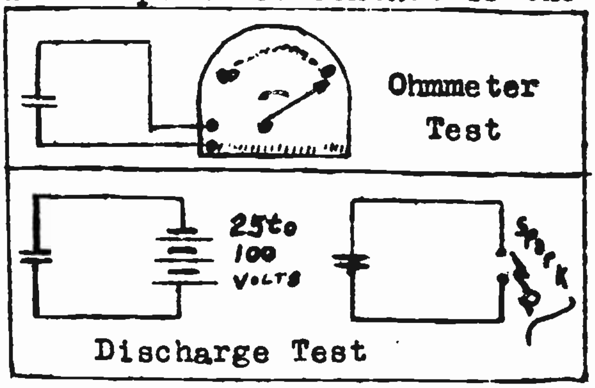
F I X E D   C O N D E N S E R S

Condensers commonly used in radio sets are so constructed that their capacity is fixed at one definite value. The exception is the variable condenser used for tuning the radio circuits into resonance. For low capacity, under .02 mfd., mica insulation is employed. Such condensers are molded in bakelite and are uneffected



by moisture. The value of capacity is marked on the case and for service work suitable similar replacements are easily obtained; Larger sizes are made with paper dielectric and in tubular form. We urge you to carefully note (1) the relation of capacity, break down voltage or the working voltage, and the physical size, (2) the general appearance of the units, and (3) the general methods used for connecting the units into the circuits.

While special condenser testers may be used to detect the faults in condensers, a simple ohmmeter will serve the purpose. A small capacity fixed condenser should test open on an ohmmeter. If the condenser has noticeable low resistance (below 50,000 ohms) or is completely shorted, the unit should be replaced. A good test is to connect the condenser momentarily to a source of D. C. potential between 25 and 100 volts. Quickly disconnect the condenser and connect the terminals together. A spark should be noted at the point of contact if the condenser is in good condition.



Electrolytics can be quickly tested by the ohmmeter method. They will first upon being connected show a shorted condition, but the resistance will quickly increase. The ohmmeter must be correctly connected, i.e. positive side of the battery to the positive side of the electrolytic condenser. The D.C. potential discharge test may also be used.

In replacing fixed condensers, the serviceman need not be too critical. A slight difference of capacity will ordinarily not upset the circuit and this is especially true if the unit is used as a filter. 8 or 12 mfd. units may be used for 10 mfd. However, the rated working voltage is important and must not be overworked. Condensers rated at 550 volts D.C. may be used on any voltage up to this maximum rated voltage, but not above. A.C. voltage peaks are 1.4 higher than the measured and indicated R.M.S. voltage. For example 110 volts A.C. has peak voltage of 110 x 1.4 or 154 volts.

THEORATICAL CONSIDERATIONS OF ELECTROLYTIC CONDENSERS ....

An electrolytic condenser is a fixed condenser of high capacity and compact size suitable for use with voltages not exceeding about 550 volts. These condensers must further be used only with D.C. or pulsating D.C. Because of these characteristics electrolytic condensers are especially well suited for use in radio filter circuits where these advantages over paper type condensers are fully realized, and their limitations are of no consequence.

The electrolytic condenser consists of an anode to which the positive connection is made, the cathode used in conjuction with the negative connection, and the electrolyte. Aluminum is usually used as the anode in condensers for radio application. Other metals such as tantalum and magnesium find some use; the chief advantage of tantalum being its ability to withstand acid corrosion. For the cathode either aluminum or copper is used in connection with aluminum anode.

Many different electrolytes are used and their choice depends greatly upon the voltages to be applied to the condenser. A few electrolytes appear below with their respective critical voltages:

$NaSO_4$	40 volts
$KMnO_4$	112
KCN	295
NH_4HCO_3	425

Sometimes mixtures of two or more compounds are used. The density of the electrolyte varies from a liqued which contains a fairly large percentage of water to a paste which is commercially called "dry".

The dielectric film forms electro-chemically on the surface of the anode. The properties of the electrolytic condenser are due to this film formation. The exact nature of this film is not known, but it is extremely thin making possible high capacity per unit area. The capacitance of a film formed at 300 volts on aluminum is 0.12 mfd. per square inch, about eight hundred times that of a paper condenser for this voltage.

The film is formed by applying a potential of the proper value. The capacity is almost inversely proportional to the potential at which the film is formed.

In the actual circuit when the potential is first applied, the current is only limited by the resistance of the electrolyte and the external resistance present. Naturally under this condition high currents flow. The film forms quite rapidly, however, and the leakage current drops to a safe value of about 0.2 milliamperes per microfarad. A radio rectifier circuit takes care of this leakage current without difficulty. The rectifier tube does not heat-up instantaneously and, because of this, the voltage at first is of a small value. This voltage partially forms the film which reduces the leakage current when the rectifier tube heats-up to the full value and supplies the maximum voltage.

Temperature has an effect that is of a distinct advantage in radio application of electrolytic condensers. The capacity increases with the temperature up to certain limits. By mounting the electrolytic condensers near the power and rectifier tubes, temperature around the condensers may be raised. Very little change occurs past 120° Fahrenheit, and because of other factors it is best not to surpass this value. A condenser having a capacity of 8 mfd. at 70° F., will have over 11 mfd. capacity at 120° F.

SOME IMPORTANT PRACTICAL FACTS CONCERNING CONDENSER REPLACEMENTS

When there is something wrong with a radio you are servicing, you are safest in saying, "It's a condenser." Of course, there are more different kind condensers used in a radio set than any other parts. And also stresses occuring in circuits usually result in higher voltage on some condenser. Keeping this in mind, you will want to know how to find a faulty condenser and how to make the replacement quickly and inexpensively.

You know that condensers do not pass D.C. If they do, you better start replacing the condensers. Now most condensers used in circuits have a higher potential on one side than the other. Test for voltage across such units -- if there is no voltage there must be a short in the unit. You may proceed to shunt similar condenser across each unit suspected. If the condenser under test is in good operating condition, the test condenser will take a charge at the voltage impressed on the original unit. The discharge may be noticed and will be an indication that the unit is not shorted.

What about open condensers? The test suggested will take the place of the defective condenser when used in the circuit for test. Therefore, if this is the fault, during the moment the test is being made operation will be restored. Then just replace the condensers and the radio is repaired.

Are the values of condensers important? Voltage rating is important only in so far as the new unit used for replacement must have equivalent or higher rating. Notice that a higher rating can always be used. In fact it is advisable to use a replacement condenser of higher voltage rating to prevent the same fault to re-appear again.

Condensers used for by-pass purposes may be replaced by similar units but either larger or smaller in capacity. For example, a 0.1 mfd. cathode condenser can be replaced with a condenser anywhere from 0.01 to 1. mfd. capacity. Filter condensers are in the same line. Larger capacity is strongly recommended. Occasionally you will replace the parallel padder condenser or tone correction unit that is fairly critical.

REVIEW QUESTIONS

1. If 20 mfd. capacity is needed and only 4 and 8 mfd. units are available, how can the required capacity be obtained?

2. What three factors determine the capacity of a condenser?

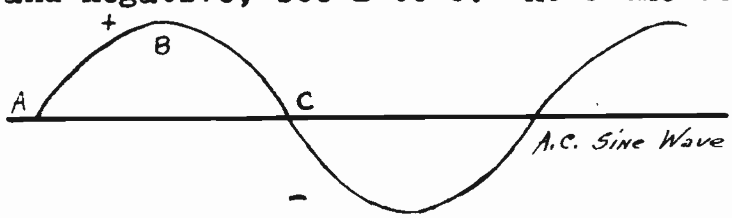
3. Why cannot electrolytic condensers be in A.C. circuits?

4. If a single section of a multi-section electrolytic condenser was at fault, would you replace the entire unit, or would you install an extra condenser to replace the damaged section? Explain why.

LESSON 7

ALTERNATING CURRENT THEORY & FILTERS

In our discussion of batteries we talked about direct current, (D.C.). This current is of constant or varying value but flows in one direction all the time. When the magnitude of D.C. changes, we call this pulsating direct current. Alternating current (A.C.) has a constantly changing magnitude and also direction. First one terminal is positive having its value rising, see chart A to B. Then the value begins to fall, but the same terminals are still positive and negative, see B to C. At C the voltage present is zero, and then it begins to rise in the opposite direction. The process is repeated, but the terminals are reversed. The usual A.C. generated forms sine waves which graphically appear as the ones illustrated.



When the voltage has started from zero, has risen to its maximum value in one direction, returned to zero, risen to the maximum value in the opposite direction, and then returned to zero, one complete cycle has been completed. The common power line frequency is 60 cycles per second; this means that sixty such changes occur every second. This explains why in dealing with A.C. time must be considered.

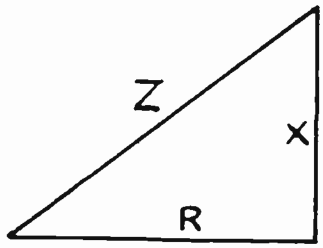
Inductance opposes changes in current intensity. Because in an A.C. circuit the voltage is constantly varying, the current too will vary in accordance. But the inductance present will attempt to prevent a change in the current, and the current will lag behind the voltage. In a pure inductive circuit (no resistance being present) the current will lag 90° behind the voltage and no power will be used. In actual circuits, of course, resistance is always present and the phase angle by which the current will lag behind the voltage will always be less than 90°.

Since in A.C. circuits current changes continuously, an inductance will show a definite "resistance" or opposition to the flow of A.C. current. This opposition is known as <u>reactance</u>. The reactance of a coil in ohms may be calculated if the frequency F, and inductance L in henries are known.

INDUCTIVE REACTANCE $X_L = 6.28 \times F \times L$ in ohms

Since every circuit contains resistance, in fact an inductance itself uses wire and therefore has resistance, both the reactance and the resistance constitute an impeding force. Please bear in mind that this opposition is equivalent to resistance in a D.C. circuit and by itself has nothing to do with the time lag. The relation between the inductance and the resistance of the circuit will determine the angle of the lag; the frequency does not enter directly in this case. The total opposition to the current is that of the resistance and the reactance and is expressed as the <u>impedance</u> of the circuit, designated by the symbol Z. Impedance like reactance is expressed in ohms. The formular given is used to compute the impedance.

$$Z = \sqrt{R^2 + X_l^2}$$



This means that the impedance Z is the hypotenuse (long, slant side) of a right triangle that has the resistance R, and the reactance X, as its two sides; see figure. From these two formulas we see that where inductance is involved, the impedance and reactance increase with the frequency.

In a radio filter circuit, the current that comes from a full wave rectifier tube contains a large 120 cycle component. It is interesting to see what impedance is offered by a 10 henry choke coil having 300 ohm D.C. resistance, to this 120 cycle component. Substituting the values and solving:

$$X_l = 6.28 \times F \times L = 6.28 \times 120 \times 10 = 7{,}536 \text{ ohms}$$

$$Z = \sqrt{(300)^2 + (7{,}536)^2} = 7{,}542 \text{ ohms}$$

The 120 cycle component receives a reactance from the choke of 7,536 ohms as compared to the 300 ohm resistance offered to D.C. The impedance or the combined effect of the choke's reactance and resistance is equal to 7,542 ohms.

CAPACITANCE REACTANCE If a D.C. voltage is impressed across the plates of a perfect condenser, there will be an initial rush of current which will charge the condenser to the supply voltage. After this there is no further flow of current if the voltage remains constant. If the plates are short-circuited current will flow out of the condenser.

The current in a capacitance circuit tends to keep the voltage constant and leads the voltage. This is exactly opposite to the action of an inductance. Therefore, the capacitance reactance is assumed to be opposite to inductive reactance and when both appear in a circuit the following formula is applied to calculate the capacitance reactance. This formula is also used when the capacity exists in a non-inductive circuit.

CAPACITANCE REACTANCE $X_c = \dfrac{1}{6.28 \times f \times C}$ in ohms

Here also F is the frequency and C is the capacity in farads. Use the simplified formula

$$X_c = \frac{159{,}236}{f \times C}$$

when C is expressed in microfarads.

If a circuit has both inductive and capacitance reactances, their effects will be opposite to each other and the larger will predominate. For example in a 60 cycle circuit there is an inductance of 3 henries and a condenser of 10 mfd. connected in series Figuring we find the inductance having a reactance of 1130.4 ohms, the capacitance reactance equal to 265.4 . The total reactance is equivalent to 1130.4 - 265.4 = 865. ohms and the circuit will behave inductively.

The impedance formula for circuits having capacity and resistance is similar to the one we already had where inductance was present instead of the condenser. X_c is simply substituted for X_l

$$Z = \sqrt{R^2 + X_c^2} \text{ in ohms}$$

If both inductive and capacitance reactances are present, X the total reactance is the algenraic sum of the two, vis:

$$Z = \sqrt{R^2 + (X_L - X_c)^2}$$

Note: X_L AND X_c are always taken to be opposite in sign.

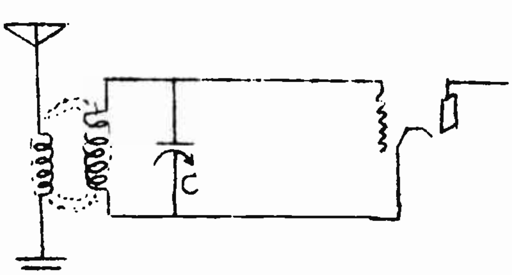
The student should design simple series circuits envolving resistance, capacity, and inductance and apply these formulas.

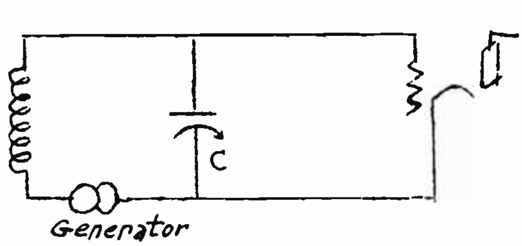
FILTERS Filters are electrical circuits that show varied "shut-out" discrepancies to different frequencies present. In other words, filters change their impedance to different frequencies. By utilizing capacity and inductance (also resistance sometimes) in circuit combinations it is possible to vary the amount of suppression of any group of frequencies. By combining a number of similar sets of filters much sharper and more exact results may be obtained.

The use of filters in radio receivers and similar equipment is large. By-pass condensers across bias resistances, detector radio frequency chokes, and power supply chokes and condensers are but a few representative examples.

In one manner filters may be divided into four classes, depending upon the functions they are called to perform. Filters may be low pass, high pass, band pass, and band elimination types. The classification is relative to the frequencies passed or attenuated (kept out). Formulas have been worked out to help a designer to arrive at the correct values of the parts for any one of the mentioned filter types.

TUNED CIRCUITS A radio frequency air core transformer is used to couple the antenna to the radio set. A simple input R.F. circuit is illustrated; the secondary of the transformer is shunted with a variable condenser C. For practical purposes we may assume that the antenna picks up all signals equally well. These signals are transformed to the secondary with a slight voltage step up. On first appearance the secondary of the tuning transformer and the condenser seem to be in a parallel circuit; however, this is not so. The voltage in the tuned circuit is induced in the windings of the secondary coil, and is in series with the winding. The induced current may be assumed to be coming from a generator connected in series, see illustation.





REACTANCE AND RESISTANCE*

IN PARALLEL

When a resistance is in parallel with a reactance (either inductive or capacitive), the resultant impedance of the combination is found from the expression

$$Z = \frac{XR}{\sqrt{R^2 + X^2}}$$

Sometimes Z and R are given and X has to be found or Z and X are given and R is the unknown. In that case the equation can be solved for X and R and we have

$$X = \frac{ZR}{\sqrt{R^2 - Z^2}} \qquad R = \frac{ZX}{\sqrt{X^2 - Z^2}}$$

In all three of the above equations X can be either inductive reactance (X=6.28 fL) or it can be capacitive in which case X=1/(6.28 f C) where f is in cycles, L in henries and C in farads.

The table, Figure 3, has been prepared to permit the finding of any one of the three quantities X, R or Z when the other two are given. When X and R are given, divide the larger of the two quantities into the smaller one and thus get a ratio less than 1. Find this ratio in the left column and multiply the number obtained in the second column by R or X whichever is the larger and find Z.

Suppose R equals 1000 ohms and X is 200 ohms, which makes X/R = .20. The table shows us that Z/R is then 0.1961. Multiplying by R, we have Z = 0.1961 x 1000 = 196.1 ohms.

IN SERIES

The impedance, Z, of a combination resistance, R, and a reactance, X, in series is given by the equation

$$Z = \sqrt{R^2 + X^2}$$

When Z is given and either X or R is the unknown, this equation can be re-written:

$$R = \sqrt{Z^2 - X^2}$$

$$X = \sqrt{Z^2 - R^2}$$

In all these equations all three quantities are expressed in ohms and X can be either capacitive reactance (1/6.28 fC) or inductive reactance (6.28 fL).

The table, Figure 4, gives the value of all three quantities for the case that either X or Z is equal to 1. In other cases, find the ratio R/X or X/R refer to the table and find the corresponding ratio Z/X or Z/R. The table can also be used when Z is given together with one of the other quantities. It was for this reason that the table had to be extended for values of R/X or X/R from .1 to 10 since otherwise it would have been sufficient to include values from 1 upwards or downwards but not both. Example: suppose X = 1,600 ohms and R = 1,000 ohms. Then X/R = 1.6; the table shows Z/R = 1.8868. Then Z equals 1.8868 R or 1886.8 ohms.

Reactance and Resistance in Parallel reprinted from January 1936 Research Worker.

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Reactance and Resistance in Series reprinted from July 1936 Research Worker.

REACTANCE AND RESISTANCE VALUES IN PARALLEL

X/R or R/X	Z/R or Z/X	X/R or R/X	Z/R or Z/X	X/R or R/X	Z/R or Z/X
0.10	0.0995	0.49	0.4400	0.88	0.6606
0.11	0.1093	0.50	0.4472	0.89	0.6648
0.12	0.1191	0.51	0.4543	0.90	0.6690
0.13	0.1289	0.52	0.4613	0.91	0.6730
0.14	0.1386	0.53	0.4683	0.92	0.6771
0.15	0.1483	0.54	0.4751	0.93	0.6810
0.16	0.1580	0.55	0.4819	0.94	0.6849
0.17	0.1676	0.56	0.4886	0.95	0.6888
0.18	0.1771	0.57	0.4952	0.96	0.6925
0.19	0.1867	0.58	0.5017	0.97	0.6963
0.20	0.1961	0.59	0.5082	0.98	0.6999
0.21	0.2055	0.60	0.5145	0.99	0.7036
0.22	0.2149	0.61	0.5208	1.00	0.7071
0.23	0.2242	0.62	0.5269	1.10	0.7400
0.24	0.2334	0.63	0.5330	1.20	0.7682
0.25	0.2425	0.64	0.5390	1.30	0.7926
0.26	0.2516	0.65	0.5450	1.40	0.8137
0.27	0.2607	0.66	0.5508	1.50	0.8320
0.28	0.2696	0.67	0.5566	1.60	0.8480
0.29	0.2785	0.68	0.5623	1.70	0.8619
0.30	0.2874	0.69	0.5679	1.80	0.8742
0.31	0.2961	0.70	0.5735	1.90	0.8850
0.32	0.3048	0.71	0.5789	2.00	0.8944
0.33	0.3134	0.72	0.5843	2.20	0.9104
0.34	0.3219	0.73	0.5895	2.40	0.9231
0.35	0.3304	0.74	0.5948	2.60	0.9333
0.36	0.3387	0.75	0.6000	2.80	0.9418
0.37	0.3470	0.76	0.6051	3.00	0.9487
0.38	0.3552	0.77	0.6101	3.20	0.9545
0.39	0.3634	0.78	0.6150	3.40	0.9594
0.40	0.3714	0.79	0.6199	3.60	0.9635
0.41	0.3793	0.80	0.6246	3.80	0.9671
0.42	0.3872	0.81	0.6289	4.00	0.9702
0.43	0.3950	0.82	0.6341	5.00	0.9807
0.44	0.4027	0.83	0.6387	6.00	0.9864
0.45	0.4103	0.84	0.6432	7.00	0.9902
0.46	0.4179	0.85	0.6477	8.00	0.9921
0.47	0.4254	0.86	0.6520	9.00	0.9939
0.48	0.4327	0.87	0.6564	10.00	0.9950

Figure 3

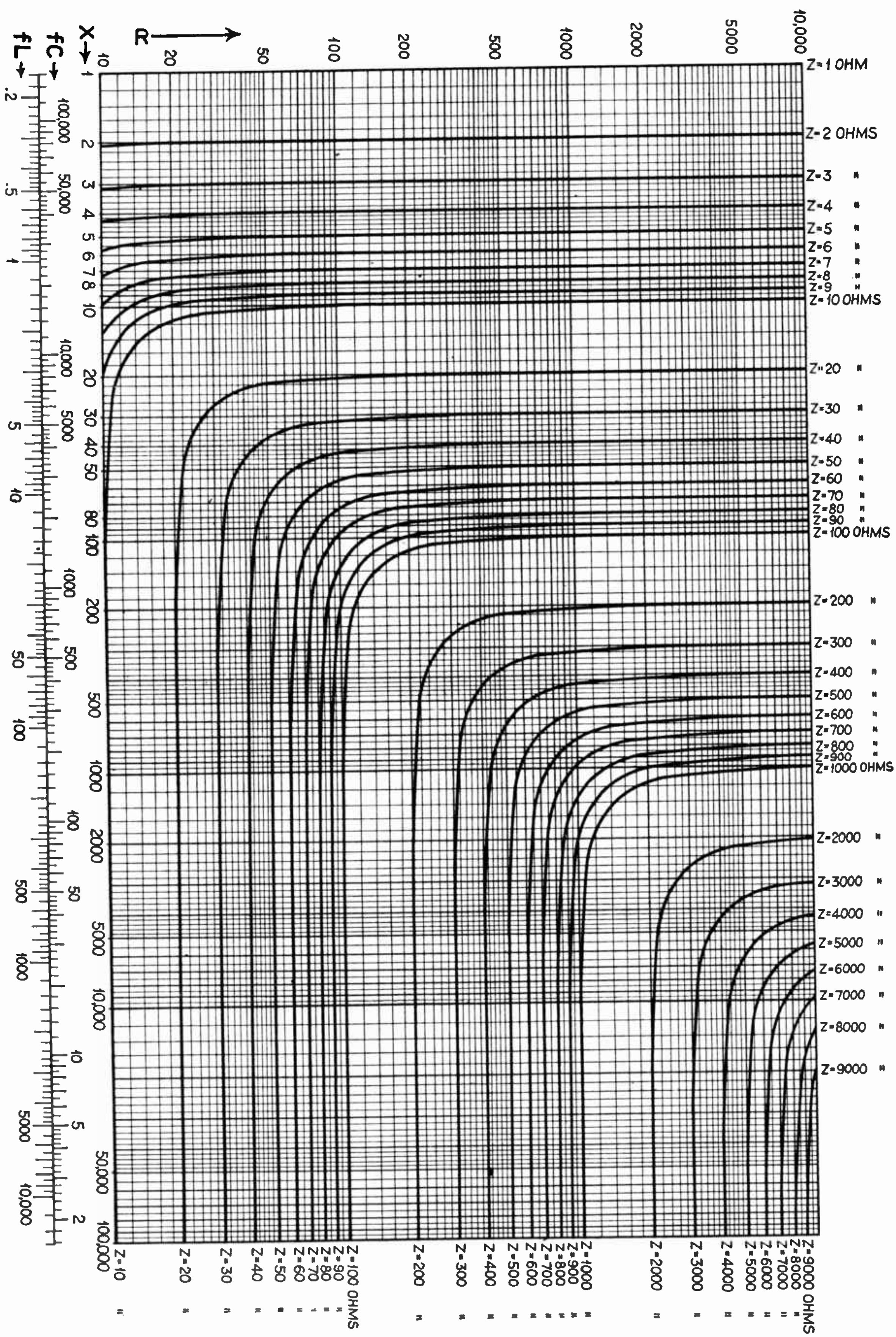
REACTANCE AND RESISTANCE VALUES IN SERIES

X/R or R/X	Z/R or Z/X	X/R or R/X	Z/R or Z/X	X/R or R/X	Z/R or Z/X
0.10	1.0050	0.70	1.2207	4.1	4.2202
0.11	1.0060	0.71	1.2264	4.2	4.3174
0.12	1.0072	0.72	1.2322	4.3	4.4147
0.13	1.0084	0.73	1.2381	4.4	4.5122
0.14	1.0097	0.74	1.2440	4.5	4.6098
0.15	1.0112	0.75	1.2500	4.6	4.7074
0.16	1.0127	0.76	1.2560	4.7	4.8052
0.17	1.0144	0.77	1.2621	4.8	4.9030
0.18	1.0161	0.78	1.2682	4.9	5.0009
0.19	1.0179	0.79	1.2744	5.0	5.0990
0.20	1.0198	0.80	1.2806	5.1	5.1971
0.21	1.0218	0.81	1.2869	5.2	5.2952
0.22	1.0239	0.82	1.2932	5.3	5.3935
0.23	1.0261	0.83	1.2996	5.4	5.4918
0.24	1.0284	0.84	1.3060	5.5	5.5901
0.25	1.0308	0.85	1.3125	5.6	5.6885
0.26	1.0333	0.86	1.3190	5.7	5.7871
0.27	1.0358	0.87	1.3255	5.8	5.8856
0.28	1.0384	0.88	1.3321	5.9	5.9841
0.29	1.0412	0.89	1.3387	6.0	6.0828
0.30	1.0440	0.90	1.3454	6.1	6.1814
0.31	1.0469	0.91	1.3521	6.2	6.2801
0.32	1.0499	0.92	1.3588	6.3	6.3789
0.33	1.0530	0.93	1.3656	6.4	6.4777
0.34	1.0562	0.94	1.3724	6.5	6.5764
0.35	1.0595	0.95	1.3793	6.6	6.6752
0.36	1.0628	0.96	1.3862	6.7	6.7741
0.37	1.0662	0.97	1.3932	6.8	6.8731
0.38	1.0698	0.98	1.4001	6.9	6.9720
0.39	1.0733	0.99	1.4071	7.0	7.0711
0.40	1.0770	1.00	1.4141	7.1	7.1701
0.41	1.0808	1.1	1.4866	7.2	7.2691
0.42	1.0846	1.2	1.5621	7.3	7.3681
0.43	1.0885	1.3	1.6401	7.4	7.4671
0.44	1.0925	1.4	1.7205	7.5	7.5662
0.45	1.0966	1.5	1.8028	7.6	7.6654
0.46	1.1007	1.6	1.8868	7.7	7.7646
0.47	1.1049	1.7	1.9723	7.8	7.8638
0.48	1.1092	1.8	2.0591	7.9	7.9630
0.49	1.1136	1.9	2.1471	8.0	8.0623
0.50	1.1180	2.0	2.2361	8.1	8.1615
0.51	1.1225	2.1	2.3259	8.2	8.2608
0.52	1.1271	2.2	2.4166	8.3	8.3600
0.53	1.1318	2.3	2.5080	8.4	8.4594
0.54	1.1365	2.4	2.6000	8.5	8.5580
0.55	1.1413	2.5	2.6926	8.6	8.6576
0.56	1.1461	2.6	2.7857	8.7	8.7572
0.57	1.1510	2.7	2.8792	8.8	8.8566
0.58	1.1560	2.8	2.9732	8.9	8.9560
0.59	1.1611	2.9	3.0676	9.0	9.0554
0.60	1.1662	3.0	3.1623	9.1	9.1548
0.61	1.1714	3.1	3.2573	9.2	9.2542
0.62	1.1765	3.2	3.3526	9.3	9.3536
0.63	1.1819	3.3	3.4482	9.4	9.4530
0.64	1.1873	3.4	3.5440	9.5	9.5524
0.65	1.1927	3.5	3.6400	9.6	9.6518
0.66	1.1981	3.6	3.7362	9.7	9.7512
0.67	1.2037	3.7	3.8327	9.8	9.8507
0.68	1.2093	3.8	3.9293	9.9	9.9503
0.69	1.2149	3.9	4.0262	10.0	10.0499
		4.0	4.1231		

Figure 4

*Reprinted from Aerovox Research Worker.

Reactance and Resistance in Parallel



REACTANCE AND RESISTANCE IN SERIES

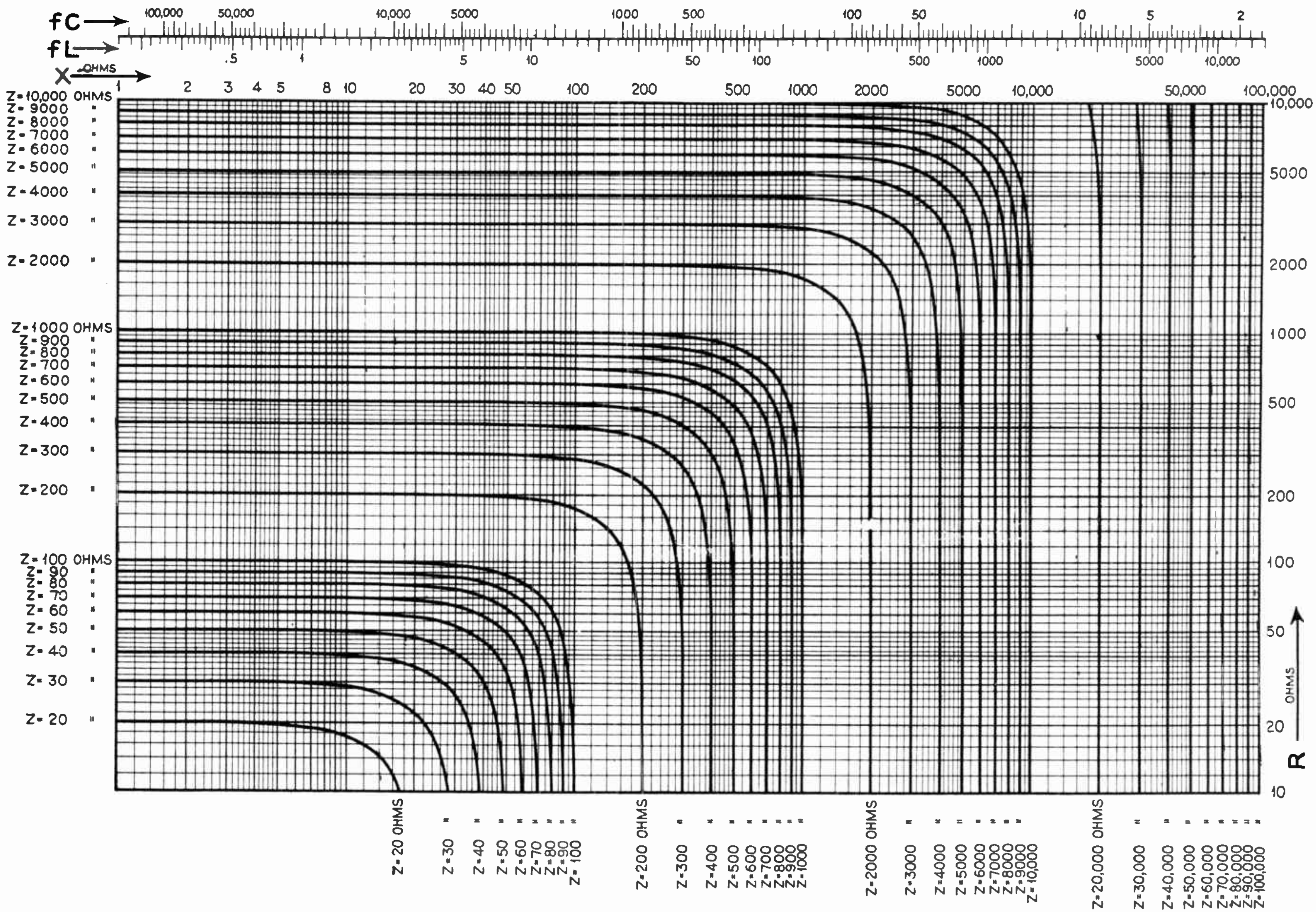
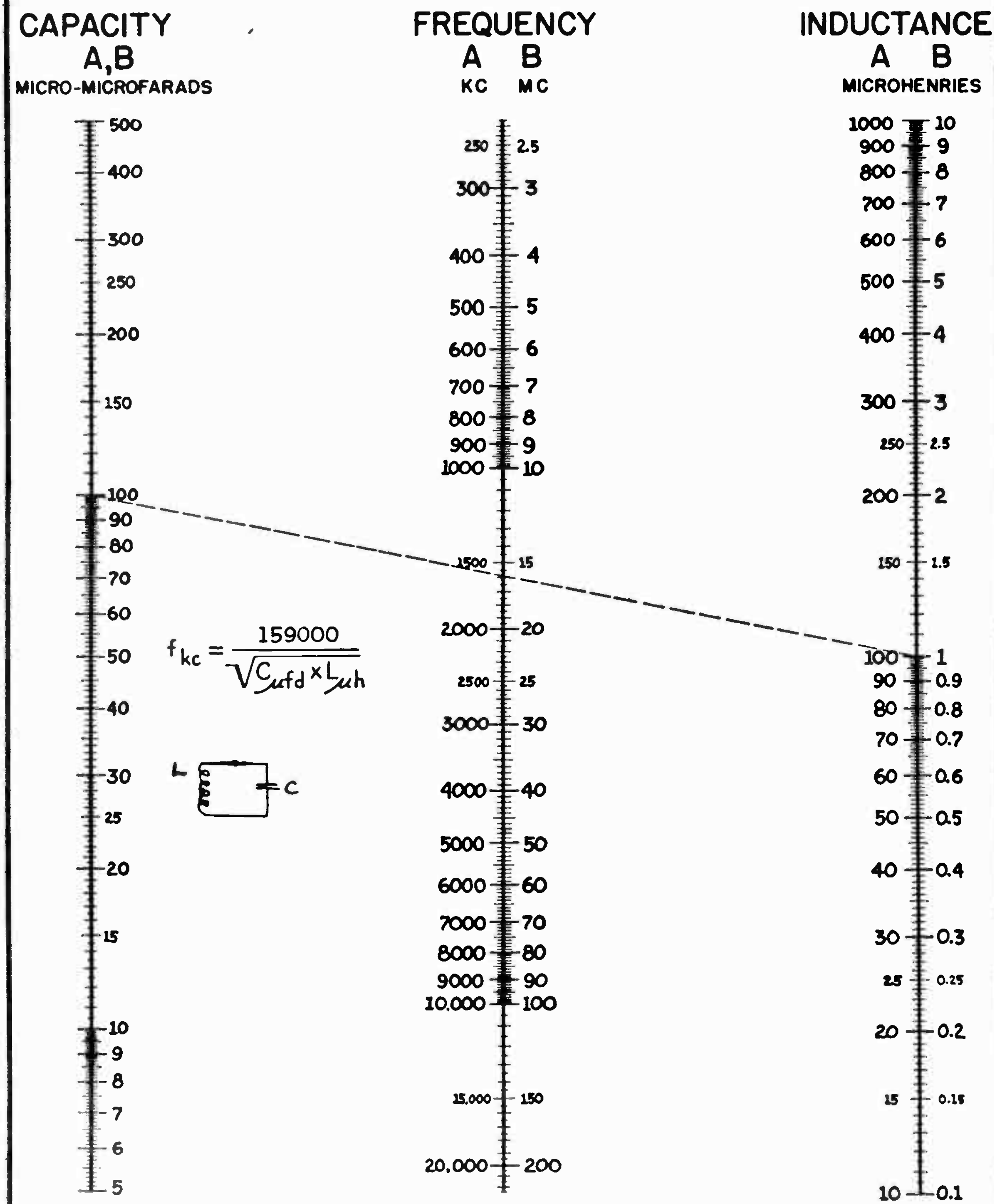


Figure 6



$$f_{kc} = \frac{159000}{\sqrt{C_{\mu fd} \times L_{\mu h}}}$$

When any two of the quantities F, L, or C are known the third can be found by drawing a straight line. Example: 100 mmfd. and 100 microhenries tune to 1590 kc. (reading all A scales) or 100 mmfd. and 1 microhenry reonates at 15.9 mc. (reading all B scales).

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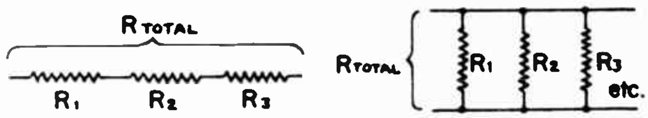
HANDY RADIO FORMULAE

Direct Current Relations

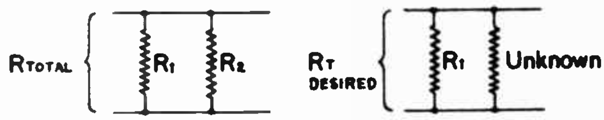
VOLTS	=	IR	$\frac{W}{I}$	$\sqrt{RW}$
AMPERES	=	$\frac{E}{R}$	$\frac{W}{E}$	$\sqrt{\frac{W}{R}}$
OHMS	=	$\frac{E}{I}$	$\frac{W}{I^2}$	$\frac{E^2}{W}$
WATTS	=	EI	I^2R	$\frac{E^2}{R}$

Resistance Relations



$R_{TOTAL} = R_1 + R_2 + R_3$ etc. $\frac{1}{R_{TOTAL}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$ etc.

Two Resistances Only



$R_{TOTAL} = \frac{R_1 \times R_2}{R_1 + R_2}$ Unknown $= \frac{R_T \times R_1}{R_1 - R_T}$

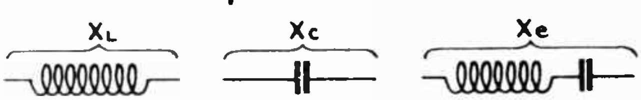
Capacity Relations

$C_{TOTAL} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$ etc. $C_{TOTAL} = C_1 + C_2 + C_3$ etc.

Two Capacities Only

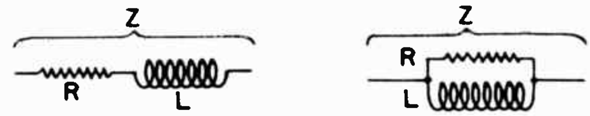
$C_{TOTAL} = \frac{C_1 \times C_2}{C_1 + C_2}$ Unknown $= \frac{C_1 \times C_T}{C_1 - C_T}$

Simple Reactance



$X_L = 2\pi FL$ $X_C = \frac{1}{2\pi FC}$ $X_e = 2\pi FL - \frac{1}{2\pi FC}$

Complex Impedance



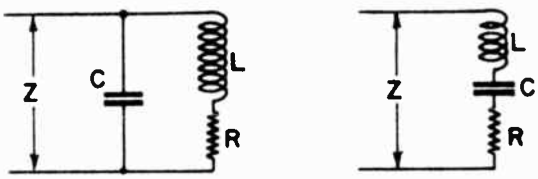
$Z = \sqrt{R^2 + 4\pi^2 L^2}$ $Z = \frac{2\pi LR}{\sqrt{R^2 + 4\pi^2 L^2}}$

$Z = \sqrt{R^2 + \frac{1}{4\pi^2 C^2}}$ $Z = \frac{R}{\sqrt{4\pi^2 R^2 C^2 + 1}}$

Resonance Formulae

$F = \frac{1}{2\pi\sqrt{LC}}$ $L = \frac{1}{4\pi^2 F^2 C}$ $C = \frac{1}{4\pi^2 F^2 L}$

Where F is in cycles, L is in henries, and C in Farads



$Z = \frac{2\pi FL}{4\pi^2 F^2 LC - 1}$

At Resonance:

$Z = Q\, 2\pi FL$

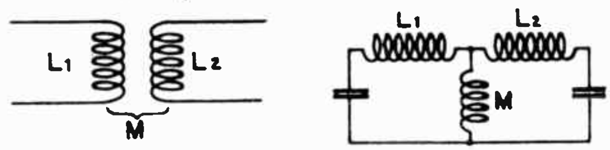
Where $Q = \frac{2\pi FL}{R}$

$Z = \sqrt{\left(2\pi FL - \frac{1}{2\pi FC}\right)^2 + R^2}$

At Resonance:

$Z = R$

Coupling Coefficient

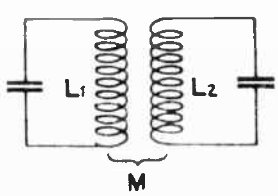


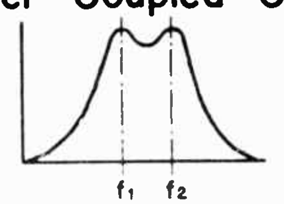
$K = \frac{M}{\sqrt{L_1 + L_2}}$ $K = \frac{M}{\sqrt{(L_1+M)(L_2+M)}}$

$K = \frac{\sqrt{\frac{C_1 \times C_m}{C_1 + C_m} \times \frac{C_2 \times C_m}{C_2 + C_m}}}{C_m}$ $K = \frac{\sqrt{\frac{C_1 \times C_m}{C_1 + C_m} \times \frac{C_2 \times C_m}{C_2 + C_m}}}{C_m}$

Where $C_m = \frac{C_3 \times C_4}{C_3 + C_4}$

Over-Coupled Circuit Frequencies





$f_1 = \frac{F}{\sqrt{1+K}}$

$f_2 = \frac{F}{\sqrt{1-K}}$

Where F is the resonant frequency of each circuit independent of the other and K is the coupling-coefficient

REVIEW QUESTIONS

1. How many changes of direction does 60 cycle current have each second?

2. In an inductive circuit does voltage lead the current?

3. What is the inductive reactance of a 10 henry choke in a 60 cycle A.C. circuit?

4. What is the total impedance if this choke is connected in series with a 1,000 ohm resistor? Work this problem and then check with the chart.

5. What reactance does a 0.1 mfd. condenser offer to 500 cycle current? What happens if a 1. mfd. is used instead?

6. In a series circuit, the resistance is 4 ohms, the inductive reactance 11 ohms, and the capacitive reactance 8 ohms. Find the equivalent impedance.

7. What kind of filter would be needed to eliminate the high frequencies in an audio amplifier?

8. Is it true that when a condenser and a choke are connected in series, the resulting impedance is in value smaller than the inductive reactance or the capacitive reactance taken separately? Why?

9. Set up several circuit problems and solve them with the aid of the charts included.

10. Using a coil of 220 microhenries and a condenser that can be varied from 20 to 400 micro-microfarads, what frequency coverage will be secured?

11. Refer to the "Handy Radio Formulae" listing and make up a problem with real values for each of the formulae. Then proceed to solve this problem.

12. Remembering the results obtained in problem 10, try to see the reason why several different coils must be used for all wave coverage.

13. If the F (frequency) term in any of the A.C. formulae is set at zero, will the formula then be true for D.C.?

14. If the cost of condensers is much less than the cost of power chokes, is there an advantage to use much capacity and small chokes in power supply filters? Is this actually done in practice?

15. Examine a power supply circuit. Remembering that a D.C. voltage of varying intensity enters here into the filter, try to analyze the actual action.

LESSON 8

ANTENNA SYSTEMS, USES AND INSTALLATION. SIMPLE RECEIVING CIRCUITS.

The antenna system consists of the actual aerial, lead-in wires, and the ground or its equivalent. The antenna's aerial and ground act as the two plates of a large condenser. As in any condenser, the resistance should be low to eliminate losses. At the transmitting station the antenna system is used to create electromagnetic waves and must do this task efficiently. At the receiving end in conjunction with the receiving radio set the antenna system must pick up these radio waves and induce a signal voltage of maximum obtainable value.

The attention given to antenna systems declined when screen grid tubes came into use. "A few feet of wire under the carpet" would serve as the aerial. True, little energy pickup is needed with modern high gain sets, but when a set is made to operate at its maximum sensitivity certain noises developed in the set proper become much more pronounced. It is also known that the noise to signal ratio may be decreased with a suitable antenna. Further, short wave reception calls for a more efficient antenna system.

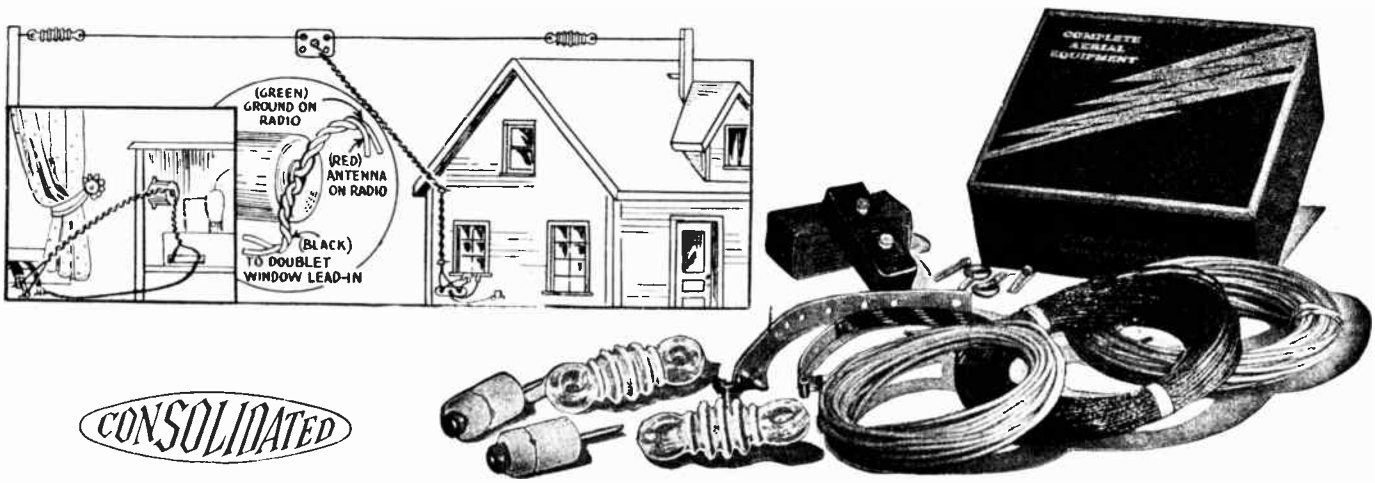
An ideal antenna system would be nondirectional, pick up very little background noises of man made static, and be equally effective on all frequencies. There is hardly need to say that such an antenna does not exist. Modern aerials with their associated special lead-ins and coupling systems do, however, approach the ideal case.

To eliminate undesirable pickup and insure satisfactory signal energy, the aerial should be errected as far away as possible from interference sources such as power lines, transformers, street car or elevated lines, or any other electrical devices, and at the same time the aerial should be placed as high as practical above the roof or other structures.

Another way to reduce the pickup of man made static is to employ a lead-in of such design that pickup by the lead-in is completely eliminated. This is adventageous since it may be possible to place the antenna wire sufficiently high and away from sources of interference, it may not be possible to do the same with the lead-in wire. There are two types of lead-in systems that posses no pickup qualities: (1) the shielded type, and (2) the balanced transposed line used with doublet antennas. Although a shielded line is suitable for ordinary broadcast frequencies, it is not suitable for higher frequencies. Since almost all modern sets are designed to receive one or more high frequency bands, we will consider the transposed balanced line. When employed in connection with a correctly designed coupling unit, the pickup of the lead-in is negligible.

Generally a modern all wave doublet antenna system consists of two aerial wires of equal and suitable length suspended in a straight line between two supports and insulated there-from and between themselves. From the point where both wires join the insulator, two separate lead-in wires are connected to the two wires respectively. These wires may be twisted, but for best results they should be transposed every couple of feet with the aid of transposition blocks.

The two lead-in wires will carry two distinct antenna currents, out of phase, while the pickup of the two wires of the lead-in will be in phase. Now if a transformer is used to transform energy to the radio set, the in-phase components will balance each other out. The signal component of each wire being out of phase will add up in the transformer.



The antenna supports should be sturdy and firmly secured. The antenna wire should be tightly stretched. Many antennas constructed with neglect in this connection sway and cause the set to reproduce sharp clicking noises or fade on and off. The clicking is due to some connection moving, while the fading effect is due to the antenna changing its capacity as its sways.

For outdoor antennas a lightning arrester is always recommended. The chance of lightning causing any damage is very slight, but why risk an expensive radio and the possibility of a fire? The lightning arrester is connected to the aerial and ground. There is a short gap inside between these two connections and when lightning strikes it jumps across this gap. In this manner the radio set is protected.

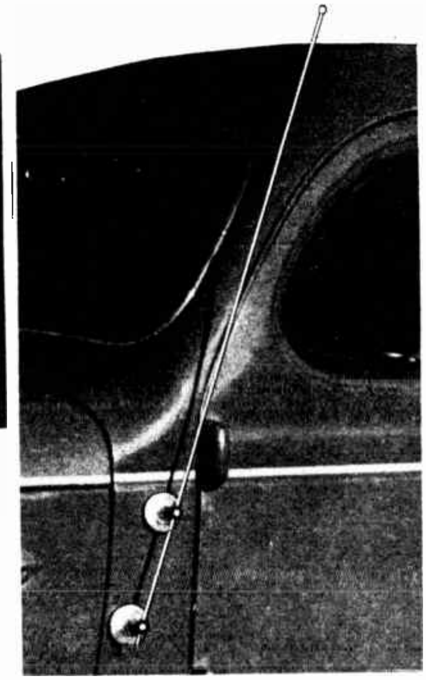
A suitable ground may be obtained from the water pipe. A copper screen placed in moist soil also makes an excellent ground connection. The doublet antennas do not require a ground connection, except for the arrester.

AUTOMOBILE SET ANTENNAS

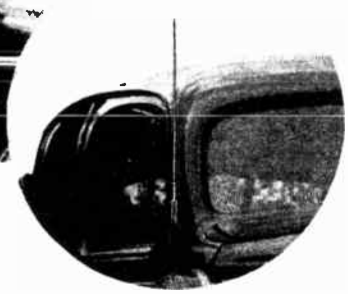
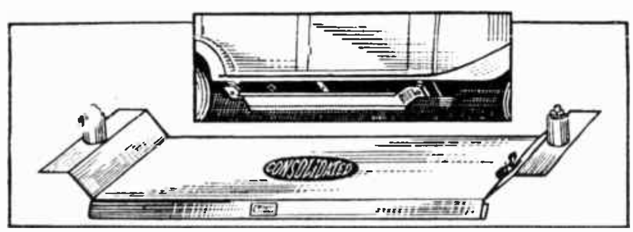
With the advent of auto radios certain new requirements as well as limitations had to be considered. While on one hand an antenna placed in an auto is limited in height, shielded undesirably by the metal parts of the car's body, and usually must be comparatively small, it must possess the theoretical requirements of fixed house antennas previously described.

Auto radio antennas are either mounted under the car between the axles or under the running boards, outside the car along the roof, or along the sides or back, or in non-metal roof types inside the roof inside of the car. The different types in use are easily noticed in passing cars.





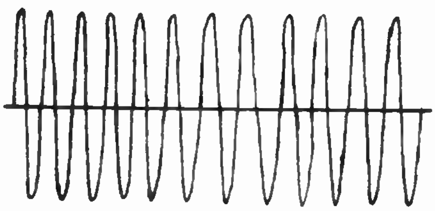
Photographs courtesy
Consolidated "Products"

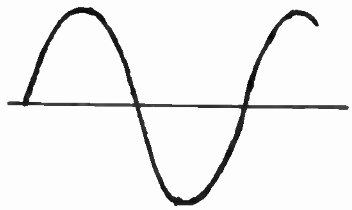
The auto radio antennas are usually required to receive only stations of the broadcast band, thereby considerably simplifying the problem. Auto radios are made very sensitive to further simplify the pickup problem.

<u>ANTENNA ACTION</u> The electro-magnetic waves induce a current in the antenna circuit. This current is very minute in intensity, but is an exact duplicate in form of the original signal sent out. Of course, the antenna is excited by the waves sent out by all stations throughout the world. The closer and more powerful stations produce a greater current, but every transmitting program, code or music, near and far, on any frequency produces and effects the antenna. Since we want to receive but one station at a time, stations in the same geographical locality send out signals on different frequencies. For example, the broadcasting stations in the U. S. transmit on frequencies separated by 10 k.c. An antenna in any one vacinity will receive all signals of these different frequencies. By using a number of tuned circuits it is possible to select the desired signal from among all others. A tuned circuit also builds up the resonance frequency and by this method increases the strength of the wanted signal.

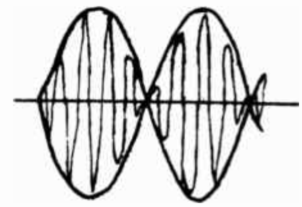
MODULATION At the station a carrier signal of Radio Frequency is generated, usually by means of vacuum tube oscillators. The sound for broadcasting is amplified separately by means of suitable audio amplifiers (explained in Lesson 14). The increased audio signal is superimposed on the carrier frequency by a process called modulation. The intensity of the carrier is modified by the audio signal as illustrated.



Carrier Wave



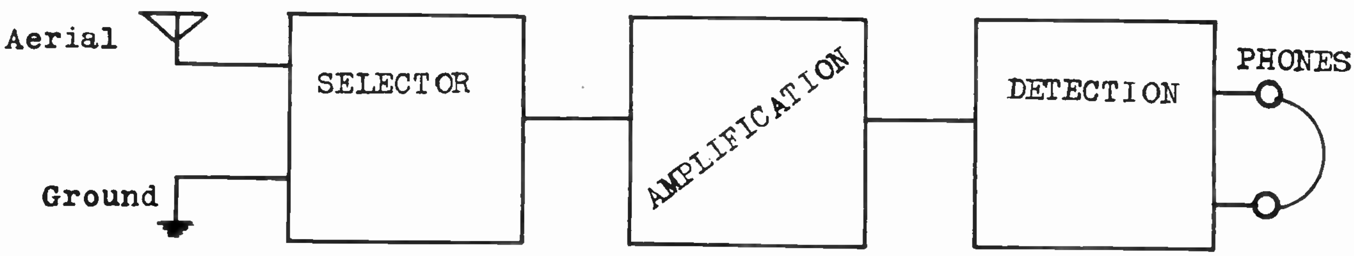
Audio Frequency



Modulated Wave

Actually the carrier frequency modulated occupies a channel plus and minus the signal's audio frequency. Since the present day broadcasting channels are 10 k.c. wide, or 5 k.c. on each side of the carrier, the program transmitted may have frequencies up to 5,000 cycles per second.

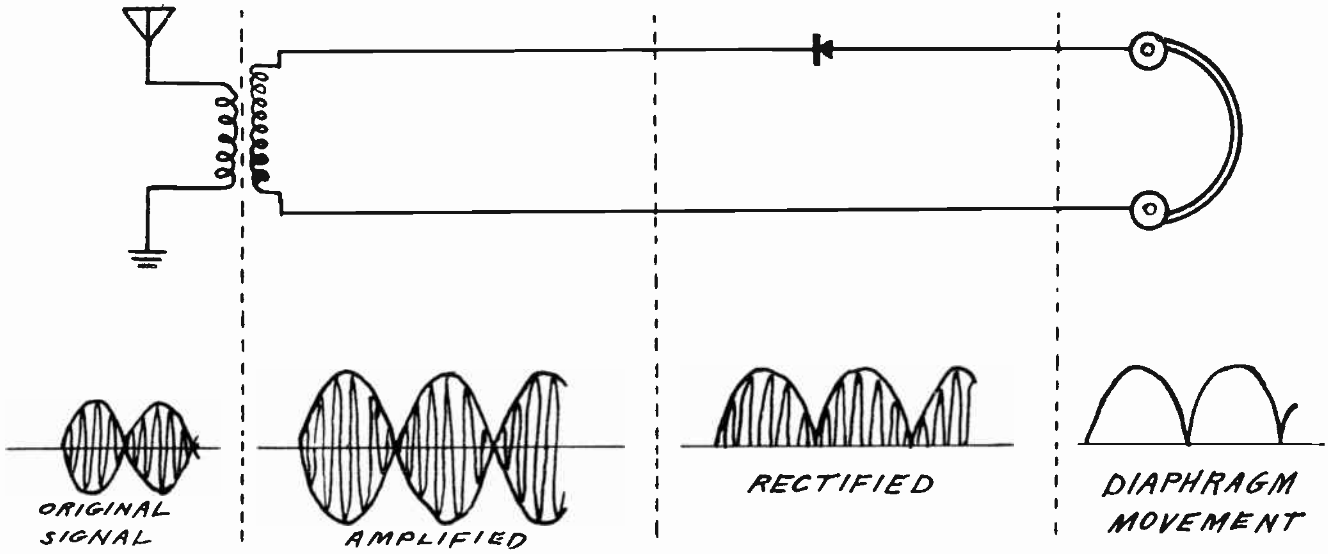
At the receiving set a loudspeaker or headphones are used to change the electrical energy back to acoustical energy. The energy needed to operate the speaker is the actual audio frequency and this frequency must be separated (demodulated or detected) from the R.F. carrier.



A DIAGRAMATICAL ILLUSTRATION OF A SIMPLE RECEIVING RADIO SET

CRYSTAL DETECTOR Although in modern radio sets vacuum tubes are used as the detectors, in the early days of radio crystal detectors were extensively employed. A crystal detector consists of a mounted crystal of some particular material such as galena, iron pyrites, or carborundum, and has a fine wire for making the contact. When an alternating current of any frequency is applied to the crystal, it is permitted to flow in one direction only. In the reverse direction a very high resistance will be present. In this manner detection takes place since the intensity of the radio wave is directly controlled by the audio signal.

The student will easily see that the antenna picks up the signals, a particular signal is selected by the tuned circuit consisting of a fixed R.F. transformer (coil) and variable condenser, this signal is then rectified or detected by means of the crystal detector, and the diaphragms of the headphones follow the actual audio variation impossed upon the carrier at the broadcasting studio.



The reception permitted by a crystal detector is limited in volume because of lack of amplification. To permit loudspeaker operation and to obtain necessary selectivity vacuum tubes are employed. These more advanced circuits have been briefly mentioned and will be discussed in greater detail later on.

At this stage of your study, you should bégin to notice radio parts in the radio set you may have at home. Try to name every part, trace out some of the simpler connections, notice the arrangement of the different parts.

If your funds will allow you, purchase from one of the radio jobbers a simple radio kit and try to build this set. A two tube set of the battery or A.C. operated type is best for the start. The Knight DX-ER is a good circuit to follow and is described on the next two pages.

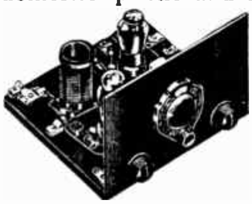
You are also now ready to attempt radio repair of the easier type. Try to obtain work locally. If the set needing repair presents too many particular problems to you with your limited knowledge, turn it over to some other serviceman in your locality and assume the part of an agent. The easier tasks, of course, can be handled by you.

REVIEW QUESTIONS

1. What advantages does the doublet antenna system give?
2. What tube in the receiver does the demodulation?
3. Why is it not practical to have loud speaker reception with a simple crystal set?
4. How is the reception of different bands accomplished in the two tube DX-ER?
5. How can the circuit of the crystal set on this page be changed to receive several different stations?

KNIGHT 2 TUBE "DX-ER"

The 2-Tube "DX-er" is a dependable battery operated short-wave receiver which can be built quickly and easily. The tuning range is 15 to 500 meters when used with proper coils, covering the important foreign and domestic 'phone and code Amateur bands, as well as regular standard broadcast programs.



Assembled "DX-er"

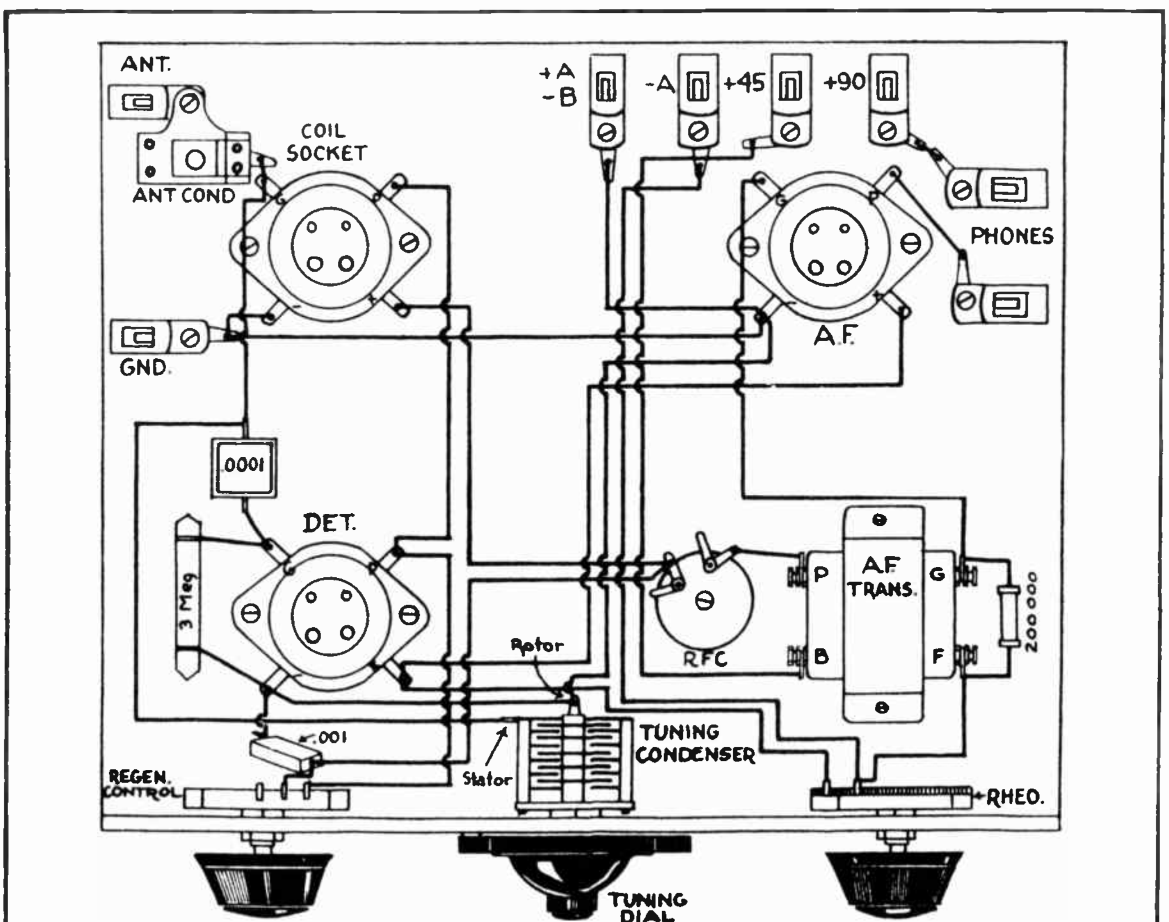
Before you begin to wire, you should mount all the parts as indicated on the pictorial diagram. This is extremely important for effective results. You can then start the wiring, following the schematic diagram and checking your work from time to time with the pictorial diagram. As you proceed, trace the completed connections with a colored pencil. This will help you to remember exactly which connections have already been made.

After the set has been wired and one of the coils and the two type 30 tubes are in place, connect the "A" battery and advance the rheostat until a filament glow is noticeable in the tubes. This is a safety step to check if the filaments are wired correctly. No glow indicates that an error has been made in the filament circuit of the tubes. When the filament glows, connect the "B" battery and insert the headphones into the proper Fahenstock clips.

Now test the set to see if it will regenerate. Advance the regeneration control to the right, and a whistle will be heard. If you do not hear this whistle, check the coil socket and the "B" batteries to see that they are wired correctly.

Next, connect the antenna and ground. With these in place and the regeneration control just below oscillation (whistling point), turn the tuning control and you will receive several stations. You will find that adjusting the antenna trimmer will help a great deal. The antenna condenser should be adjusted so that the detector tube will oscillate at all points on the tuning dial. The point of adjustment depends entirely upon the degree of absorption of the antenna circuit from the tuning circuit. Once the trimmer is adjusted for any one of the coils, no other changes need be made until

PICTORIAL WIRING DIAGRAM



Courtesy Allied Radio Corp.

KNIGHT 2 TUBE "DX-ER"

a different coil is used. This adjustment is not critical except when you actually want some real DX. It is worth mentioning here that a good aerial is essential for efficient short wave reception, particularly for a set of the "DX-er" type. Both the aerial and lead-in should be well insulated and kept as far away from walls, roofs, etc., as possible.

You will soon learn in using the "DX-er" that broadcast and amateur 'phone stations come in best when the regeneration control is below the point where oscillation starts. Code signals, however, come in best above this point. In working on the short wave bands, keep the set just oscillating, and tune very slowly. The incoming "dit-dit-dah" will tell you that you have a code station. A whistle, on the other hand, should serve as a warning to reduce the regeneration control setting, and then to listen to a 'phone station at this dial setting.

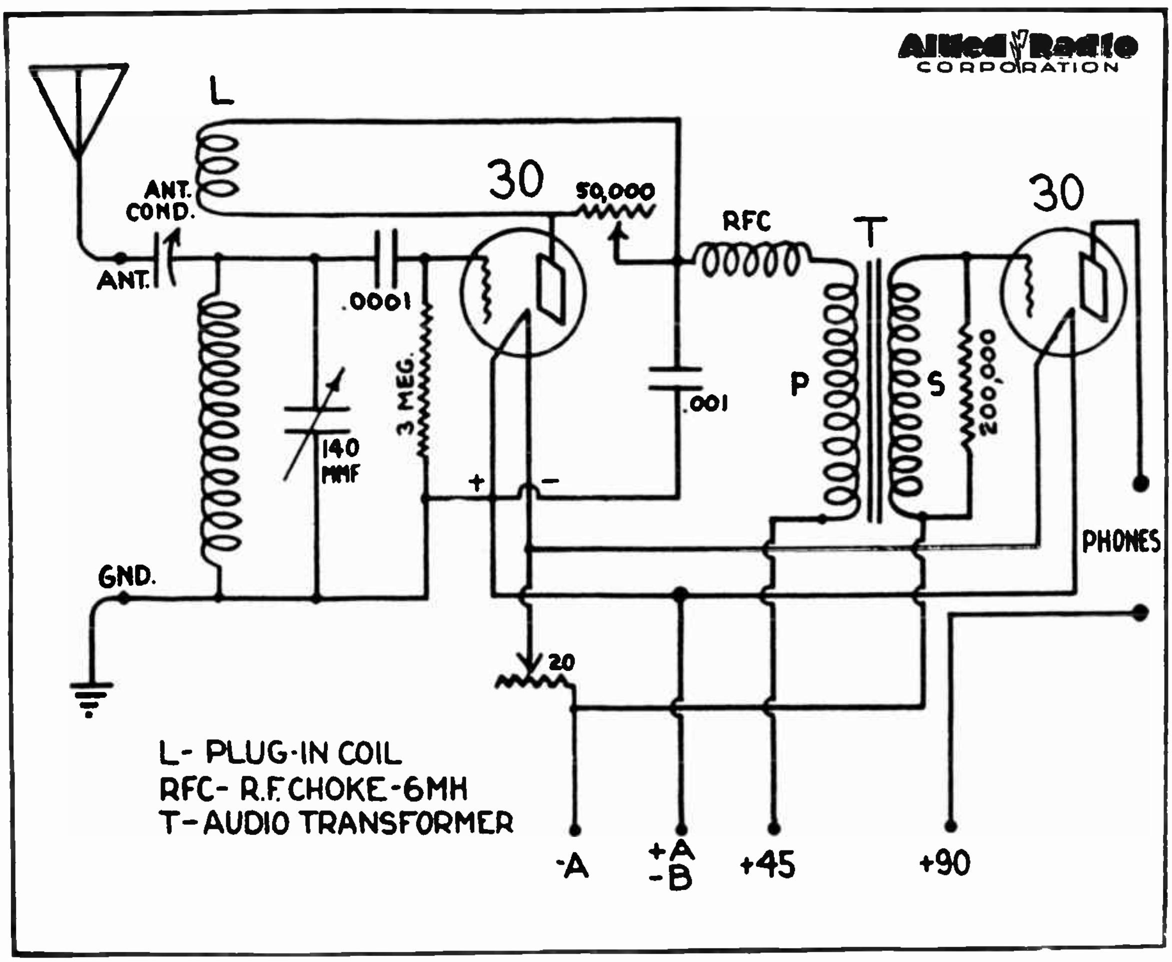
While there is nothing tricky about the operation of the "DX-er," it is well to spend some time in learning how to tune it so that you may derive maximum reception. (See right for complete parts list.)

1 Knight 7x9 drilled Masonite panel
3 Eby 4-prong sockets
1 140 mmf. variable condenser
1 Carter 30 ohm rheostat
1 Knight 50,000 ohm regeneration control
1 3 to 1 audio transformer
1 Hammarlund antenna condenser
1 Knight R.F. choke
1 " .0001 mfd. condenser
1 " .001 mfd. condenser
1 I. R. C. 3 megohm resistor
1 Knight 200,000 ohm resistor
8 Fahenstock single clips
1 Knight baseboard
1 Kurz Kasch dial
2 Knight knobs
1 " hardware kit of screws, nuts, wire, etc.

1 Coil kit 16 to 217 meters

2 Raytheon 30 tubes
2 Knight dry cells
2 " "B" batteries
2 " plugs for batteries

SCHEMATIC WIRING DIAGRAM



LESSON 9

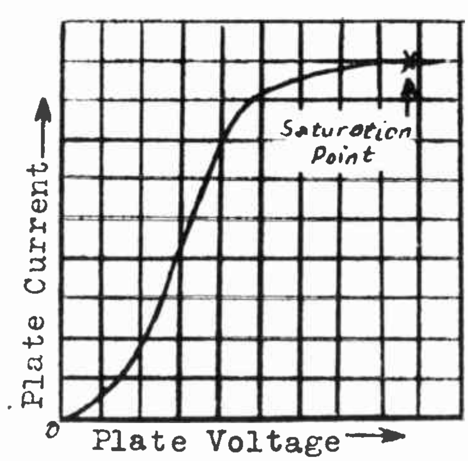
RADIO TUBES

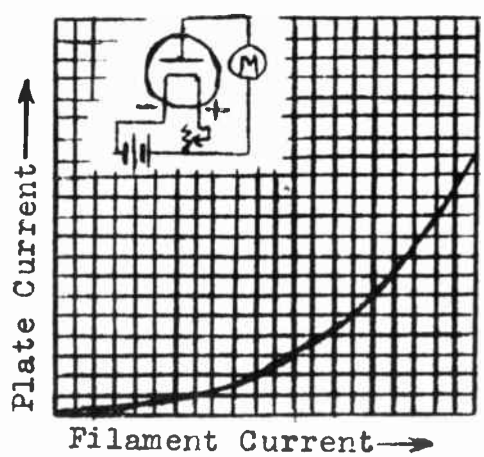
The basis of all vacuum tubes operation, be they rectifiers, or multi-purpose tubes, in glass or metal envelopes, is electron emission. Electrons are emitted from an electrically heated filament or from a covering placed over this filament and insulated from it. This later type of emission is called indirect. The element emitting the electrons is known as the cathode. Some substances are far better emitters than others. Coating a poor emitter with an oxide of certain metals may raise the emission thousand times. The emission also increases with the temperature.

In 1883, Thomas Edison discovered that when an additional electrode was placed inside an incandescent lamp and this electrode connected to a positive potential with respect to the filament, a current passed through the circuit. This is actually a simple vacuum tube of the diode type. It contains but two elements, the cathode to emit and the plate (anode) to receive the electrons. Under the influence of a positive potential applied to the plate, electrons will flow from the cathode to the positively charged plate. An increase in the plate potential will increase the plate current. The complete action is easy to analyze.

From a heated cathode many electrons venture out, forming a cloud around it. If a negative potential is applied to the plate the electrons around the cathode will be repelled back into the cathode and no current will pass between these two elements. If, however, the plate becomes positive with respect to the cathode, the electrons around the cathode will be attracted to the plate, since unlike charges attract, and current will pass. In a rectifier an alternating current is applied, during the positive cycle current will flow, but not during the negative. In this manner the alternating current will be rectified into pulsating direct.

Of the electrons leaving the cathode not all, of course, reach the plate. Many return to the cathode while others remain for short periods of time between the cathode and the plate forming a <u>space charge</u>.





Since this charge consists of electrons it is electically negative and has a repelling force exerted upon other electrons and thereby impedes the passage of current between cathode and plate. By increasing the plate voltage, more electrons will be attracted and the tendency to form a space charge will be reduced.

Once the plate voltage reaches a certain maximum when all the electrons leaving the cathode are attracted to the plate, a further increase of the plate voltage will have no effect on the plate current. This maximum current is known as the saturation current.

Tubes having a third electrode for control purposes are known as triodes. This control electrode is usually called the grid because it is made of fine wire in a form of a mesh. The purpose of the grid is to control plate current. With a negative voltage on the grid, the grid exerts a force on electrons in the space between cathode and grid. This force drives the electrons back to the cathode. In this way, the negatively charged grid opposes the flow of electrons to the plate. When the voltage on the grid is made more negative, the grid exerts a stronger repelling force on the electrons and the plate current is decreased. When the grid voltage is made less negative, there is less repeling force exerted by the grid and the plate current increases. When the voltage on the grid is varied in accordance with a signal, the plate current also varies with the signal. Because a small voltage applied to the grid can control a comparatively large amount of plate current, the signal is amplified by the tube.

The grid, plate, and cathode of a triode form an electrostatic system, each electrode acting as one plate of a small condenser. The capacitances are those existing between grid and plate, plate and cathode, and grid and cathode. The capacitance between grid and plate is of greatest importance and, in high gain radio-frequency circuits, this capacitance may produce undesired coupling between the input and output circuits.

A much smaller change in the grid voltage will produce the same change in the plate current as a much larger plate voltage change. The ratio of the small change in the plate voltage (E_p) to the smaller change in the grid voltage (E_g) that will vary the plate current by an equal small amount is called the amplification factor, or μ (mu). Mathematically:

$\mu = \frac{dE_p}{dE_g}$ where d means the differential, a very small change.

For example, a type 56 triode tube operating in a conventional circuit with

$E_g = -13.5$ volts, $E_p = 250$ volts, $I_p = 5$ milliamperes

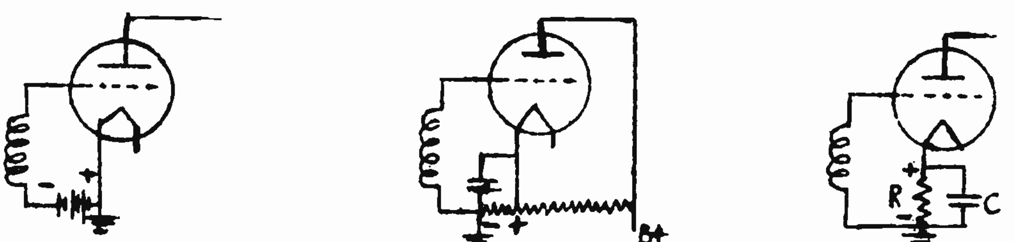
will have one milliampere less of plate current (I_p) by either a change of 0.87 volts in E_g, or a change in E_p of approximately 12 volts. The ratio of the two will give about 13.8 as the mu of this particular tube.

The plate resistance (r) of a tube is the resistance to the alternating current of the path between the plate and the cathode. It is the ratio of a small change in plate voltage (E_p) to the corresponding change in the plate current (I_p). That is:

$$r = \frac{dE_p}{dI_p}$$

The grid may be made to assume either positive or negative values with respect to the cathode. When the grid is negative with respect to the cathode, the grid will not attract electrons and no current will flow between it and the cathode. This means that the grid will not take power from the circuit connected to it. In this manner minute power can be used to control comparatively large plate power. Because of this and other reasons, it is desirable to keep the grid at some negative potential at all times. The negative potential applied to the grid must, therefore, be at all times larger than the greatest positive swing of the grid input voltage.

This constant negative potential is called the bias and may be obtained from batteries, but usually a section of the voltage divider is tapped off for this purpose or a resistor of a correct value is placed in the cathode return circuit and causes a drop of potential because of the passage of the direct plate current. A by-pass condenser offering very low impedance to the alternating current component of the plate current is employed to act as an easy path for all currents except the direct current component.



Battery Bias   Voltage Divider Bias   Self Bias

The detrimental effect of the grid-plate capacitance is reduced greatly by the introduction of a fourth electrode, called the screen grid, placed between the grid and the plate. This screen in ordinary application is connected to a positive potential somewhat lower than the plate potential. Since the screen voltage largely determines the electron flow, large variations in the plate voltage will have but little effect on the plate current.

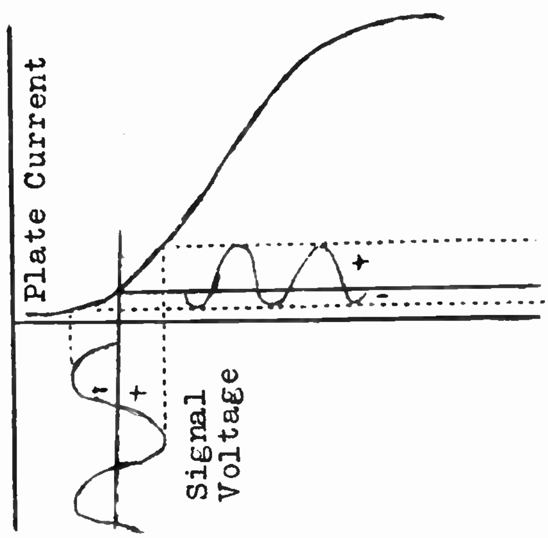
Electrons striking the plate dislodge other electrons from it. This indirect emission of electrons from the plate is called secondary emission in contrast to primary emission from the heated cathode. In the diode or triode this action does not cause any difficulties because of the absence of any positive bodies in the vicinity of the plate. In the screen grid type tetrode, however, the screen is positive and close to the plate and does attract electrons emitted by the secondary emission action. This effect lowers the plate current and limits the permissible plate swing.

This limitation in turn may be removed by a further introduction of another electrode, known as the suppressor, between the screen and the plate. The suppressor may be connected directly to the cathode or, as in some tubes for special applications, have an external prong. Since such tubes have five elements they are called pentodes.

BEAM POWER TUBES A beam power tube makes use of a different method for suppressing secondary emission. In this tube there are four electrodes, a cathode, control grid, screen grid, and plate so spaced that secondary emission from the plate is suppressed without an actual suppressor. Because of the way the electrodes are spaced, electrons traveling to the plate slow down when the plate voltage is low, almost to zero velocity in a certain region between the screen and plate. In this region the electrons form a stationary cloud, a space charge, repelling secondary electrons emitted from the plate and cause them to return to the plate. In this manner, secondary emission is suppressed. Another feature of the beam power tube is the low current drawn by the screen, as well as economical operation.

At the present time there are also many special tubes designed to serve some special purpose or combine in a single envelope two or more tubes. The student is urged to carefully study the Sylvania Tube characteristic chart. You should have a good idea of the characteristics and applications of the more common tubes.

BIAS DETECTOR After about 1929 detectors were operated at the lower bend of their characteristic curves by using sufficient bias. Detection took place because a positive swing in the grid voltage caused a much larger increase in plate current than a corresponding decrease when an equal negative grid voltage was applied. Notice the rectification-detection that takes place in the illustrated example of a single sine wave.



The bias may be obtained in any of the ways described previously, i.e. C batteries, voltage divider, or self biased.

GRID LEAK DETECTOR Working on a different principle, grid leak detectors were extensively used some time ago. However, these detectors have many disadvantages when considered for use in modern radio receivers and find but little present day application.

Plate Characteristics, 46 Class A

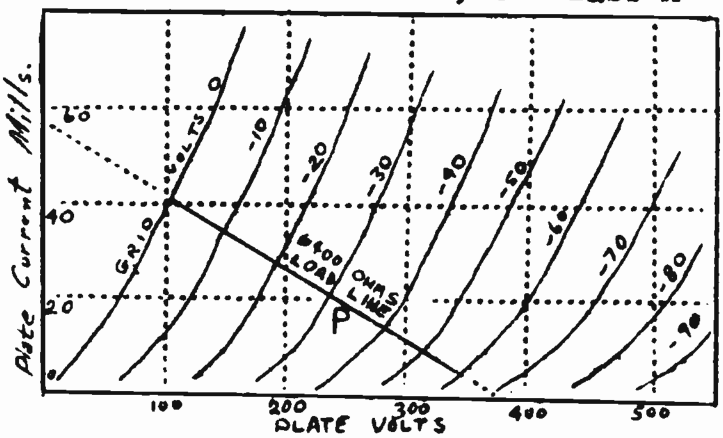


Plate characteristic curves are useful in determining the best operating conditions of a tube. The plate current is plotted as the ordinate, and the plate voltage as the abscissa. Keeping the grid potential fixed at some value, the variations in plate voltage are plotted against the corresponding variations of plate current. By repeating this process for a number of different grid potentials, a group of similar curves are obtained, as illustrated for type 46 tube in class A operation. It will be noted that an increase in negative grid potential shifts the curve to the right.

To plot the load line having been given: E_g = -31 volts E_p = 250 volts, I_p = 22 milliamperes, Load resistance = 6,400 First, find where the given E_p and I_p intersect, mark this point P. Place a straight edge on point P; rotate it until the value of plate voltage intersected divided by the plate current also intersected, will equal the given load resistance, 6,400 ohms in this case. The edge will cut 58 milliamperes and 371 volts at the same time. Since 371/.058 = 6,400, this is the correct line.

If the grid swing may be considered to be between zero and the value twice the fixed bias, than the formulas below may be applied in calculating the amount of second harmonics and power output. Second harmonics are frequencies twice the signal frequency generated by the tube and usually not wanted.

At any value of grid potential, the plate current value is directly to the left of the load line and that grid potential intersection; the plate voltage is directly below this intersection. For example in the previous graph, when E_g = -10, the plate voltage is 150, and the plate current is about 34 milliamp.

$$\text{POWER OUTPUT} = \frac{(I_{max} - I_{min}) \times (E_{max} - E_{min})}{8}$$

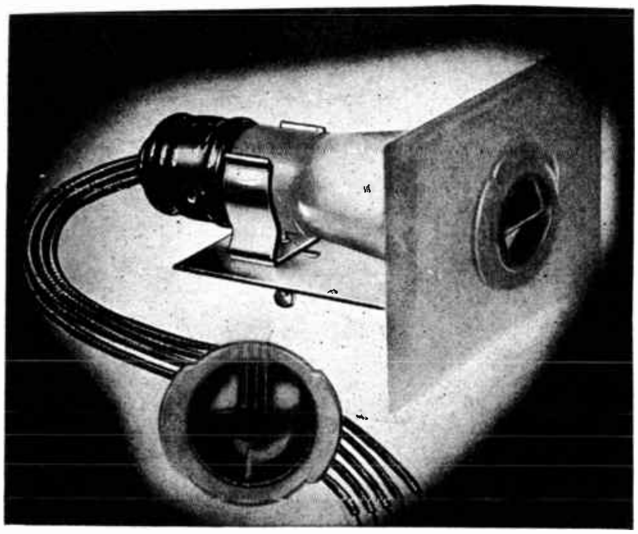
$$\text{\% 2nd HARMONICS} = 50 \times \frac{(I_{max} + I_{min} - 2I_{average})}{I_{max} - I_{min}}$$

The functions of vacuum tubes are varied. In a receiving radio set vacuum tubes are used primarily as voltage and power amplifiers, and to a limited extent as detectors and oscillators. The current change in the plate circuit of a vacuum tube may produce a voltage variation across a resistance, a high impedance, or the impedance of the primary of an audio transformer or a R.F. transformer. If the plate current is passed through a high resistance connected between the plate and the positive side of the plate voltage supply, voltage variations will be produced in proportion to the changes in the plate current. The voltage drop will distribute itself in proportion to the resistance of the tube (r) and the load resistance (R). The voltage amplification will be a fraction of the amplification factor μ, expressed by the relation:

$$\text{Voltage Amplification} = \frac{\mu R}{r + R}$$

In case the load is an impedance Z, it may be substituted for R in the above formula.

The types 6E5, 6G5, and other tuning indicator tubes are finding extensive use in modern sets, and may be added to any radio having automatic volume control. The tube's filament is simply wired in series with other tubes in A.C.-D.C. type sets, or connected to the power transformer filament winding. Usually the transformer can easily handle an additional tube. In sets using 2.5 volt tubes type 2E5 must be employed.



MAGIC EYE ASSEMBLY

The adapter sockets supplied (as illustrated) have an internal screen resistor and are simply connected to the filament supply, B plus point, chassis or negative return, and a point of the correct A.V.C. voltage. Complete instructions are always supplied with the unit you may purchase.

Photograph of American Phenolic Corporation unit.

There are a great many different tubes used in radio receiving sets. All the types are listed in the SYLVANIA tube chart following. A great many types are identical except for the fact that one series is for 2.5 volt operation, the second series for 6.3 volt use. Note for example the corresponding types 58 and 78, or 55 and 85. Also in the same series there are many tubes almost alike, see 6C6, 77,& 6J7. There are tubes to serve in A.C. sets, in combination A.C.-D.C. sets, in battery sets, and for many other special applications.

All the metal tubes have equivalent glass types. For example, 6K7 has a glass equivalent 6K7-G. The G type tubes may be used for metal or vice versa, provided space permits and the glass tubes substituted are provided with shields in certain cases. There are also many G type tubes not having metal equivalents, see 6K6G, 25A7G.

Now you have already noticed that the first column of the chart gives the type number. The next column tells the class of the tube. Is the tube a triode, a pentode, or is it a complex tube such as duotriode. Next is the "base" data. The code letters refer to the tube diagrams on pages 6 and 7 of the chart booklet. Look up type 6A8 for practice. You will note that it is a heptode (six elements). For base connections you are to refer to 8-A. As you find 8-A diagram you will note that the tube requires an octal socket uses eight pins and a grid cap on top. And in the next column you are told that the bulb is 8A-1. This information will give you the actual outside physical dimentions.

The filament current and voltage are given in the next listing. Of course, the wattage is the product of the two. Note that the old style tubes (now used for replacement only) required much more power than the modern more economical tubes. Also note that the battery tubes take less filament power; see types 1A4, 30, and 32.

Other important and useful data about the tubes is given also. The average operating conditions are stated. This information will permit you to check sets and to design circuits. As practice, check all the tubes in several sets you may be able to examine and see that the tubes are used as recommended, have the correct type of bases, and are of the proper series to be used.

REVIEW QUESTIONS

1. In the consideration of plate current and plate voltage of a vacuum tube, what is the saturation point?
2. Can any element in a tube, having a negative potential in respect to the cathode, attract electrons?
3. How does the screen grid of a tetrode reduce the capacity between the control grid and plate?
4. What is the meaning of amplification factor?
5. In radio receiving circuits, why must the control grid be biased negatively?
6. How does secondary emission take place?
7. What advantages do beam power tubes have?
8. Examining the chart, state the average amplification of triodes? Pentodes?
9. What is the advantage of metal type tubes?
10. What tube fits a 7 small prong socket? What tube fits a 7 large prong socket? (refer to the chart).
11. List the different filament voltages used for the many different series of tubes? Will all these be needed in a good tube tester?
12. Check the tubes used in several radio sets with the listing on the chart. See if each tube is used in accordance with the recommended procedure.
13. Find two tubes that could be used in a circuit to replace type 6F7. Two types to replace type 25A7-G.

Sylvania

REG. U.S. PAT. OFF.

SET-TESTED

RADIO TUBES

CHARACTERISTICS

Printed in U. S. A.

Rerun 10M 7-18-40 Form 211

SYLVANIA AVERAGE

Type	Class	Base	Bulb	Filament Rating Volts	Filament Rating Amps.	Use	Plate Volts	Negative Grid Volts	Screen Volts	Plate Current Ma.	Screen Current Ma.	Plate Resistance Ohms	Micromhos Trans-conductance	Amplification Factor	Ohms Load for Stated Power Output	Undistorted Power Output Milliwatts
0Z4	Duodiode	4-R	8A-2	....	....	F-W Rect.	300 A	. C. Volts	Per Plate, R	MS, 75 Ma	. Max. 30	Ma. Min.	Output Cur	rent.	....	....
0Z4G	Duodiode	4-R	T-7NIC	....	....	F-W Rect.	300 A	. C. Volts	Per Plate, R	MS, 75 Ma	. Max. 30	Ma. Min.	Output Cur	rent.	....	....
01A	Triode	4-D	ST-14	5.0	0.25	Amplifier	90	4.5	......	2.5	......	11,000	725	8.0	....	....
							135	9.0	......	3.0	......	10,000	800	8.0	....	....
1A1	Monode	4-A	ST-12	(Batter	y Rece	iver Ballast Wi	th Avera	ge Filame	nt Voltage	Drop of 1.0	Volts at 50	0 Ma.)				
1A4	Tetrode	4-K	ST-12C	2.0	0.06	R-F Amp.	New Nu	mbering I	s 1A4T. Se	e Characteri	stics Below.					
1A4P	Pentode	4-M	ST-12C	2.0	0.06	R-F Amp.	135	3.0	67.5	2.2	0.9	500,000	675	325	....	....
							180	3.0	67.5	2.3	0.8	850,000	700	600	....	....
1A4T	Tetrode	4-K	ST-12C	2.0	0.06	R-F Amp.	135	3.0	67.5	2.2	0.7	350,000	625	220	....	....
							180	3.0	67.5	2.2	0.7	600,000	650	400	....	....
1A5G	Pentode	6-X	T-9B	1.4	0.05	Power Amp.	85	4.5	85.0	3.5	0.7	300,000	800	240	25,000	100
							90	4.5	90.0	4.0	0.8	300,000	850	255	25,000	115
1A6	Heptode	6-L	ST-12C	2.0	0.06	Converter	135	3.0	67.5	1.8	2.0	400,000	275 ▲	(G2=135	V. Max.,	2.0 Ma.)
							180	3.0	67.5	1.5	2.5	500,000	300 ▲	(G2=180	V. Max.,	2.5 Ma.)
1A7G	Heptode	7-Z	T-9C	1.4	0.05	Converter	90	0.0	45.0	0.55	0.60	600,000	250 ▲	(G2=90	V. Max.,	1.2 Ma.)
1B1	Monode	4-A	ST-12	(Batter	y Rece	iver Ballast Wi	th Avera	ge Filame	nt Voltage	Drop of 1.0	Volts at 36	0 Ma.)				
1B4P	Pentode	4-M	ST-12C	2.0	0.06	R-F Amp.	135	3.0	67.5	1.6	0.7	700,000	625	440	....	....
							180	3.0	67.5	1.7	0.6	1.1 Meg.	650	700	....	....
1B5/25S	Duodiode Tri.	6-M	ST-12	2.0	0.06	Detector	135	3.0	......	0.8	......	35,000	575	20	....	....
1C1	Monode	4-A	ST-12	(Batter	y Rece	iver Ballast Wi	th Avera	ge Filame	nt Voltage	Drop of 1.0	Volts at 74	5 Ma.)				
1C5G	Pentode	6-X	T-9B	1.4	0.10	Power Amp.	83	7.0	83.0	7.0	1.6	110,000	1500	165	9,000	200
							90	7.5	90.0	7.5	1.6	115,000	1550	180	8,000	240
1C6	Heptode	6-L	ST-12C	2.0	0.12	Converter	135	3.0	67.5	1.7	2.3	500,000	400 ▲	(G2=135	V. Max.,	3.0 Ma.)
							180	3.0	67.5	1.3	2.7	600,000	325 ▲	(G2=180	V. Max.,	3.8 Ma.)
1C7G	Heptode	7-Z	ST-12C	2.0	0.12	Converter	135	3.0	67.5	1.7	2.3	500,000	400 ▲	(G2=135	V. Max.,	3.0 Ma.)
							180	3.0	67.5	1.3	2.7	600,000	325 ▲	(G2=180	V. Max.,	3.8 Ma.)
1D1	Monode	4-A	ST-12	(Batter	y Rece	iver Ballast Wi	th Avera	ge Filame	nt Voltage	Drop of 1.0	Volts at 24	0 Ma.)				
1D5G	Tetrode	5-R	ST-12C	2.0	0.06	R-F Amp.	New Nu	mbering I	s 1D5GT. S	ee Characte	ristics Belo	w.				
1D5GP	Pentode	5-Y	ST-12C	2.0	0.06	R-F Amp.	135	3.0	67.5	2.2	0.9	500,000	675	325	....	....
							180	3.0	67.5	2.3	0.8	850,000	700	600	....	....
1D5GT	Tetrode	5-R	ST-12C	2.0	0.06	R-F Amp.	135	3.0	67.5	2.2	0.7	350,000	625	220	....	....
							180	3.0	67.5	2.2	0.7	600,000	650	400	....	....
1D7G	Heptode	7-Z	ST-12C	2.0	0.06	Converter	135	3.0	67.5	1.8	2.0	400,000	275 ▲	(G2=135	V. Max.,	2.0 Ma.)
							180	3.0	67.5	1.5	2.5	500,000	300 ▲	(G2=180	V. Max.,	2.5 Ma.)
1E1	Monode	4-A	ST-12	(Batter	y Rece	iver Ballast Wi	th Avera	ge Filame	nt Voltage	Drop of 1.0	Volts at 48	0 Ma.)				
1E4G	Triode	5-S	T9-B	1.4	0.05	Amplifier	90	0.0	....	4.5	....	11,000	1,325	14.5	....	....
							90	3.0	....	1.5	....	17,000	825	14	....	....
1E5G	Tetrode	5-R	ST-12C	2.0	0.06	R-F Amp.	New Nu	mbering I	s 1E5GP. S	ee Characte	ristics Belo	w.				
1E5GP	Tetrode	5-Y	ST-12C	2.0	0.06	R-F Amp.	135	3.0	67.5	1.6	0.7	700,000	625	440	....	....
							180	3.0	67.5	1.7	0.6	1.1 Meg.	650	700	....	....
1E7G	Duo Pentode	8-C	ST-12	2.0	0.24	Power Amp.	135	7.5	135	6.5ƒ	2.0ƒ	220,000	1,600	350	24,000¶	650
1F1	Monode	4-A	ST-12	(Batter	y Rece	iver Ballast Wi	th Avera	ge Filame	nt Voltage	Drop of 1.0	Volts at 72	0 Ma.)				
1F4	Pentode	5-K	ST-14	2.0	0.12	Power Amp.	135	4.5	135	8.0	2.6	200,000	1,700	340	16,000	340
1F5G	Pentode	6-X	ST-14	2.0	0.12	Power Amp.	135	4.5	135	8.0	2.6	200,000	1,700	340	16,000	340
1F6	Duodi. Pent.	6-W	ST-12C	2.0	0.06	R-F or I-F	180	1.5	67.5	2.0	0.6	1 Meg.	650	650	....	....
						A-F Amp.	135*	2.0	(Screen Sup	ply=135V	. Thru 0.8	Meg. Rest.,	Grid Rest.	1.0 Meg.,	Voltage	Gain 46.)
1F7G	Duodi. Pent.	7-AD	ST-12C	2.0	0.06	R-F or I-F	180	1.5	67.5	2.0	0.6	1 Meg.	650	650	....	....
						A-F Amp.	135*	2.0	(Screen Sup	ply=135V	. Thru 0.8	Meg.Rest.,	Grid Rest.1	.0 Meg.,	Voltage	Gain46.)
1G1	Monode	4-A	ST-12	(Batter	y Rece	iver Ballast Wi	th Avera	ge Filame	nt Voltage	Drop of 1.0	Volts at 42	0 Ma.)				
1G4G	Triode	5-S	T9-B	1.4	0.05	Amplifier	90	6.0	......	2.3	....	....	825	8.8	....	....
1G5G	Pentode	6-X	ST-14	2.0	0.12	Power Amp.	90	6.0	90.0	8.5	2.5	135,000	1,500	200	8,500	250
1G6G	Duotriode	7-AB	T9-B	1.4	0.10	Power Amp.	90	0.0	......	1.0	....	45,000	675	30 (Eac	h Triode	Class A)
							90	0.0	......	1.0	Zero Signal,Per	Triode	....	....	12,000¶	450
1H4G	Triode	5-S	ST-12	2.0	0.06	Det. Amp.	90	4.5	......	2.5	......	11,000	850	9.3	....	....
							135	9.0	......	3.0	......	10,300	900	9.3	....	....
							180	13.5	......	3.1	......	10,300	900	9.3	....	....
1H5G	Diode-Triode	5-Z	T9-C	1.4	0.05	Det., Amp.	90	0.0	......	0.15	......	240,000	275	65	....	....
1H6G	Duodiode Tri.	7-AA	ST-12	2.0	0.06	Detector	135	3.0	......	0.8	......	35,000	575	20	....	....
1J1	Monode	4-A	ST-12	(Batter	y Rece	iver Ballast Wi	th Avera	ge Filame	nt Voltage	Drop of 1.0	Volts at 62	0 Ma.)				
1J5G	Pentode	6-X	ST-14	2.0	0.12	Power Amp.	135	16.5	135	7.0	2.0	125,000	1,000	125	13,500	575
1J6G	Duotriode	7-AB	ST-12	2.0	0.24	Power Amp.	135	0.0	......	27.0†	......	(Class B O	peration)	......	10,000¶	2,100
							135	3.0	......	25.0†	......	(Class B O	peration)	......	10,000¶	1,900
							135	6.0	......	22.0†	......	(Class B O	peration)	......	10,000¶	1,600
1K1	Monode	4-A	ST-12	(Batter	y Rece	iver Ballast Wi	th Avera	ge Filame	nt Voltage	Drop of 1.0	Volts at 55	0 Ma.)				
1N5G	Pentode	5-Y	T9-C	1.4	0.05	R-F Amp.	90	0.0	90.0	1.2	0.3	1.5 Meg	750	1,160	....	....
1Q5G	Tetrode	6-AF	T9-B	1.4	0.10	Power Amp.	90	4.5	90.0	9.5	1.6	....	2,100	......	8,000	270
1R1G	Monode	4-T	ST-12	(Batter	y Rece	iver Ballast Wi	th Avera	ge Filame	nt Voltage	Drop of 1.0	Volts at 54	0 Ma.)				
1T1G	Monode	4-T	ST-12	(Batter	y Rece	iver Ballast Wi	th Avera	ge Filame	nt Voltage	Drop of 1.0	Volts at 56	0 Ma.)				
1V	Diode	4-G	ST-12	6.3	0.30	H-W Rect.	350 A.	C. Volts	Per Plate, R	MS, 60 Ma	. Output Cu	rrent				
1Y1	Monode	4-A	ST-12	(Batter	y Rece	iver Ballast Wi	th Avera	ge Filame	nt Voltage	Drop of 1.0	Volts at 54	0 Ma.)				
1Z1	Monode	4-A	ST-12	(Batter	y Rece	iver Ballast Wi	th Avera	ge Filame	nt Voltage	Drop of 1.0	Volts at 90	0 Ma.)				
2	Monode	4-A	S-14	(D.C.	or A.C	.-D.C.Receive	r Plug-in	Resistor	With Avera	ge Filament	Voltage D	rop of 9.0	Volts at 30	0 Ma.		
2A3	Triode	4-D	ST-16	2.5	2.50	Power Amp.	250	45.0	......	60.0	......	800	5,250	4.2	2,500	3,500
							300	68.0	......	40.0 per.	Tube, Push	Pull, Fixed	Bias		3,000¶	15,000
2A5	Pentode	6-B	ST-14	2.5	1.75	Power Amp.	250‡	16.5	250	34.0	7.5	79,000	2,350	185	7,000	3,000
							315‡	22.0	315	42.0	8.5	100,000	2,600	260	7,000	5,000
							250**	20.0	Tie Gs to P	33.0	......	2,700	2,300	6.2	3,000	650
							350**	38.0ƒ	Tie Gs to P	22.5 pe	r Tube, Push	Pull, No Si	gnal		8,000¶	15,000
2A6	Duodiode Tri.	6-G	ST-12C	2.5	0.80	Detector	250	2.0	......	1.0	......	91,000	1,100	100	....	....
2A7, 2A7S	Heptode	7-C	ST-12C	2.5	0.80	Converter	100	1.5	50.0	1.1	1.3	500,000	350 ▲	(G2=100	V. 2.0 M	a.)
							250	3.0	100	3.5	2.7	300,000	550 ▲	(G2=200	V. Max.,	4.0 Ma.)
2B7, 2B7S	Duodi. Pent.	7-D	ST-12C	2.5	0.80	R-F or I-F	100	3.0	100	5.8	1.7	300,000	950	285	....	....
						Amplifier	180	3.0	75.0	3.4	0.9	1 Meg.	840	840	....	....
							250	3.0	100	6.0	1.5	800,000	1,000	800	....	....
						A-F Amp.	250*	4.5	50.0	0.65	......	......	......	......	....	....
2E5	Triode	6-R	ST-12	2.5	0.80	Indicator	100§	(Series P	late Rest. 0.	5 Meg. Tar	get Cur. 2.0	Ma., Grid	Bias -3.3 for	0° Shadow)		
							250§	(Series P	late Rest. 1.	0 Meg. Tar	get Cur. 3.0	Ma., Grid	Bias -8.0 f	or 0° Shado	w)	
2S/4S	Duodiode	5-D	ST-12	2.5	1.35	Detector	The Two	Diode Pl	ates each D	raw Approx	imately 40.	0 Ma. with	50 Volts D.	C. on the Pl	ates	
2Z2/G84	Diode	4-B	ST-12	2.5	1.50	H-W Rect.	350 A.	C. Volts	Per Plate, R	MS, 50 Ma	. Output Cu	rrent	......	......	....	....
3	Monode	4-A	ST-16	(D.C.	or A.C	.-D.C. Receive	r Plug-in	Resistor	With Avera	ge Filament	Voltage D	rop of 128.	0 Volts at	300 Ma.)		
4	Monode	4-A	ST-16	(D.C.	or A.C	.-D.C. Receive	r Plug-in	Resistor	With Avera	ge Filament	Voltage Dr	op of 115.	0 Volts at	400 Ma.)		
5	Monode	4-A	ST-16	(D.C.	or A.C	.-D.C. Receive	r Plug-in	Resistor	With Avera	ge Filament	Voltage Dr	op of 115.	0 Volts at	460 Ma.)		
5T4	Duodiode	5-T	10A-2	5.0	2.00	F-W Rect.	450 A.C	. Volts P	er Plate, R	MS, 250 M	a. Output C	urrent	......	......	....	....
5U4G	Duodiode	5-T	ST-16	5.0	3.00	F-W Rect.	500 A.C	. Volts P	er Plate, R	MS, 250 M	a. Output C	urrent	......	......	....	....
5V4G	Duodiode	5-L	ST-14	5.0	2.00	F-W Rect.	400 A.C	. Volts P	er Plate, R	MS, 200 M	a. Output C	urrent	......	......	....	....
5W4	Duodiode	5-T	8B-1	5.0	1.50	F-W Rect.	350 A.C	. Volts P	er Plate, R	MS, 110 M	a. Output C	urrent	......	......	....	....
5X4G	Duodiode	5-Q	ST-16	5.0	3.00	F-W Rect.	500 A.C	. Volts P	er Plate, R	MS, 250 M	a. Output C	urrent	......	......	....	....
5Y3G	Duodiode	5-T	ST-14	5.0	2.00	F-W Rect.	350 A.C	. Volts P	er Plate, R	MS, 125 M	a. Output C	urrent	......	......	....	....
							400 A.C	. Volts P	er Plate, R	MS, 110 M	a. Output C	urrent				
							550 A.C	. Volts P	er Plate, R	MS, 135 M	a. with Cho	ke Input on	ly.			
5Y4G	Duodiode	5-Q	ST-14	5.0	2.00	F-W Rect.	Character	istics Sam	e as Type 5	Y3G Abov	e.		......	......	....	....
5Z3	Duodiode	4-C	ST-16	5.0	3.00	F-W Rect.	500 A.C	. Volts P	er Plate, R	MS, 250 M	a. Output C	urrent.	......	......	....	....
5Z4	Duodiode	5-L	8B-1	5.0	2.00	F-W Rect.	400 A.C	. Volts P	er Plate, R	MS, 125 M	a. Output C	urrent.	......	......	....	....
6	Monode	4-A	ST-12	(Batter	y Rece	iver Ballast Wi	th Avera	ge Filame	nt Voltage	Drop of 1.0	Volts at 68	5 Ma.)				
6A3	Triode	4-D	ST-16	6.3	1.00	Power Amp.	250	45.0	......	60.0	......	800	5,250	4.2	2,500	3,200
							325	68.0	......	40.0	Per Tube, P	ush Pull, Fi	xed Bias	......	3,000¶	15,000
							325	....	......	40.0	Per Tube, P	ush Pull, Se	lf Bias	......	5,000¶	10,000

*Applied through 250,000 ohms. **Triode operation. ‡Pentode Operation. ¶Plate to Plate. ϕ—Approximate
▲Conversion Conductance. †—Fixed Bias. ƒPer Tube—No Signal. ‡‡Applied through 200,000 ohms.

CHARACTERISTICS

Type	Class	Base	Bulb	Filament Rating Volts	Filament Rating Amps.	Use	Plate Volts	Negative Grid Volts	Screen Volts	Plate Current Ma.	Screen Current Ma.	Plate Resistance Ohms	Micromhos Trans-conduct-ance	Ampli-fication Factor	Ohms Load for Stated Power Output	Undis-torted Power Output Milli-watts
6A4/LA	Pentode	5-B	ST-14	6.3	0.30	Power Amp.	100	6.5	100	7.5	1.6	83,250	1,700	150	11,000	300
							135	9.0	135	13.0	2.8	52,600	2,100	150	9,500	700
							180	12.0	180	22.0	4.5	60,000	2,500	150	8,000	1,500
6A5G	Triode	6-T	ST-16	6.3	1.25	Power Amp.	250	45.0	......	60.0	....	800	5,250	4.2	2500	3,750
							325	68.0	......	40.0 Per	Tube, P	ush Pull, Fi	xed Bias	....	3,000¶	15,000
6A6	Duotriode	7-B	ST-14	6.3	0.80	Power Amp.	250	0.0	......	14.0 per	Plate, Class	B Operatio	n	......	8,000¶	8,000
							300	0.0	......	17.5 per	Plate, Class	B Operatio	n	......	10,000¶	10,000
						Driver	250	5.0	......	6.0	......	11,300	3,100	35	(Class A	Driver)
						Driver	294	6.0	......	7.0	......	11,000	3,200	35	(Class A	Driver)
6A7, 6A7S	Heptode	7-C	ST-12C	6.3	0.30	Converter	100	1.5	50.0	1.1	1.3	600,000	360 ▲	(G2=100	V. 2.0 M	a.)
							250	3.0	100	3.5	2.7	360,000	550 ▲	(G2=200	V. Max.,	4.0 Ma.
6A8	Heptode	8-A	8A-1	6.3	0.30	Converter	100	1.5	50.0	1.1	1.3	600,000	360 ▲	(G2=100	V., 2.0	Ma.)
							250	3.0	100	3.5	2.7	360,000	550 ▲	(G2=200	V. Max.,	4.0 Ma.)
6A8G	Heptode	8-A	ST-12C	6.3	0.30	Converter	100	1.5	50.0	1.1	1.3	600,000	360 ▲	(G2=100	V. 2.0 M	a.)
							250	3.0	100	3.5	2.7	360,000	550 ▲	(G2=200	V. Max.	,4.0Ma.
6A8GT	Heptode	8-A	T9-E	6.3	0.30	Converter	Characte	ristics Sa	me as Type	6A8G Ab	ove.					
6AB5	Triode	6-R	T9-A	6.3	0.15	Indicator	135§	(Series P	late Rest. 0.	25 Meg., T	arget Cur. 4.	5 Ma., Gri	d Bias -7.5	for 0° Shad	ow.)	
6AC5G	Triode	6-Q	ST-12	6.3	0.40	Power Amp.	250	+13	......	32.0	......	36,700	3,400	125	....	....
							250	(Bias Fro	m 76 Driver	) 32.0	(Class A,	One Tube,	Dynamic C	oupled)	7,000	3,700
							250	0.0	......	2.5ƒ	(Class B, T	wo Tubes)	......	......	10,000¶	8,000
6AF6G	Duodiode	7-AG	T9-H	.3	0.15	Indicator	100§	(Ray Co	ntrol Volts	= Approx.	60 for 0° S	hadow; Ap	p ox. Zero	Volts for 10	0° Shad	ow.)
							135§	(Ray Co	ntrol Volts	= Approx.	81 for 0° S	hadow; Ap	prox. Zero	Volts for 10	0° Shad	ow.)
6B4G	Triode	5-S	ST-16	6.3	1.00	Power Amp.	250	45.0	......	60.0	......	800	5,250	4.2	2,500	3,200
							325	68.0	......	40.0 Per	Tube,	Push Pull,	Fixed Bias	......	3,000¶	15,000
							325	....	......	40.0 Per	Tube,	Push Pull,	Self Bias	......	5,000¶	10,000
6B5	Duotriode	6-AS	ST-14	6.3	0.80	Power Amp.	300	0.0 (I	nput Sectio	n) 9.0	......	......	......	......	....	....
							300	0.0(O	utput Sectio	n)42.0	......	24,000	2,400	58	7,000	4,000
6B7, 6B7S	Duodi. Pent.	7-D	ST-12C	6.3	0.30	R-F or I-F	100	3.0	100	5.8	1.7	300,000	950	285	....	....
						Amplifier	180	3.0	75.0	3.4	0.9	1 Meg.	840	840	....	....
							250	3.0	100	6.0	1.5	800,000	1,000	800	....	....
						A-F Amp.	250*	4.5	50.0	0.65	......	......	......	......	....	....
6B8	Duodi. Pent.	8-E	8A-1	6.3	0.30	R-F or I-F	250	3.0	125	10.0	2.3	600,000	1,325	800	....	....
6B8G	Duodi. Pent.	8-E	ST-12C	6.3	0.30	R-F or I-F	250	3.0	125	10.0	2.3	600,000	1,325	800	....	....
6C5	Triode	6-Q	8A-2	6.3	0.30	Amplifier	250	8.0	......	8.0	......	10,000	2,000	20	....	....
6C5G	Triode	6-Q	ST-12	6.3	0.30	Amplifier	250	8.0	......	8.0	......	10,000	2,000	20	....	....
6C6	Pentode	6-F	ST-12C	6.3	0.30	R-F Amp.	100	3.0	100	2.0	0.5	1 Meg.+	1,185	1,185	....	....
							250	3.0	100	2.0	0.5	1.5 Meg—	1,225	1,500	....	....
						Detector	250*	4.3♦	100	(Plate Cur	rent to be a	djusted to 0	.1 Ma. with	no Input S	ignal)	
						A-F Amp.	250*	1.0	50.0	0.5	......	3 Meg.	600	1,800	....	....
6C7	Duodiode Tri.	7-G	ST-12C	6.3	0.30	Detector	250	9.0	......	4.5	......	16,000	1,250	20	....	....
6C8G	Duotriode	8-G	ST-12C	6.3	0.30	Amplifier	250	4.5	......	3.2	......	22,500	1,600	36	(One Se	ction)
						Inverter	250	3.0	{Plate Load	50,000 O	hms, Self-Bi	as Resistor 9	00 Ohms,	Voltage		
									{ Amplifica	tion 45, Ou	tput Volts 6	0, RMS, for	Inverter Se	rvice		
6D6	Pentode	6-F	ST-12C	6.3	0.30	R-F Amp.	100	3.0	100	8.0	2.2	250,000	1,500	375	....	....
							250	3.0	100	8.2	2.0	800,000	1,600	1,280	....	....
6D7	Pentode	7-H	ST-12C	6.3	0.30	R-F Amp.	100	3.0	100	2.0	0.5	1 Meg.+	1,185	1,185	....	....
							250	3.0	100	2.0	0.5	1.5Meg.—	1,225	1,500	....	....
6D8G	Heptode	8-A	ST-12C	6.3	0.15	Converter	100	1.5	50.0	1.0	1.7	550,000	300 ▲	(G2=100	V. 1.8 M	a.)
							250	3.0	100	3.0	3.5	320,000	500 ▲	(G2=200	V. 4.5 M	a.)
6E5	Triode	6-R	ST-12	6.3	0.30	Indicator	100§	(Series P	late Rest. 0.	5 Meg. Tar	get Cur. 2.0	Ma., Grid	Bias -3.3 for	0° Shadow	)	
							250§	(Series P	late Rest. 1.	0 Meg. Tar	get Cur. 3.0	Ma., Grid	Bias -8.0 for	0° Shadow	)	
6E6	Duotriode	7-B	ST-14	6.3	0.60	Power Amp.	180	20.0	......	23.0	......	2,150	2,800	6.0	15,000¶	750
						(2 Sections)	250	27.5	......	36.0	......	1,750	3,400	6.0	14,000¶	1,600
6E7	Pentode	7-H	ST-12C	6.3	0.30	R-F Amp.	100	3.0	100	8.0	2.2	250,000	1,500	375	....	....
							250	3.0	100	8.2	2.0	800,000	1,600	1,280	....	....
6F5	Triode	5-M	8A-1	6.3	0.30	Amplifier	250	2.0	......	1.1	......	66,000	1,500	100	....	....
6F5G	Triode	5-M	ST-12C	6.3	0.30	Amplifier	250	2.0	......	1.1	......	66,000	1,500	100	....	....
6F6	Pentode	7-S	8B-1	6.3	0.70	Power Amp.	250‡	16.5	250	34.0	7.5	79,000	2,350	185	7,000	3,000
							315‡	22.0	315	42.0	8.5	70,000	2,600	185	7,000	5,000
							250**	20.0	Tie Gs to P	31.0	......	2,600	2,700	7.0	4,000	850
							375‡	26.0f	250	17.0ƒ	2.5ƒ	2 Tubes Cl	ass AB Pen	tode Oper.	10,000¶	19,000
							350**	38.0f	......	22.5ƒ	......	2 Tubes Cl	ass AB Trio	de Oper.	6,000¶	18,000
6F6G	Pentode	7-S	ST-14	6.3	0.65	Power Amp.	250‡	16.5	250	34.0	7.5	79,000	2,350	185	7,000	3,000
							315‡	22.0	315	42.0	8.5	100,000	2,600	260	7,000	5,000
							250**	20.0	Tie Gs to P	33.0	......	2,700	2,300	6.2	3,000	650
							350**	38.0f	Tie Gs to P	22.5ƒ 2	Tubes Class	AB Triode	Operation	......	8,000¶	15,000
6F7, 6F7S	Pent.-Triode	7-E	ST-12C	6.3	0.30	Pent. Amp.	100	3.0	100	6.3	1.6	290,000	1,050	300	Pentode	Section
						Pent. Amp.	250	3.0	100	6.5	1.5	850,000	1,100	900	Pentode	Section
						Triode Amp.	100	3.0	......	3.5	......	16,200	525	8.5	Triode	Section
6F8G	Duotriode	8-G	ST-12C	6.3	0.60	Amplifier	250	8.0	......	9.0	......	7,700	2,600	20	(One Se	ction)
						Inverter	250	5.5	{PlateLoa	d 50,000	Ohms, Self	Bias Resistor	1,150 Oh	ms, Voltag	e	
									{Amplific	ation 29, O	utput Volts	65, RMS, f	or Inverter S	ervice		
6G5	Triode	6-R	ST-12	6.3	0.30	Indicator	New	Number	Is 6U5/6G	5.						
6G6G	Pentode	7-S	ST-12	6.3	0.15	Power Amp.	135	6.0	135	11.5	2.0	170,000	2,100	360	12,000	600
							180	9.0	180	15.0	2.5	175,000	2,300	400	10,000	1,100
6H6	Duodiode	7-Q	8C-1	6.3	0.30	Rectifier	100	A.C.Volt	s Per Plate,	RMS, 4.0	Ma. Outpu	t Current	......	......	....	....
6H6G	Duodiode	7-Q	ST-12	6.3	0.30	Rectifier	100	A.C.Volt	s Per Plate,	RMS, 4.0	Ma. Outpu	t Current	......	......	....	....
6J5	Triode	6-Q	8G-1	6.3	0.30	Amplifier	250	8.0	......	9.0	......	7,700	2,600	20	....	....
6J5G	Triode	6-Q	ST-12	6.3	0.30	Amplifier	250	8.0	......	9.0	......	7,700	2,600	20	....	....
6J7	Pentode	7-R	8A-1	6.3	0.30	Amplifier	250	3.0	100	2.0	0.5	1.5 Meg.	1,225	1,500	....	....
6J7G	Pentode	7-R	ST-12	6.3	0.30	Amplifier	250	3.0	100	2.0	0.5	1.5 Meg.	1,225	1,500	....	....
						Detector	250*	4.3	100	(Plate Curr	ent to be ad	justed to 0.	1 Ma. with	No Input Si	gnal)	
6J7GT	Pentode	7-R	T9-E	6.3	0.30	Amplifier	Characte	ristics Sa	me as Type	6J7G Abo	ve.)					
6J8G	Tri.-Heptode	8-H	ST-12C	6.3	0.30	Mixer	250	3.0	100	1.3	2.9	4.0 Meg.	290 ▲	(Heptode	Section)	
						Oscillator	250	Plate Su	pply Thru	20,000 Rest	., Grid Rest.	=50,000,	Grid Cur. 0.	4 Ma.(Triod	e Section	)
6K5G	Triode	5-U	ST-12C	6.3	0.30	Amplifier	100	1.5	......	0.35	......	78,000	900	70	....	....
							250	3.0	......	1.10	......	50,000	1,400	70	....	....
6K6G	Pentode	7-S	ST-12	6.3	0.40	Power Amp.	125	10.0	125	11.0	2.0	100,000	1,525	150	11,000	650
							180	13.5	180	18.5	3.0	81,000	1,850	150	9,000	1,500
							250	18.0	250	32.0	5.5	68,000	2,200	150	7,600	3,400
6K7	Pentode	7-R	8A-1	6.3	0.30	Amplifier	90	3.0	90.0	5.4	1.3	315,000	1,275	400	....	....
							180	3.0	75.0	4.0	1.0	1 Meg.	1,100	1,100	....	....
							250	3.0	100	7.0	1.7	800,000	1,450	1,160	....	....
6K7G	Pentode	7-R	ST-12C	6.3	0.30	Amplifier	Characte	ristics Sa	me as Type	6K7 Above	, Except Ca	pacitances.				
6K7GT	Pentode	7-R	T9-E	6.3	0.30	Amplifier	Characte	ristics Sa	me as Type	6K7 Above	, Except Ca	pacitances.				
6K8	Tri.-Hexode	8-K	8G-2	6.3	0.30	Mixer	250	3.0	100	2.5	6.0	600,000	350 ▲	(Hexode S	ection)	
						Oscillator	100	Grid Res	t. 50,000,P	late Cur. 3.8	Ma., Conv.	Cond. 3000	(Triode Se	ction Not O	scillating)	
6L5G	Triode	6-Q	ST-12	6.3	0.15	Amplifier	100	3.0	......	4.0	......	10,000	1,500	15	....	....
							250	9.0	......	8.0	......	9,000	1,900	17	....	....
6L6	Tetrode	7-AC	10A-2	6.3	0.90	Power Amp.	375	17.5f	250	57.0ƒ	2.5ƒ	(Class A_1,	One Tube)	......	4,500	11,000
							250	16.0f	250	60.0ƒ	5.0ƒ	(Class A_1,	Two Tubes)	......	5,000¶	14,500
							400	25.0f	300	50.0ƒ	2.5ƒ	(Class AB_1,	Two Tubes)	......	6,600¶	34,000
							400	25.0f	300	51.0ƒ	3.0ƒ	(Class AB_2,	Two Tubes)	......	3,800¶	60,000
							Refer to	the Sylva	nia Technic	al Manual f	or more co	mplete data				
6L6G	Tetrode	7-AC	ST-16	6.3	0.90	Power Amp.	Character	istics Sam	e as Type 6	L6 Above.						
6L7	Heptode	7-T	8A-1	6.3	0.30	Mixer	250	6.0	150	3.3	8.3	1 Meg.	350 ▲	(G3=Neg.	15 V., A	pprox.)
						Amplifier	250	3.0	100	5.5	5.5	800,000	1,100	(G3=Neg.	3.0 V.,	Approx.)
6L7G	Heptode	7-T	ST-12C	6.3	0.30		Character	istics Sam	e as Type 6	L7 Above,	Except Cap	acitances.				

††For two tubes with 40 volts RMS applied to each grid. †50 volts RMS applied to two grids. §Plate and Target Supply Voltage. §§With Average Power Input of 320 Mw. Grid to Grid.

SYLVANIA AVERAGE

Type	Class	Base	Bulb	Filament Rating		Use	Plate Volts	Negative Grid Volts	Screen Volts	Plate Current Ma.	Screen Current Ma.	Plate Resistance Ohms	Micromhos Trans-conductance	Amplification Factor	Ohms Load for Stated Power Output	Undistorted Power Output Milliwatts
				Volts	Amps.											
6N5	Triode	6-R	ST-12	6.3	0.15	Indicator	180§	(Series Plate Rest. 0.25 Meg., Target Cur. 2.0 Ma., Grid Bias -12.0 for 0° Shadow)								
6N6G	Duotriode	7-AU	ST-14	6.3	0.80	Power Amp.	300	0.0	(Input Section)	9.0	......	......	......	......	....	....
							300	0.0	(Output Section)	42.0	......	24,000	2,400	58	7,000	4,000
6N7	Duotriode	8-B	8B-1	6.3	0.80	Power Amp.	250	0.0	......	14.0 per Plate, Class B Operation			......	......	8,000¶	8,000
							300	0.0	......	17.5 per Plate, Class B Operation			......	......	10,000¶	10,000
						Driver	250	5.0	......	6.0	......	11,300	3,100	35	(Class A Driver)	
						Driver	294	6.0	......	7.0	......	11,000	3,200	35	(Class A Driver)	
6N7G	Duotriode	8-B	ST-14	6.3	0.80		Characteristics Same as Type 6N7 Above.									
6P5G	Triode	6-Q	ST-12	6.3	0.30	Amplifier	250	13.5	......	5.0	......	9,500	1,450	13.8	....	....
						Detector	250	20.0♦	......	(Plate Current to be adjusted to 0.2 Ma. with no Input Signal)						
6P7G	Pent.-Triode	7-U	ST-12C	6.3	0.30	Pent. Amp.	100	3.0	100	6.3	1.6	290,000	1,050	300	Pentode	Section
						Pent. Amp.	250	3.0	100	6.5	1.5	850,000	1,100	900	Pentode	Section
						Triode Amp.	100	3.0	......	3.5	......	16,200	525	8.5	Triode	Section
6Q7	Duodiode Tri.	7-V	8A-1	6.3	0.30	Detector	100	1.5	......	0.35	......	88,000	800	70	....	....
							250	3.0	......	1.1	......	58,000	1,200	70	....	....
6Q7G	Duodiode Tri.	7-V	ST-12C	6.3	0.30	Detector	Characteristics Same as Type 6Q7 Above, Except Capacitances.						......	......	....	....
6Q7GT	Duodiode Tri.	7-V	T9-E	6.3	0.30	Detector	Characteristics Same as Type 6Q7 Above, Except Capacitances.									
6R7	Duodiode Tri.	7-V	8A-1	6.3	0.30	Detector	250	9.0	......	9.5	......	8,500	1,900	16	....	....
6R7G	Duodiode Tri.	7-V	ST-12C	6.3	0.30	Detector	250	9.0	......	9.5	......	8,500	1,900	16	....	....
6S7G	Pentode	7-R	ST-12C	6.3	0.15	R-F	100	3.0	100	8.0	2.2	250,000	1,500	375	....	....
							250	3.0	100	8.5	2.0	630,000	1,750	1,100	....	....
6SA7	Heptode	8-R	8G-1	6.3	0.30	Converter	100	2.0	100	3.2	8.0	500,000♦	425 ▲	......	(Each Triode)	
							250	2.0	100	3.4	8.0	800,000♦	450 ▲	......	....	....
6SC7	Duotriode	8-S	8G-1	6.3	0.30	Amplifier	250	2.0	......	2.0	......	53,000	1,325	70	....	....
6SF5	Triode	8-P	8G-1	6.3	0.30	Amplifier	250	2.0	......	0.9	......	66,000	1,500	100	....	....
6SJ7	Pentode	8-N	8G-1	6.3	0.30	Amplifier	100	3.0	100	2.9	0.9	700,000♦	1,575	1,100	....	....
							250	3.0	100	3.0	0.8	1.5 Meg.♦	1,650	2,500	....	....
6SK7	Pentode	8-N	8G-1	6.3	0.30	Amplifier	100	3.0	100	8.9	2.6	250,000	1 900	475	....	....
							250	3.0	100	9.2	2.4	800,000	2,000	1,600	....	....
6SQ7	Duodiode Tri.	8-Q	8G-1	6.3	0.30	Detector	250	2.0	....	0.8	....	91,000	11,000	100	....	....
6T5	Triode	6-R	T9-A	6.3	0.30	Indicator	Discontinued Type, Replace with Type 6U5/6G5.									
6T7G	Duodiode Tri.	7-V	ST-12C	6.3	0.15	Detector	100	1.5	......	0.3	......	95,000	680	65	....	....
							250	3.0	......	0.9	......	65,000	1,000	65	....	....
6U5/6G5	Triode	6-R	T9-A	6.3	0.30	Indicator	100§	(Series Plate Rest. 0.5 Meg., Target Current 1.0 Ma., Grid Bias -8.0 for 0° Shadow)								
							250§	(Series Plate Rest. 1.0 Meg., Target Current 4.0 Ma., Grid Bias -22.0 for 0° Shadow)								
6U7G	Pentode	7-R	ST-12C	6.3	0.30	R-F Amp.	100	3.0	100	8.0	2.2	250,000	1,500	375	....	....
							250	3.0	100	8.2	2.0	800,000	1,600	1,280	....	....
6V6	Tetrode	7-AC	8B-1	6.3	0.45	Power Amp.	250	12.5	250	45.0♯	4.5♯	52,000	4,100	218♦	5,000	4,250
							250	15.0	250	35.0♯	2.5♯	(Class AB_1, Two Tubes)		......	10,000¶	8,500
							300	20.0	300	39.0♯	2.5♯	(Class AB_1, Two Tubes)		......	8,000¶	13,000
6V6G	Tetrode	7-AC	ST-14	6.3	0.45	Power Amp.	Characteristics Same as Type 6V6 Above.									
6V7G	Duotriode	7-V	ST-12C	6.3	0.30	Detector	135	10.5	......	3.7	......	11,000	750	8.3	25,000	75
							180	13.5	......	6.0	......	8,500	975	8.3	20,000	160
							250	20.0	......	8.0	......	7,500	1,100	8.3	20,000	350
6W7G	Pentode	7-R	ST-12C	6.3	0.15	Amplifier	250	3.0	100	2.0	0.5	1.5 Meg.	1,225	1,850	....	....
6X5	Duodiode	6-S	8B-1	6.3	0.60	F-W Rect.	350	A.C. Volts Per Plate, RMS, 75 Ma. Output Current					......	......	....	....
6X5G	Duodiode	6-S	ST-12	6.3	0.60	F-W Rect.	350	A.C. Volts Per Plate, RMS, 75 Ma. Output Current						......	....	....
6Y5	Duodiode	6-J	ST-12	6.3	0.80	F-W Rect.	350	A.C. Volts Per Plate, RMS, 50 Ma. Output Current					......	......	....	....
6Y6G	Pentode	7-AC	ST-14	6.3	1.25	Power Amp.	135	13.5	135	58.0♯	3.0♯	......	7,000	......	2,000	3,600
6Y7G	Duotriode	8-B	ST-12C	6.3	0.60	Power Amp.	180	0.0	......	7.5♯	......	(Class B Operation)		......	7,000¶	5,500
							250	0.0	......	10.5♯	......	(Class B Operation)		......	14,000¶	8,000
6Z5	Duodiode	6-K	ST-12	6.3	0.80	F-W Rect.	230	A.C. Volts Per Plate RMS, 60 Ma. Output Current					......	......	....	....
				12.6	0.40											
6ZY5G	Duodiode	6-S	ST-12	6.3	0.30	F-W Rect.	350	A.C. Volts Per Plate, RMS, 35 Ma. Output Current					......	......	....	....
6Z7G	Duotriode	8-B	ST-12	6.3	0.30	Power Amp.	135	0.0	......	6.0♯	......	(Class B Operation)		......	9,000¶	2,500‡‡
							180	0.0	......	8.4♯	......	(Class B Operation)		......	12,000¶	4,200‡‡
7	Monode	4-A	ST-16	(D.C. or A.C.-D.C. Receiver Plug-in Resistor With Average Filament Voltage Drop of 176 Volts at 300 Ma.)												
7A4	Triode	5-AC	T9-G	6.3	0.30	Amplifier	90	0.0	....	10.0	......	6,700	3,000	20	....	....
							250	8.0	....	9.0	......	7,700	2,600	20	....	....
7A6	Duodiode	7-AJ	T9-G	6.3	0.15	Rectifier	150	A-C Volts per Plate, RMS, 10.0 MA. Output Current.								
7A7	Pentode	8-V	T9-G	6.3	0.30	Amplifier	250	3.0	100	8.6	2.0	800,000	2,000	1,600	....	....
7A8	Octode	8-U	T9-G	6.3	0.15	Converter	250	3 0	100	3 0	2.8	700,000	600 ▲	(G2=250 V., 4.5 Ma.)		
7B5	Pentode	6-AE	T9-F	6.3	0.40	Power Amp.	100	7.0	100	9.0	1.6	......	1,450	150	12,000	330
							180	13.5	180	18.5	3.0	......	1,850	150	9,000	1,500
							250	18.0	250	32.0	5.5	.....	2,200	150	7,600	3,400
7B6	Duodiode Tri.	8-W	T9-G	6.3	0.30	Detector	250	2.0	....	1.0	......	91,000	1,100	100	....	....
7B7	Pentode	8-V	T9-G	6.3	0.15	Amplifier	250	3.0	100	8.5	2.0	700,000	1,700	1,200	....	....
7B8	Heptode	8-X	T9-G	6.3	0.30	Converter	100	1.5	50	1.1	1.3	600,000	360 ▲	(G2=100 V., 2.0 Ma.)		
							250	3.0	100	3.5	2.7	360,000	550 ▲	(G2=250 V., Max., 4.0 Ma.)		
7C5	Tetrode	6-AA	T9-F	6.3	0.45	Power Amp.	250	12.5	250	45.0♯	4.5♯	52,000	4,100	218♦	5,000	4,250
							250	15.0	250	35.0♯	2.5♯	(Class AB_1, Two Tubes)		....	10,000¶	8,500
							300	20.0	300	39.0♯	2.5♯	(Class AB_1, Two Tubes)		......	8,000¶	13,000
7C6	Duodiode Tri.	8-W	T9-G	6.3	0.15	Detector	250	1.0	....	1.3	......	100,000	1,000	100	....	....
7Y4	Duodiode	5-AB	T9-G	6.3	0.50	F.W. Rect.	350	A-C Volts per Plate, RMS, 60 Ma. Output Current.								
8	Monode	4-A	ST-16	(D.C. or A.C.-D.C. Receiver Plug-in Resistor With Average Filament Voltage Drop of 132.0 Volts at 300 Ma.)												
9	Monode	4-A	ST-16	(D.C. or A.C.-D.C. Receiver Plug-in Resistor With Average Filament Voltage Drop of 50.0 Volts at 300 Ma.)												
10	Triode	4-D	ST-16	7.5	1.25	Power Amp.	250	23.5	......	10.0	......	6,000	1,330	8.0	13,000	400
							350	32.0	......	16.0	......	5,150	1,550	8.0	11,000	900
							425	40.0	......	18.0	......	5,000	1,600	8.0	10,200	1,600
12A	Triode	4-D	ST-14	5.0	0.25	Det., Amp.	90	4.5	......	5.0	......	5,400	1,575	8.5	5,000	35
							135	9.0	......	6.2	......	5,100	1,650	8.5	9,000	130
							180	13.5	......	7.7	......	4,700	1,800	8.5	10,650	285
12A5	Pentode	7-F	ST-12	12.6	0.30	Power Amp.	100	15.0	100	17.0♯	3.0♯	41,000	1,700	85	4,500	800
				6.3	0.60	Power Amp.	180	25.0	180	45.0	8.0♯	35,000	2,400	85	3,300	3,400
12A7	Diode-Pent.	7-K	ST-12C	12.6	0.30	Rectifier	125 RMS		......	30.0 Max.	......	......	......	......	....	....
						Amplifier	135	13.5	135	9.0	2.5	102,000	975	100	13,500	550
12Z3	Diode	4-G	ST-12	12.6	0.30	H-W Rect.	250	A.C. Volts Per Plate, RMS, 60 Ma. Output Current					......	......	....	....
15	Pentode	5-F	ST-12C	2.0	0.22	R-F Amp.	67.5	1.5	67.5	1.85	0.3	630,000	710	450	....	....
							135	1.5	67.5	1.85	0.3	800,000	750	600	....	....
18	Pentode	6-B	ST-14	14.0	0.30	Power Amp.	250‡	16.5	250	34.0	7.5	79,000	2,350	185	7,000	3,000
							315‡	22.0	315	42.0	8.5	100,000	2,600	260	7,000	5,000
							250**	20.0	Tie Gs to P	33.0	......	2,700	2,300	6.2	3,000	650
							350**	38.0†	Tie Gs to P	22.5 per Tube, Push Pull, No Signal				......	8,000¶	15,000
19	Duotriode	6-C	ST-12	2.0	0.26	Power Amp.	135	0.0	......	27.0†	......	(Class B Operation)		......	10,000¶	2,100
							135	3.0	......	25.0†	......	(Class B Operation)		......	10,000¶	1,900
							135	6.0	......	22.0†	......	(Class B Operation)		......	10,000¶	1,600
20	Triode	4-D	T9-A	3.3	0.132	Power Amp.	90	16.5	......	2.8	......	7,800	450	3.5	9,600	50
							135	22.5	......	6.0	......	5,850	600	3.5	6,500	130
22	Tetrode	4-K	ST-14C	3.3	0.132	R-F Amp.	135	1.5	67.5	3.7	1.3	250,000	500	125	....	....
24A, 24S	Tetrode	5-E	ST-14C	2.5	1.75	R-F Amp.	180	3.0	90.0	4.0	1.7	400,000	1,000	400	....	....
							250	3.0	90.0	4.0	1.7	600,000	1,050	630	....	....
						Detector	250*	5.0♦	20 to 45	(Plate Current to be adjusted to 0.1 Ma. with no Input Signal)						
25A6	Pentode	7-S	8B-1	25.0	0.30	Power Amp.	95	15.0	95.0	20.0	4.0	45,000	2,000	90	4,500	900
							135	20.0	135	37.0	8.0	35,000	2,450	85	4,000	2,000
							180	20.0	180	38.0	7.5	40,000	2,500	100	5,000	2,750
25A6G	Pentode	7-S	ST-14	25.0	0.30	Power Amp.	Characteristics Same as Type 25A6 Above.					......	......	......	....	....
25A7G	Diode-Pent.	8-F	ST-12	25.0	0.30	Rectifier	125	A.C. Volts Per Plate, RMS, 75 Ma. Output Current					......	....	....	....
						Power Amp.	100	15.0	100	20.5	4.0	30,000	1,800	90	4,500	770

*Applied through 250,000 ohms.
▲Conversion Conductance.

**Triode operation.
†—Fixed Bias.

‡Pentode Operation.
♯Per Tube—No Signal.

¶Plate to Plate.
‡‡Applied through 200,000 ohms.

♦—Approximate

CHARACTERISTICS

Type	Class	Base	Bulb	Filament Rating Volts	Filament Rating Amps.	Use	Plate Volts	Negative Grid Volts	Screen Volts	Plate Current Ma.	Screen Current Ma.	Plate Resistance Ohms	Micromhos Trans-conductance	Amplification Factor	Ohms Load for Stated Power Output	Undistorted Power Output Milliwatts
25B6G	Pentode	7-S	ST-14	25.0	0.30	Power Amp.	95	15.0	75.0	41.0§	1.5§	......	......	......	2,000	1,900
25L6	Tetrode	7-AC	8B-1	25.0	0.30	Power Amp.	110	7.5	110	49.0§	4.0§	10,000	8,200	......	2,000	2,200
25L6G	Tetrode	7-AC	ST-14	25.0	0.30	Power Amp.	110	7.5	110	49.0§	4.0§	10,000	8,200	......	2,000	2,200
25L6GT	Tetrode	7-AC	T9-D	25.0	0.30	Power Amp.	Characte	ristics Sa	me as Type	25L6G Ab	ove.					
25S	Duodiode Tri.	6-M	ST-12	2.0	0.06	New Numb	ering is 1	B5/25S								
25Y5	Duodiode	6-E	ST-12	25.0	0.30	Doubler	250	A-C Vol	ts per Plate,	RMS, 85	Ma. Output	Current.	......	......	....	....
25Z5	Duodiode	6-E	ST-12	25.0	0.30	Doubler	125	A.C. Vol	ts Per Plate,	RMS, 100	Ma. Output	Current	......	......	....	....
25Z6	Duodiode	7-Q	8B-1	25.0	0.30	Doubler	125	A.C. Vol	ts Per Plate,	RMS, 85	Ma. Output	Current	......	......	....	....
25Z6 G	Duodiode	7-Q	ST-12	25.0	0.30	Doubler	125	A.C. Vol	ts Per Plate,	RMS, 100	Ma. Output	Current	......	......	....	....
25Z6GT	Duodiode	7-Q	T9-D	25.0	0.30	Doubler	Characte	ristics Sa	me as Type	25Z6G Ab	ove.					
26	Triode	4-D	ST-14	1.5	1.05	Amplifier	90	7.0	......	2.9	......	8,900	935	8.3	....	....
							135	10.0	......	5.5	......	7,600	1,100	8.3	....	....
							180	14.5	......	6.2	......	7,300	1,150	8.3	....	....
27, 27S	Triode	5-A	ST-12	2.5	1.75	Amplifier	90	6.0	......	3.0	......	10,000	900	9.0	....	....
							135	9.0	......	4.7	......	9,000	1,000	9.0	....	....
							180	13.5	......	5.0	......	9,000	1,000	9.0	....	....
							250	21.0	......	5.2	......	9,250	975	9.0	....	....
						Detector	250	30.0♦	......	(Plate Cur	ent to be ad	justed to 0.	2 Ma. with	no Input Sig	nal)	
3	Triode	4-D	ST-12	2.0	0.06	Det., Amp.	90	4.5	......	2.5	......	11,000	850	9.3	....	....
							135	9.0	......	3.0	......	10,300	900	9.3	....	....
							180	13.5	......	3.1	......	10,300	900	9.3	....	....
31	Triode	4-D	ST-12	2.0	0.13	Power Amp.	135	22.5	......	8.0	......	4,100	925	3.8	7,000	185
							180	30.0	......	12.3	......	3,600	1,050	3.8	5,700	375
32	Tetrode	4-K	ST-14C	2.0	0.06	R-F Amp.	135	3.0	67.5	1.7	0.4	950,000	640	610	....	....
							180	3.0	67.5	1.7	0.4	1.2 Meg.	650	780	....	....
						A-F Amp.	180*	3.0	67.5	......	......	1.2 Meg.	650	780	....	....
						Detector	180	6.0♦	67.5 (	Plate Curren	t to be adju	sted to 0.2	Ma. with	no Input Sig	nal)	
33	Pentode	5-K	ST-14	2.0	0.26	Power Amp.	135	13.5	135	14.5	3.0	50,000	1,450	70	7,000	700
							180	18.0	180	22.0	5.0	55,000	1,700	90	6,000	1,400
34	Pentode	4-M	ST-14C	2.0	0.06	R-F Amp.	67.5	3.0	67.5	2.7	1.1	400,000	560	224	....	....
							135	3.0	67.5	2.8	1.0	600,000	600	360	....	....
							180	3.0	67.5	2.8	1.0	1 Meg.	620	620	....	....
35/51, 35S/51S	Tetrode	5-E	ST-14C	2.5	1.75	R-F Amp.	180	3.0	90.0	6.3	2.5	300,000	1,020	305	....	....
							250	3.0	90.0	6.5	2.5	400,000	1,050	420	....	....
						A-F Amp.	250*	1.0	45 to 67.5	0.5	......	2 Meg.	......	......	....	....
35A5	Tetrode	6-AA	T9-F	32.0	0.15	Power Amp.	110	7.5	110	35.0	2.8	25,000	5,500	....	2,500	1,400
35Z3	Diode	4-Z	T9-F	32.0	0.15	H.W. Rect.	250	A-C Vo	lts per Plate	, RMS, 100	Ma. Outp	ut Current.				
36	Tetrode	5-E	ST-12C	6.3	0.30	R-F Amp.	135	1.5	67.5	2.8	Not Over	574,000	1,000	475	....	....
							180	3.0	90.0	3.1	½ of	500,000	1,050	525	....	....
							250	3.0	90.0	3.2	Plate Ma.	550,000	1,080	595	....	....
						Detector	250	6.0♦	20 to 25	(Plate Cur	ent to be ad	justed to 0.	1 Ma. with	no Input Sig	nal)	
37	Triode	5-A	ST-12	6.3	0.30	Det., Amp.	135	9.0	......	4.1	......	10,000	925	9.2	....	....
							180	13.5	......	4.3	......	10,200	900	9.2	....	....
							250	18.0	......	7.5	......	8,400	1,100	9.2	....	....
38	Pentode	5-F	ST-12C	6.3	0.30	Power Amp.	135	13.5	135	9.0	1.5	130,000	925	120	13,500	550
							180	18.0	180	14.0	2.4	110,000	1,050	120	11,600	1,000
							250	25.0	250	22.0	3.8	100,000	1,200	120	10,000	2,500
39/44	Pentode	5-F	ST-12C	6.3	0.30	R-F Amp.	90	3.0	90.0	5.6	1.6	375,000	960	360	....	....
							180	3.0	90.0	5.8	1.4	750,000	1,000	750	....	....
							250	3.0	90.0	5.8	1.4	1 Meg.	1,050	1,050	....	....
						A-F Amp.	250*	1.0	67.5	0.5	......	2 Meg.	......	......	....	....
40	Triode	4-D	ST-14	5.0	0.25	Amplifier	135	1.5	......	0.2	......	150,000	200	30	....	....
							180	3.0	......	0.2	......	150,000	200	30	....	....
41	Pentode	6-B	ST-12	6.3	0.40	Power Amp.	125	10.0	125	11.0	2.0	100,000	1,525	150	11,000	650
							180	13.5	180	18.5	3.0	81,000	1,850	150	9,000	1,500
							250	18.0	250	32.0	5.5	68,000	2,200	150	7,600	3,400
42	Pentode	6-B	ST-14	6.3	0.65	Power Amp.	250‡	16.5	250	34.0	7.5	79,000	2,350	185	7,000	3,000
							315‡	22.0	315	42.0	8.5	100,000	2,600	260	7,000	5,000
							250**	20.0	Tie Gs to P	33.0	......	2,700	2,300	6.2	3,000	650
							350**	38.0†	Tie Gs to P	22.5 per	Tube, Push	Pull, No Sig	nal		8,000¶	15,000
43	Pentode	6-B	ST-14	25.0	0.30	Power Amp.	95	15.0	95	20.0	4.0	45,000	2,000	90	4,500	900
							135	20.0	135	37.0	8.0	35,000	2,450	85	4,000	2,000
45	Triode	4-D	ST-14	2.5	1.50	Power Amp.	180	31.5	......	31.0	......	1,650	2,125	3.5	2,700	830
							250	50.0	......	34.0	......	1,610	2,175	3.5	3,900	1,600
							275	56.0	......	36.0	......	1,700	2,050	3.5	4,600	2,000
46	Tetrode	5-C	ST-16	2.5	1.75	Power Amp.	250	33.0	Tie Gs to P	22.0	......	2,380	2,350	5.6	6,400	1,250
							300	0.0	Tie Gs to G	4.0§	......	(Class B	Operation)	......	5,200¶	16,000††
							400	0.0	Tie Gs to G	6.0§	......	(Class B	Operation)	......	5,800¶	20,000††
46A1	Monode	5-7	ST-12	46.1	0.40	Regulator	(Plug-in	Resistor	With 46.1	Volts Drop,	at 0.4 Amp	ere)				
46B1	Monode	5-7	ST-12	46.1	0.30	Regulator	(Plug-in	Resistor	With 46.1	Volts Drop,	at 0.3 Amp	ere)				
47	Pentode	5-B	ST-16	2.5	1.75	Power Amp.	250	16.5	250	31.0	6.0	60,000	2,500	150	7,000	2,700
48	Tetrode	6-A	ST-16	30.0	0.40	Power Amp.	95	20.0	95.0	52.0	12.0	4,000	3,900	15.6	1,500	2,000
							125	22.5	100	52.0	12.0	11,000	3,900	43	1,500	3,000
49	Tetrode	5-C	ST-14	2.0	0.12	Power Amp.	135	20.0	Tie Gs to P	6.0	......	4,175	1,125	4.7	11,000	170
							180	0.0	Tie Gs to G	2.0§	......	(Two Tubes	Class B Op	eration)	12,000¶	3,500
50	Triode	4-D	ST-16	7.5	1.25	Power Amp.	300	54.0	......	35.0	......	2,000	1,900	3.8	4,600	1,600
							350	63.0	......	45.0	......	1,900	2,000	3.8	4,100	2,400
							400	70.0	......	55.0	......	1,800	2,100	3.8	3,670	3,400
							450	84.0	......	55.0	......	1,800	2,100	3.8	4,350	4,600
53	Duotriode	7-B	ST-14	2.5	2.00	Power Amp.	250	0.0	......	14.0 per	Plate, Class	B Operatio	n	......	8,000¶	8,000
							300	0.0	......	17.5 per	Plate, Class	B Operatio	n	......	10,000¶	10,000
						Driver	250	5.0	......	6.0	......	11,300	3,100	35	(Class A	Driver)
						Driver	294	6.0	......	7.0	......	11,000	3,200	35	(Class A	Driver)
55, 55S	Duodiode Tri.	6-G	ST-12C	2.5	1.00	Detector	135	10.5	......	3.7	......	11,000	750	8.3	25,000	75
							180	13.5	......	6.0	......	8,500	975	8.3	20,000	160
							250	20.0	......	8.0	......	7,500	1,100	8.3	20,000	350
56, 56S	Triode	5-A	ST-12	2.5	1.00	Amplifier	250	13.5	......	5.0	......	9,500	1,450	13.8	....	....
						Detector	250	20.0♦	......	(Plate Cur	ent to be ad	justed to 0.	2 Ma. with	no Input Sig	nal)	
56AS	Triode	5-A	ST-12	6.3	0.40		Character	istics Sam	e as Type 56	Above						
57, 57S	Pentode	6-F	ST-12C	2.5	1.00	R-F Amp.	100	3.0	100	2.0	0.5	1 Meg.+	1,185	1,185	....	....
							250	3.0	100	2.0	0.5	1.5 Meg−	1,225	1,500	....	....
						Detector	250*	4.3♦	100	(Plate Cur	ent to be ad	justed to 0.	1 Ma. with	no Input Sig	nal)	
						A-F Amp.	250*	1.0	50.0	0.5	......	3 Meg.	600	1,800	....	....
57AS	Pentode	6-F	ST-12C	6.3	0.40		Character	istics Sam	e as Type 57	Above.						
58, 58S	Pentode	6-F	ST-12C	2.5	1.00	R-F Amp.	100	3.0	100	8.0	2.2	250,000	1,500	375	....	....
							250	3.0	100	8.2	2.0	800,000	1,600	1,280	....	....
58AS	Pentode	6-F	ST-12C	6.3	0.40	R-F Amp.	Character	istics Sam	e as Type 58	Above.						
59	Pentode	7-A	ST-16	2.5	2.00	Power Amp.	250**	28.0	Tie Gs to P	26.0	......	2,300	2,600	6.0	5,000	1,250
							250‡	18.0	250	35.0	......	40,000	2,500	100	6,000	3,000
							300	0.0	Tie Gs to G	20.0	......	(Class B O	peration 2 T	ubes)	4,600¶	15,000††
							400	0.0	and Su to P	26.0	......	(Class B O	peration 2 T	ubes)	6,000¶	20,000††
71A	Triode	4-D	ST-14	5.0	0.25	Power Amp.	90	16.5	......	10.0	......	2,170	1,400	3.0	3,000	125
							135	27.0	......	17.3	......	1,820	1,650	3.0	3,000	400
							180	40.5	......	20.0	......	1,750	1,700	3.0	4,800	790
75, 75S	Duodiode Tri.	6-G	ST-12C	6.3	0.30	Detector	250	2.0	......	1.0	......	91,000	1,100	100	....	....

††For two tubes with 40 volts RMS applied to each grid. †50 volts RMS applied to two grids. §Plate and Target Supply Voltage. §§With Average Power Input of 320 Mw. Grid to Grid.

SYLVANIA AVERAGE CHARACTERISTICS

Type	Class	Base	Bulb	Filament Rating Volts	Filament Rating Amps.	Use	Plate Volts	Negative Grid Volts	Screen Volts	Plate Current Ma.	Screen Current Ma.	Plate Resistance Ohms	Micromhos Mutual Conductance	Amplification Factor	Ohms Load for Stated Power Output	Undistorted Power Output Milliwatts
76	Triode	5-A	ST-12	6.3	0.30	Amplifier	250	13.5	......	5.0	......	9,500	1,450	13.8	....	....
						Detector	250	20.0♦	......	(Plate Curr	ent to be ad	justed to 0.	2 Ma. with	no Input Sig	nal)	
77	Pentode	6-F	ST-12C	6.3	0.30	R-F Amp.	100	1.5	60.0	1.7	0.4	650,000	1,100	715	....	....
							250	3.0	100	2.3	0.5	1.5 Meg.	1,250	1,500	....	....
78	Pentode	6-F	ST-12C	6.3	0.30	R-F Amp.	90	3.0	90.0	5.4	1.3	315,000	1,275	400	....	....
							180	3.0	75.0	4.0	1.0	1 Meg.	1,100	1,100	....	....
							250	3.0	100	7.0	1.7	800,000	1,450	1,160	....	....
79	Duotriode	6-H	ST-12C	6.3	0.60	Power Amp.	180	0.0	......	7.5♯	......	(Class B	Operation)	......	7,000¶	5,500
							250	0.0	......	10.5♯	......	(Class B	Operation)	......	14,000¶	8,000
80	Duodiode	4-C	ST-14	5.0	2.00	F-W Rect.	350 A.C.	Volts Per	Plate, RM	S, 125 Ma.	Output Cur	rent	......	......	....	....
							400 A.C.	Volts Per	Plate, RM	S, 110 Ma.	Output Cur	rent	......	......	....	....
							550 A.C.	Volts Per	Plate, RM	S, 135 Ma.	with Choke	Input only.	......	......	....	....
81	Diode	4-B	ST-16	7.5	1.25	H-W Rect.	700 A.C.	Volts Per	Plate, RM	S, 85 Ma.	Output Cur	rent	......	......	....	....
82	Duodiode	4-C	ST-14	2.5	3.00	F-W Rect.	500 A.C.	Volts Per	Plate, RM	S, 125 Ma.	Output Cur	rent	......	......	....	....
83	Duodiode	4-C	ST-16	5.0	3.00	F-W Rect.	500 A.C.	Volts Per	Plate, RM	S, 250 Ma.	Output Cur	rent	......	......	....	....
83V	Duodiode	4-AD	ST-14	5.0	2.00	F-W Rect.	400 A.C.	Volts Per	Plate, RM	S, 200 Ma.	Output Cur	rent	......	......	....	....
84/6Z4	Duodiode	5-D	ST-12	6.3	0.50	F-W Rect.	350 A.C.	Volts Per	Plate, RM	S, 75 Ma.	Output Cur	rent	......	......	....	....
85	Duodiode Tri.	6-G	ST-12C	6.3	0.30	Detector	135	10.5	......	3.7	......	11,000	750	8.3	25,000	75
							180	13.5	......	6.0	......	8,500	975	8.3	20,000	160
							250	20.0	......	8.0	......	7,500	1,100	8.3	20,000	350
85AS	Duodiode Tri.	6-G	ST-12C	6.3	0.30	Detector	250	9.0	......	4.5	......	16,000	1,250	20	....	....
89	Pentode	6-F	ST-12C	6.3	0.40	Power Amp.	160**	20.0	Gs & Su to P	17.0		3,300	1,425	4.7	7,000	300
							180‡	18.0	180	20.0	3.0	80,000	1,550	125	8,000	1,500
							180	0.0	......	3.0♯ Cl	ass B Opern	' Tie Su to P	& Gs to G (	2 Tubes)	9,400¶	3,500††
VR90	Diode	4-W	ST-12	Voltag	e Regu	lator. With St	arting Vo	ltage at 1	25. Operati	ng Current	10 Ma. Mi	n., 30 Ma.	Max.			
V99	Triode	4-E	T-8	3.3	0.063	Det. Amp.	90	4.5	......	2.5	......	15,500	425	6.6	....	....
X99	Triode	4-D	T9-A	3.3	0.063	Det. Amp.	90	4.5	......	2.5	......	15,500	425	6.6	....	....
VR150	Diode	4-W	ST-12	Voltag	e Regu	lator. With St	arting Vo	ltage at 1	80, Operati	ng Volts 15	0, Operatin	g Current 5	Ma. Min.,	30 Ma. Ma	x.	
182B/482B	Triode	4-D	ST-14	5.0	1.25	Power Amp.	250	35.0	......	20.0	......	2,500	2,000	5.0	4,500	1,350
183/483	Triode	4-D	ST-14	5.0	1.25	Power Amp.	250	65.0	......	20.0	......	2,000	1,500	3.0	4,500	1,800
210T	Triode	4-D	ST-16	7.5	1.25	Power Amp.	(Standar	d Type 1	0 with Cera	mic Base. S	ee Type 10	Characterist	ics)			
485	Triode	5-A	ST-12	3.0	1.25	Det., Amp.	180	9.0	......	5.8	......	8,900	1,400	12.5	....	....
864	Triode	4-D	T9-A	1.1	0.25	Det., Amp.	90	4.5	......	2.9	......	13,500	610	8.2	....	....
							135	9.0	......	3.5	......	12,700	645	8.2	....	....
879	Diode	4-P	ST-12C	2.5	1.75	H-W Rect.	2,650	A.C. Vo	lts Per Plate	, RMS, 7.5	Ma. Outpu	t Current				
950	Pentode	5-K	ST-14	2.0	0.12	Power Amp.	135	16.5	135	7.0	2.0	125,000	1,000	125	13,500	575
1221	Pentode	6-F	ST-12C	6.3	0.30	Det., Amp.	Special	Non-Mic	rophonic Tu	be, Characte	ristics Same	as Type 6C6				
1223	Pentode	7-R	ST-12C	6.3	0.30	Det. Amp.	"G" Eqiv	alent of T	ype 1221	Above.						
1231	Pentode	8-V	T9-F	6.3	0.45	Pent. Amp.	300	....	150	10.0	2.5	700,000	5,500	3,850	....	
							Cathode	Bias Rest.	—200. Tie	Su to K.						
						Tet. Amp.	300	....	150	12.0	0.5	540,000	6,500	3,500	....	....
							Cathode	Bias Rest.	—200. Tie	Su to Gs.						
						Tri. Amp.	250	....	......	13.0	......	5,200	6,300	33	....	....
							Cathode	Bias Rest.	—400. Tie	Gs & Su to	P.					
1612	Heptode	7-T	8A-1	6.3	0.30	Mixer	250	6.0	150	3.3	8.3	1 Meg.	350 ▲	(G3 = Neg.	15 V.,	Approx.)
						Amplifier	250	3.0	100	5.5	5.5	800,000	1,100	(G3 = Neg.	3.0 V.,	Approx.)
1852	Pentode	8-N	8G-1	6.3	0.45	Amplifier	300	3.0	150	10.0	2.5	750,000♦	9,000	6,750♦	....	....
1853	Pentode	8-N	8G-1	6.3	0.45	Amplifier	300	3.0	200	12.5	3.2	700,000♦	5,000	3,500♦	....	....

*Applied through 250,000 ohms. **Triode operation. ‡Pentode Operation. ¶Plate to Plate. ♦—Approximate
▲Conversion Conductance. ƒ—Fixed Bias. ♯Per Tube—No Signal. ‡‡Applied through 200,000 ohms.
††For two tubes with 40 volts RMS applied to each grid. †50 volts RMS applied to two grids. §Plate and Target Supply Voltage. §§With Average Power Input of 320 Mw. Grid to Grid.

SYLVANIA "GT" TUBES

Type	Class	Base View	Filament Rating Volts	Filament Rating Amps.	Use	Plate Volts	Negative Grid Volts	Screen Volts	Plate Current Ma.	Screen Current Ma.	Plate Resistance Ohms.	Micromhos Trans-Conductance	Amplification Factor	Ohms Load for Stated Power Output	Undistorted Power Output Milliwatts
1A5GT	Pentode	6-X	1.4	0.05	Power Amp.	Characterist	ics Same as	Type 1A5	G	......	......	......	......	....	....
1A7GT	Heptode	7-Z	1.4	0.05	Converter	Characterist	ics Same as	Type 1A7	G	......	......	......	......	....	....
1C5GT	Pentode	6-X	1.4	0.10	Power Amp.	Characterist	ics Same as	Type 1C5	G	......	......	......	......	....	....
1D8GT	Diode	8-AJ	1.4	0.10	Detector	Diode Loc	ated at Neg	ative End of	Filament, P	in 7	......	......	......	....	....
	Triode	....	...	...	Triode Amp.	90	0.0	......	1.1	......	43500	575	25	....	....
	Pentode	....	...	...	Power Amp.	90	9.0	90	5.0	1.0	.2 Meg.	925	......	12000	200
1G4GT	Triode	5-S	1.4	0.05	Det., Amp.	Characterist	ics Same as	Type 1H5	G	......	......	......	......	....	....
1H5GT	Diode-Triode	5-Z	1.4	0.05	R-F Amp.	Characterist	ics Same as	Type 1N5	G	......	......	......	......	....	....
1N5GT	Pentode	5-Y	1.4	0.10	Power Amp.	Characterist	ics Same as	Type 1Q5	G	......	......	......	......	....	....
1Q5GT	Tetrode	6-AF	1.4	0.05	Power Amp.	90	6.0	90	6.5	1.4	......	1150	......	14000	170
1T5GT	Tetrode	6-AF	1.4	0.05	Amplifier	Characterist	ics Same as	Type 1G4	G	......	......	......	......	....	....
3A8GT	Diode Triode	8-AS	1.4	0.10	Tri.-Amp.	90	0.0	......	0.15	......	.24 Meg.	275	......	....	....
	Pentode		2.8	0.05	Pent.-Amp.	90	0.0	90	1.2	0.3	.6 Meg.	750	......	....	....
3Q5GT	Tetrode	7-AP	1.4	0.10	Power Amp.	90	4.5	90	9.5	1.6	.1 Meg.	2100	......	8000	270
		Series Fil.	2.8	0.05	Power Amp.	90	4.5	90	8.0	1.0	.11 Meg.	1950	......	8000	230
6A8GT	Heptode	8-A	6.3	0.30	Converter	Characterist	ics Same as	Type 6A8	G Except C	apacitances	......	......	......	....	....
6AC5GT	Triode	6-Q	6.3	0.40	Amplifier	Characterist	ics Same as	Type 6AC	5G	......	......	......	......	....	....
6C5GT	Triode	6-Q	6.3	0.30	Amplifier	Characterist	ics Same as	Type 6C5	G Except C	apacitances	......	......	......	....	....
6F5GT	Triode	5-M	6.3	0.30	Amplifier	Characterist	ics Same as	Type 6F5	G Except C	apacitances	......	......	......	....	....
6H4GT	Diode	5-AF	6.3	0.15	Detector	100	......	......	40	......	......	......	......	....	....
6H6GT	Duodiode	7-Q	6.3	0.30	Duodiode	Characteristic	Same as	Type 6H6	G	......	......	......	......	....	....
6J5GT	Triode	6-Q	6.3	0.30	Amplifier	Characterist	ics Same as	Type 6J5	G Except C	apacitances	......	......	......	....	....
6J7GT	Pentode	7-R	6.3	0.30	Det., Amp.	Characterist	ics Same as	Type 6J7	G Except C	apacitances	......	......	......	....	....
6K5GT	Triode	5-U	6.3	0.30	Amplifier	Characterist	ics Same as	Type 6K5	G Except C	apacitances	......	......	......	....	....
6K6GT	Pentode	7-S	6.3	0.40	Power Amp.	Characterist	ics Same as	Type 6K6	G	......	......	......	......	....	....
6K7GT	Pentode	7-R	6.3	0.30	Amplifier	Characterist	ics Same as	Type 6K7	G Except C	apacitances	......	......	......	....	....
6K8GT	Tri.-Hexode	8-K	6.3	0.30	Mix., Osc.	Characterist	ics Same as	Type 6K8	G Except C	apacitances	......	......	......	....	....
6P5GT	Triode	6-Q	6.3	0.30	Det.-Amp.	Characterist	ics Same as	Type 6P5	G Except C	apacitances	......	......	......	....	....
6Q7GT	Duodiode Tri.	7-V	6.3	0.30	Detector	Characterist	ics Same as	Type 6Q7	G Except C	apacitances	......	......	......	....	....
6SA7GT	Heptode	8-AD	6.3	0.30	Converter	Characterist	ics Same as	Type 6SA7	Except C	apacitances	......	......	......	....	....
6SF5GT	Triode	8-P	6.3	0.30	Amplifier	Characterist	ics Same as	Type 6SF5	Except C	apacitances	......	......	......	....	....
6SJ7GT	Pentode	8-N	6.3	0.30	Amplifier	Characterist	ics Same as	Type 6SJ7	Except C	apacitances	......	......	......	....	....
6SK7GT	Pentode	8-N	6.3	0.30	Amplifier	Characterist	ics Same as	Type 6SK7	Except C	apacitances	......	......	......	....	....
6SQ7GT	Duodiode-Tri.	8-Q	6.3	0.30	Detector	Characterist	ics Same as	Type 6SQ7	Except C	apacitances	......	......	......	....	....
6V6GT	Tetrode	7-AC	6.3	0.45	Power Amp.	Characterist	ics Same as	Type 6V6	G	......	......	......	......	....	....
6X5GT	Duodiode	6-S	6.3	0.60	Rectifier	Characterist	ics Same as	Type 6X5	G	......	......	......	......	....	....
12A8GT	Heptode	8-A	12.6	0.15	Converter	Characterist	ics Same as	Type 6A8	G Except C	apacitances	......	......	......	....	....
12B8GT	Pentode Tri.	8-T	12.6	0.30	Pent. Amp.	100	3.0	100	8.0	2.0	.17 Meg.	2100	360	.Pentode	Section
					Tri. Amp.	100	1.0	......	0.6	......	73000	......	110	Triode	Section

♯Zero Signal.

Type	Class	Base View	Filament Rating		Use	Plate Volts	Negative Grid Volts	Screen Volts	Plate Current Ma.	Screen Current Ma.	Plate Resistance Ohms.	Micromhos Mutual Conductance	Amplification Factor	Ohms Load for Stated Power Output	Undistorted Power Output Milliwatts
			Volts	Amps.											
12F5GT	Triode	5-M	12.6	0.15	Amplifier	Characterist	ics Same as	Type 6F5	G Except C	apacitances	......	......	......	....	....
12J5GT.	Triode	6-Q	12.6	0.15	Amplifier	Characterist	ics Same as	Type 6J5	G Except C	apacitances	......	......	......	....	....
12J7GT	Pentode	7-R	12.6	0.15	Det., Amp.	Characterist	ics Same as	Type 6J7	G Except C	apacitances	......	......	......	....	....
12K7GT	Pentode	7-R	12.6	0.15	Amplifier	Characterist	ics Same as	Type 6K7	G Except C	apacitances	......	......	......	....	....
12Q7GT	Duodiode-Tri.	7-V	12.6	0.15	Detector	Characterist	ics Same as	Type 6Q7	G Except C	apacitances	......	......	......	....	....
12SA7GT	Heptode	8-AD	12.6	0.15	Converter	Characterist	ics Same as	Type 12SA	7 Evcept C	apacitances	......	......	......	....	....
12SF5GT	Triode	8-P	12.6	0.15	Amplifier	Characterist	ics Same as	Type 6SF5	Except C	apacitances	......	......	......	....	....
12SJ7GT	Pentode	8-N	12.6	0.15	Amplifier	Characterist	ics Same as	Type 12SJ	7 Except C	apacitances	......	......	......	....	....
12SK7GT	Pentode	8-N	12.6	0.15	Amplifier	Characterist	ics Same as	Type 12SK	7 Except C	apacitances	......	......	......	....	....
12SQ7GT	Duodiode-Tri.	8-Q	12.6	0.15	Detector	Characterist	ics Same as	Type 12SQ	7 Except C	apacitances	......	......	......	....	....
25A6GT	Pentode	7-S	25.0	0.30	Power Amp.	Characterist	ics Same as	Type 25A6	G	......	......	......	......	....	....
25A7GT	Diode Pent.	8-F	25.0	0.30	Rectifier	Characterist	ics Same as	Type 25A7	G	......	......	......	......	....	....
					Power Amp.										
25B8GT	Pentode Tri.	8-T	25.0	0.15	Pent. Amp.	100	3.0	100	7.6	2.0	185000	2000	370	.Pentode	Section
					Tri.-Amp.	100	1.0	......	0.6	......	75000	1500	112.5	Triode	Section
25D8GT	Dio-Tri.	8-AF	25.0	0.15	Tri. Amp.	100	1.0	......	0.5	......	......	1100	......	....	....
	Pentode				Pent.-Amp.	100	3.0	100	8.5	2.7	......	1900	......	....	....
25L6GT	Tetrode	7-AC	25.0	0.30	Power Amp.	Characterist	ics Same as	Type 25L6	G	......	......	......	......	....	....
25Z6GT	Duodiode	7-Q	25.0	0.30	Doubler	Characterist	ics Same as	Type 25Z6	G	......	......	......	......	....	....
32L7GT	Diode, Tetrode	8-Z	32.5	0.30	Rectifier	125 RMS		......	60	......	......	......	......	....	....
					Power Amp.	110	7.5	110	40♯	3.0♯	15000	6000	81	2600	1000
35L6GT	Tetrode	7-AC	35.0	0.15	Power Amp.	Characterist	ics Same as	Type 35L6	G	......	......	......	......	....	....
35Z4GT	Diode	5-AA	35.0	0.15	H-W Rect.	125 RMS		......	100	......	......	......	......	....	....
35Z5GT	Diode	6-AD	35.0	0.15	Rectifier	Characterist	ics Same as	Type 35Z5	G	......	......	......	......	....	....
40Z5/45Z5 GT	Diode	6-AD	45.0	0.15	H-W Rect.	125 RMS		......	100 Ma	. or 60 Ma.	with Panel	Lamp Conn	ected	....	....
50L6GT	Tetrode	7-AC	50.0	0.15	Power Amp.	110	7.5	110	49♯	4.0♯	10000♦	8200	......	1500	2100
						110	7.5	110	49♯	4.0♯	10000♦	8200	......	2000	2200
70L7GT	Diode-Triode	8-AA	70.0	0.15	Rectifier	125 RMS		......	70	......	......	......	......	....	....
					Amplifier	110	7.5	110	40♯	3.0♯	15000	7500	......	2000	1800

♯Zero signal. ♦Approximate.

SPECIAL TUBES

0A4G

Is a gas filled, cold cathode type of tube for use in the remote control of line operated units. This is made possible by transmitting radio frequency impulses over the power line. The tube may also be used as a voltage regulator and as a relaxation oscillator.

The tube consists of a cathode, anode, and starter-anode. Its characteristics are such that with no voltage on the starter-anode a relatively large voltage is required between the cathode and anode to cause the tube to start.

Characteristics

Bulb	ST-12
Base	4-V
Anode to Cathode Breakdown Voltage (Starter-Anode tied to Cathode)	225 Volts Min.
Starter-Anode to Cathode Breakdown Voltage	70 Volts Min.
	90 Volts Max.
Starter-Anode Current for Transition of Discharge to Anode at 140 Volts, Peak	100 μamps. Max.
Starter-Anode to Cathode Operating Voltage Drop	60 Volts Approx.
Anode to Cathode Operating Voltage Drop	70 Volts Approx.
Anode to Cathode Current	
Continuous	25 Ma. Max.
Instantaneous	100 Ma. Max.

Typical Operating Conditions (A-C Supply)

Anode-Supply Voltage (RMS)	105–130 Volts
Starter Anode Voltage (Peak) A-C	70 Volts Max.
Starter-Anode Voltage (Peak) R-F	55 Volts Min.
Sum of A-C and R-F Starter-Anode Voltages (Peak)	110 Volts Min.

2A4G

Is a hot cathode, argon filled, single grid, thyratron tube particularly useful in applications where constancy of characteristics is necessary even with large variations in ambient temperature. The plus filament leg is connected to pin number 2 of the "G" type base with the minus leg connected to pin number 7. The maximum allowable voltage between any two electrodes is 250 volts.

Characteristics

Bulb	ST-12
Base No.	5-S
Filament Voltage	2.5 Volts
Filament Current	2.5 Amperes
Maximum Anode Voltage: (Instantaneous)	
Forward	200 Volts
Inverse	200 Volts
Maximum Anode Current:	
Peak	1.25 Amperes
Average	0.10 Ampere
Maximum Averaging Time:	45 Seconds
Tube Voltage Drop	15 Volts
Cold Starting Time	2 Seconds

VR90 and VR150

Are gas filled cold cathode voltage regulator tubes. These tubes are characterized by a practically constant internal voltage drop across which a load requiring good voltage regulation may be connected. Operating characteristics are shown in the tabulated data for receiving tubes.

884, 885

Are heater type gas triodes designed for use in sweep circuit oscillators or as grid controlled rectifiers. Type 884 is designed for 6.3 volts heater operation and is equipped with an octal base. Type 885 is designed for 2.5 volts heater operation and is equipped with a standard 5-pin base.

Characteristics

Type	884	885
Bulb	ST-12	ST-12
Base	6-Q	5-A
Heater Voltage	6.3	2.5 Volts
Heater Current	0.6	1.4 Amperes

Operating Conditions

Anode Voltage (Instantaneous)	300	300 Max. Volts
Peak Voltage (between any two electrodes)	350	350 Max. Volts
Peak Anode Current	300	300 Max. Ma.
Average Anode Current:		
For frequencies below 200 cycles/sec.	3	3 Max. Ma.
For frequencies above 200 cycles/sec.	2	2 Max. Ma.
Grid Resistor	**	**

Grid-Controlled Rectifier Service

Peak Voltage (between any two electrodes)	350	350 Max. Volts
Peak Anode Current	300	300 Max. Ma.
Average Anode Current (over period of 30 sec.)	75	75 Max. Ma.
Grid Resistor	**	**
Tube Voltage Drop	16	16 Approx. Volts

Heater voltage should be applied for 30 seconds before drawing anode load current.

**The grid resistor should be not less than 1000 ohms per maximum instantaneous volt applied to the grid. Resistance values in excess of 500,000 ohms may cause circuit instability.

879

Is a high-voltage low-current rectifier tube used primarily with cathode-ray tubes in television work. The tube is constructed with a coated type filament and a single plate. The Plate connection is brought out to a top-cap. During operation the bulb becomes quite hot, therefore, adequate ventilation should be provided Type 879 will generally replace types H2-10 and 143D rectifiers.

Characteristics

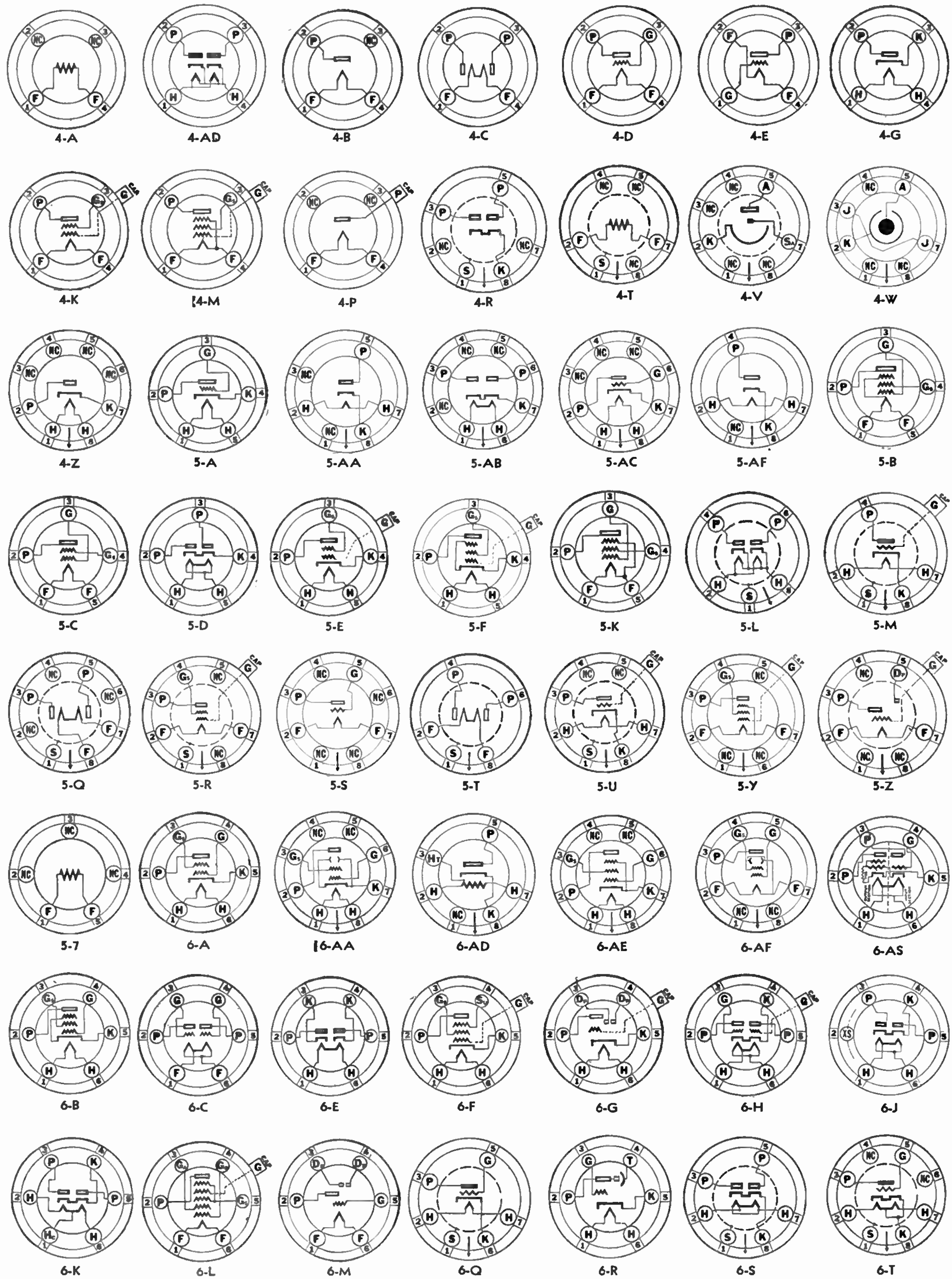
Filament Voltage	2.5 Volts
Filament Current	1.75 Amperes
Bulb	ST-12C
Base No.	4-P

Operating Conditions

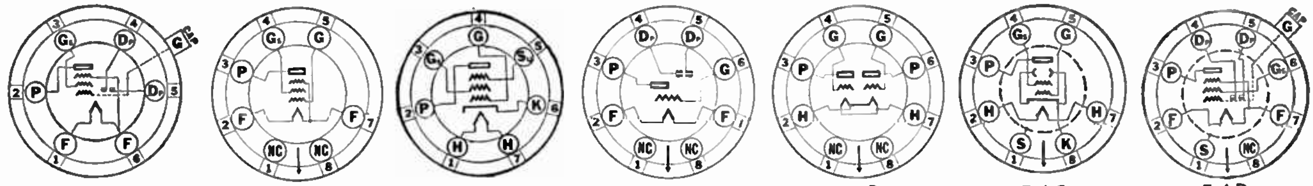
A-C Plate Voltage (RMS)	2650 Volts Max.
Peak Inverse Voltage	7500 Volts Max.
Peak Plate Current	100 Ma. Max.
D-C Output Current (continuous)	7.5 Ma. Max.

TUBE AND BASE DIAGRAMS

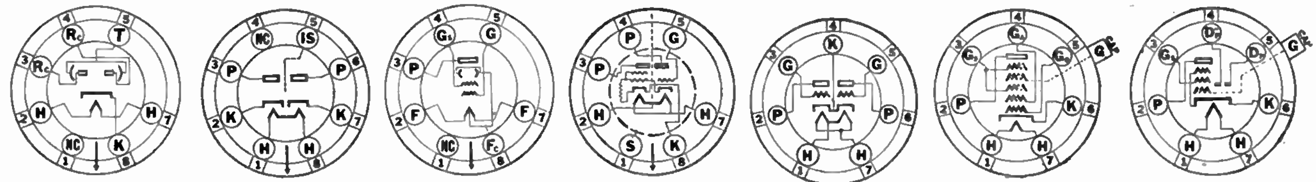
(Viewed From Bottom of Base—RMA Numbering System)



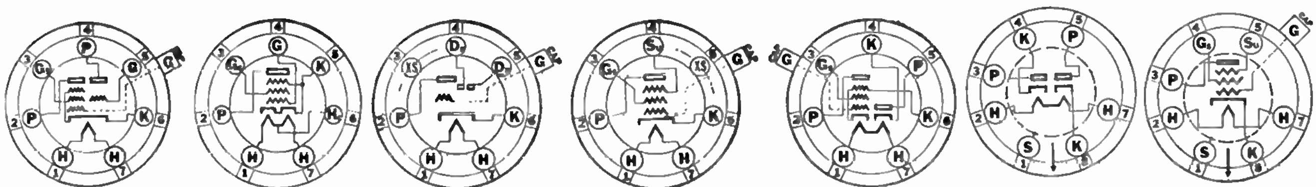
TUBE AND BASE DIAGRAMS (*Continued*)



6-W | 6-X | 7-A | 7-AA | 7-AB | 7-AC | 7-AD

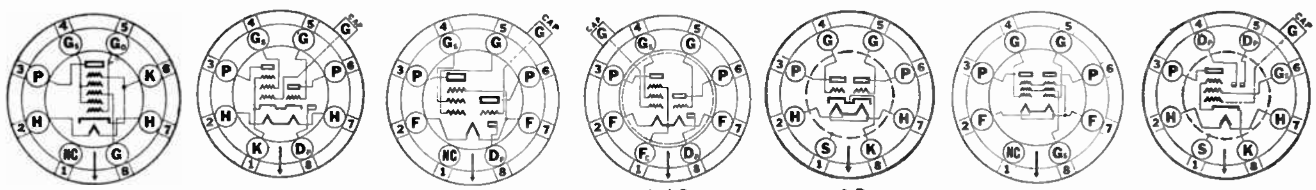


7-AG | 7-AJ | 7-AP | 7-AU | 7-B | 7-C | 7-D

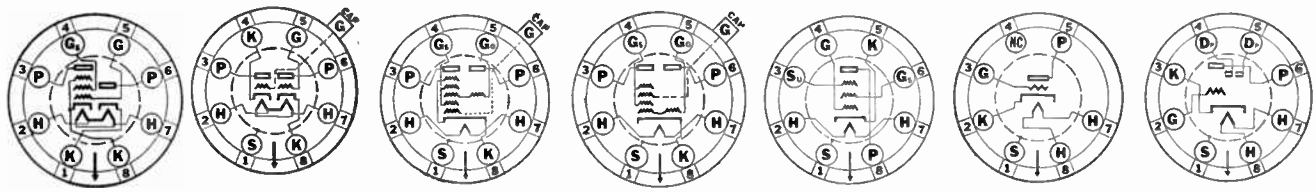


7-E | 7-F | 7-G | 7-H | 7-K | 7-Q | 7-R

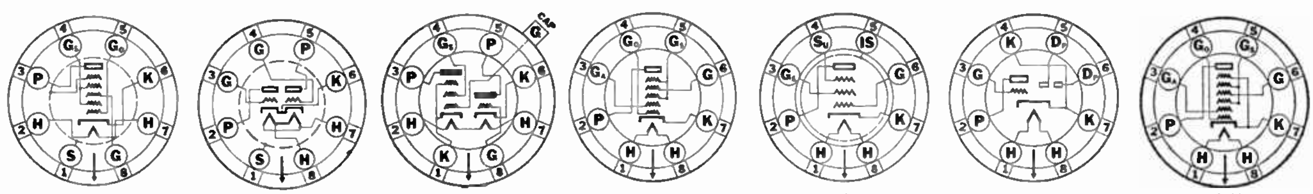
7-S | 7-T | 7-U | 7-V | 7-Z | 8-A | 8-AA



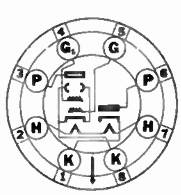
8-AD | 8-AF | 8-AJ | 8-AS | 8-B | 8-C | 8-E



8-F | 8-G | 8-H | 8-K | 8-N | 8-P | 8-Q



8-R | 8-S | 8-T | 8-U | 8-V | 8-W | 8-X



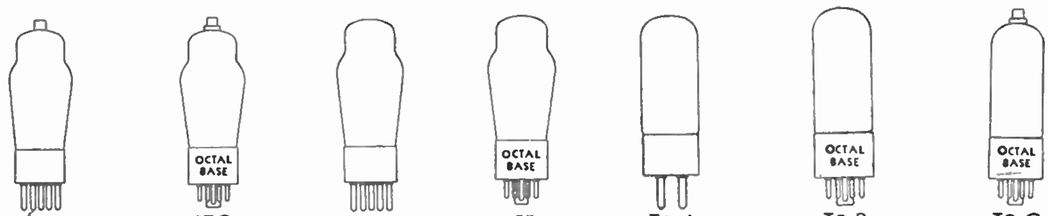
8-Z

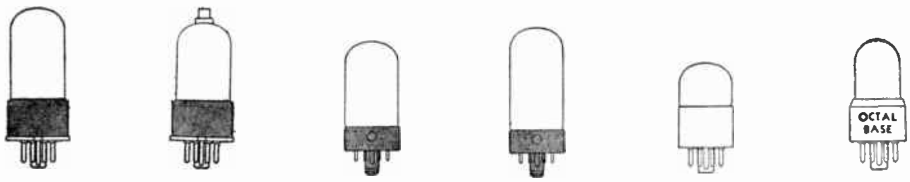
SYMBOLS: A—Anode; A1—Anode 1; A2—Anode 2; D1—Deflector 1; D2—Deflector 2; D3—Deflector 3; D4—Deflector 4; Dp—Diode Plate; F—Filament; Fc—Filament center; G—Control Grid; Ga—Anode Grid; Gm—Modulator Grid; Go—Oscillator Grid; Gs—Screen Grid; H—Heater; Hc—Heater Center; Ht—Heater; tap; IS—Internal Shield; J—Jumper; K—Cathode; Nc—No Connection; P—Plate; Rc—Ray Control; S—Metal Shell; SA—Starter Anode; Su—Suppressor Grid; T—Target; XS—External Shield; ☐—Top Cap; ➤—Locating Pin.

NOTES ON OCTAL TUBE BASE VIEWS—All "G" tube base views except those for Types 6C5G, 6F5G, 6J7G, and 6J7GT, have pin No. 1 open, but the pin is lettered "S" since many of the views also represent metal tube base connections in which case pin No. 1 is the termination of the metal shell. Types 6C5G, 6F5G, 6J7G, and 6J7GT, have an internal cage construction connected to pin No. 1 for shielding purposes. Some of the "G" or Metal Tubes may have extra pins in the bases. These extra pins are not connected and are to be disregarded since the only pin connections are those shown on the base views.

TUBE ILLUSTRATIONS AND DIMENSIONS

GLASS TUBES





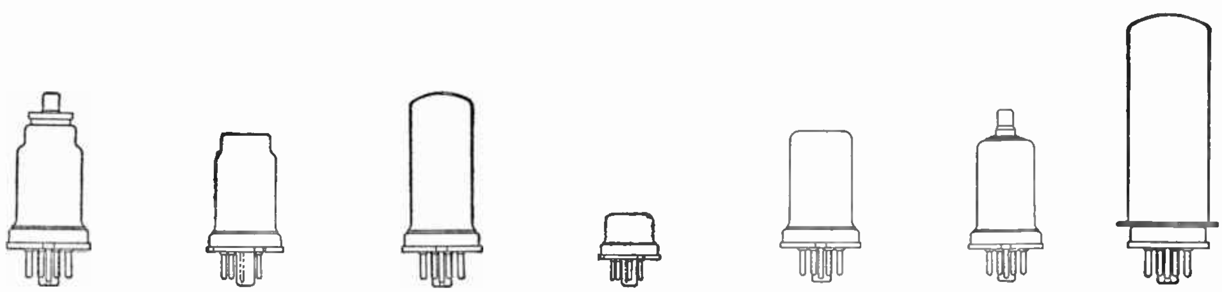
Bulb	Over All Height	Maximum Diameter
ST-12	4 3/16"	1 9/16"
ST-12 Octal .	4 1/8"	1 9/16"
ST-12C*	4 17/32"	1 9/16"
ST-12C* Octal .	4 15/32"	1 9/16"
ST-14	4 11/16"	1 13/16"
ST-14 Octal .	4 5/8"	1 13/16"

Bulb	Over-All Height	Maximum Diameter
ST-14C.	5 1/32"	1 13/16"
ST-16	5 3/8"	2 1/16"
ST-16 Octal. . .	5 5/16"	2 1/16"
T7	2 5/8"	1 1/16"
T8	3 5/16"	1 1/16"
T9-A**	4 3/16"	1 3/16"
T9-B	4"	1 3/16"

Bulb	Over-All Height	Maximum Diameter
T9-C	4 5/16"	1 3/16"
T9-D	3 5/16"	1 5/16"
T9-E	3 5/16"	1 5/16"
T9-F	3 5/32"	1 3/16"
T9-G	2 25/32"	1 3/16"
T9-H	2 5/16"	1 3/16"

*ST12C Over-all height for types 6C6, 6D6, 6D7, 6E7, 57, 57S, 57AS, 58, 58S, and 58AS is 4 15/16".
*ST12C (Octal) Over-all height for type 6U7G is 4 7/8".
**T9-A Over-all height for types 20, X99 and 864 is 3 13/16".

METAL TUBES



	Overall Height	Maximum Diameter
8A-1	3 1/8"	1 5/16"
8A-2	2 5/8"	1 5/16"
8B-1	3 1/4"	1 5/16"
8C-1	1 5/8"	1 5/16"

	Overall Height	Maximum Diameter
8G-1	2 5/8"	1 5/16"
8G-2	3 1/8"	1 5/16"
10A-2	4 5/16"	1 5/8"

SYLVANIA PANEL LAMPS

A complete line of Sylvania Panel Lamps, especially designed for radio dials, tuning meters, flash-tuning arrangements and the like, is now available. A market for some types of these lamps will also be found in flashlights, parking lights, auto panel boards, record players, pin-ball machines, and wherever a miniature lamp of this style is required.

The early types of panel lamps were used primarily as on-or-off indicators in radio receivers. Present-day panel lamps must be constructed to withstand speaker vibrations, have noise-free operation, current drain within the required limit (particularly when used in ac-dc receivers and battery receivers), and to provide shadowless illumination. Sylvania radio panel lamps have been constructed for all these requirements.

The replacement of panel lamps should be made with lamps having the same type number. This is particularly true in tuning meters, battery, and ac-dc receiver replacements. Sylvania type S47 is the same as other lamps marked 40A. Lamps marked 49A may be replaced with Sylvania type S49. Type S292 is mainly for use in 2.5 volt receivers where the line voltage is high and regular 2.5 volt lamps will not stand up.

The filament wires of all standard panel lamps are mounted through a small colored glass bead located above the bulb press. If the markings on the lamp to be replaced are not legible, the bead color may be used as identification, since the color identifies the lamp type. The bead color of each lamp is shown in the tabulated data below, and it will be noted that in some cases the bead colors identify more than one particular type of lamp. In these cases other means of identification will be required, such as comparison of bulb, base, and circuit voltage.

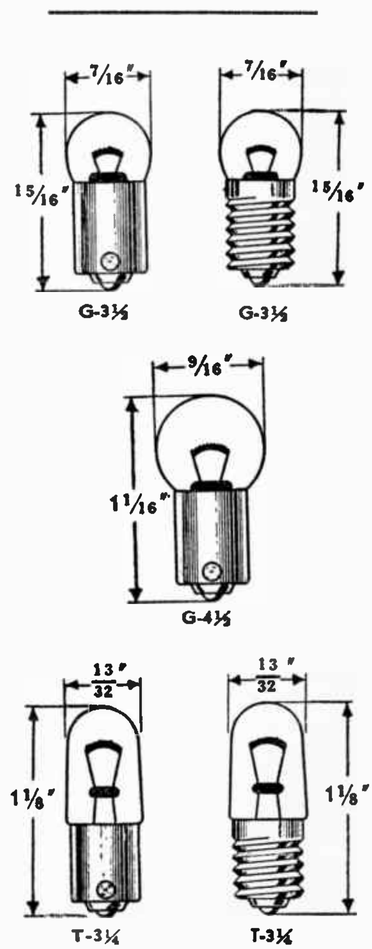
It is recommended that complete replacement of all panel lamps be made in a receiver at one time. Additional profit and a satisfied customer will be the result. The average life of panel lamps is considerable, but unpredictable, because of varying applications and conditions. Therefore, because of the low unit cost, complete replacement is recommended whenever convenient.

CHARACTERISTICS

Type No.	Circuit Volts	Design		Bead Color	Bulb Style	Miniature Base	Usual Service	Type No.
		Volts	Ampere					
S40	6–8	6.3	0.15	Brown	T-3¼	Screw	Radio Dials	S40
S41	2.5	2.5	0.50	White	T-3¼	Screw	Radio Dials	S41
S42	3.2	3.2	0.35	Green	T-3¼	Screw	Radio Dials	S42
S43	2.5	2.5	0.50	White	T-3¼	Bayonet	Radio Dials and Tuning Meters	S43
S44	6–8	6.3	0.25	Blue	T-3¼	Bayonet	Radio Dials and Tuning Meters	S44
S45	3.2	3.2	0.35	White	T-3¼	Bayonet	Radio Dials	S45
S46	6–8	6.3	0.25	Blue	T-3¼	Screw	Radio Dials and Tuning Meters	S46
*S47	6–8	6.3	0.15	Brown	T-3¼	Bayonet	Radio Dials	*S47
S48	2.0	2.0	0.06	Pink	T-3¼	Screw	Battery Set Dials	S48
*S49	2.0	2.0	0.06	Pink	T-3¼	Bayonet	Battery Set Dials	*S49
S50	6–8	7.5	0.20	White	G-3½	Screw	Auto Sets, Flash Lights	S50
S51	6–8	7.5	0.20	White	G-3½	Bayonet	Auto Sets, Auto Panels	S51
S55	6–8	6.5	0.40	White	G-4½	Bayonet	Auto Sets, Parking Lights	S55
S292	2.9	2.9	0.17	White	T-3¼	Screw	Radio Dials	S292
S1455	18.0	18.0	0.25	Brown	G-5	Screw	Coin Machines	S1455
S1455A	18.0	18.0	0.25	Brown	G-5	Bayonet	Coin Machines	S1455A

*Sylvania Types S47 and S49 are interchangeable with Types 40A and 49A, respectively, in other brands.

BULB ILLUSTRATIONS



COMPILED BY

SYLVANIA RADIO TUBE DIVISION

Hygrade Sylvania

CORPORATION

EMPORIUM, PENNA.

REG. U.S. PAT. OFF.

CORRELATION OF TUBE TYPES

Type	Style	Service	Characteristics Equivalent to	Characteristics Similar to
OZ4	Metal	Full Wave Rectifier	OZ4G*	6X5, 6X5G
OZ4G	"G"	Full Wave Rectifier	OZ4*	6X5, 6X5G
01A	Glass	Amplifier		
1A4P	Glass	R-F Amplifier	1D5GP	34, 1N5G
1A4T	Glass	R-F Amplifier	1D5GT	34
1A5G	"G"	Power Output Amplifier		1C5G, 1G5G
1A6	Glass	Pentagrid Converter	1D7G	1C6
1A7G	"G"	Pentagrid Converter		1C7G, 1D7G
1B4P	Glass	R-F Amplifier	1E5GP	32
1B5/25S	Glass	Duodiode Detector	1H6G	
1C5G	"G"	Power Output Amplifier		1A5G, 1G5G
1C6	Glass	Pentagrid Converter	1C7G	1A6
1C7G	"G"	Pentagrid Converter	1C6	1A6, 1A7G, 1D7G
1D5GP	"G"	R-F Amplifier	1A4P	1N5G, 34
1D5GT	"G"	R-F Amplifier	1A4T	34
1D7G	"G"	Pentagrid Converter	1A6	1A7G, 1C6, 1C7G
1E5GP	"G"	R-F Amplifier	1B4P	32
1E7G	"G"	Power Output Pentode		(Two 1F4's)
1F4	Glass	Power Output Pentode	1F5G	33, 1G5G, 1J5G
1F5G	"G"	Power Output Pentode	1F4	33, 1G5G, 1J5G
1F6	Glass	Duodiode Pentode	1F7G	1B5/25S, 1H6G
1F7G	"G"	Duodiode Pentode	1F6	1B5/25S, 1H6G
1G5G	"G"	Power Output Pentode		1F4, 1F5G, 1J5G, 33
1H4G	"G"	Amplifier	30	
1H5G	"G"	Diode-Triode Amplifier		
1H6G	"G"	Duodiode Detector	1B5/25S	
1J5G	"G"	Power Output Pentode		1F4, 1F5G, 1G5G, 33
1J6G	"G"	Power Output Amplifier	19#	(Two 31's)
1N5G	"G"	R-F Amplifier		1A4P, 1D5GP, 34
2A3	Glass	Power Output Triode	6A3#, 6B4G#	45
2A5	Glass	Power Output Pentode	6F6G#, 42#	47
2A6	Glass	Duodiode Detector	6Q7G#, 75#	
2A7, 2A7S	Glass	Pentagrid Converter	6A7#, 6A7S#, 6A8G#	
2B7, 2B7S	Glass	Duodiode Pentode	6B7#, 6B7S#, 6B8G#	
2E5	Glass	Tuning Indicator	6E5#	
5U4G	"G"	Rectifier	5Z3, 5X4G	5T4
5V4G	"G"	Rectifier	83V	5T4
5W4	Metal	Rectifier		5Y3G, 5Z4, 80
5X4G	"G"	Rectifier	5Z3, 5U4G	
5Y3G	"G"	Rectifier	5Y4G, 80	5Z4*
5Y4G	"G"	Rectifier	5Y3G, 80	5Z4
5Z3	Glass	Rectifier	5U4G, 5X4G	83
5Z4	Metal	Rectifier		5Y3G*, 5Y4G
6A3	Glass	Power Output Triode	2A3#, 6B4G	45
6A4/LA	Glass	Power Output Pentode		41
6A5G	"G"	Power Output Triode		6A3, 6B4G*
6AC5G	"G"	Power Output Triode		
6A6	Glass	Power Output Amplifier	6N7, 6N7G, 53#	
6A7, 6A7S	Glass	Pentagrid Converter	6A8+, 6A8G, 2A7#, 2A7S#	
6A8	Metal	Pentagrid Converter	6A7+, 6A8G+*	6D8G
6A8G	"G"	Pentagrid Converter	6A7, 6A8+*	6D8G
6B4G	"G"	Power Output Triode	6A3, 2A3#	6A5G, 45
6B5	Glass	Power Output Amplifier	6N6G	42
6B7, 6B7S	Glass	Duodiode Pentode	6B8G	6B8+
6B8	Metal	Duodiode Pentode	6B8G*	6B7
6B8G	"G"	Duodiode Pentode	6B7	6B8*
6C5	Metal	Triode Amplifier	6C5G+*	6J5G, 6L5G, 6P5G, 37, 76
6C5G	"G"	Triode Amplifier	6C5+*	6J5G, 6L5G, 6P5G, 37, 76
6C6	Glass	R-F Amplifier	6D7, 1221, 1223	6J7, 6J7G, 6W7G, 77*
6C7	Glass	Duodiode Triode Detector		75, 85
6C8G	"G"	Duotriode Amplifier		6F8G
6D6	Glass	R-F Amplifier	6E7, 6U7G	6K7, 6K7G, 6S7G, 78*
6D7	Glass	R-F Amplifier	6C6, 1221, 1223	6J7, 6J7G, 6W7G, 77
6D8G	"G"	Pentagrid Converter		6A7, 6A8, 6A8G
6E5	Glass	Tuning Indicator	2E5#	6G5, 6T5, 6U5
6E6	Glass	Power Output Amplifier		
6F5	Metal	Triode Amplifier	6F5G+*	6K5G
6F5G	"G"	Triode Amplifier	6F5+*	6K5G
6F6	Metal	Power Output Pentode		6F6G*, 42
6F6G	"G"	Power Output Pentode	2A5#, 42	6F6*
6F7, 6F7S	Glass	Triode-Pentode Amplifier	6P7G	
6F8	Glass	Duotriode Amplifier		6C8G, (Two 6J5G's)
6G5	Glass	Tuning Indicator	6T5*, 6U5*	6E5
6G6G	"G"	Power Output Pentode		
6H6	Metal	Duodiode	6H6G+*	
6H6G	"G"	Duodiode	6H6+*	
6J5	Metal	Triode Amplifier	6J5G+*	6C5, 6C5G, 6L5G, 37, 76
6J5G	"G"	Triode Amplifier	6J5+*	6C5, 6C5G, 6L5G, 6P5G, 37, 76
6J7	Metal	R-F Amplifier	6J7G+*, 77+	6C6, 6W7G
6J7G	"G"	R-F Amplifier	6J7+*, 77	6C6, 6W7G
6J8G	"G"	Triode Heptode Converter		6K8
6K5G	"G"	Triode Amplifier		6F5, 6F5G
6K6G	"G"	Power Output Pentode	41	6F6, 6F6G, 42
6K7	Metal	R-F Amplifier	6K7G+*, 78+	6D6, 6S7G, 6U7G
6K7G	"G"	R-F Amplifier	6K7+*, 78	6D6, 6S7G, 6U7G
6K8	Metal	Triode Hexode Converter		6J8G
6L5G	"G"	Triode Amplifier		6C5, 6C5G,

SYMBOLS: *Indicates direct interchangeability. In some cases realignment of tuned circuits may be necessary particularly where capacitances differ.
#Equivalent Characteristics except for filament rating.
+Characteristics same as listed type except capacitances.

Type	Style	Service	Characteristics Equivalent to	Characteristics Similar To
6L6G	"G"	Power Output Amplifier	6L6*	
6L7	Metal	Pentagrid Mixer	6L7G+*, 1612	
6L7G	"G"	Pentagrid Mixer	6L7+*, 1612	
6N6G	"G"	Power Output Amplifier	6B5	6F6G, 42
6N7	Metal	Power Output Amplifier	6A6, 6N7G*	53#
6N7G	"G"	Power Output Amplifier	6A6, 6N7*	53#
6P5G	"G"	Triode Amplifier	76, 56#	6C5, 6C5G, 6J5G, 6L5G, 37
6P7G	"G"	Triode Pentode Amplifier	6F7, 6F7S	
6Q7	Metal	Duodiode Triode	6Q7G+*	6T7G, 75
6R7	Metal	Duodiode Triode	6R7G+*	6V7G, 85
6R7G	"G"	Duodiode Triode	6R7+*	6V7G, 85
6S7G	"G"	R-F Amplifier		6D6, 6J7, 6K7G 6U7G, 78
6T5	Glass	Tuning Indicator	6G5*, 6U5*	6E5
6T7G	"G"	Duodiode Triode Amplifier		6Q7, 6Q7G, 75
6U5/6G5	Glass	Tuning Indicator	6G5*, 6T5*	6E5
6U7G	"G"	R-F Amplifier	6D6, 6E7	6K7, 6K7G*, 6S7G, 78
6V6	Metal	Power Output Amplifier	6V6G*	
6V6G	"G"	Power Output Amplifier	6V6*	
6V7G	"G"	Duodiode Triode	55#, 85	6R7, 6R7G
6W7G	"G"	R-F Amplifier		6C6, 6J7, 6J7G, 77
6X5	Metal	Rectifier	6X5G*, 84	0Z4G
6X5G	"G"	Rectifier	6X5*, 84	0Z4G
6Y5	Glass	Rectifier		6X5, 6X5G, 84
6Y6G	"G"	Power Output Amplifier		
6Y7G	"G"	Power Output Amplifier	79	6Z7G
6Z5	Glass	Rectifier		
6ZY5G	"G"	Rectifier		
6Z7G	"G"	Power Output Amplifier		6Y7G, 79
10	Glass	Power Output Triode	210T*	50
12A	Glass	Power Output Triode		01A, 71A
12A5	Glass	Power Output Pentode		
12A7	Glass	Rectifier and Amplifier		25A7G
12Z3	Glass	Rectifier		
15	Glass	R-F Pentode		24A
18	Glass	Power Output Amplifier		2A5, 42
19	Glass	Power Output Amplifier	1J6G#	(Two 31's)
20	Glass	Power Output Amplifier		X99
22	Glass	R-F Amplifier		1B4P, 32
24A, 24S	Glass	R-F Amplifier		35/51, 35S/51S
25A6	Metal	Power Output Amplifier	25A6G*, 43	
25A6G	"G"	Power Output Amplifier	25A6*, 43	
25A7G	"G"	Rectifier and Amplifier		12A7
25B6G	"G"	Power Output Amplifier		25A6G, 43
25L6	Metal	Power Output Amplifier	25L6G*	
25L6G	"G"	Power Output Amplifier	25L6*	
25Z5	Glass	Rectifier	25Z6G	25Z6
25Z6	Metal	Rectifier		25Z5, 25Z6G*
26	Glass	Amplifier		
27, 27S	Glass	Amplifier		56*, 56S
30	Glass	Amplifier	1H4G	
31	Glass	Power Output Amplifier		
32	Glass	R-F Amplifier		1A4T, 1D5GT
33	Glass	Power Output Amplifier		1F4, 1F5G, 1G5G, 1J5G
34	Glass	R-F Amplifier		1A4P, 1A4T, 1D5GP, 1D5GT, 1N5G
35/51	Glass	R-F Amplifier	35S/51S	24A
35S/51S	Glass	R-F Amplifier	35/51	24S
36	Glass	R-F Amplifier		6C6, 6J7, 6J7G, 77
37	Glass	Triode Amplifier		6C5, 6C5G, 6J5G, 6P5G, 76*
38	Glass	Power Output Amplifier		6K6G, 41
39/44	Glass	R-F Amplifier		6D6, 6K7, 6K7G, 6S7G, 78
40	Glass	Amplifier		
41	Glass	Power Output Pentode	6K6G	38, 42
42	Glass	Power Output Pentode	2A5#, 6F6G	6F6
43	Glass	Power Output Pentode	25A6, 25A6G	48
45	Glass	Power Output Triode		2A3
46	Glass	Power Output Amplifier		
47	Glass	Power Output Pentode		2A5
48	Glass	Power Output Tetrode		43
49	Glass	Power Output Tetrode		
50	Glass	Power Output Triode		10
53	Glass	Power Output Amplifier	6A6#, 6N7#, 6N7G#	
55, 55S	Glass	Duodiode Triode	6V7G#, 85#	
56, 56S	Glass	Triode Amplifier	76#	27, 27S
56AS	Glass	Triode Amplifier	76#	
57, 57S	Glass	R-F Amplifier	6C6#	
57AS	Glass	R-F Amplifier	6C6#	77
58, 58S	Glass	R-F Amplifier	6D6#, 6E7#, 6U7G#	
58AS	Glass	R-F Amplifier	6D6#, 6E7#, 6U7G#	78
59	Glass	Power Output Amplifier		
75, 75S	Glass	Duodiode Triode	2A6#	6Q7, 6Q7G, 6T7G
76	Glass	Triode Amplifier	6P5G, 56#	6C5, 6C5G 6J5G, 6L5G, 37*
77	Glass	R-F Amplifier	6J7+, 6J7G	6C6*, 6W7G
78	Glass	R-F Amplifier	6K7+, 6K7G	6D6*, 6S7G, 6U7G
79	Glass	Power Output Amplifier	6Y7G	
80	Glass	Rectifier	5Y3G, 5Y4G	
81	Glass	Rectifier		
82	Glass	Rectifier		
83	Glass	Rectifier		5U4G, 5X4G, 5Z3, 5Z4G, 83V
83V	Glass	Rectifier	5Z4G	83
84	Glass	Rectifier	6X5, 6X5G	
85	Glass	Duodiode Triode	6V7G, 55#	6R7, 6R7G
85AS	Glass	Duodiode Triode		6R7, 6R7G, 85
89	Glass	Power Output Amplifier		
V99	Glass	Triode Amplifier		X99
X99	Glass	Triode Amplifier		V99, 20
182B/482B	Glass	Power Output Amplifier		183/483*, 71A
183/483	Glass	Power Output Amplifier		182B/482B*, 71A

LESSON 10

Radio Frequency Amplification

Superheterodyne Principles

The actions of tuned circuits and of vacuum tubes are utilized to select and increase the weak signals received by the antenna. The amplification in any modern radio set is accomplished at radio frequencies before detection, and at audio frequencies after detection.

SELECTIVITY A radio receiver must separate the signals of any station wanted from the signals of all remaining operating stations. The degree of selectivity is the ability of the receiver to perform this function. Since the broadcast band stations are separated by 10 K.C., selectivity that is sufficient to separate stations 10 K.C. apart is employed.

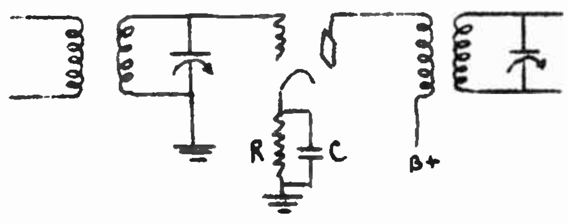
SENSITIVITY The receiving set must also amplify the incoming signal voltage to a sufficient degree to operate the loud-speaker. The sensitivity of a receiver is the measurement of overall amplification from the antenna input to the loud-speaker connections. Sensitivity should be as large as practical; it is possible to over do this in modern high gain sets.

All noise picked up by the receiver, collectively is known as the noise level. If a station's signal has less strength than the strey impulses forming the noise level, that station cannot be received successfully. Therefore, a radio set that can "go down" to the noise level is as sensitive as is required.

FIDELITY The exactness with which the receiver reproduces speech and music is an indication of its fidelity. The radio receiver should not distort, add, change, or alter the original broadcasted sound in any way.

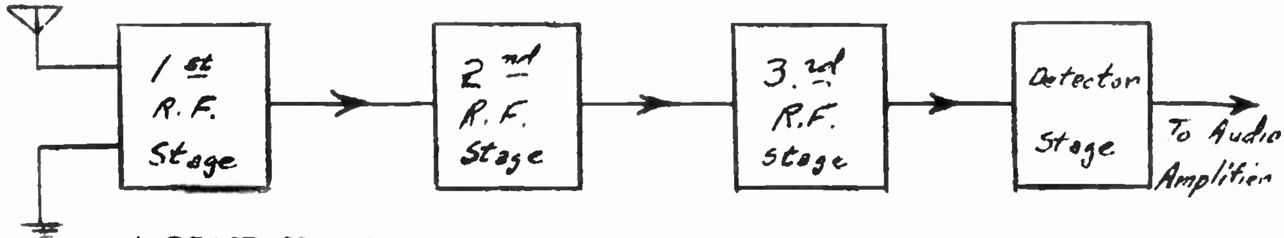
SIGNAL STRENGTH. The transmitted radio energy is spread out in all directions and is quickly reduced to a very low comparative value. In order to have a method of comparison of the signals received from various stations and of the sensitivity of different receivers, it is practical to call the voltage induced in the receiving antenna, the field strength of the transmitter at a particular point on the earth's surface. The voltage induced in a higher antenna will be greater than that set up in a lower one. Since the voltage in the average antenna is a few thousands of a volt (millivolts), the field strength is rated as so many millivolts or microvolts per meter of the antenna effective height. An antenna having an effective height of 3 meters and receiving a signal 15 microvolts, will have 5 (15/3) microvolts per meter field strength.

T. R. F. A tuned radio frequancy amplification stage consists of an input tuned transformer and an output tuned transformer which also serves as the means of input for the next stage. It is possible to use a number of such T.R.F. stages pre-



A TRIODE T. R. F. STAGE

ceeding the detector to obtain the needed sensitivity and selectivity. The condensers used to tune the transformers are usually ganged together for single dial control. Each condenser section is identical and about .000365 mfd. capacity. Small trimmer condensers shunt each section and are adjusted to make up for the differences in capacity, etc.



A DIAGRAMATICAL ILLUSTRATION OF A T.R.F. RECEIVER

VOLUME CONTROL REPLACEMENT A large number of radio repairs center around the volume and tone control replacement. Every radio set has a volume control and the greater majority have tone controls. These units receive about as much handling and mechanical motion as the tuning dial and consequently do wear out with time. A volume control fault is easily detected even by the non-technical owner of the radio. It is bad practice to attempt to repair the original control, but in a few cases replacement resistor strips are available and are easily installed. For best results and time economy a bad volume control should be replaced. To detect the fault notice if the volume change is gradual; if it is sudden the arm does not make good contact or the resistance is worn out in spots. Another positive test is to short the different terminals of the control, if no change is noticed the unit is at fault. Either there is an internal short, or an open circuit.

To replace a volume control is about the easiest task the servicemen comes across. Look the set up in a volume control manual (available from any manufacturer of volume controls or the jobbers), obtain proper control, remove old control, install the new unit.

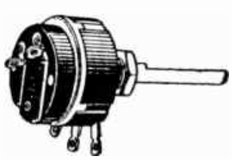
The servicemen, however, should have some knowledge of volume control replacement practice. You may in some extreme cases be called to service a receiver which is obsolete or which is not listed in the manuals. Or you with the additional knowledge, can actually improve some volume control circuits.

Controls are either of the wire-wound or carbon types. A wire-wound control is constructed of high resistance wire and is usually found in the lower resistance values. Such a control is capable of dissipating power effectively in relatively large amounts, but is subject to a number of objections. Such a control corrodes at the worn surfaces, cannot be made with a smooth changing taper, and creates noise due to the voltage drop between the adjacent turns.

The carbon type can be manufactured with any desired taper without any difficulties. Values can be made up to about 10 meg. These controls are noiseless, but have a change of resistance with temperature and humidity.

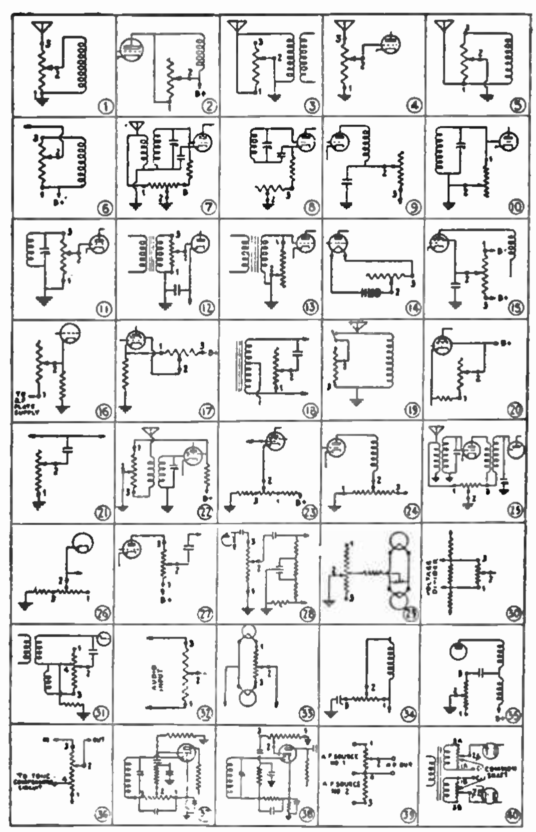
Both types have certain advantages and are used in radio sets. The choice of the control depends on the application. In a circuit where a high resistance 1 megohm potentiometer is needed a carbon type would be used. In a circuit where a control of about 100 ohms is needed and current up to 200 M.A. must be controlled, a wire-wound unit must be employed.

The life of a wire-wound control depends on the mechanical construction and the actual wear of the wires under the slider. In a carbon control the resistance element due to variable humidity and temperature will physically disintegrate. At first this is apparent as a change in resistance or as noise, followed with an open circuit or short.



Various circuits are employed for controlling volume in radio sets, but the circuits illustrated show the essential ones commonly used.

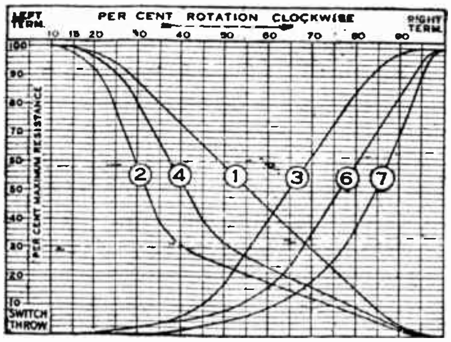
In most older receivers the volume level was controlled by the regulation of the antenna input. Circuits 1, 3, 4, and 5, show various such methods employed. Many sets prior to 1930 used variable resistance shunting the R.F. transformer primaries as a means of control; see Circuits 2 and 6.



Circuit 7, illustrates the use of the popular method of volume control, usually called antenna-cathode method. The control in this position simultaneously shunts the antenna input and increases the grid bias. No. 25 is similar.

Circuits 8 and 16 show the use of a variable resistor to control the bias of a R.F. stage. Circuits 9 and 24 vary the plate voltage of a R.F. tube.

Circuit 11 shows the application of a potentiometer to vary the voltage impressed on the grid of a R.F. stage. In 12, the same is used in an A.F. stage. Circuit 13 shows a variable resistor shunting the secondary of an audio transformer, lowering the voltage impressed on the grid by increasing the secondary load.



Circuit 14 illustrates a conventional filament current limiting control. Circuits 15, 17, and 20 use variable resistors to vary the trans-conductance of a screen grid R.F. amplifier by changing the screen voltage. Circuit 22 is a combination screen-grid antenna control, where-in the voltage on the screen-grid is lowered while resistance is introduced in the antenna circuit. A tone control schematic is illustrated in 18. The high frequencies are attenuated (suppressed) by the by-pass action of the grid circuit. Circuit 21 is very similar. In 19, a local-distance switch control is shown together with an antenna input control.

Circuits 23 and 26 operate by varying the cathode potential of one or more tubes in a bleeder arrangement.

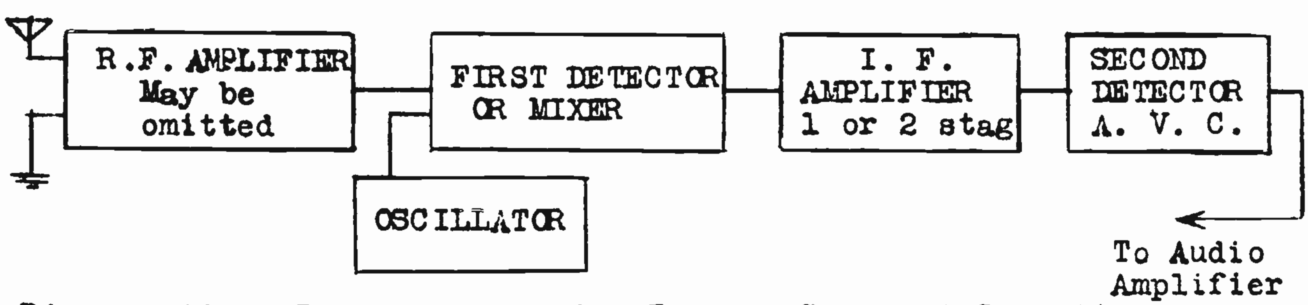
In circuit 27 a potentiometer is employed as the load of an audio amplifier tube. In 28 and 32, a voltage divider circuit employed for volume control is illustrated.

Circuit 38 shows a potentiometer controlling a grid voltage of a triode. This is a very popular method of manual control in radio sets using A.V.C.

Some less common methods of controlling volume in radio sets are illustrated in 31, 34, 35, 36, and 37. Tone controls and balancing arrangements are shown in 29, 30, 33, 39, and 40.

THE SUPERHETERODYNE PRINCIPLE

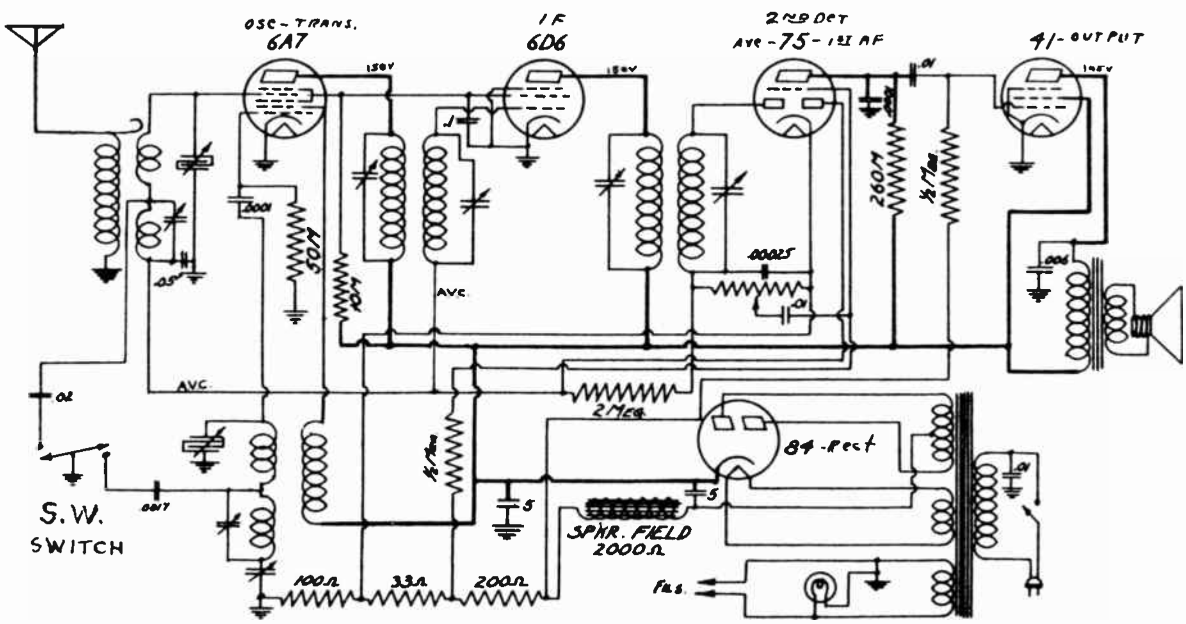
Present day receivers use in majority of cases the superhet circuit. In a superheterodyne the high carrier frequency of a desirable station is changed to a lower fixed frequency and amplified at that frequency. By a proper arrangement it is possible to select any one station and change with the tuning equipment the frequency of that station or any other station on the same band to the same fixed frequency known as the intermediate frequency or I,F. Since the I.F. is constant the amplifier used can be of the fixed type (no variable condensers used for tuning) and can be made more efficient (higher gain) than similar R.F. types.



Diagramatical Illustration of a Typical Superhet Circuit

The R.F. stage or the antenna tuned circuit separates to a limited degree the wanted signal from all others. This signal is mixed with the local oscillator signal to form the I.F. signal. The I.F. amplifier suppresses all unwanted signals and amplifies the desirable signal. A very high gain may be obtained from a single I.F. stage (a gain of 75 is common) because only a single frequency is handled and more efficient design is possible.

If two different frequencies are mixed, signals will be produced that are equal to the sum and to the difference of the original frequencies. For example 650 K.C. and 475 K.C. will produce 650 + 475 = 1125 K.C. and 650 - 475 = 175 K.C. Now suppose we are considering an actual case in a radio set where the I.F. amplifier is designed to pass 175 K.C. (plus and minus 5 K.C.) and we wish to receive a station transmitting on 650 K.C. By simply adjusting the R.F. input stage to 650 K.C. and the oscillator to produce a frequency of 475 K.C., we will obtain 175 and 1125 K.C. frequencies. Of course, the I.F. amplifier will pass and amplify only the 175 K.C. signal and the 1125 K.C. frequency will not be used. When a different station is selected, the oscillator frequency is correspondingly changed to produce the required 175 K.C. I.F. signal.



The above schematic diagram shows a two-band superhet of the A.C. type. Assuming that the switch is in the open position for broadcast reception, try to follow the action of the signal. Notice especially the mixing action that takes place in the 6A7 tube, and the resulting I.F. signal.

THE PRE-SELECTOR R.F. AMPLIFIER

The R. F. amplifier is not employed to provide additional gain although it dees add to the gain of the superhet. The main two functions of a R.F. amplifier, if employed, in a superhet are (1) to prevent powerful local stations from producing cross modulation in the first detector, and (2) to suppress the image frequency which will be explained.

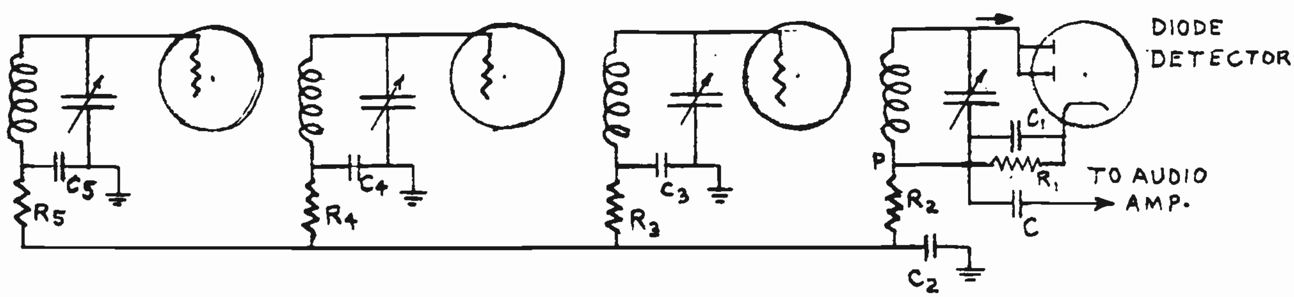
It is evident that for any setting of the oscillator frequency there will be two signal frequencies that will beat to provide the I.F. For example, if the I.F. is 252 K.C. than to receive a station of 650 K.C. the oscillator must produce 902 K.C. (902 - 650 = 252 K.C.) But an oscillator frequency of 902 will also beat with 1154 K.C. station to produce 252 K.C. I.F. (1154 - 902 = 252 K.C.), so that stations operating on these two frequencies will be received together if they have about the same field strength. The R.F. amplifier selects the desired signal and greatly suppresses the image frequency station.

The antenna coil (also R.F. if used) and the oscillator coil must be tuned with variable condensers ganged for single dial control. The frequency of the oscillator circuit, however, must always be different from the other circuit by the intermediate frequency used. One solution to this problem is to employ an oscillator condenser with specially shaped plates to cause this difference of frequency. Such condensers are known as cut section types and are hard to duplicate since they must match the exact set of coils.

Much more often you will find regular TRF condensers used, and the frequency difference is obtained by properly adjusting the trimmers of the condenser gang, as well as the padder included in the oscillator coil circuit, to have the oscillator always track in step.

AUTOMATIC VOLUME CONTROLS *

There are numerous varieties of automatic volume control (A.V.C.) circuits, but they all work on the same principle. The A.V.C. arrangement is intended to maintain the strength of the signal arriving at the detector nearly constant, thus compensating for different signal strengths of different stations and for fading. It does this by varying the sensitivity of the R.F. and I.F. amplifiers. Actually A.V.C. changes the bias on these amplifier tubes to obtain this action. The actual volume is of course not kept constant because it depends on the percentage of modulation at the transmitter. This is being varied in accordance with the volume of the transmitted sound and music. To try keeping this constant would be ruining the effect of music.



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* Information obtained from: "The Aerovox Research Worker."

The schematic above illustrates an A.V.C. system often used in up-to-date sets. Forgetting for the moment the grid return resistors in the R.F. circuits, let us begin with the detector. The signal is rectified by a diode. Current can flow only when the diode becomes positive and the coil must then be considered as the generator. This will perhaps help to explain why the resistor R_1 will carry current in the direction of the arrow, making the point P negative with respect to the cathode and the chassis. This seems to be difficult to understand by many. The current flowing between P and the chassis consists of a direct current component, a radio frequency component, and an audio frequency component. The condenser C_1 has been placed across the resistor to pass most of the radio frequency currents and the audio frequency component is taken off to be applied to the grid by means of the coupling condenser C. The steady voltage at P, which is proportional to the strength of the incoming signal, must now be fed back to the R.F. and I.F. amplifiers, but the A.F. component must be filtered out and precautions for interstage coupling should be taken. This latter requirement is accomplished by the network of resistors and condensers. Since the grids of the amplifying tubes are never drawing current, it does not matter, within limits, how much resistance there is between the point P and the individual grids.

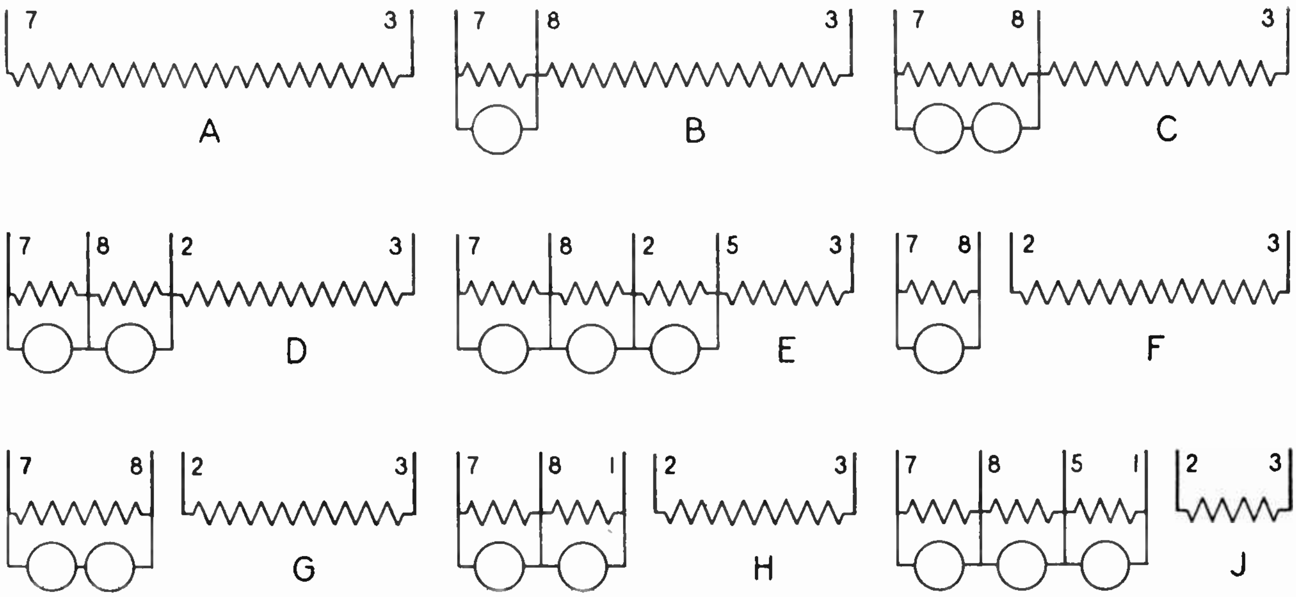
Resistor R_2 and condenser C_2 form a resistance-capacity filter which smoothes out most of the audio frequency fluctuations. That it does so is best seen from a consideration of the laws of alternating currents. Since the condenser which is in series with the resistor R_2, forms a path for alternating currents, a great part of the audio signal will pass through C_2 in preference to following the paths through R_3-C_3, R_4-C_4, R_5-C_5.

WIRE-WOUND TUBE TYPE RESISTORS

It is hard to remember who was the first to place a resistor in a metal or glass vacuum tube envelope and pass this resistor as a tube. Naturally nothing is gained by giving a resistor this special shape, but the public in trying to judge the value of any radio set usually referred to the number of tubes used. And anything that looked like a tube was a tube to the poor radio customer. This practice continued until "15 tube" sets sold for $10.00 -- the resistor tubes retail for 42¢.

Action by the better radio manufacturers with the cooperation of the National Better Business Bureau finally resulted in several special rulings. Only those tubes that performed useful functions and were required in the radio circuit were to be counted. This, of course, left out the resistor tubes and the cases where two and three rectifier tubes were used needlessly.

STANDARD BASE WIRINGS



Usually the resistor tubes were used to produce the needed additional voltage drop in AC-DC sets. The four or five tubes used required, as for example, 69 volts, and the remaining 46 volts of the 115 volt supply was lost in the ballast tube. At times several such tubes were used in series. In modern sets, using Loktal or GT type tubes requiring .15 amperes and designed to operate at fairly high voltages, all the available line EMF is used up in the tube filaments.

The serviceman does need to replace resistor tubes in older sets. Sometimes non-standard ballast tubes are used, and the actual wiring has to be altered. In almost every case the resistor in the tube is tapped for use with a pilot light of smaller current drain.

In the standard series the first letter K means that a 6 to 8 volt, 150 ma. pilot bulb is to be used. L means a 250 ma. bulb. The number following means the voltage drop in the resistor of the tube. The last letter designates the base wiring as illustrated above. Of course, at all times a plain wire-wound resistor of proper power rating can be substituted.

REVIEW QUESTIONS

1. How is it possible to increase the sensitivity but not the selectivity of a radio receiver?

2. In a radio receiver having a 456 KC. I.F., when tuning in a station at 670 KC., what is the frequency of the oscillator?

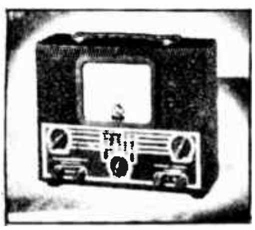
3. Can a different AVC voltage be applied to each tube of two separate circuits? How?

4. A ballast tube is needed to produce a voltage drop of 55 volts and serve a single 150 ma. pilot bulb. The base connections are to be made to prongs 7, 3, and tapped at 8. What would be the number of the tube?

LESSON 11

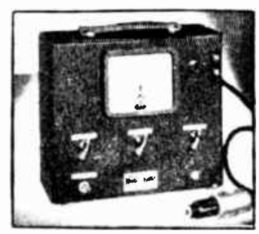
METERS - TESTING METHODS

The factors associated with electricity are measured, directly or indirectly, by means of meters. For example the voltage of a circuit may be measured directly by simply connecting a voltmeter to the circuit. Inductance, on the other hand, may be measured directly only by means of complex meter equipment and simple meters will serve only indirectly and necessitate the use of formulas for a solution. To repair radio sets faults existing must be discovered. In a radio set not in good working condition, voltage, current, resistance, and other electrical quantities present are commonly of values that are not wanted or expected. The discovery of incorrect electrical quantity points to the trouble and gives an easy, and quick solution.



20,000 Ohms-Per-Volt
Unimeter No. 120

Vacuum Tube Voltmeter
Model 88-A



While magnetic, heating, or electro-chemical effect may be used to measure current, for D.C. and A.C. of lower frequencies the magnetic effect is employed. For higher frequencies the heat produced is used as the indicating effect.

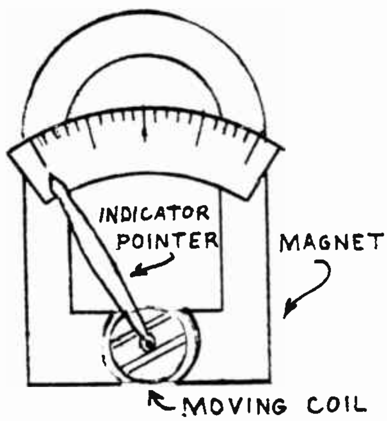
The actual theory underlying the test meters may be of interest to the servicemen, but certainly is of little practical application and will receive little attention. You do want to know how to use meters for testing and that's exactly what we will tell you.

The sensitivity of a voltmeter is expressed in "ohms per volt" and equals the total resistance of the meter divided by the number of volts indicated at full scale deflection. This figure indicates how much current is required to operate the meter. For instance, if an 0-10 voltmeter has a resistance of 10,000 ohms, the sensitivity would be 1,000 ohms per volt, and from Ohm's Law it is easily found, that the meter requires 1 MA. for full scale deflection. Similarly, if the 0-10 voltmeter had a resistance of but 1,000 ohms, the sensitivity would be 100 ohms per volt and it would require 10 MA. to move the needle to full scale deflection. This illustrates that the higher the resistance of the voltmeter for any given range the greater the sensitivity. In cases where very minute currents only can be taken from the circuit, 20,000 ohms per volt meters are used.

METER MULTIPLIERS#

A Convenient Method of Increasing the Range of Various Meters.

The movement generally used in D.C. meters is the D'Arsonval movement illustrated in a simple form on the next page. In this type of instrument, a delicate coil wound with very fine wire is suspended in the field of a strong permanent magnet. A needle is attached to this coil and held at zero by a fine spring. When the terminals of the moving coil are connected in a circuit so that current flows through the coil, this current will make the coil into an electro-magnet with the north and south poles as indicated.



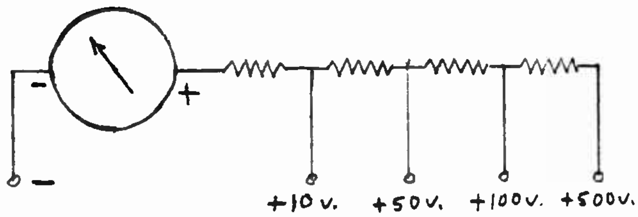
Due to the attraction of unlike poles and repulsion of like poles, the coil and the indicating pointer attached to it will move in a clockwise direction to an extent depending on the strength of the fields of the electromagnet and the permanent magnet. The relative field strength produced in the electro-magnet depends on the current flowing through it, therefore the movement of the coil is a measure of the current. By properly designing the constants of the permanent magnet and the electro-magnet, a full scale deflection can be produced by different values of current flowing through the meter.

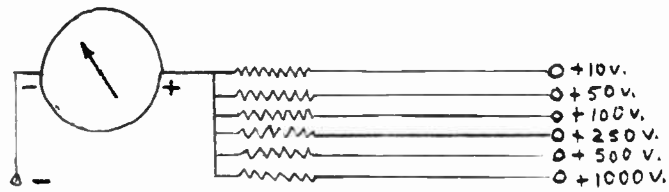
EXTENDING VOLTMETER RANGES To extend the range of a voltmeter, a multiplier resistor is placed in series with it. Although it seems almost needless to say so, one cannot extend the range of a meter downward, neither can the sensitivity be increased by resistors. The proper value of the multiplier resistor is found from the equation:

$$R = (n - 1) R_m$$

where Rm is the meter resistance and n is the factor whereby the range is to be multiplied. When a 10 volt range is to be increased to a 100 volt range, the multiplier should equal 9 times the meter resistance. When the meter resistance is not known it may be measured. However, if the sensitivity of the meter is known, the following rule may be found convenient. The multiplier range should equal to the sensitivity of ohms per volt, times the volts which are to be added to the range. For instance, a 1000 ohms per volt meter requires 1000 ohms for every folt added. Increasing the range from 10 to 100 volts (adding 90 volts) requires a 90,000 ohm multiplier. Changing a range from 150 to 750 volts, takes 600,000 ohms for a 1,000 ohms-per-volt meter. Remember that in extending the range of a voltmeter, the multiplying resistors are connected in series with the meter.

#NOTE: Contents taken from The Aerovox Research Worker.

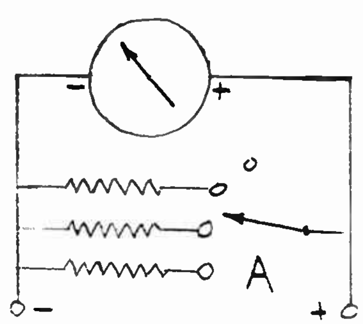


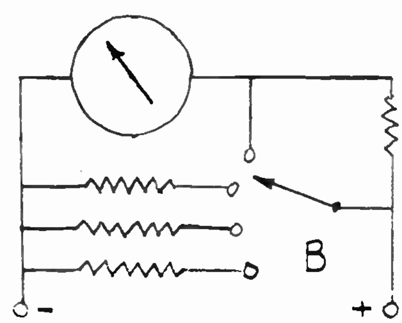


It is obvious that a multi-range instrument can be made by tapping the multiplier resistors and connecting the circuit to the taps by means of switches or by separate terminals. The two methods of connecting the resistors are illustrated above.

<u>MILLIAMMETERS</u> The range of a milliammeter can be extended by shunting it with a resistor. The proper size of the shunt is found from the following consideration: Suppose the shunt was equal to the meter resistance. Equal currents would then flow through the two branches, or the meter would show one-half the current and the range has been multiplied by two. For similar reasons, a shunt equal to one-half of the meter resistance will multiply the range by three. A shunt of 1/3 of the meter resistance will multiply the range by four, etc. A milliammeter of low range can be converted to a multi-range milliammeter by the addition of several such shunts. Large errors may be introduced and the instrument may be damaged unless proper precautions are taken when designing the switching circuits. The most obvious circuit for this purpose is shown in A. In the first position, no shunt is in the circuit, therefore the original range of the meter is used. In the other positions one of the shunts is used. Suppose that one switches from one range to another and the switch arm breaks contact with one terminal before it makes contact with the next. During the time that the shunt is open the lower range is in use. If the switching is done while measuring relatively heavy current the meter will burn out. Also, should the switch fail to make contact at any point, the unsuspecting user may again overload and damage the meter.

There is still another drawback to this arrangement. The switch contact is a part of the shunt and if a switch should make a bad contact, the resistance of the shunt is increased with a consequent error in reading.





A switch that will short all previous terminals as it is turned will eliminate the first objection. The circuit illustrated in B, will serve to partially eliminate these other faults. A series resistor is used in the meter branch; in order to multiply the meter range by n, the shunt must now be

$$R = \frac{Rm + Rs}{n - 1}$$

If R_s is chosen sufficiently large, the shunt does not have to be of so low a resistance. The importance of a perfect switch then becomes less, but the milliammeter will have a higher resistance. This lowers the sensitivity, but radio circuits generally have rather high resistance which makes the high resistance milliammeter still practical.

It is possible to keep the shunt constant and to obtain different ranges by providing different values of Rs. These series resistors can often be the same ones which are used when the meter is employed as a voltmeter.

The various test instruments available for the servicemen combines these test circuits for testing radio sets. By using a small battery in connection with a low range milliammeter, and having a special scale, resistance may be measured directly.

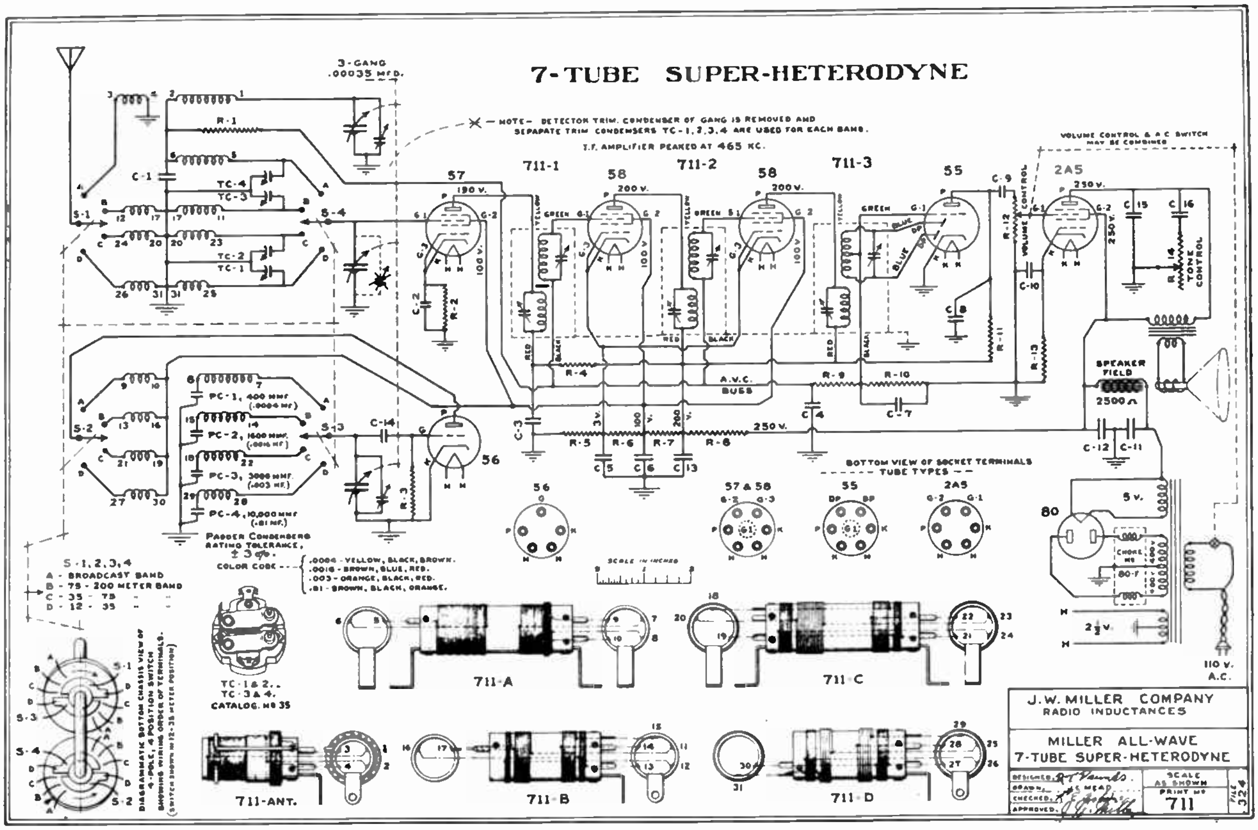
RADIO SERVICING INSTRUMENTS

Every radio circuit consists of vacuum tubes, resistors, condensers and inductors interconnected to give the desired results. Any of these parts may become faulty and either completely stop the radio from operating or prevent the radio from working properly. The real objective of every radio job is to place the faulty radio set in good operating condition. This problem is of a two fold nature: (1) the fault must be discovered, and (2) repaired. The actual repairing is commonly a simple mechanical task, a part or tube is replaced, a wire soldered, or an adjustment made. But to find the fault is the big job and various test equipment is used to help the servicemen do this quicker.

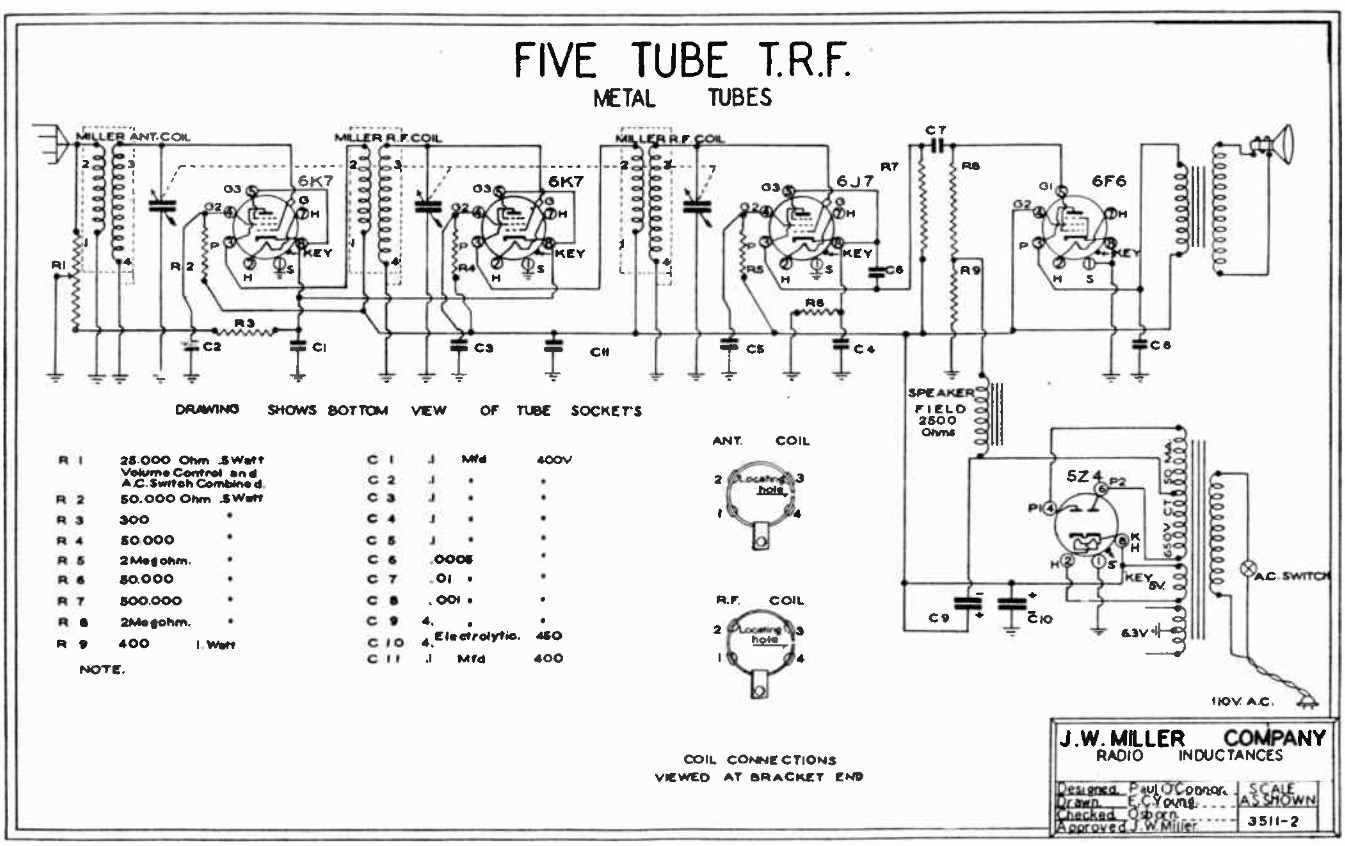
In the testing process either the actual electrical characteristics of the component parts must be measured or the related voltages and currents must be noted. It is easier, of course, to measure the existing voltage and current present in the circuit and strike at the fault by realizing what may be causing the abnormal values. Voltage test methods are especially useful. Examination of a circuit easily discloses the voltage present at any one point. (Many times one voltage value will be present and another lower value will be indicated if a low resistance voltmeter is used. This is one reason for the high resistance 5,000 ohm/volt and 20,000 ohm/volt meter use in high resistance, critical circuits.) Note the example over. Voltages indicated have ground as zero potential reference point.

In a similar manner an ohmmeter test is applied. This test is superior to the voltmeter because it can be used even when the set is completely "dead." Good condensers on an ohmmeter will test as open, and coils as shorted. Resistors will give their corresponding resistance values. See the well operating circuit over.

A volt-ohm milliammeter incorporates a meter, series resistors, shunts, and a switching method to permit tests under all these methods. The different scale readings will permit accurate tests of common radio circuits.



7-TUBE SUPER-HETERODYNE
3-GANG .00035 MFD.
NOTE- DETECTOR TRIM. CONDENSER OF GANG IS REMOVED AND SEPARATE TRIM CONDENSERS TC-1, 2, 3, 4 ARE USED FOR EACH BAND.
I.F. AMPLIFIER PEAKED AT 465 KC.
VOLUME CONTROL & A.C. SWITCH MAY BE COMBINED
57
711-1
58
711-2
58
711-3
55
2A5
56
80
A.V.C. BUSS
SPEAKER FIELD 2500 Ω
BOTTOM VIEW OF SOCKET TERMINALS - TUBE TYPES
S-1, 2, 3, 4
A - BROADCAST BAND
B - 75 - 200 METER BAND
C - 35 - 75
D - 12 - 35
PADDER CONDENSERS RATING TOLERANCE, ± 3%.
PC-1, 400 MMF (.0004 MF)
PC-2, 1600 MMF (.0016 MF)
PC-3, 3000 MMF (.003 MF)
PC-4, 10,000 MMF (.01 MF)
COLOR CODE
.0004 - YELLOW, BLACK, BROWN.
.0016 - BROWN, BLUE, RED.
.003 - ORANGE, BLACK, RED.
.01 - BROWN, BLACK, ORANGE.
TC-1 & 2, TC-3 & 4, CATALOG. No 35
711-A
711-C
711-ANT.
711-B
711-D
110 V. A.C.
J.W. MILLER COMPANY
RADIO INDUCTANCES
MILLER ALL-WAVE
7-TUBE SUPER-HETERODYNE
SCALE AS SHOWN
PRINT No 711



FIVE TUBE T.R.F.
METAL TUBES
MILLER ANT. COIL
MILLER R.F. COIL
MILLER R.F. COIL
6K7
6K7
6J7
6F6
5Z4
SPEAKER FIELD 2500 Ohms
A.C. SWITCH
110V. A.C.
DRAWING SHOWS BOTTOM VIEW OF TUBE SOCKETS
R 1 25.000 Ohm .5 Watt Volume Control and A.C. Switch Combined.
R 2 50.000 Ohm .5 Watt
R 3 300
R 4 50.000
R 5 2 Megohm.
R 6 50.000
R 7 500.000
R 8 2 Megohm.
R 9 400 1 Watt
NOTE.
C 1 .1 Mfd 400V
C 2 .1
C 3 .1
C 4 .1
C 5 .1
C 6 .0005
C 7 .01
C 8 .001
C 9 4.
C 10 4. Electrolytic. 450
C 11 .1 Mfd 400
ANT. COIL
R.F. COIL
COIL CONNECTIONS VIEWED AT BRACKET END
J.W. MILLER COMPANY
RADIO INDUCTANCES
Designed Paul O'Connor
Drawn E.C. Young
Checked
Approved J.W. Miller
SCALE AS SHOWN
3511-2

REVIEW QUESTIONS

1. Assuming you have a 1 ma. movement meter with a 100 ohm internal resistance, design a simple voltmeter around this istrument. Make up the scales you would want for radio testing.

2. Can the voltmeter test method be used if the set to be repaired is completely dead?

3. In the 7 tube Superhet, shown schematically on the previous page, about what voltage is lost in the speaker field? How many watts are being used in exciting the field?

4. In the same circuit, what current is passing in Resistor R-8? (Apply Ohm's Law since you know the voltage and resistance.)

5. In the coil assembly, what happens to the coils that are not being used? What frequencies are actually covered?

6. If in this circuit the screen grid G-2 voltage of the 58 tube would be very low, what would you suspect?

7. If no voltage was present on the plate of the 57 tube, what would you suspect?

8. Now considering the circuit of the five tube set, in testing with an ohmmeter from either 6K7 grid to ground, what reading will you obtain?

9. Explain the action of the volume control. The volume will be at maximum when the slider of the control is at the lower end.

10. What is the purpose of R-3?

11. Notice how the bias is obtained for the 6F6 tube. The choke and R-9 are in series in the negative leg of the power supply. The drop in R-9 is just right to serve as the bias. What advantage has this method over the self bias method where the resistor goes from cathode to ground?

12. Make up a list of parts used in this circuit. Remember to list small items such as dials, grid caps, etc. Then price these parts by using some jobber's catalog. You will notice that it will cost much more to build a set from parts than to buy a similar ready-built model.

13. Referring to the tube chart, find two other tubes that could be used as rectifiers, instead of 5Z4.

14. How many gang condenser is used?

15. What would happen if C-8 shorts?

LESSON 12

Radio Service Fundamentals

A Discussion of Test Equipment for the Radio Service Man

PRESENTED BY

WESTON ELECTRICAL INSTRUMENT CORPORATION

O. J. MORELOCK, JR.

HAROLD L. OLESEN

THE SERVICEMAN AND HIS FUNCTION

1. The Serviceman.

1.1—The radio serviceman is an individual whose function it is to maintain broadcast receivers and similar equipment in operating condition. In general the serviceman may be divided into two groups: the first operating in the field and dealing with equipment that has already been purchased by the customer; and the second, the factory serviceman, who deals with equipment during the process of manufacture.

2. Servicing in the Home.

2.1—The serviceman, answering a service call from the customer's home, generally tests the tubes to locate the trouble, either in the tubes or in the receiver and then makes such tests on the receiver itself to permit diagnosis of the difficulty and an estimate of repair charges. Arrangements are then made with the customer for such new tubes and any repair work as may be required. The chassis of the radio set is generally taken to the radio serviceman's shop for any elaborate repair work where the serviceman has adequate equipment to do whatever service job may be required.

2.2—For the work in the home the serviceman generally uses abbreviated (portable) service equipment for home use and more elaborate and complete equipment (not portable) for shop use.

3. Servicing in the Radio Set Factory.

3.1—The set manufacturer must also maintain a factory service department or repair department. This is required for those sets that are sent in directly for repairs from the outlying districts (customers or dealers) or which are covered directly by the manufacturer's thirty to ninety day guarantee. Servicemen in this department as well as those in the production department must be equipped with complete up-to-date service equipment to handle all of the various service problems that are encountered.

4. Installation and Operation of Public Address Systems.

4.1—An additional source of income for the independent serviceman or the independent radio service organization, is from the rental of public address systems for all kinds of public gatherings. This business is growing rapidly and in many cases has come to be an exceedingly profitable line for the radio serviceman to carry. The systems are often owned by the serviceman himself and rented out for each particular function. In other cases, the serviceman rents suitable equipment for the particular gathering in question and sells his service with the rental of the equipment to those in charge of the gathering. In such cases the serviceman guarantees the successful operation of the installation.

4.2—There is also some income to the independent serviceman or service organization from the servicing of permanent installations of public address equipment. These systems require the same type of service and the same type of test equipment for servicing as the standard household receiver.

5. Requirements.

5.1—From the above it is obvious that the serviceman is limited only by his ability and by his equipment to function properly either in the home, on a public address system, or in the factory. The better the man, the better his training, the better his equipment, the greater and better job he can do.

5.2—The serviceman relies for information on two general sources: the set manufacturer and his service notes for each receiver that he builds; and compiled published data such as Rider's Manual. Obviously, the serviceman who maintains the best file of manufacturers' notes, or who possesses the best set of compiled data, is in the best position to render radio service.

5.3—There is a great variety of service equipment offered by manufacturers for the serviceman's use. As in any other field, some of this equipment is of better design, workmanship, and quality than others. The serviceman who chooses his equipment with the greatest care will find that over a period of years that he is best equipped for the least total cost.

Figure 1—Model 773

SERVICE EQUIPMENT AND ITS USE

1. Tube Testers.

1.1—Tube Testers are of two general types: counter type for use in the store; and portable type for use by the serviceman in the field. See figures 1 and 2.

1.2—Counter type tube testers may further be divided into standard tube testers as such, and special tube testers of the so-called "merchandising" type. In each case the fundamental circuit is essentially the same—the merchandising tube-checker being arranged so as to invite the customer who comes into the store to make purchases of radio tubes in addition to the other purchases originally contemplated.

Figure 2—Model 771

1.3—Originally, tube testers used a circuit, for testing, that checked the tube's mutual conductance. This circuit was found to be too complicated and too expensive for general use as the number of tubes increased. As a result it has largely been replaced during the last two years by a more simple circuit which checks the tube for the emission of its filament under certain test conditions.

1.4—Assuming the tube is correctly designed and manufactured, and correctly tested by the manufacturer before being shipped to the field, a test for emission is an indication of the ability of the filament or cathode to supply current when the proper voltages are applied to the various electrodes of the tube. This test is therefore a satisfactory test for a tube that has been placed on the market.

1.5—The dealer is particularly interested in a tube tester in that it helps him in analyzing the difficulty that a customer may have with his radio set since the customer can bring his tubes into the store for testing. Obviously the dealer will sell to the customer replacing tubes for any tubes that may be found deficient on test.

1.6—The serviceman is equally interested in a tube tester since it provides him with a means of determining whether the customer's trouble is in the radio set itself or in the tubes. The majority of difficulty being located in the tubes it is logical for the serviceman to test the tubes before starting work on the set itself.

1.7—Because the serviceman prefers to operate on the radio chassis itself in his own shop, and because he is limited in the amount of equipment that he can carry into the field it has become common practice recently to add certain resistance and voltage ranges to the serviceman's portable tube tester so that the one device can be used to test the tube in the home and to make such other quick checks on the chassis itself that will permit the serviceman to analyze the nature of the trouble thus permitting him to give the customer an estimate as to the repair charges. Since a combination of this kind is of necessity a compromise between what is recognized as the best and essential equipment, and a portable device that can be carried into the field on one hand e, the ranges supplied are generally limited as to range and as to number.

1.8—Tube Testers vary somewhat in their use but in general it may be said that they are supplied with power from a lighting circuit, that the tube is placed in one of the sockets supplied on the face of the panel, and that the circuit is manipulated by means of steps so as to produce a reading on an indicating instrument, telling whether the tube is good or bad.

1.9—It is obvious that a tube tester whether counter or portable is no better than the limits which have been set for the various tubes which it is designed to test. After many years of constant effort, the tube manufacturers have agreed on a test procedure and a set of test limits for all recognized radio receiver tubes. A circuit has been developed which is recognized as a standard test circuit for dealer use. Limits have been established for use on this circuit and are supplied by the manufacturer of the tube tester to the serviceman or dealer for his use.

1.10—It should be noted that unless the mechanical design, quality of material used, and the workmanship, are appropriate the tubechecker cannot possibly hold the limits with the degree of accuracy necessary to meet the serviceman's or the dealer's requirements. Therefore, in selecting a tube tester, be sure that the testing limits are proper and adequate and that the device itself is so made that these limits can be used with assurance that the device is not changing from time to time due to changes in material or poor workmanship.

TUBE CHECKERS

Although faults in vacuum tubes can be detected without the aid of a tube tester, to make a positive statement that a vacuum tube is in good operating condition requires the use of a good tube tester. Testing and replacing tubes constitutes a large amount of work of the radio servicemen. A very large number of apparent radio receiver defects do not actually require any repairs, but merely a replacement of one or two tubes. The more accurate and the more sensitive a tube tester is, the better it will test the tubes and there will not be any chance of a tube in bad condition getting into the set to spoil the operation.

Occasionally when a tube tests defective, it will play quite well in the receiver tuned to a powerful local station. It is rather difficult matter to convince the owner that a tube needs replacing when he can hear the receiver working apparently fine.

To convince the receiver owner that the tube in question is really defective, simply place a new tube in place of the one not testing GOOD. Tune in a rather weak distant station. Now replacing the BAD tube in the set will probably stop the reception of the weak station completely.

Different test methods are used by the various tube manufacturers. Tube checkers and testers are usually A.C operated and employ four to as many as twenty-five sockets. The grid shift method is commonly used in the testers. The grid voltage is altered a small amount which in turn causes a corresponding change in the plate current. This change in the plate voltage is the index by which we judge the condition of the tube and this current is indicated on the meter. The tube tester meter is usually marked GOOD-BAD, so that the public can understand the results. If A.C. is employed as the grid voltage, the test is called dynamic. If D.C. is used, the test is static.

In some testers the majority of the elements are tied together, in others each element receives a relatively correct potential for the test. In the emission type tester all the elements are tied together with the exception of the cathode and the filament. A positive potential is applied to the collection of the elements and the current passing is measured. Obviously if the screen grid prong of a 24-A tube is completely missing the tube will still test GOOD and this is why the grid shift dynamic testers are superior and do detect such faults.

The emission type tester is much simpler and is much cheaper to built that the dynamic type. For modern tubes and requirements the emission test proved to be accurate enough and does serve the purpose.

Besides low emission, about the only other defect that occurs in a tube is a short between some elements. Modern tube testers of all makes incorporate a short test, placing a high potential between the different elements and using a sensative neon bulb for the indicator.

Miscellaneous Equipment.

2.1—D. C. VOLTMETERS

(a) Prior to radio broadcasting and its service problems a standard voltmeter had a sensitivity of approximately 100 ohms per volt. This sensitivity was adequate since the instruments were used primarily on power circuits.

(b) With the introduction of radio broadcasting it became immediately apparent that a much higher sensitivity voltmeter was required, since the load placed on the power pack of the radio set by the then standard voltmeter was often as great as the load of the set itself. At that time instruments having a sensitivity of exactly 1,000 ohms per volt were introduced and have been standard for radio servicing to date.

(c) With the continued interest in resistance coupled stages, high resistance grid circuits and similar circuits of high impedance, the need for a voltmeter of still greater sensitivity has been evidenced.

(d) As a separate instrument the serviceman's voltmeter is extremely handy, provided that it has an adequate number of ranges and that these ranges are readily available on pin jacks or through some switching mechanism permitting the ready use of a pair of test leads. The instrument is used for measuring potentials across various parts of the circuit so as to permit the prediction of the functioning of that or some preceding portion of the circuit.

(e) For greatest accuracy an indicating instrument should be used only on the upper one-half of its scale. To make use of this accuracy a sufficient number of ranges should be provided so that all readings over the spread to be covered can be made to appear on the upper one-half of the scale. Generally speaking, voltmeters for radio servicing should provide for a coverage of 1 to 1,000 volts.

2.2—A. C. VOLTMETERS.

(a) A. C. voltmeters as such are generally of the moving iron vane type and require a considerable amount of energy for indication. Because of the limited amount of power available in the radio receiver it has been customary for a number of years to obtain readings of a.c. potential by using the more sensitive d.c. instrument in conjunction with a bridge type copper oxide rectifier—this arrangement permitting the indication of a.c. potential with a minimum power required.

(b) It has been standard for a number of years to make the sensitivity of the d.c. copper oxide combination exactly 1,000 ohms per volt so as to permit the use of the same set-up for a.c. and d.c. voltage measurements—the rectifier being omitted in the second case.

(c) The a.c. voltmeter is of particular interest to the serviceman in that it permits him to measure two very fundamental readings—the first that of line voltage and the second that of filament voltage. Line voltage is of extreme importance in that it controls all a.c. and d.c. voltages as supplied by the power pack. When the line voltage is high, power pack output voltages are high. Tube life is a function of filament voltage. Therefore it is important that the serviceman be sure that the filament voltage as supplied to the tubes in the receiver or amplifier is correct.

(d) A further use of the a.c. voltmeter is to check the secondary voltage of the power pack transformer. Some difficulty is encountered from time to time which appears in the form of excessive hum when the voltages supplied by the two halves of the transformer supplying high voltage to the rectifier tubes are not equal.

(e) A further use of the a.c. voltmeter is that of measuring the output signal as supplied to the speaker. A low range may be connected across the speaker coil itself or a high range may be connected from plate to ground, of the output tube. In the latter case a series blocking condenser is necessary in order to keep the d.c. current out of the instrument. By maintaining a constant input to the radio set from an oscillator or signal generator and by noting changes in the voltmeter readings the serviceman can determine whether or not the adjustments that he has been making are increasing or decreasing the sensitivity of the receiver. Obviously, he is interested in producing the best possible signal in the output for a given input.

(f) As mentioned before for greatest accuracy an indicating instrument should be used only on the upper one-half of its scale whenever possible; hence a sufficient number of ranges should be provided so that all readings over the spread to be covered can be made to appear on the upper one-half of the scale. Generally speaking, voltmeters for radio servicing should provide for a coverage of 1 to 1,000 volts.

2.3—CURRENT MEASUREMENTS.

(a) Most of the currents encountered in radio receivers are of the order of milliamperes. Hence a good separate current indicator for radio service use would be one that would have sufficient ranges to measure the range of 1 to 500 MA. The number of ranges should be sufficient to make it unnecessary to often use the instrument on the lower one-third of its scale.

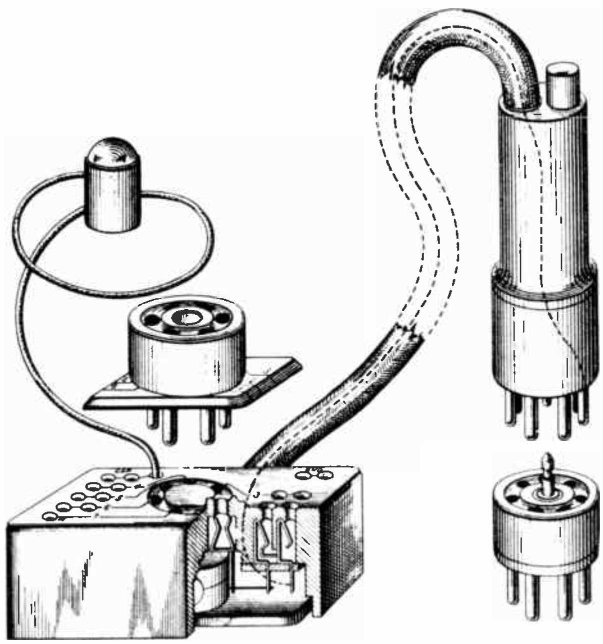


Figure 3 Weston Model 666 Socket Selector

(b) A separate milliammeter is used in conjunction with a pair of binding posts and pin jacks or a pair of test leads. It is necessary to open the circuit into which this instrument is introduced and to connect the instrument in series with the circuit itself.

(c) For the above reason current measurements are not particularly popular with the serviceman since considerable inconvenience is often encountered when an attempt is made to place the instrument in the circuit. Milliammeters in connection with analyzers and other built-up service equipment, are generally more convenient to use. Hence the separate milliammeter is not often found among servicemen's equipment.

(d) With a switching means such as originally supplied on analyzers the circuits in question were opened up and the instrument inserted by the manipulation of proper switches. See Figure 3. When the Weston Model 666 socket, cord and plug, arrangement is used the milliammeter is connected into the circuit by the proper manipulation of the patch cords without disturbing the radio set wiring in any way. See the details shown in the cutaway portion of the socket pictured in Figure 3.

(e) The proper interpretation of the current readings obtained, permit the serviceman to predict the operating condition of the circuit being tested.

2.4—OHMMETERS.

(a) Independent ohmmeters have been available for a number of years for service use. In their simplest form they consist of a series ohmmeter circuit providing one or more ranges of resistance on the instrument scale. Ohmmeters of this type depend on a voltage as supplied from a self-contained battery for their operation.

(b) For good radio servicing a number of ranges are required. Generally speaking, the center mark of the lowest range should not exceed 25 ohms and the center mark of the highest range should be at least 250,000 ohms. An ohmmeter having these limits with a total of five ranges will be found to give readings that cover the vast majority of resistances encountered in radio receiving circuits.

(c) The divisions of an ohmmeter range of a series type ohmmeter are widely spaced at the low resistance end of the ohmmeter scale and are considerably congested at the high resistance end of the scale. For this reason it is necessary to have an appreciable number of ranges in order to get adequate, accurate readings of a wide range of resistance values.

(d) The interpretation of the resistance readings is very important. One method of analysis was based on resistance readings alone. Its failure to become widely used was due to the lack of information as supplied by the set manufacturers concerning the correct values of resistance of each part in the circuit and the improper interpretation of the obtained readings by the servicemen themselves.

(e) Voltage and resistance readings are probably the most important single readings that can be obtained by the serviceman.

(f) Use is made of an ohmmeter by connecting the instrument by means of a pair of test leads across that part of the circuit, the resistance of which is desired.

(g) Ohmmeters are used quite extensively for taking measurements of fixed condensers for leakage since the leakage of a condenser is an indication of its electrical insulation.

(h) Paper condensers in general should give a very high reading of resistance, a good condenser having a resistance of at least 100 megohms per microfarad of capacity. (Note that a 2 microfarad condenser on this basis would show 50 megohms or more and a .5 microfarad condenser would show 200 megohms or more).

(i) Electrolytic condensers however are much lower in their internal resistances. The resistance of this type of condenser depends primarily on its capacity and having ranges of 25 volts may have resistance as low as 25,000 ohms.

(j) Power pack condensers of the electrolytic type having volt ratings of 500 volts or more are usually discarded if the resistance is below 400,000 ohms. Again, measurements on such condensers are quite finite and when they are found to be off, the condensers should be discarded. They will probably heat up too much in a power pack and eventually destroy themselves.

(k) Resistors used in an average radio receiver will be found to vary in value from approximately 1.5 ohms for a low resistance voice coil to several megohms for grid leaks. It is therefore necessary to have an ohmmeter equipped with sufficient ranges to give this spread of readings on an accurately readable scale.

2.5—CAPACITY METERS.

(a) Capacity Meters are similar as to circuit, to the series type ohmmeter mentioned above. The chief difference is that while the ohmmeter uses a self-contained battery and measures resistance, the capacity meter is connected to an alternating current lighting circuit for power supply and measures impedance. Capacity Meters indicate the impedance or reactance of the condenser being tested at a known frequency and wave form. The instrument can therefore be calibrated directly in microfarads.

(b) Capacity meters are dependent on frequency, the readings being directly proportional to the frequency of the supply circuit. They are therefore usable in circuits of different frequency providing the readings taken on the instrument are adjusted accordingly. Most capacity meters are designed for use on a 60 cycle circuit this being the most common frequency encountered.

(c) For best all around service, a capacity meter should indicate over the range of .0002 to 200 microfarads. This can be accomplished by using six or seven ranges, thus giving good indications on each range. Simpler capacity meters omit the higher and lower ranges.

(d) Capacity meter scales are very open on the low capacity ends of the scale and are very congested at the high capacity ends of the scale. For this reason it is necessary to have a relatively large number of ranges in order to cover a wide spread of capacity values.

(e) When capacities below .0002 are to be read, a special circuit using higher frequencies, is generally employed. Since these condensers are not particularly important as far as the serviceman in his work is concerned, equipment reading lower than .0002 microfarad is not popular on the market.

(f) The capacity meter, like the ohmmeter, is used in conjunction with a pair of test leads, the leads being connected across the terminals of the capacitor to be measured. The readings obtained permit the serviceman to indicate whether or not trouble exists in the unit tested.

Figure 4—Model 664

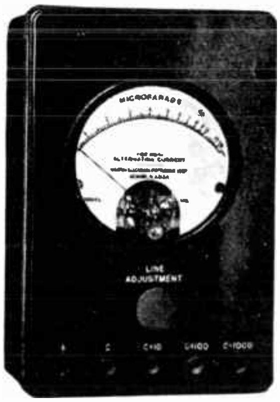


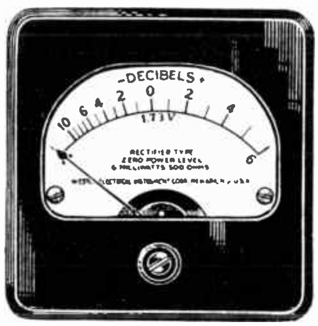
Figure 5—Model 780

(h) In a like manner, the lower ranges of capacity, which are generally paper or mica condensers, are read on moderate voltages so that there is no danger of breakdown or damage to the condenser.

(i) As capacity meters are of the series type, shorted condensers cause no damage to the instrument. The instrument simply indicates infinite capacity for a shorted condenser. In a like manner, open condensers indicate zero capacity, again causing no damage to the instrument.

2.6—OUTPUT METERS.

(a) Output meters are essentially electrical sound level indicators. They are used to bridge standard sound lines or receiver output circuits to measure



Model 301—3¼" Rectangular

the level of the signal as compared to some arbitrary zero value.

(b) Output meters generally consist of rectifier type instruments equipped with suitable multipliers so as to provide a number of ranges. The rectifier type instrument is essentially for this application in that the power taken by the instrument should be negligible as compared to that taken by the loud speaker across which the output meter is generally connected.

(c) Output meters may be calibrated either in a.c. volts or in decibel units; the latter being the standard reference for signal level used in American communication fields. The Neper, a unit similar to the decibel, is used in a similar manner in Europe.

(d) For the average serviceman, the a.c. voltage reading is entirely adequate since his use of the output meter is merely to indicate whether the changes that he has made in the receiver, produce more or less signal—his chief object being to produce the greatest signal from a given input from his oscillator.

(e) For certain public address work and for more advanced receiver applications the output meter should be calibrated in decibel (D.B.) units. See Figure 6. An instrument so calibrated must be used across lines or circuits of known impedance since the D.B. unit depends on the impedance of the line across which the instrument is connected. The use of the output meter is the same regardless of whether the readings are in a.c. volts or D.B. units. The advantage of the latter being that the level of the signal is indicated with reference to a definite level.

(f) Output meters for service work are generally calibrated in a.c. volts as indicated above. They are also generally supplied with an extra terminal so that a blocking condenser may be inserted in the circuit. This blocking condenser permits the serviceman to connect his output meter directly from the plate of any tube to ground, the blocking condenser preventing the d.c. potential available at such points from passing a current through the output meter, thus giving an erroneous reading. The signal, available at such points, passes through the condenser, causing the instrument to indicate as desired.

(g) There are a few output meters available on the market which are designed to take the place of the loud speaker during the test on the receiver. Such output meters are designed to have a constant impedance of 4,000 ohms on all of their various ranges. The output meter then forms the entire load on the receiver, no speaker being necessary to supply this load. Output meters of this type are generally used for production testing or testing under conditions where the loud speaker signal would be objectionable.

(h) Interpretation of the readings obtained on output meters is left to the serviceman. His experience and his ability will determine the use that he can make of these readings.

Figure 7—Model 660

3. Analyzers.

3.1—The older types of analyzers which were equipped with a permanently attached cord and plug have become hopelessly out of date at the present time. See Figure 7. The rapid developments in the tube industry with the new system of basing, have made the design of such an instrument entirely too complicated. The number of switches required to set up the various pin connections for plate, grid, and screen potential measurements become excessive when an attempt is made to cover the 300 odd types of tubes available at the present time.

3.2—The analyzer method of receiver analysis is, however, extremely valuable in that it allows rapid break in for current measurements in addition to bringing out the tube electrodes for all kinds of potential and resistance measurements.

3.3—Making use of this selective analysis system several models have been brought out which are fundamentally volt-ohm-milliammeters and which depend only on the fundamental units of volts, ohms and milliamperes. See Figure 8. Electrical units such as these will be encountered independently. Therefore, if these instruments are designed with a wide enough scope they will be up-to-date continually.

Figure 8—Model 665

3.4—The selector block is molded with a small 7 prong socket connected through suitable jacks to a cord and plug. See Figure 3. Opposite each pin with the execption of the filament, a double set of jacks appears. The inner jack is used only for current measurements while the outer jack is available for all voltage tests. The inner jack contains a built-in switch which opens when a test pin is inserted in the jack. The cut-away section of the block showing how this jack operates is shown in Figure 3. To make a current measurement or in other words, to insert the milliammeter in series with any electrode it is merely necessary to plug into the two jacks opposite this particular electrode. Automatically the meter is connected in series and will read the current in that particular circuit.

3.5—Current jacks have purposely been left out of the filament circuit as the currents encountered here are never of any value to the serviceman and are of such a magnitude that a small switch of this type could not be used.

3.6—Two adapters are supplied for each of the other bases these being color coded in accord with the number of pins on the tube base. One of these two adapters fits on the end of the plug and automatically equips it for insertion in the receiver socket. The other adapter carries a skirted section on which are engraved the numbers of the tube pins. The lines on this section carry over the tube pins to the proper jacks so that when this adapter is inserted in the selector block only the active pins show any engraving. Along with this block is supplied a tube base chart. Opposite each tube number is listed a base number. Reference to the tube base charts will show the exact electrode layout for the tube in question. These base charts are tied in directly with the engraving on the adapters. Therefore, the serviceman armed with this tube base chart and selector block may rapidly and directly connect the instrument into the plate, grid, screen or cathode circuit of any tube under test.

3.7—It will be noted that this selector block is entirely independent from the analyzer, it being equipped with a single pair of pins on the bottom side. These pins are not for electrical connection but are merely for mechanical mounting and will fit in all cases the molded jacks on top of the Weston analyzers or may be used with a standard pair of pin jacks mounted in an old analyzer. Many of these blocks are sold separately for modernizing obsolete analyzers, the old attached cord and plug being removed from the equipment. This method of attack in supplying an analyzer unit has entirely licked any difficulties that the serviceman encountered previously with the multiplicity of vacuum tubes.

3.8—Three types of analyzers are available as new equipment in the Weston line. The first of these models, the Weston 665, is furnished in two types. Type 1 is equipped with a rotary switch whereby any of the ranges may be selected by indexing this switch to the proper position. Type 2 is a pin jack model wherein all of the ranges are brought out to pin jacks. With either of these units the Model 666 block mounts directly in position in the top jacks and small jumper leads are used to carry over the connections to the instrument ranges. Thus basically, the Model 665 is a volt-ohm-milliammeter equipped with 10 volt ranges, 10 milliampere ranges and 5 ohm ranges and grid test. A self-contained rectifier provides the a.c. voltages used directly in testing transformers or a.c. lines and in output meter work.

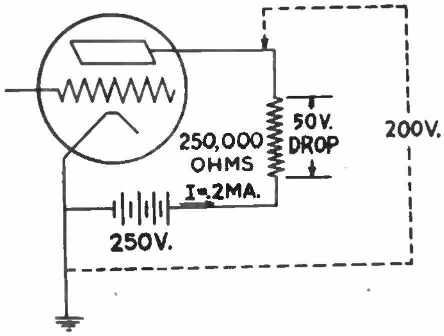
Figure 9—Model 697

3.9—The Model 697 is a very popular pocket size volt-ohm-milliammeter. Measurements of a-c and d-c voltage, d-c milliamperes and resistance can be made. As on the 665, precision resistors are used throughout and self-contained batteries are included for the ohmmeter ranges. A battery adjustment knob, available from the front of the panel, allows for compensation of battery voltage which permits accurate readings to be taken on any resistor choke, voltage divider or any other receiver component. The internal circuit of the meter is so designed that this adjustment will cover a 25% change in battery potential without in any way affecting the meter accuracy.

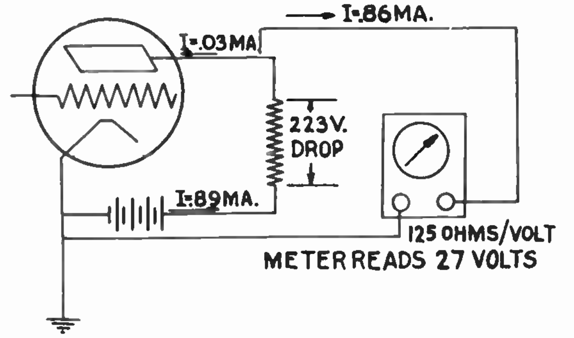
3.10—Weston has recently added a super-sensitive analyzer to their line of test equipment. This particular unit is known as the Model 772 and stands alone in the equipment field as a 20,000 ohm per volt analyzer. See Figure 10. Since the advent of the vacuum tube, high resistance and high impedance circuits have been required in receiver design. This type of circuit is essential for use with a vacuum tube as the tubes themselves are extremely high resistance devices and

EFFECT OF DIFFERENT METER SENSITIVITIES ON TYPICAL RESISTANCE COUPLED PLATE CIRCUIT

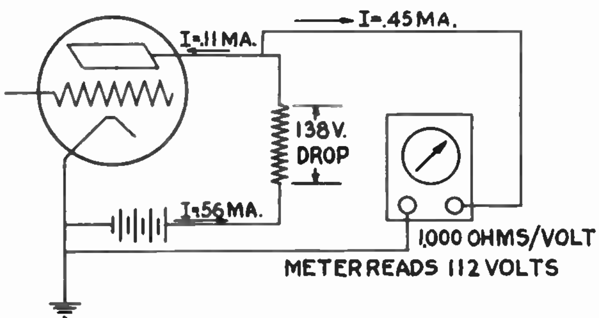
Meter Range—250 Volts Full Scale in All Cases



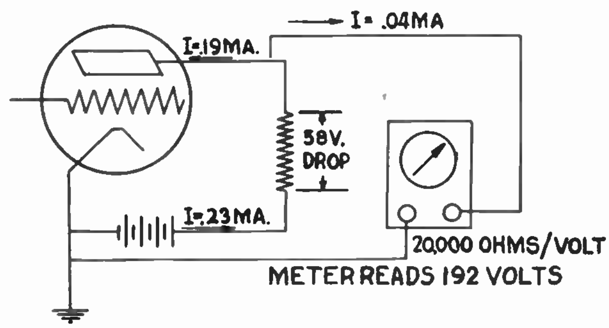
Normal Operation No Meter In Circuit



Conditions Using 125 Ohms Per Volt Meter



Conditions Using 1,000 Ohms Per Volt Meter



Conditions Using 20,000 Ohms Per Volt Meter

Figure 11

must work into circuits of this same type. In nearly all receivers today circuits with 50,000, 250,000 and 1 megohm resistances are found.

Figure 10—Model 772

3.11—To measure the plate voltage for instance, in a circuit of this type best accuracy would be obtained with the most sensitive instrument. Any current drawn by the voltmeter will pull the voltage down considerably and will, therefore, cause an appreciable error in the reading of plate potential. Figure 11 shows four diagrams giving a comparison in readings between voltmeters of 125 ohms per volt, 1,000 ohms per volt, and 20,000 ohms per volt.

3.12—The first diagram shows the normal plate circuit of a resistance coupled tube under operating conditions. The second diagram shows voltage conditions when the 125 ohm per volt meter is inserted in the circuit. Note that the instrument reads correctly the potential while it is in the circuit, but also note how badly it upsets the conditions. The third diagram indicates conditions with a 1000 ohm per volt instrument, this being considerably better than the first or old style instrument. The fourth diagram gives the readings that would be obtained with the new Model 772 supersensitive instrument. In comparison to the current drawn by the tube this instrument is extremely sensitive and does not upset the potential conditions in this circuit to any appreciable extent. These diagrams illustrate the value of a 50 microampere instrument in taking potential readings in all types of receivers.

3.13—With modern receivers using a.v.c. circuits and low current tubes the Model 772 tester is extremely valuable in making all kinds of low current measurements. Take for instance measurements of diode current in detector circuits. Diode currents vary from 1 microampere to approxi-

Figure 12

View Showing Model 666 Socket Selector Block Mounted on Model 772 Analyzer

mately 40 or 50 microamperes. On a 1 milliampere instrument these readings are hardly perceptible whereas in this new model the first scale division is .5 microampere. Therefore, a very definite and accurate reading can be taken of all a.v.c. and detector diode currents.

3.14—This analyzer has likewise been designed for use with the socket selector block. The tester panel is equipped with 2 jacks directly above the instrument correctly spaced to fit the pins on the base of the block. By fitting the block in position and using the small jumper leads supplied with the block, voltage, CURRENT, resistance and output readings can be taken rapidly and accurately on any type of tube regardless of its pin arrangement and electrode position. The photograph of this block set up in position on the Model 772 panel is shown in Figure 12. The jumper leads are plugged into the plate circuit jacks for measurement of plate current on a type 6-A-8 tube.

3.15—Measurements of rectified diode current are of vital importance in making tests of a.v.c. and diode detector action on receivers. See Figure 13. Diode currents seldom run over 100 microamperes and are usually somewhere between 1 and 50 microamperes. A diagram showing the method of taking these measurements in a typical diode detector and a.v.c. circuit is shown in Figure 3. If a 1 megohm resistor is used in the a.v.c. circuit connecting from the diode plate to ground, the a.v.c. bias can be read directly on the instrument by converting each reading in microamperes directly to volts, as 1 microampere through one megohm will give a reading of 1 volt. In most cases the 100 microampere range is used for taking these readings as its resistance is quite low, i. e., in the order of 1250 ohms. For more sensitive readings the 2.5 volt position can be used for reading 50 microamperes full scale, but the 50,000 ohms in this circuit will sometimes slightly upset the a.v.c. or detector current. With either of these ranges note that accurate readings can be taken down to .5 microamperes.

3.16—Condenser leakage measurements are very valuable in segregating shorted or leaky condensers. The sensitive ohm ranges on the Models 772 and 663 make these tests very easy. Measurements of paper condensers should always be made using top or Rx10,000 range. All paper condensers should not show any appreciable leakage on this range due to the fact that leakage lower than 50 megohms is liable to indicate moisture in the condenser which may result later on in a final breakdown. Electrolytic condensers should in most cases be measured on the Rx1000 range as their resistance is always a finite value somewhere in the low megohm group.

3.17—A true advantage of a sensitive ohmmeter of this type is shown here where a maximum potential on any range of only 15 volts d.c. is used to obtain the high megohm readings. Any ohm test can, therefore, be taken on any electrolytic condenser regardless of its voltage rating as it will never be exceeded on this model.

3.18—In general electrolytic condensers used in power supplies should be rejected if their leakage resistance is below 400,000 ohms. Any value much below this will cause heating in the condenser which may in turn result in further injury and final breakdown. On by-pass condensers used on cathode circuits of the 5, 10 and 25 microfarad types with voltage ratings as low as 50 volts, considerably lower resistance readings may be obtained, and where they are shunted by cathode resistors having low values they will probably function all right. However, any electrolytic condenser should have a resistance of at least 100,000 ohms to function correctly in receiver circuits.

3.19—A multiplier for the top d.c. ohm range can be made if even higher ohm readings are desired. See Figure 13. The extreme sensitivity of the tester makes it possible and by adding 60 volts of "B" battery (anything from 50 to 70 volts will do) in series with the ohm jacks shown in the circuit below a 5 to 1 multiplier giving readings up to 150 megohms may be used. It should be noted that a 1 megohm resistor is used and to obtain accurate readings this resistor should be adjusted to 1%. If the voltage in the battery allows adjustment of the pointer to top mark when the leads are shorted together, the readings on this top range will multiply exactly by 5 if the external resistor used has been accurately adjusted and is so constructed that it will hold its accuracy through moisture and temperature variations. This additional 5 to 1 multiplier is often valuable in measuring paper condensers for leakage as estimates of as high as 200 and 250 megohms can be made by watching the pointer. Top reading on this range would be 150 megohms.

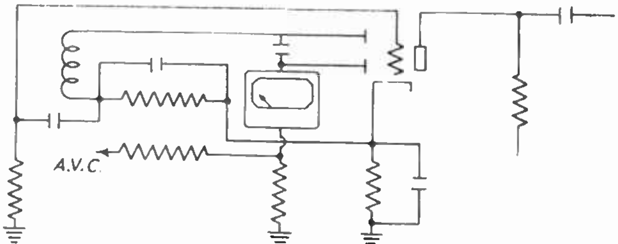


Figure 13

Meter in A. V. C. Diode Circuit to Check A. V. C. Action

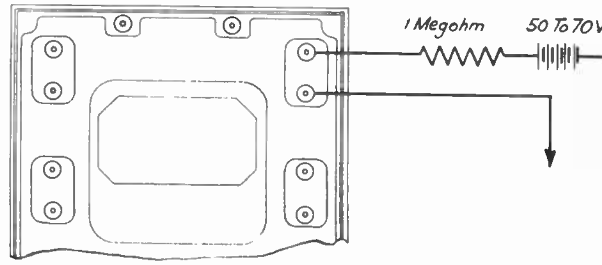


Figure 14

Circuit for Rx50,000 Used on Top or Rx10,000 Ohm Switch Position of Model 772

3.20—Decibel readings can be taken easily on this instrument by referring to the table

It was felt not wise to add a d.b. scale to this instrument as in most cases it would be confusing unless the a.c. ranges were specifically laid out for decibels. By taking the readings in a.c. volts and referring to the table following, the plus or minus d.b. values above a zero level of 6 milliwatts in a 500 ohm line will be obtained directly. This zero level is standard for all broadcasting lines and is used widely by the telephone companies. It is, therefore, the most commonly used line impedance and zero level. An example of a reading on a 500 ohm line would be covered as follows:

3.21—Assume that the instrument is connected across a 500 ohm line and on the 10 volt position a reading of 7.3 volts a.c. is obtained. This reading is taken on the second red arc. Referring to the decibel readings on page 11, the second column entitled "Volts—Based on 6 mw. at 0 db. in 500 ohms", the next reading below 7.3 volts should be noted. Reference to the first column entitled "Power Level DB" will show that this is equivalent to a reading of approximately +12. By interpolation it will be noted that this reading is half way between 6.89 and 7.73 volts, and therefore, the exact level will be +12.5 db. This means that the actual level in the particular line in question is 12.5 dbs. above the 0 level of 6 milliwatts. If the power ratio of this level to the 0 level is required, reference to the fourth column should be made and by noting the difference between these readings a power ratio of 17 would be obtained. This means that the ratio of the power at this level to that of the 0 level is equal to 17. If the actual power in watts being dissipated in the circuit is required, reference should be made to the fifth column where a reading of approximately 1 watt would be obtained. Further, if the voltage ratio to the 0 level is required, reference should be made to the last column. The reading of 7.3 volts corresponds to a voltage ratio of 4.2. This means that the voltage in this circuit is 4.2 times the voltage available at the zero level.

4. Oscillators.

4.1—The testing of all types of equipment in use today is centering around measurements taken when the equipment is operating under load. New test boards are used in automotive repair stations testing compression, timing and other functions of automobile engines while they are running. While a radio set is not a dynamic piece of machinery, it is analogous to an automobile engine in that many parts run in an electrical field rather than in a mechanical one. Following along this same line, it seems reasonable to expect that dynamic tests on a receiver, with a signal passing through, it would be of extreme value.

4.2—Static tests may indicate that potentials on the electrodes of the various tubes are of the correct value, but they do not indicate what happens to the a.v.c. circuit when a signal is presented to the second detector tube, nor do they indicate the condition in the receiver oscillator circuit, etc.

4.3—The oscillator is the serviceman's tool by which he can run actual oscillations and tests on receivers. With the advent of the superheterodyne and its almost complete acceptance, the serviceman is forced to align these receivers with an oscillator. This is necessary because, first—superheterodyne receivers are equipped with an intermediate frequency amplifier which must be aligned first. No signals are available at these frequencies and, therefore, a well calibrated oscillator is absolutely required. Second, each receiver is designed for a particular intermediate frequency, and this frequency must be set accurately or the receiver will not track.

4.4—The oscillator, therefore, must be accurately calibrated so that the serviceman can set the oscillator control to the intermediate frequency specified by the manufacturer and proceed with the alignment. Without an oscillator he cannot even begin to align this very important portion of the set. Third, he must generate signals on the various short wave bands many of which are silent most of the time. Those few stations that are on seldom give their frequency assignments and, therefore, the operator is working entirely in the dark on these bands unless a calibrated oscillator is at his disposal. See Figure 15.

Figure 15—Model 692

4.5—Although it is impossible to standardize alignment procedure in the sense that any single routine can be set up for all types of receivers, there are a number of fundamental principles which always apply. The first of these is the necessity for controlled test conditions. The Service Man who must trust his ear rather than an output meter, or depend upon the varying characteristics of broadcast signals for test input, faces unsurmountable obstacles right from the start. Modern receivers, particularly those of the all-wave type, involve enough complexities without the introduction of external variables during the adjustment.

4.6—Assuming, however, that controlled test conditions are available in the form of an accurate test oscillator and output meter, it seems desirable to set up general methods of alignment, standardized in the sense that they should be modified only for definite scientific reasons known to the tester. (The necessity for working continuously below the volume level affected by automatic volume control devices, for instance, may seem to complicate the routine, but failure to follow this precaution makes accurate alignment impossible.)

4.7—A specific step-by-step routine for (A) aligning tuned-radio-frequency receivers, (B) neutralizing T-R-F Receivers and (C) aligning superheterodyne receivers is given below in tabular form:

Aligning Tuned-Radio-Frequency Receivers

(A.1) Connect output posts of test oscillator to antenna and ground posts of the receiver.

(A.2) Connect output meter through its series condenser from the plate of the output tube to the ground. (Or from plate to plate of the push-pull output tubes, if this type of output circuit is encountered.)

DECIBEL READINGS

Power Level DB	Volts—Based on 6 M.W. at 0 DB In 500 ohms	600 ohms	Power Ratio to 0 DB	Power 6 MW at 0 DB Watts	Voltage Ratio to 0 DB
-10	0.5477	.6000	0.1000	0.0006000	0.31623
- 9	0.6145	.6732	0.1259	0.0007553	0.35481
- 8	0.6895	.7554	0.1585	0.0009509	0.39811
- 7	0.7737	.8475	0.1995	0.0011972	0.44668
- 6	0.8681	.9509	0.2512	0.0015071	0.50119
- 5	0.9740	1.0670	0.3162	0.0018975	0.56234
- 4	1.0928	1.1972	0.3981	0.0023886	0.63096
- 3	1.2262	1.3433	0.5012	0.0030071	0.70795
- 2	1.3758	1.5071	0.6310	0.0037857	0.79433
- 1	1.5437	1.6910	0.7943	0.0047660	0.89125
0	1.7321	1.8974	1.0000	0.0060000	1.00000
+ 1	1.9434	2.1289	1.2589	0.0075535	1.1220
+ 2	2.1805	2.3886	1.5849	0.0095093	1.2589
+ 3	2.4466	2.6801	1.9953	0.0119716	1.4125
+ 4	2.7451	3.0071	2.5110	0.0150713	1.5849
+ 5	3.0801	3.3741	3.1623	0.0189747	1.7783
+ 6	3.4559	3.7867	3.9811	0.0238865	1.9953
+ 7	3.8776	4.2477	5.0119	0.030071	2.2387
+ 8	4.3507	4.7660	6.3096	0.037857	2.5119
+ 9	4.8816	5.3475	7.9433	0 047660	2.8184
10	5.4772	6.0000	10.0000	0.060000	3.1623
11	6.1455	6.7321	12.589	0.075535	3.5481
12	6.8954	7.5536	15.849	0.095093	3.9811
13	7.7368	8.4752	19.953	0.119716	4.4668
14	8.6808	9.5094	25.119	0.150713	5.0119
15	9.7400	10.670	31.623	0.189747	5.6234
16	10.9285	11.972	39.811	0.238865	6.3096
17	12.2620	13.433	50.119	0.30071	7.0795
18	13.7582	15.071	63.096	0.37857	7.9433
19	15.4369	16.910	79.433	0.47660	8.9125
20	17.3205	18.974	100.000	0.60000	10.0000
21	19.434	21.289	125.89	0.75535	11.220
22	21.805	23.886	158.49	0.95093	12.589
23	24.466	26.801	199.53	1.19716	14.125
24	27.451	30.071	251.19	1.50713	15.849
25	30.801	33.741	316.23	1.89747	17.783
26	34.559	37.867	398.11	2.38865	19.953
27	38.776	42.477	501.19	3.0071	22.387
28	43.507	47.660	630.96	3.7857	25.119
29	48.816	53.475	794.33	4.7660	28.184
30	54.772	60.000	1000.00	6.0000	31.623
31	61.455	67.321	1258.9	7.5535	35.481
32	68.954	75.536	1584.9	9.5093	39.811
33	77.368	84.752	1995.3	11.9716	44.668
34	86.808	95.094	2511.9	15.0713	50.119
35	97.400	106.70	3162.3	18.9747	56.234
36	109.285	119.72	3981.1	23.8865	63.096
37	122.620	134.33	5011.9	30.071	70.795
38	137.582	150.71	6309.6	37.857	79.433
39	154.369	169.10	7943.3	47.660	89.125
40	173.205	189.74	10000.0	60.000	100.000
41	194.34	212.89	12589.2	75.535	112.20
42	218.05	238.86	15848.9	95.093	125.89
43	244.66	268.01	19952.6	119.716	141.25
44	274.51	300.71	25118.9	150.713	158.49
45	308.01	337.41	31622.8	189.747	177.83
46	345.59	378.67	39810.7	238.865	199.53
47	387.76	424.77	50118.7	300.71	223.87
48	435.07	476.60	63095.7	378.57	251.19
49	488.16	534.75	79432.7	476.60	281.84
50	547.72	600.00	100000.0	600.00	316.25

(A.3) Turn on receiver with volume control in maximum position; turn on the oscillator, and adjust the receiver dials to bring in the test signal at approximately 1,400 kilocycles.

(A.4) Adjust the oscillator attenuator to provide a workable reading on the output meter. (In the case of receivers equipped with automatic volume control, use the lowest possible signal which provides an observable reading.)

(A.5) Using an insulated screw-driver, adjust the trimmer condenser on the detector stage condenser section until the output indicator reaches a peak deflection and begins to decrease. Then re-adjust the trimmer screw to provide the peak reading.

(A.6) Now adjust the trimmer condenser on the condenser section preceding the detector stage in the same way, and repeat the procedure step-by-step back to the first radio-frequency tube.

(*Note:* The indications on the output meter will constantly increase as the trimmers are adjusted, and the pointer may even tend to go off the scale. This reading should be lowered by adjusting the oscillator attenuator, leaving the volume control of the receiver in the maximum position. In the case of avc receivers, keep the output reading constantly at the lower end of the scale in this way.)

(A.7) After adjusting all the trimmers, it is best to go back and make a final re-adjustment for exact resonance at each stage.

(A.8) The receiver should next be tuned to approximately 1,000 kilocycles, and the oscillator controls set to provide a workable output on the output meter at this frequency.

(A.9) (Do *not* adjust the trimmer condensers again at this frequency or the receiver will not track correctly at the high-frequency end of the band. Slotted end plates are provided on each condenser section for such adjustment.) Using a fibre rod or similar non-conductor, simply deflect the sections of these slotted end plates that are in mesh with the stationary plates at this condenser setting, and note the effect upon the output reading. Bend the plates slightly as required to give the maximum output at this point. This adjustment should be made first on the detector section, and then repeated on each of the gang sections back to the first radio-frequency stage.

(A.10) Repeat this adjustment at a setting of 600 kilocycles, this time bending the additional slotted sections of the end plates that have moved into mesh with the new condenser setting. Again the trimmer condensers should be left untouched. If this procedure has been followed with reasonable care using insulated tools, the set should now be well aligned.

Neutralizing Adjustments on T-R-F Receivers

(B) *Note:* Many receivers of the tuned-radio-frequency type also require neutralizing adjustments. These should in all cases be made *after* the trimming of the condenser gang. The following neutralizing routine may be carried out directly after the alignment:

(B.1) Connect the antenna and ground terminals of the receiver to the high output and ground posts of the oscillator.

(B.2) Connect the output meter as before, through a series condenser from the plate of the output tube to the ground, or across the plates of the push-pull tubes.

(B.3) Turn on the set and oscillator, tuning in a signal at approximately 1,000 kilocycles.

(B.4) Remove the first radio-frequency tube and substitute a dummy (one with the filament burned out), or insulate one of the prongs with a piece of paper so that the filament does not heat up.

(B.5) When the oscillator and receiver volume controls are at full setting, a signal should be indicated on the output meter. The neutralizing trimmer for this stage is then adjusted to reduce this signal to zero, or to a minimum value.

(B.6) Now move the dummy tube to the second stage (restoring the first stage to operation) and adjust the neutralizing trimmer on this stage until the signal is again reduced to zero or a minimum.

(B.7) Successive r-f stages should be neutralized in the same way, up to and including the detector stage.

Aligning Superheterodyne Receivers

(C.1) First determine whether the receiver is equipped with automatic volume control. If it is, and the avc is actuated by a separate tube, this tube should be removed before proceeding with the alignment. (Be sure, however, that this tube does not serve a double function in the receiver, as in this case it must be left in the socket and the alignment carried out with the avc functioning.)

(C.2) Short circuit the antenna and ground posts of the receiver, and make connections from the service oscillator to the grid of the first detector tube and the chassis. (When a converter tube such as type 2A7 is employed in the receiver circuit, internal oscillation is cut off by placing a shorting clip across the stationary and rotary condenser plates of the oscillator tuning section.)

(C.3) Connect the output meter to the receiver in the regular way, and turn on the set and oscillator.

I-F Adjustments

(C.4) Adjust the tuning controls of oscillator to the intermediate frequency specified by the receiver manufacturer. (The calibration curve supplied with Weston test oscillators permits this setting to be made *exactly*, an important factor in the results subsequently obtained.)

(C.5) Now increase the signal volume by means of the oscillator attenuator until a reading is indicated on the output meter. *Important:* If no reading is obtained even with the oscillator volume at a maximum, *do not change the oscillator tuning control from the specified frequency setting in order to obtain a signal.* The absence of an output reading at this point means that the intermediate-frequency transformers are far out of alignment, and the trimmers should be given a preliminary adjustment to obtain an initial output reading. If such a reading is obtained by varying the oscillator tuning control, the receiver will be lined up at an intermediate setting inconsistent with its design, and will never track correctly with the radio-frequency section.

(C.6) If the set is equipped with automatic volume control which operates in conjunction with some other function and thus cannot be made inoperative, adjust the oscillator attenuator so that the signal used for alignment is as low as possible. Then the secondary trimmer condenser on the intermediate-frequency transformer should be adjusted to give a peak deflection on the output meter.

(C.7) Repeat this procedure for each intermediate-frequency transformer, working back to the first detector section. Where low volume signals must be utilized because of avc on the receiver, it may be necessary to go over these adjustments a second time to determine the peak resonance at each stage.

Flat-Topping

(C.8) *Flat-Topping* (Optional) — For receivers of high quality, where the operator is anxious for fidelity of reproduction at the expense of great sensitivity, the intermediate-frequency transformers may be "flat-topped" so that a band width of approximately 5 kilocycles is obtained in equal volume through the i-f amplifier. This is accomplished as follows:

(a) Set the tuning control of the test oscillator 2.5 kilocycles below the specified intermediate frequency of the receiver. This will cause the output meter to drop a few degrees if the set has already been accurately aligned. Then adjust one of the intermediate-frequency stages to bring the output meter back to within a degree or two of what it originally read.

(b) Now set the tuning control of the oscillator 2.5 kilocycles *above* the specified frequency setting. The decrease in output which results should again be partially offset by adjusting *another* of the intermediate-frequency transformer trimmers.

(c) Now rotate the oscillator tuning control back and forth over this 5-kilocycle band, noting the effect on the output meter. If proper adjustment has been made, the resonance point should be less sharp, and a fairly constant output maintained over this band.

R-F and Oscillator Adjustments

(C.9) The intermediate-frequency amplifier should now be satisfactory as a result of the previous operations, and attention should be given to the radio-frequency and oscillator adjustments.

(C.10) Connect the test oscillator directly to the antenna and ground posts of the receiver; turn on the oscillator and adjust the frequency to approximately 1,400 kilocycles.

(C.11) Remove the shorting clip from the receiver oscillator gang section and tune in the signal to obtain a peak reading on the output meter. (If the receiver dial has slipped out of calibration on the condenser shaft, it should be readjusted at this point).

(C.12) Decrease the output reading to a good working level with the oscillator volume control, and adjust the high-frequency trimmer on the condenser section tuning the mixer circuit. When the peak output has been obtained at this point, make similar adjustments on the trimmer for the radio-frequency section. (Some receivers have both a high- and low-frequency trimmer for each condenser section, and in such cases only the high-frequency trimmer should be adjusted at this frequency setting. Other condensers have but one trimmer, along with slotted end plates. Only the trimmer should be adjusted in this case, leaving the end plates for low-frequency alignment.)

(C.13) After aligning the mixer and radio-frequency section, adjust the high-frequency trimmer of the receiver oscillator in a similar way. (These adjustments, all made at 1,400 kilocycles, should suffice to bring the high-frequency end of the broadcast band into good alignment. For high-frequency adjustment of the short-wave bands, individual trimmers are sometimes used on each coil, but these should be left untouched until a final alignment is made on each of the short-wave bands.)

(C.14) To align the low-frequency end of the band, tune the test oscillator to approximately 600 kilocycles and adjust the receiver dial until a peak indication is obtained on the output meter.

(C.15) If the receiver is equipped with low-frequency trimmer condensers, they should be adjusted on the r-f and mixer sections for maximum output reading. If slotted end plates on the condenser sections are used instead, then the slotted sections of these end plates that are in mesh with the stationary plates should be bent to produce the maximum output. (The trimmer condensers on the condenser gang should *not* be adjusted at this point, as they control only the high-frequency end of the band.)

(C.16) As the trimmer on the oscillator condenser section affects the frequency setting of the entire receiver, the tuning of the main condenser dial will vary with this adjustment. Therefore, the main condenser control should be moved back and forth and the trimmer adjusted to give a maximum output-meter reading irrespective of the dial setting.

Short-Wave Adjustments

(C.17) If there are separate trimmer condensers on the various short-wave coils these can now be re-aligned for the short-wave bands covered. All the adjustments made up to this time on the high- and low-frequency trimmers and oscillator padders should remain fixed, and all additional adjustments made on these high-frequency *coil trimmers* only.

(C.18) To adjust the first short-wave band, tune in on oscillator signal at the high-frequency end of this particular band, and adjust the small trimmer condenser associated with the particular coil connected in the circuit on this band as before. Then make this same adjustment on the r-f, mixer and oscillator coils.

(C.19) Finally, repeat the procedure outlined in step (18) at the high-frequency end of each short-wave band in turn, wherever trimmer condensers are available on the various coils for making such adjustments. If the coil constants have remained substantially the same as when the receiver was manufactured, the short-wave bands should now track correctly, and the receiver show a real improvement in selectivity and sensitivity.

4.8—As the circuits used in short-wave receivers vary widely in design and operation, detailed instructions for aligning these bands are usually supplied by the manufacturer. These instructions should be obtained by the Service Man either from the owner of the receiver or from the manufacturer if a satisfactory job is to be done in every case. The general routine outlined, however, will meet the requirements of most receivers, and result in an alignment job that may well be classed as "standard."

4.9—The average well-equipped serviceman, although he may not realize it, has at his command, in the form of a test oscillator, the means for making many tests without going to the expensive outlay equivalent to that of an elaborate test board. Some of the very helpful uses that this oscillator may be put to in analyzing a receiver, are outlined in the following paragraphs.

Trouble in R.F. Amplifiers

4.10—In checking a receiver of the superheterodyne variety, a very quick analysis can be made without removing the chassis from the cabinet, by making use of the test oscillator. Perhaps the first thing to do in analyzing such a set where a very weak signal is apparent, or where no signal at all is available, is to remove the second detector tube and note whether or not a click is heard in the speaker. If continuity is indicated through the audio section of the receiver by this sound it is reasonable to expect the difficulty to be in the r.f. portion of the receiver.

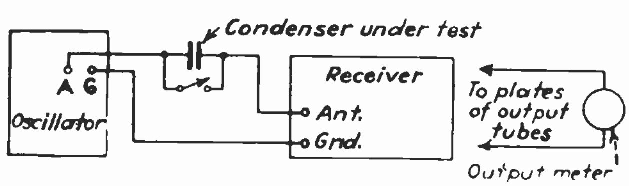


Figure 16

Testing small capacitors for continuity

4.11—By connecting the oscillator to the grid of the tube preceding the first detector, and tuning the oscillator to the intermediate frequency, a signal should be heard in the speaker, indicating that the set is functioning correctly from this point on. If no signal is heard, the trouble is probably occurring in this circuit, and an analysis with a voltohmmeter of the plate, grid, screen and cathode circuits surrounding this tube should be made, to segregate the individual defective part. If continuity is indicated from this point on, the oscillator should be connected to the grids of the preceding tubes with a resultant gain in each case,

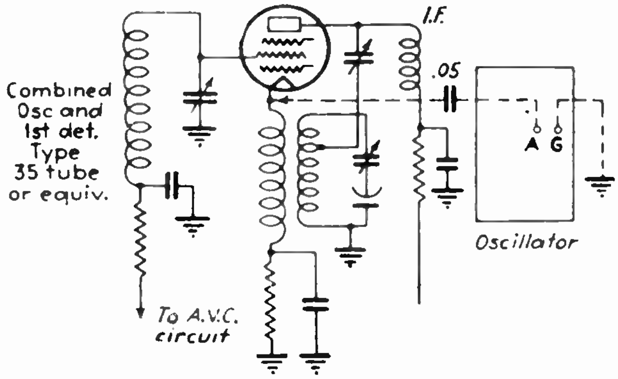


Figure 17

Substituting external oscillator for Autodyne

working back to the first detector tube grid. In this way continuity can be quickly checked back to this point, and as soon as the tube is found where no signal passes through it should be investigated for trouble.

4.12—Likewise by changing over to the broadcast band, the r.f. section of the receiver can be checked back to the antenna and ground terminals of the receiver.

Testing Small Capacitors

4.13—Radio frequency by-pass condensers having small capacity values are difficult to check for continuity and often cause no end of trouble in superheterodyne oscillator circuits or as by-passes. These condensers can be checked by using an oscillator and a receiver, the latter being turned on and a signal from the oscillator being tuned

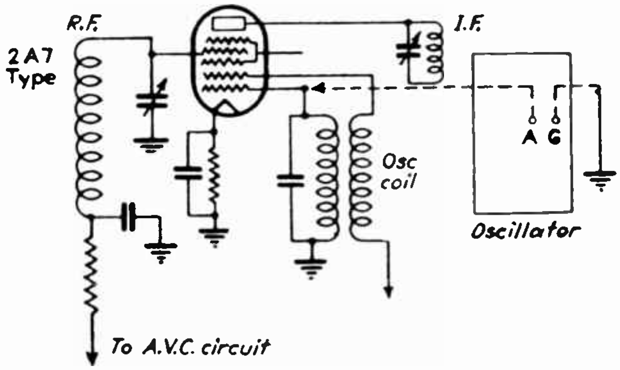


Figure 18

Substituting external oscillator for oscillator of duo-purpose 2A7

in. The hot or antenna lead can then be disconnected, and the small condenser under test can be placed in series with the oscillator antenna lead and connected to the antenna post of the receiver. If no signal comes through, it is obvious that the condenser is open and has been the source of trouble. If the signal is much weaker than before, and the reactance of the condenser is such that it will have an impedance of several hundred ohms, at the oscillator frequency a weaker signal will be noted in the receiver due to this impedance being introduced into the antenna circuit. This however will still indicate that there is continuity through the condenser and that it should function correctly in a receiver. This method is extremely helpful in checking condensers having capacities of 25 to 1,000 micro micro farads.

Superhet Oscillator Circuits

4.14—Occasionally a receiver is found to show continuity from the first detector grid through to the speaker when tested, but will show no indication when a signal is fed into the antenna and ground terminals. This condition is nearly always due to trouble in the superheterodyne oscillator section and the oscillator tube has probably ceased to function. If the set contains a converter tube such as the 2A7 or equivalent, the test oscillator should be connected to the No. 1 grid socket terminal of this tube and ground, and an unmodulated signal fed in on the broadcast range of the oscillator.

4.15—By manipulating the oscillator tuning control a broadcast signal should appear at some point, indicating that substitution of an external oscillator for the one in the receiver clears the trouble. If the receiver has a combined oscillator-first detector tube, such as the type 35 or equivalent, where the oscillator coil is connected in the cathode circuit of the tube, connection should be made from the output of the oscillator to the cathode socket terminal of the tube and ground. If the receiver employs a separate oscillator tube, connections should be made through a series condenser having a capacity of approximately .002 mfd. to the plate socket terminal of the oscillator tube. If substitution for the receiver oscillator clears the trouble, the oscillator circuit should be checked carefully for continuity. Often the trouble is in the cathode resistor of the converter tube and would be cleared by substituting a new one or one of lower value. An open by-pass in this same circuit would also cause trouble.

A.V.C. Circuits

4.16—As automatic volume control circuits are regulated purely by incoming signal, it is only possible to study the action of such circuits by making use of a controlled input signal. For alignment procedure the a.v.c. action should be stopped, either by pulling out the a.v.c. tube or by disconnecting, the a.v.c. voltage control lead to the grid circuits of the various tubes. It is not always possible to kill the a.v.c. by removing a tube, because in many receivers several functions are combined with a.v.c. control in the same tube such as, for instance, the 55. Likewise it is not always convenient and is often dangerous to disconnect or open the a.v.c. circuit by meddling with the set wiring.

4.17—The only other way to nullify the a.v.c. control is to work with an oscillator signal of such a low magnitude that it will not work the a.v.c. tube. To work at such a low level, a very well shielded and carefully designed oscillator is required, as many receivers on the market today have sensitivities around one micro volt or lower where the a.v.c. action may take place at an average of 4 or 5 micro volts. In selecting an oscillator, it is extremely important to look out for this factor as a receiver aligned with the automatic volume control functioning will be as broad as a barn after the job is finished.

4.18—Likewise an oscillator with a well designed attenuator is important in studying automatic volume control affects, as a wide range of attenuation allows for observation over a broad automatic volume control range.

4.19—In testing A.V.C. circuits the oscillator should be connected to the antenna and ground posts of a receiver and a signal of low volume fed into the set. If the receiver does not have a tuning indicator or a tuning light, it is often advantageous to connect a milliammeter into the plate circuit of one of the controlled tubes. As the oscillator attenuator setting is decreased or in other words as a stronger signal is fed into the receiver, a reduction in plate current should be noticed on the milliammeter if the circuit is functioning normally. As the signal is brought up to higher values it may be noticed that the milliammeter indication ceases to decrease. This indicates that the a.v.c. action is cutting off at a definite value and requires some adjustment. In many sets this

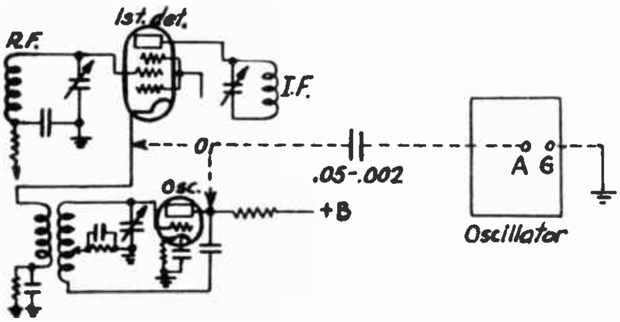


Figure 19

Locating trouble in superhet oscillator circuits

adjustment is accomplished by tuning a circuit resonant to the intermediate frequency of the receiver. If this trimmer adjustment is available it should be made at this time by feeding in a fairly strong signal to the receiver and adjusting this trimmer condenser for the *minimum* plate current indication on the milliammeter, tuning meter or tuning light. Such an adjustment will greatly increase the efficiency of the a.v.c. circuit and will definitely lower noise level or, rather, will improve the signal-to-noise ratio of the receiver.

4.20—If no adjustment is available for increasing the a.v.c. action when it appears to cut off with a signal of moderate strength the resistor in the diode plate or diode detector circuit, the drop across which regulates the bias on the controlled tubes, should be checked carefully for its resistance value. The usual resistor used in this circuit has a value of one megohm although this will vary in receivers of different makes. If this resistor seems to be correct and a cut off point is noted in the a.v.c. action the other components of the controlling circuit should be checked.

4.21—In making these measurements and adjustments it should be understood that the signal fed in from the test oscillator should not be much stronger than the maximum signal normally appearing on the antenna. This comparison can be made by tuning in the strongest station in the locality and noting the deflection on the tuning meter or the brilliance of the tuning light, and then reconnecting the oscillator and adjusting the attenuator to give the same meter deflection or tuning light brilliance. On a good oscillator it is possible to obtain a signal too strong for any a.v.c. control to handle.

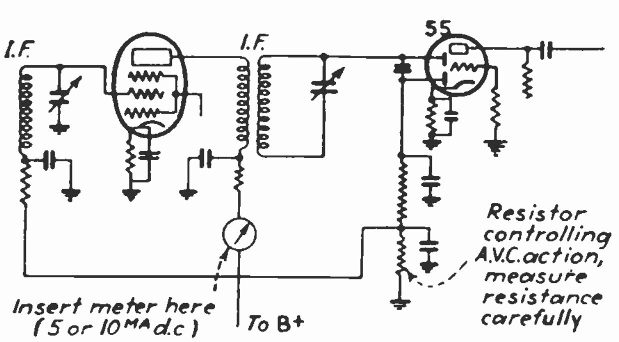


Figure 20

Testing and adjusting a.v.c. circuits

Locating Hum

4.22—One of the most difficult hum sources to trace is that known as tunable hum, a very annoying condition that can spoil radio reception. A receiver will appear to function normally with a very low hum level between stations, but when a signal is tuned in a strong hum will be noted in the speaker. The only way to trace this hum down quickly and locate the source of trouble is to connect a battery operated oscillator to the antenna and ground posts of the receiver and feed in an unmodulated C.W. signal. With the receiver tuned to the oscillator signal, a loud hum will be noted with no modulation superimposed on the carrier to upset measurements. By connecting an output meter through its series condenser from plate to plate of output tubes or from plate to ground a hum indication will be obtained on this meter. By leaving this instrument in the circuit with the oscillator turned on, additional by-pass and filter condensers can be substituted in the circuit with a notation made as to whether or not they decrease the reading on the output meter. Hum on station is usually due to one of the following causes:

1—Insufficient power supply filtering.
2—Insufficient screen and cathode by-passing either at the voltage divider or at the tube sockets.
3—A tube having bad cathode leakage.
4—Modulation of the carrier due to proximity of one of the R.F. grid leads to a filament or primary lead carrying 60 cycle alternating current.
5—Open by-pass condensers.

4.23—A battery operated oscillator is definitely required for measurements of this type as any a.c. oscillator has a definite amount of 60 cycle carrier modulation, this in most cases, causing a definite indication on the output meter. To be absolutely sure that the hum modulation of the carrier is occurring in the receiver, it is necessary to use a battery operated oscillator.

Flat Topping I.F.

4.24—With continually increasing discussion coming up in connection with high fidelity receivers and circuits, the requirement for flat topping with resultant increased audio frequency response, is often called for. This can be done very simply with a good oscillator and output meter, by connecting the oscillator to the grid terminal of the first detector tube and tuning in an i.f. signal. For best results in making this alignment, the a.v.c. tube should be pulled, if it is a separate tube, and a low signal should be fed into the first detector circuit so that it will function below the a.v.c. control point. An output meter should be connected to the receiver and an indication obtained at approximately ⅔rds scale deflection. If the i.f. amplifier has not already been aligned this should be done at this point, all circuits being peaked for maximum deflection at the rated intermediate frequency called for by the manufacturer.

4.25—Having made this alignment, the oscillator control should be adjusted to a frequency approximately 2.5 or 3 kilocycles below the required i.f. frequency, i.e. if the receiver requires an i.f. frequency of 456 kc. the oscillator should be adjusted to 453 kc. A resultant decrease in deflection will be noted on the output meter. One of the trimmer condensers should then be adjusted to bring the output meter reading up to as high a value as possible. This trimmer should then be left alone and the oscillator control set for a frequency 3 kc. higher than the intermediate frequency, i.e. 459 kc. and similar adjustment made on *another* trimmer condenser. It should then be noted when the test oscillator control is manipulated back and forth over about 5 kc. a relatively flat characteristic is noted, or in other words, the output meter reading remains reasonably constant. Of course it should be understood that this adjustment will decrease the sensitivity of the receiver, but in all cases it should improve the overall frequency response at least as far as the r.f. section is concerned. It also may be found that a 3 kc. setting on each side of the i.f. will broaden the i.f.

amplifier to too great an extent. A little experience along this line in trying one or two adjustments, will determine the frequency settings required.

4.26—It should be noted at this point that if the resonant frequency characteristic of the receiver is desired, a graph or chart of frequency versus output meter reading can be calibrated, and a picture of the band width of the i.f. amplifier obtained.

Fidelity Tests

4.27—Approximate fidelity curves can be run on a receiver with a comparatively small cash outlay for equipment. An oscillator equipped with an input circuit for external modulation having good audio frequency response characteristics is hooked up directly to the grid of the modulator tube. A phonograph pickup and turntable is connected into the oscillator input through a proper matching transformer. Constant frequency records, accurate in frequency and within ± 1 d.b. in output are available at a price of 75c. each from R.C.A. distributors for obtaining a constant modulation over the audio spectrum.

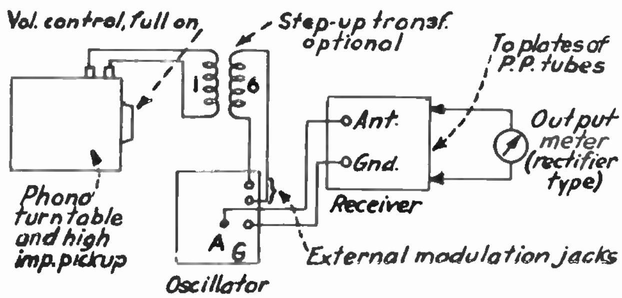


Figure 21

Fidelity test with oscillator

4.28—Three records are required to cover frequencies from 84 to 5000 c.p.s. The titles of these records are "Constant Note Record"—Nos. 22, 23 and 24. With the oscillator connected to the antenna and ground posts of the receiver, a signal should be tuned in and the modulation switch of the oscillator thrown to the "External" position. A frequency record can then be placed on the turntable and with the volume control on the turntable turned to the maximum position, a modulation note should be heard in the speaker. The output meter can then be connected across the output tubes and the various outputs noted as the pickup progresses across the record.

4.29—Each frequency is held for a period of approximately 10 seconds, so that a definite reading can be obtained on the output meter. If a fidelity curve is desired the readings of frequency versus the indications on the output meter can be plotted and an overall fidelity curve would be obtained on the receiver. It will be noted that this type of measurement covers the frequency response of the r.f. and i.f. sections of the receiver as well as the audio section.

5. Vacuum Tube Voltmeter.

5.1—In all equipment associated with or including vacuum tubes of any kind whatsoever, resonant and other types of high impedance circuits are always found. Such circuits must be used in order to obtain sufficient amplification from the tubes, which are in themselves high resistance devices. The impedance for instance of an r.f. circuit such as is used in the first and second stage of a receiver may be as high as 2 or 3 megohms when tuned to resonance with an incoming signal.

5.2—To make any measurements of potential across such a circuit it is obvious that a meter having a resistance as high as 3 or 4 megohms would be required as a lower meter resistance placed across the circuit might change the potential conditions as much as 50%. About the only connection that can be made across a circuit of this type without upsetting the circuit potentials would be that of another vacuum tube, the connection being made across the grid and cathode of said tube.

5.3—A properly designed vacuum tube voltmeter will enable the serviceman to take direct measurements on gain per stage on receivers to check the operation of the oscillator tube in superheterodyne models and to locate trouble in automatic volume control circuits. For uses such as these the instrument will be found practically indispensable as readings on such circuits cannot be obtained without equipment of this type.

5.4—The vacuum tube voltmeter is, as the name implies, nothing more than a vacuum tube connected through a meter in its plate circuit to a

Figure 22

Weston Model 669 Vacuum Tube Voltmeter

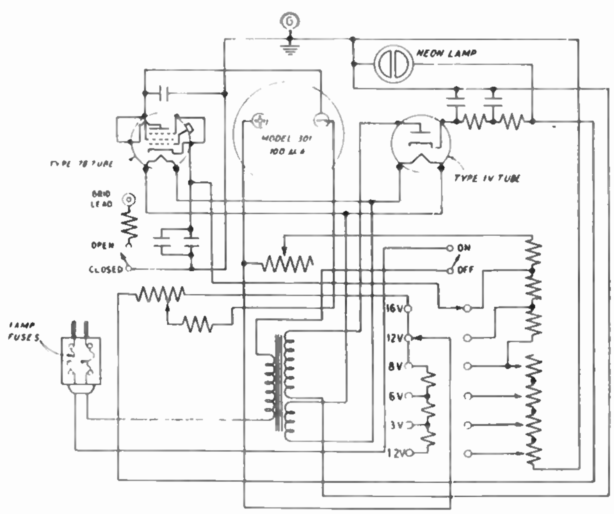


Figure 23

SCHEMATIC WIRING DIAGRAM

suitable power supply. The grid and cathode of the tube are connected across the circuit to be measured, the potential across said circuit causing a change in grid voltage on the tube and thus, a resultant change in plate current is indicated on the instrument. As the impedance from grid to cathode of the tube is practically infinite, no load whatsoever is placed on the circuit and under normal conditions the potential will not be altered in any way.

5.5—As the vacuum tube is also a rectifier, potentials of any frequency placed across the grid and cathode of the vacuum tube voltmeter will result in a direct current deflection on the instrument in the plate circuit. For this reason the vacuum tube voltmeter can be used for measuring audio as well as radio frequency potentials provided the circuit is worked out correctly to cover this broad range of frequency.

5.6—Because any given vacuum tube is considerably limited as to the range of potentials, which may be applied to its grid circuit the overall direct range of a vacuum tube voltmeter is restricted as compared to a standard a.c. or d.c. voltmeter as such. Further, the scale of a vacuum tube voltmeter is not uniform throughout its entire operating range. These two reasons make it essential that the vacuum tube voltmeter selected by the serviceman have a number of ranges so that accurate readings may be made over the entire range of the device.

5.7—A satisfactory vacuum tube voltmeter for modern servicing should read as low as .5 volt and as high as 15 volts in order that measurements may be made of gain per stage and overall gain in an amplifier.

5.8—Because of the characteristics of the vacuum tube and of the vacuum tube voltmeter circuit, it is necessary to have several arcs on the scale of the indicating instrument because the several ranges will not track accurately on a common arc.

5.9—Since the vacuum tube voltmeter requires an appreciable amount of power to drive it and since it is rarely used by the serviceman in the field, most satisfactory equipment will be that which is operated from the lighting circuit provided that the design of the equipment is such as to eliminate the effect of line voltage fluctuations.

5.10—Care should be used in selecting the vacuum tube voltmeter, to make sure that the device will function satisfactorily over a wide frequency range since the vacuum tube voltmeter will be used occasionally on d.c., occasionally on commercial frequencies, frequently in the audio range, and most often on radio frequency currents. With receivers now including the short-wave bands, it is necessary that the vacuum tube voltmeter be able to handle frequencies of the order of 10 to 20 megacycles with negligible errors.

5.11—Care should be used in selecting the vacuum tube voltmeter to insure the selection of an instrument that has a minimum number of controls to operate for any given purpose. This statement is not intended to convey the idea that a vacuum tube voltmeter with a minimum number of controls would be the best, but rather that the number of controls that must be manipulated for any given reading or between any two successive readings, should be a minimum. The device must be provided with adequate controls for adjustment and the conversion of the circuit to take care of RMS, peak, and d.c. readings. Since the vacuum tube voltmeter contains radio tubes which will change from time to time it is essential that the circuit be equipped with adequate adjustments to maintain calibration in use.

5.12—Up to approximately 15 volts the vacuum tube voltmeter input circuit should be connected directly to the grid of the tube so as to make the input impedance of the device as high as possible, thus placing the least possible load on the circuit under test. For voltages above 15 volts the serviceman may provide himself with a voltage divider. If such a divider is used the resistance of the total divider should be appropriate for the circuit across which it is connected. Obviously, for high impedance circuits the voltage divider must have considerable resistance and for best results should contain a resistance equal to 10 to 20 times the impedance of the circuit across which it is connected. For low impedance circuits the resistance of the voltage divider can be proportionately lower. It should be noted that for practically all normal uses of a vacuum tube voltmeter, the range .2 to 16 volts is ample. Only occasional requirements will be encountered for voltages in excess of 16 volts.

5.13—When using a voltage divider in conjunction with a vacuum tube voltmeter care must be taken to allow for the load introduced on the circuit by the voltage divider since the high impedance of the grid circuit of the vacuum tube voltmeter is no longer the determining factor.

5.14—When taking measurements on circuits where there is no returned path for the grid circuit of the vacuum tube voltmeter it is only necessary to return the grid through a suitable resistor and to connect the vacuum tube voltmeter to the circuit under test through a suitable blocking condenser. For most vacuum tube voltmeters, a three megohm resistor and a .00025 microfarad condenser will be found satisfactory for this application.

5.15—It should be noted that readings taken with the above combination on alternating currents, will be peak values and that to obtain the effective value of the reading a multiplying factor of .707 should be used. Since most vacuum tube voltmeter indications are used proportionately it is often unnecessary for the user of the device to reduce peak readings to effective value readings.

5.16—It should be noted that when taking measurements across grid circuits that are a.v.c. controlled, or where a d.c. grid voltage is introduced between the grid of the receiver tube and the ground, if direct measurements are to be made across this grid circuit, the bias voltage should be eliminated by grounding the a.v.c. lead in the receiver, or the d.c. blocking connector should be used with the vacuum tube voltmeter. The former method is preferred as the blocking connector does place a slight load, i.e. approximately 3 megohms, across the circuit to be measured. If neither of these precautions are taken, the d.c. bias voltage will be read on the vacuum tube voltmeter causing extreme errors in reading.

5.17—The vacuum tube voltmeter should be so designed and built as to permit direct access to the grid terminal of the vacuum tube voltmeter tube so that for high frequency work the connecting circuit between the circuit under test and the vacuum tube voltmeter grid and its cathode, can be as short and free from loss as possible. This precaution becomes increasingly necessary as the frequency is increased over five megacycles.

5.18—One of the most important measurements that can be made on a superheterodyne receiver is that of oscillator performance. To make this measurement the vacuum tube voltmeter should be set on its highest range. Connection can then be made from the stationary plates of the oscillator tuning condenser to ground. For this connection it is recommended that the grid be connected to the stationary plate and the ground terminal to the chassis. See Figure 24.

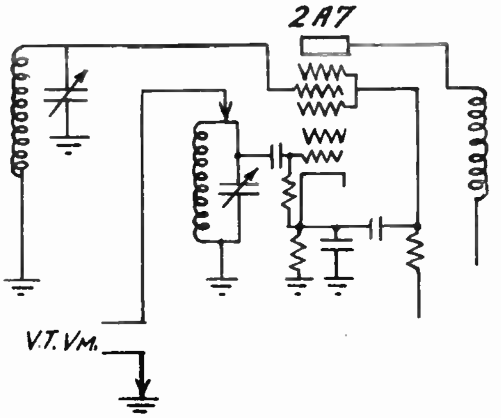


Figure 24

5.19—With the receiver turned on, a reading should be obtained on this range, the usual potential of oscillator circuits running somewhere between 6 and 16 volts. There is no need to use any d.c. blocking condenser as the oscillator test circuit is always connected from the grid of the oscillator tube to ground.

5.20—It may be found that a better reading will be obtained on one of the lower voltage ranges, and if so, the switch should be turned to one of these ranges, either the receiver turned off or the lead disconnected from it, and the zero setting readjusted if necessary. The receiver can then again be turned on and with approximately a half scale reading the receiver dial should be rotated from one end of the band to the other. The oscillator voltage will vary to some extent but should in all cases maintain a potential of at least 60% of the highest value.

5.21—If the receiver is an all-wave type, it should be switched to each of the short-wave bands and operation of the oscillator tube on each of these bands noted. If there are any dead spots or points where the oscillator ceases to function they will be immediately apparent by sudden drops to zero of the instrument pointer. These conditions can then be rectified by inspection of the oscillator circuit, inspection of the tube electrodes and a test of the tube itself. The oscillator cathode biasing resistor and its associated by-pass condenser are often causes of trouble in this circuit.

5.22—These should be inspected carefully and if erratic operation is still apparent either the plate voltage on the oscillator should be increased or the bias resistance dropped in value approximately 10%. An open in the oscillator grid coupling condenser is often the cause of dead spots.

5.23—Measurements of gain per stage are of extreme value in all types of receivers as such measurements tell definitely how much work each tube with its associated circuit is doing. To make this measurement, an oscillator having a reasonably high output voltage and good attenuation charactertistics should be connected to the antenna and ground posts of the receiver to be tested.

5.24—The Weston Model 692 Oscillator having been specifically designed to cover this weak point in most oscillators, is particularly recommended for this type of use.

5.25—With the oscillator turned on and a signal tuned in, the meter can be connected directly across the grid circuit of the stage to be measured. If it is an r.f. or i.f. stage, the leads from the meter to the test circuit should be kept as short as possible, and preferably, the short voltmeter grid lead should be removed entirely.

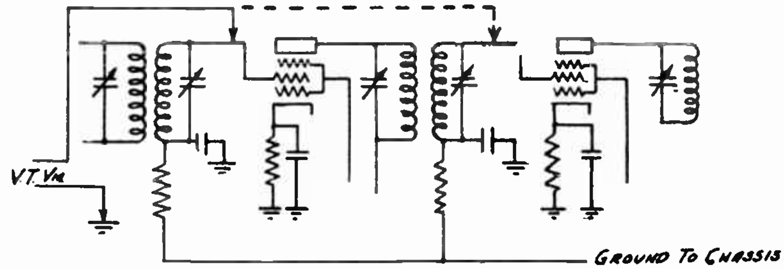


Figure 25

5.26—The a.v.c. tube should be removed from the receiver or, if this is not possible, the a.v.c. lead should be grounded to the chassis. See Figure 25. If neither of these operations can be carried out, then the d.c. blocking connector should be used.

5.27—By turning the oscillator to its full output and tuning in the signal a reading should be obtained on the vacuum tube voltmeter. This reading should be noted and the meter connected to the grid of the following tube. The ratio of the two readings will be the gain across this particular stage. In making this measurement the circuit under test may be thrown slightly off resonance by the tube capacity placed across the circuit. The shunt trimmers for this circuit should be slightly readjusted to allow for the tube capacity if exact readings are required.

5.28—Each individual coil of the receiver may be checked for resonance with its tuning condenser by referring to the circuit of Figure 26. The vacuum tube voltmeter is connected directly across the grid circuit, and the oscillator tuned to the required resonant frequency of the tuned circuit under test. The padder, trimmer or air dielectric condenser should be adjusted until a sharp resonant point is noted on the vacuum tube voltmeter scale. A definite peak indication should be obtained showing that the coil actually resonates and is not just passing energy from previous circuits, the resonant characteristic being proof that the coil and condenser are doing their job correctly.

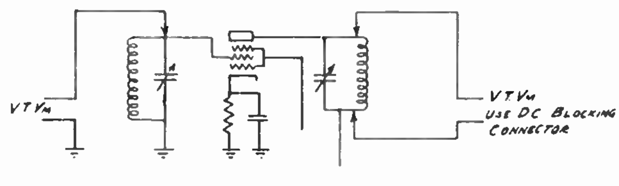


Figure 26

5.29—While measurements are made across plate tuned circuits, care should be taken to protect the input of the vacuum tube voltmeter from the d.c. plate potential applied to the tube. The meter should be connected either directly across the plate coil or through the d.c. blocking connector to the chassis of the receiver. By using this same type of circuit the actual r.f. potential across any coil can be measured. When making either the adjustment for resonance or the measurement it may be found that a slight readjustment of the trimmer condenser will be required due to the tube capacity of the 78 tube being placed in parallel with the trimmer or the padder condenser. However, this correction can be made by moving the vacuum tube voltmeter on to the next stage and readjusting the trimmer of the first stage to give maximum reading across the second circuit.

5.30—The first requirement for making adjustments of this type is an r.f. voltage of sufficient magnitude to give ample readings on the vacuum tube voltmeter. If the frequency of the trap circuit to be adjusted appears in the broadcast band, then a tuned r.f. receiver can be set up and turned on, with the oscillator connected to the antenna and ground terminals. By setting the oscillator control to the frequency required for the resonance of the trap circuit and tuning the receiver to this frequency, considerable voltage can be built up across the second or third receiver stage.

5.31—When adjusting the oscillator be sure to set the attenuator at the maximum position using the high output jack. A small coupling coil of 10 to 20 turns having the same diameter as that of one of the tuned r.f. coils can be wound up quickly and placed over the end of the receiver tuning coil. With the same number of turns on the other end of this coil circuit brought out at a convenient place on the bench or table, a field can be set up for adjusting the trap circuit. See Figure 27.

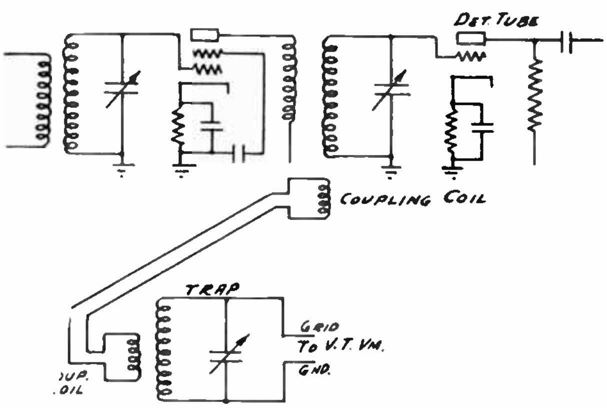


Figure 27

5.32—The coil and condenser forming the trap circuit should be connected directly across the input to the vacuum tube voltmeter with the coil brought out from the receiver coupled closely to the trap circuit. The trap padder should be adjusted for maximum deflection on the vacuum tube voltmeter. If the trap is to be resonated with a fixed condenser, turns should be removed from the coil one at a time until a maximum reading is obtained.

5.33—If it is convenient to get at the coils in the tuned r.f. receiver, the trap circuit can be adjusted by placing it directly in the field of the receiver coil. To make sure that the efficiency of the trap circuit is good, the trap should be tested for continuity at other frequencies. To do this the trap should be connected as shown in Figure 28, in series with the test oscillator and with the receiver and oscillator tuned to a frequency other than that to which the trap is adjusted, a reading should be obtained on the vacuum tube voltmeter. If no reading or a very low reading is obtained, it is obvious that the trap circuit will not pass to a great extent, frequencies on each side of the resonant point. This can be corrected by using a smaller coil and a larger condenser.

5.34—The degree of attenuation of the trap circuit on any frequency can be measured by taking a reading with the trap in series with the oscillator and then shorting out the trap circuit and noting the second reading.

5.35—If the trap circuit is to be designed for frequencies somewhere in the intermediate band then a superheterodyne receiver should be set up and the oscillator connected from the grid of the first detector tube to the chassis. The amplification obtained in the i.f. section of the receiver can then be used to build up the voltage as mentioned in the previous paragraphs.

5.36—It is quite often found advantageous to connect a trap circuit resonated to the intermediate frequency in series with the antenna connection in the superheterodyne receiver. Such an arrangement will cut down to a considerable extent the image ratio of the receiver or, in other words will limit feedback of the intermediate frequency potential into the antenna circuit.

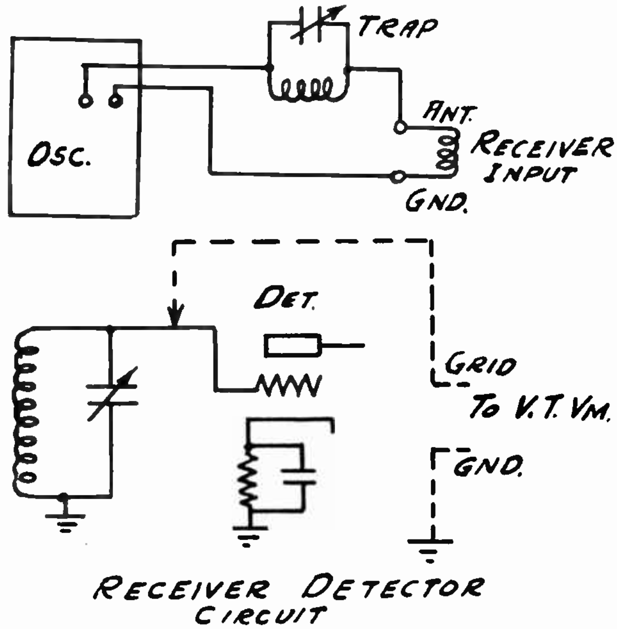


Figure 28

5.37—Alignment and adjustment of a.v.c. receivers can be handled accurately and rapidly by making use of the vacuum tube voltmeter as an a.v.c. voltmeter indicator. The ground connection should be made directly to the a.v.c. lead which carries voltage to the various r.f. and i.f. tubes with the grid of the vacuum tube voltmeter connected to the chassis of the receiver. With the test oscillator connected either to the first detector tube or to the antenna and ground posts of the receiver, adjustments of the various trimmers can be made for maximum a.v.c. swing on the vacuum tube voltmeter.

5.38—If exact alignment is to be carried out by this method, the r.f. stages should be aligned first. As an increase in signal at the input to the second detector tube will result in an increase in a.v.c. voltage, exact alignment of all the tuned circuits can be made without changing the position of the vacuum tube voltmeter.

5.39—On some receivers a.v.c. amplification is used. In such cases with the oscillator connected to the first detector tube and a signal tuned in, the trimmers that resonate the a.v.c. amplifier tube circuits should be adjusted for maximum a.v.c. voltage, this being indicated directly on the Model 669 instrument. D.C. voltage readings can be taken directly with the vacuum tube voltmeter. The indications must be transferred to d.c. volts by reference to calibration curves supplied with the device. Line a.c. volts at all frequencies are most important, the instruments are calibrated in a.c. with d.c. curves supplied.

5.40—To make sure that the a.v.c. operation of the receiver is correct, the attenuator of the oscillator should be manipulated back and forth with a corresponding change in a.v.c. potential indicated by the Model 669 meter. If correct action does not take place the resistors in the a.v.c. circuit of the diode detector should be examined, as the drop across these resistors determines the a.v.c. potential. If a separate a.v.c. amplifier tube is used, this tube and its associated circuit should be examined to make sure that it is functioning properly.

5.41—Occasionally the resistors connecting from the return circuits of the r.f. or i.f. coils to the a.v.c. control lead become open or the by-pass condensers in the grid return circuits become shorted. Either of these two difficulties will stop a.v.c. action on the tube grid. To make sure that this action is taking place directly on the grid of the tube, the circuit shown in Figure 29 should be used. The condenser across the input circuit of the vacuum tube voltmeter will short out the radio frequency at that point while the d.c. potential applied to the grid of the tube will be indicated by the meter.

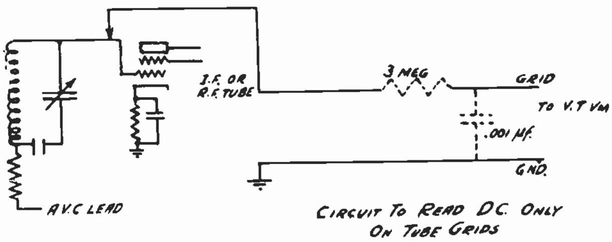


Figure 29

5.42—Following out this same arrangement proportional a.v.c. action on each tube can be determined. On some receivers twice the a.v.c. voltage is applied to the i.f. and pre-selector circuits as is used on the converter tube. To note a.v.c. action, adjust instrument to read full scale on 1.2, 3, or 6 volt range. When voltmeter is connected to tube grid, deflection will be down scale.

5.43—Tests for gain per stage can be made quickly and accurately by making use of the Model 669. The amplifier or audio section of the receiver under test should be connected to an oscillator which will produce a constant audio output reading. The oscillator can then be turned up until a reading is obtained across the first audio transformer on the vacuum tube voltmeter as shown in Figure 30. By connecting the Model 669 to the secondary of this same transformer the step-up ratio in voltage can be determined. The voltmeter can then be moved along to the primary and secondary windings of the transformers in succeeding stages and readings taken giving the overall gain or gain per stage.

5.44—If gain per stage or overall gain measurements in decibels is required, the voltage ratio can be converted to decibels using any of the d.b. charts available such as that shown on page 11. The readings may be taken directly by using any of the d.b. meters shown in Figure 6. It should be remembered when calculating the overall d.b. gain of an amplifier that the input and output impedances should be figured at the same level; in other words if an amplifier is equipped with a 500 ohm input and the output terminates in a speaker voice coil, the reading taken across the speaker voice coil should be referred back to the reading that would have been obtained were it a 500 ohm line. If this correction is not made, then care should be taken in stating the overall gain of the amplifier with reference to the two different output impedances.

5.45—If the gain of the amplifier is to be tested at some other frequency a beat frequency oscillator should be connected across the input and readings taken at other audio frequencies. If fidelity curves are wanted they can be taken by making use of the circuit shown in Figure 31. or best results the rectifier voltmeter placed across the output of the beat frequency oscillator should be replaced by the vacuum tube voltmeter so as to permit the reading of the input and output voltages of the amplifier on the same device. In this connection it should be noted that the vacuum tube voltmeter has a flat frequency curve, the instrument being good to better than 3% for the frequency range 40 cycles through 50 megacycles. This flat frequency response curve of the vacuum tube voltmeter permits accurate fidelity curves to be taken.

5.46—The Model 669 can be used to measure voltages across by-pass condensers at various frequencies determining the by-passing action of these condensers in any circuit. When making such measurements, care should be taken to make sure that electrostatic pickup to the grid lead of the voltmeter is not taking place. This can be avoided in extreme cases by using a short shielded lead to the grid or by keeping the other side of the voltmeter grounded.

5.47—Audio transformer ratios can be measured quickly and accurately by using the circuit in Figure 32. This figure shows the method of measuring impedance ratio and frequency response characteristic of a 200 ohm to grid audio transformer. It should be noted from the figure that 200 ohms appear across the input, whereas the transformer secondary is across the grid and ground connections of the vacuum tube voltmeter. If the transformer under test is to work into a definite load, say 10,000 ohms, then a 10,000 ohm carbon resistor should be connected across the secondary using the same type of circuit. If the correct loading resistors are not used, the frequency characteristic and impedance ratio of the transformer will not correspond at all with the actual conditions in the amplifier or the receiver.

5.48—It is often difficult to obtain continuity readings on condensers having capacities below 250 micro-microfarads. These may be checked for continuity by connecting them in series with the condenser used in the d.c. blocking connector making connection to an audio frequency source of potential. If the condenser is O.K. a reading will be obtained on the vacuum tube voltmeter. If the condenser is open, no deflection will be obtained when the audio source of potential is turned off.

5.49—The voltmeter can be used in many other circuit measurements including the drop across chokes, resistances, r.f. coils and other such circuits. The only general precautions that are to be taken in these cases, is to make sure that no electrostatic pickup is appearing in the grid of the tube or in other words, the reading is determined only by the drop across the circuit component being measured.

5.50—The vacuum tube voltmeter is limited only in its usefulness to the ability of the operator. Many uses beyond those mentioned above can be made of this instrument. As the serviceman becomes more familiar with his vacuum tube voltmeter he will find it of greater and greater help and will ultimately consider it to be one of the tools with which he cannot function properly.

6. Cathode Ray Tubes.

6.1—Cathode ray tubes and oscillographs have found their place in the radio field and will continue to be of importance in receiver design and occasionally in test work. The cathode ray tube and vacuum tube voltmeter are similar in that neither instrument draws any appreciable current from the circuit to which it is connected. The oscillograph gives a picture of the wave form of voltage or current in the circuit under test.

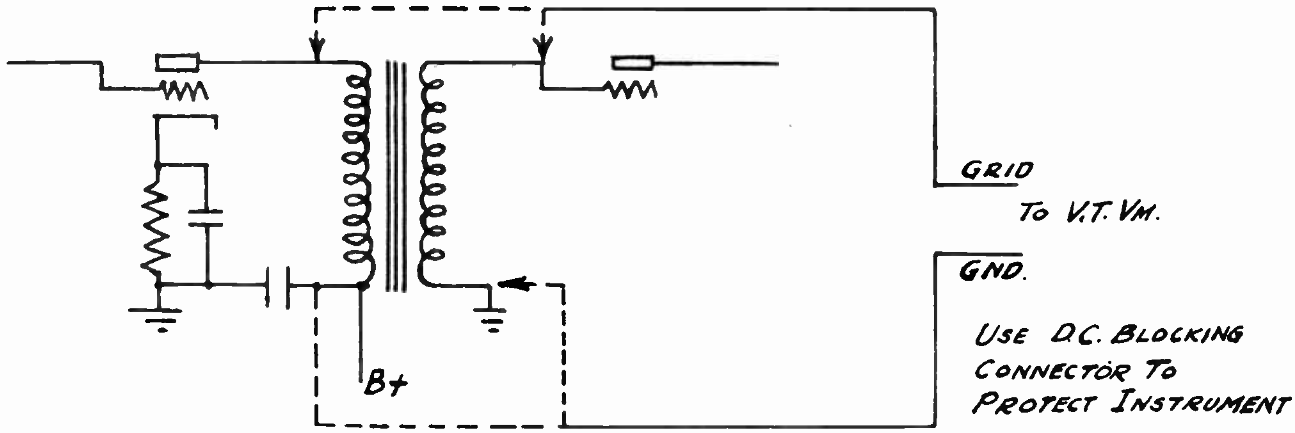


Figure 30

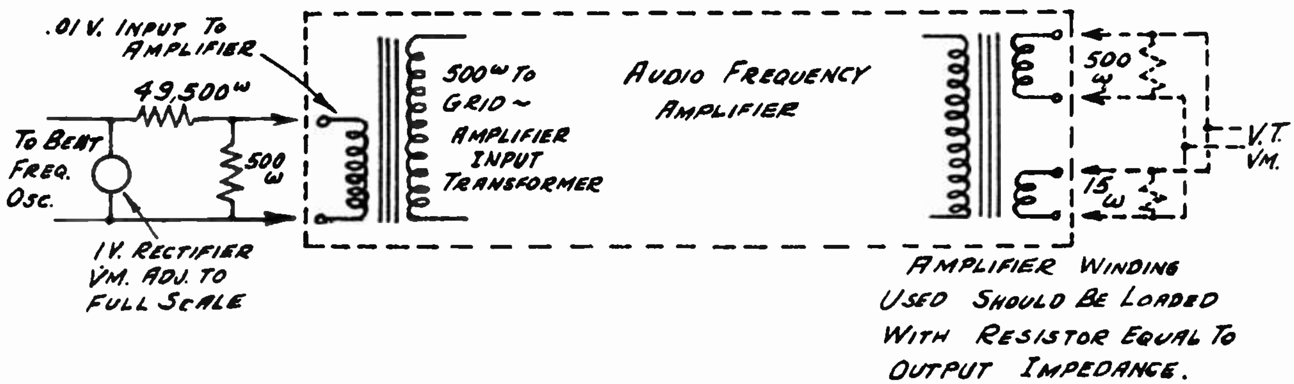


Figure 31

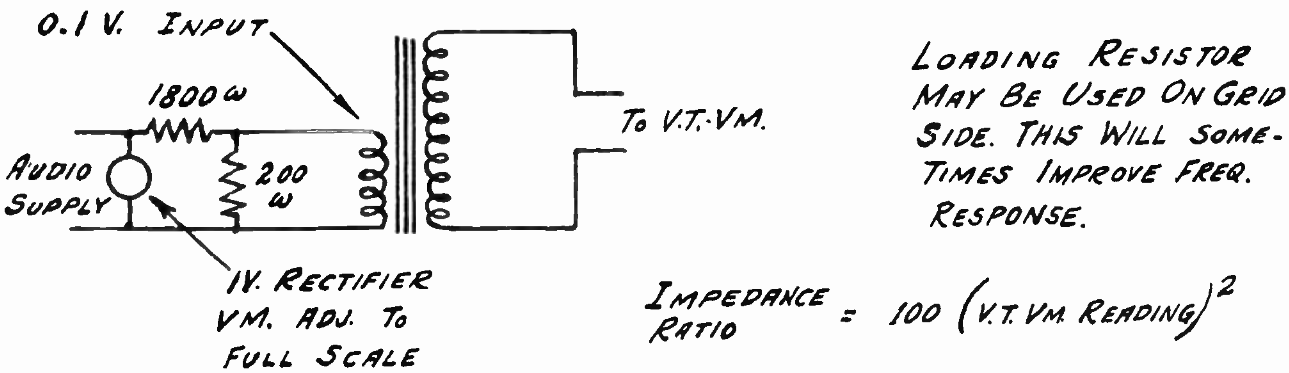


Figure 32

6.2—The vacuum tube voltmeter, on the other hand, reads potential or voltage drop across a resistor or condenser but will not give a picture of the wave form. As most of the measurements that the serviceman encounters are in connection with amplitude the vacuum tube voltmeter is in general of greater value than the oscillograph. Actually, when measurements of wave form are taken on an oscillograph there is not a great deal that the serviceman can do about altering this wave form. The single exception to this is that of flat topping intermediate frequency transformers in superheterodyne receivers. This particular procedure can be carried out with an oscillator and an output meter, or an oscillator and vacuum tube voltmeter but of course a better picture of conditions is obtained with the oscillograph.

6.3—Other measurements on receivers can, of course, be made with the oscillograph showing pictures of the wave form at different points in the receiver, particularly in the audio circuit. However, when attempts are made to obtain readings of gain per stage, a.v.c. action, or oscillator r.f. potential, no accurate measurements in volts can be taken. In addition, the vacuum tube voltmeter will read d.c. potential directly in volts whereas on the oscillograph a shift in position of the axis will be the only visible effect.

6.4—With these facts in mind it appears that the oscillograph and the vacuum tube voltmeter will run concurrently in service work but to the average serviceman it is felt that a great deal more use can be made of the vacuum tube voltmeter, as most of the measurements are in volts, either r.f., a.f., or a.v.c.

CONCLUSION

1. General.

1.1—In analyzing any piece of radio equipment the service expert can immediately break it down into three general classifications of parts.

1.2—Each device contains vacuum tubes and the serviceman is licked from the start if he has no tubechecker to test these tubes. Basically, they are parts of the equipment and they must be tested to make sure that they are functioning properly.

1.3—Component parts such as resistors, condensers, chokes, etc., must be tested for continuity, resistance in ohms, or voltage breakdown, and the serviceman is at a loss to make any finite measurements on these parts without complete analyzer equipment. To isolate the defective part it must be "spotted" by an erratic voltage current or resistance measurement, removed from the set, and tested for the particular defect in question after which a quick replacement can be made.

1.4—Resonant circuits form the third classification and the serviceman cannot even start to make any tests on such circuits without an oscillator, an output meter, and in addition a vacuum tube voltmeter. This is essentially the alignment part of the set and r.f. measurements only will be of value. A test signal at the resonant frequency must be presented to each circuit to allow for test of resonance or alignment. With the superheterodyne receivers flooding the market nothing can be done with the intermediate frequency amplifier or the short wave band without an accurately calibrated and well designed oscillator.

1.5—Comparative increases in the output with adjustments of the trimmers cannot be made by ear as this particular part of the anatomy is very indifferent to small changes in sound. Actual tests of resonance on a coil and condenser combination are very difficult to make without both an oscillator and a vacuum tube voltmeter; the first to generate the signal and present it to the circuit and the second to measure the voltage built up across the combination.

1.6—With these three basic differentiations it should be apparent to the serviceman that attempts to do any real work on radio equipment are practically impossible without a well equipped shop.

The WHY of 20,000 Ohms per Volt and 50 Microamperes!

The many new and intricate circuits to be found in the modern radio receivers present servicing problems of unusual complexity to most servicemen. In the background, too, is the possibility of television. In other words, radio servicing is a growing profession—"growing" in the design of circuits and "growing" in the design of test equipment to service these circuits.

The Model 772, the most advanced analyzer on the market with 20,000 ohms per volt and with a 50 microampere instrument, fills the needs of the progressive serviceman. The paragraphs below contain the answers to the "growing" problems. Read them over carefully. Learn WHY you need this 20,000 ohm per volt, 50 microampere instrument.

1. RESISTANCE COUPLED PLATE CIRCUITS!

Resistances used in these circuits range from 10,000 ohms up to 1 megohm. When measuring the voltage on the plate of a tube in these circuits, the voltmeter current must pass through these resistors. In so doing, this current creates an additional voltage drop. The meter current, therefore, ***must be kept very small:*** that is to say, in microamperes. If this is done, the plate voltage reading will not be pulled down to 50 or 100 volts. To put it rather bluntly, the possibility of errors in such readings is no insignificant matter, and a supersensitive instrument must be used!

2. POWER DETECTOR BIAS!

This voltage is measured directly across the cathode resistor of a power detector. To obtain a reasonably accurate voltage reading, the voltmeter resistance must be higher than that of the cathode resistor across which the measurement is to be made. With an ordinary 1000 ohm per volt instrument, the voltmeter resistance would be 50,000 ohms. Since the resistors used in these power detector bias circuits are usually 100,000 or 150,000 ohms, the one megohm resistance on the 50 volt range of the 20,000 ohm per volt instrument will not shunt the cathode resistors or throw it badly out of balance.

3. CATHODE RAY TUBE PLATE POTENTIAL!

The voltages on the plates of cathode ray tubes are almost always applied through very high resistances making it ***impossible*** to obtain any plate voltage readings without using a high sensitivity 20,000 ohm per volt instrument. The current drawn by the meter will pull these voltages down unless the instrument current is kept within the range of microamperes. Television receivers, in general, employ cathode ray tubes. Therefore, instruments of 20,000 ohm per volt sensitivity are, and will be, in demand for servicing these sets.

4. AUTOMATIC FREQUENCY CONTROL!

Automatic frequency control circuits which shift the frequency of the oscillator tube to correspond with the resonance frequency of the incoming signal, are found in most of the higher-grade and higher-priced receivers this year. This particular circuit requires a voltage balance across the two diode plates of a type 6H6 tube, when the receiver is tuned to exact resonance with an incoming signal. Using a 20,000 ohm per volt instrument (such as the Model 772) across these two diode plates on the 50 or 250 volt range, this circuit can be accurately balanced for correct operation with the instrument drawing but three or four microamperes. It is absolutely impossible to make any adjustment of this type using a less sensitive or lower "ohm per volt" voltmeter.

5. SERIES RESISTANCE SCREEN CIRCUITS!

In many recently produced receivers, high resistance series voltage dropping circuits are used to minimize distortion. The screen electrode is tied through a high resistance (one megohm) to the positive end of the voltage divider. The screen current of the tube drops the voltage to the correct value. It is practically impossible to read the screen voltage on such a tube without a 20,000 ohm per volt analyzer, since the additional current drawn by the voltmeter will pull this screen voltage down to a much lower value . . . hence, an incorrect reading. Even a current as small as 1 milliampere, drawn through such a resistance, may drop the voltage 50 or possibly 75 volts.

6. CONTROL GRID VOLTAGE MEASUREMENTS!

Many grid bias voltages are supplied from reasonably high resistance networks . . . in many cases, the potentials are supplied through resistances of 10,000 ohms or higher. These voltages can be measured far more accurately with a 20,000 ohm per volt analyzer as the extremely high resistance of the voltmeter ranges of the analyzer will not upset these networks to any great degree. For example, if the 10 volt range is used on a 1,000 ohm per volt analyzer, 10,000 ohms will be shunted across these circuits when the meter is connected into the circuit. However, on the 20,000 ohm per volt analyzer, the resistance of this same range is 200,000 ohms—a resistance that is 20 times that of the previously mentioned type. With the 20,000 ohm per volt meter, these networks should not be disturbed.

7. POWER TUBE GRID CURRENT!

Distortion, in many receivers, can be traced to grid current drawn by the output pentode tube. In most cases, the input circuit to these tubes is through a grid coupling resistor. A grid current of several microamperes will, of course, upset the bias conditions and cause bad distortion. A supersensitive analyzer such as the Model 772 being equipped with a 50 microampere instrument, can be connected into this grid circuit using the Model 666 socket selector block. With this combination, grid current down to .5 microamperes may be measured. Typical tubes, such as the type 47, do not draw more than one or two microamperes of current in a normal receiver . . . therefore, none but an analyzer with a 50 microampere instrument can successfully "spot" this source of distortion.

8. HIGH *mu* TRIODE PLATE CURRENT!

Plate current on the high ***mu*** triodes and on the triode section of duplex diode high ***mu*** triode tubes, does not often exceed 100 microamperes. This plate current cannot be accurately measured or correctly adjusted without a sufficiently sensitive instrument capable of taking these low current readings. Only a 20,000 ohm per volt analyzer, with CURRENT ranges as low as 50 microamperes, can satisfactorily handle this job.

9. AUTOMATIC VOLUME CONTROL DIODE CURRENT—*microamperes*!

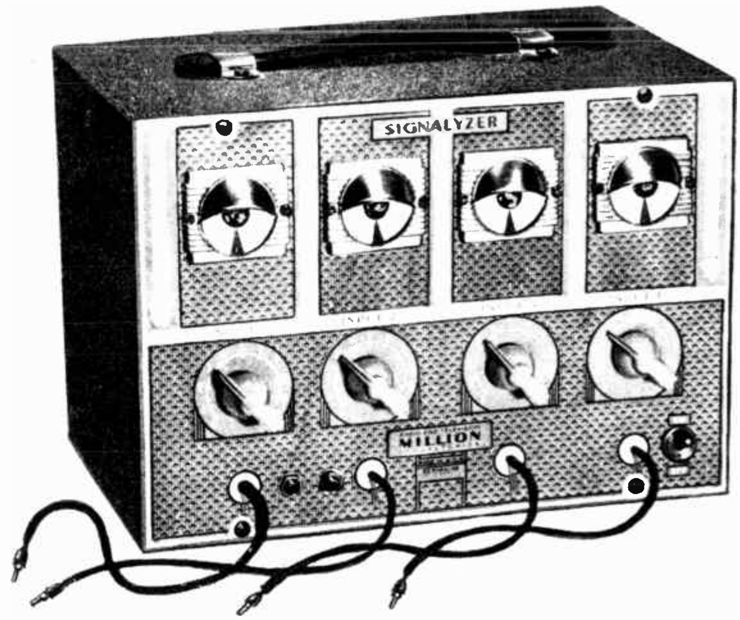
(Rectified Radio Frequency Currents)

Measurements of rectified diode current are of vital importance in making tests of automatic volume control and of diode detector receivers. Diode currents seldom run over 10 microamperes except on very strong signals which makes the Model 772 particularly valuable since it reads as low as .5 microamperes. For example, if a one megohm resistor is used in an automatic volume control circuit, its particular bias can be read directly on the instrument by converting each reading in microamperes ***directly*** into volts—remembering that one microampere through one megohm will give a reading of one volt. In making measurements of this sort, only a 20,000 ohm per volt analyzer, with its ability to take readings as low as .5 microamperes, will do a perfect job of receiver servicing.

10. OSCILLATOR TUBE GRID CURRENT!

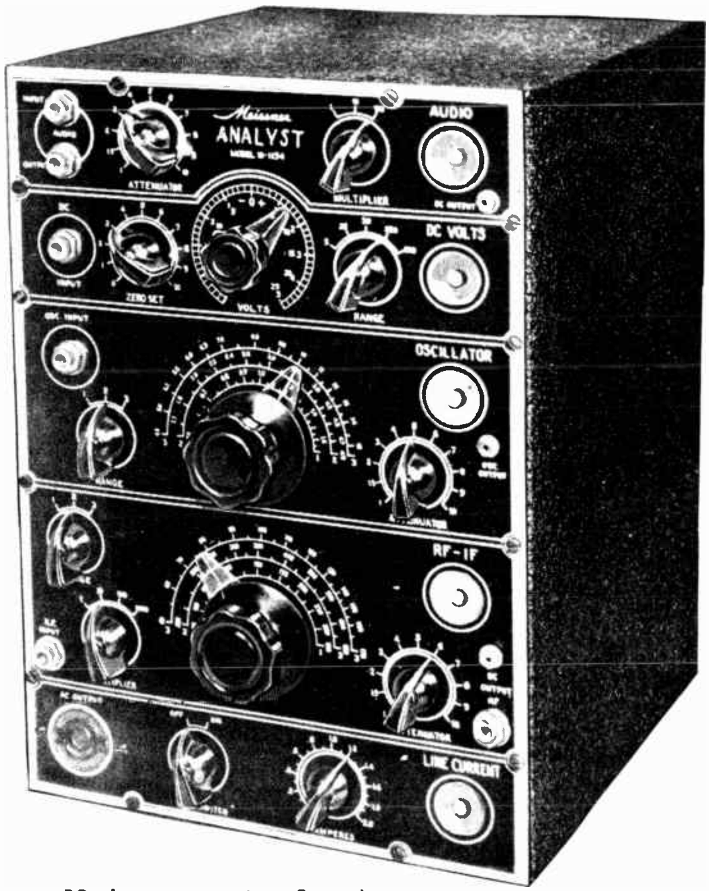
Grid current in oscillator tubes varies from 10 to 250 microamperes depending upon the type of receiver and the band on which the receiver is operating. This grid current is a measure of the amplitude of oscillation and is, therefore, a vital measurement in determining whether the oscillator in a superheterodyne receiver is delivering the correct output to the mixer tube. This measurement is made very easily and simply with a 20,000 ohm per volt analyzer using one of its low current ranges.

SIGNAL TRACING SERVICING



Million Signalyzer

In quest for a better adaptable, more efficient servicing procedure, John Rider developed a new servicing technique based on signal tracing in the receiver. Realizing that the signal, be it in the form of R.F. or audio, exists in each section of every radio, Mr. Rider developed the Chanalist. Since then units of similar nature and perhaps even of superior design have been released on the market by other manufacturers.



Meissner Analyst

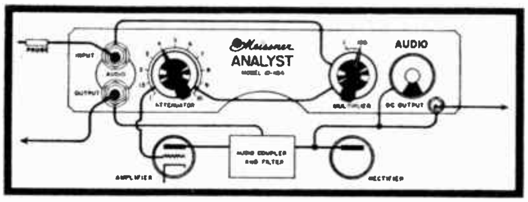
A unit of this type consists of sections that correspond to branches of a superhet or TRF set. It is possible to isolate one section of the receiver at a time and have the corresponding "analyzer" unit perform the function. The effects also may be noticed in the visual indicator of that section.

As you will see this advanced testing unit is of great help in certain types of baffling service problems, but ordinarily is of but little use.

The information that follows is presented by the Meissner Mfg. Co. on their Analyst, but is also applicable to other similar units.

To give anything like a complete listing of the many possible applications of the ANALYST would require a great deal more space than we have here provided. We have endeavored below to outline the functions of the individual test channels and to provide a representative listing of the more important tests that can be made by that portion of the instrument. It will be very evident to the reader that each of these tests will suggest a number of variations, any of which might present a serious problem to the service man without such a versatile instrument as the ANALYST. The operating notes which accompany each ANALYST kit describe many methods of locating trouble.

AUDIO



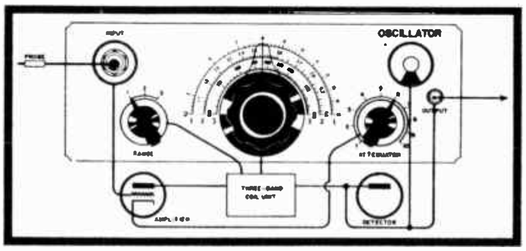
50 to 50,000 Cycles

The audio channel, located at the top of the main panel, is a single stage audio amplifier having a flat response characteristic over a frequency range of 50 to 50,000 cycles. A 6SQ7 amplifier tube is used in conjunction with a diode rectifier and an electronic indicator tube. A two position multiplier and a continuously variable resistive attenuator permit operation of this channel over its full range of 0.1 volt to 1,000 volts for full indication. Headphones may be plugged into the output jack for audible check of the signal and provisions are also made for oscillographic examination of the signal. This section may also be used for audio amplification of the signal obtained from any of the other channels.

Some of the many tests which may be performed with this channel are as follows:

- Measure hum and locate source
- Determine presence and condition of audio signal at any suspected point in the audio circuit of set.
- Determine extent of distortion and locate cause.
- Determine amplification characteristics of any audio element, tubes, coupling devices, etc.
- Determine signal level at any point during operation
- Balance push-pull amplifier circuits
- Determine audio oscillation and locate source
- Locate noise in controls or other components
- Locate open or shorted audio by-pass condensers
- May be employed as output indicator
- May be used as separate voltage amplifier where required.

OSCILLATOR



0.6 to 15.0 MC

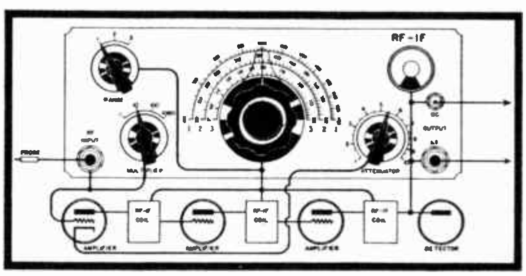
The Oscillator Channel is a single-stage tuned amplifier using a high-gain 1852 amplifier tube, a diode rectifier and an electronic indicator tube. Input is made to the circuit through a very small capacitance (contained in the probe) and level is controlled by a variable resistor attenuator. Three frequency ranges are covered by the tuning components, 600 to 1700 kc, 1650 to 4900 kc and 4800 to 15,000 kc. The centrally located tuning dial operates the single-section variable condenser while the range switch at the left selects the frequency range desired. The attenuator, at the right, measures oscillator voltage. The coils for the oscillator channel are contained in a single shield mounted adjacent to the tuning condenser on top of the chassis. The trimmers for each band are located inside of this shield.

This channel supplements the R. F.-I. F. Channel for testing of oscillators; it finds particular application during the testing of intermittent faults or at other periods when the regular R. F.-I. F. Channel is in use. Some of its many uses are as follows:

- Determine output level of oscillator under test.
- Measurement of oscillator frequency
- Determination of amount and direction of drift
- Determine operation of oscillator

In application a single probe is used which is connected to any part of the oscillator tuned circuit. The Oscillator Channel is then resonated to the frequency of the generated signal.

R. F.—I. F.



95 to 1700 KC

The R. F.-I. F. Channel is a high-gain, three-stage tuned amplifier employing three 6SK7 tubes. These are followed by a diode rectifier and an electronic indicator tube. The signal is fed to the input jack through the special input cable and full control of the level is provided by a four-position capacitive "Multiplier" and a resistive "Attenuator." Three frequency ranges are provided, selected by the "Range" switch. The bands covered are 600 to 1700 kc, 240 to 615 kc and 95 to 250 kc. The rectified output is available at the output jacks through suitably designed circuits so that headphones may be used to determine the quality of the signal at the point under examination or oscillographic examination may be made. The output is solely dependent upon the carrier voltage and is not affected by the modulation component of the signal.

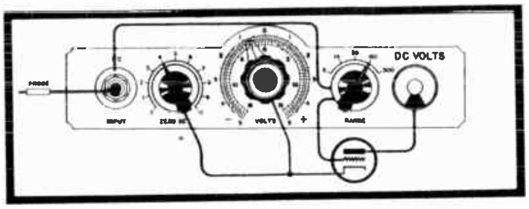
The coils for this channel are contained in a fully-shielded compartment beneath the chassis. The three coils for each stage are located in an individually-shielded section of this assembly in conjunction with their associated switch wafers, trimmers, by-pass condensers and connections to the corresponding tube socket. Thus all connections are made as short and direct as possible to provide the utmost in electrical efficiency. With the R. F.-I. F. probe, R. F. voltages from .005 to 50 in the frequency range of the channel can be measured. The direct-connected probe may be used where additional sensitivity is required.

In listing below a few of the many applications of the R. F.-I. F. Channel, it should be understood that reference to an R. F. circuit is equally applicable to the R. F. portion of a super-het or to the tuned stages of a T. R. F. receiver. Likewise statements regarding measurements on mixer circuits will apply as well to the detector of the T. R. F. receiver.

- Location of oscillating R. F. Mixer or I. F. stage
- Measure antenna pickup over Broadcast band
- Use channel as a comparison receiver
- Determine change in level through tubes or transformers
- Determine distortion in R. F. Mixer or I. F. circuits
- Locate noise source in R. F. Mixer or I. F. circuits
- Determine presence of signal at any point in circuit
- Check Oscillator signal at Mixer-Oscillator coupling unit
- Locate open by-pass condensers in R. F. or I. F. circuits
- Determine undesirable signal leakage
- Determine an unknown I. F. frequency
- Determine lack of I. F. alignment
- Use channel as a comparison I. F. channel
- Accurately adjust I. F. Wave traps
- Determine regeneration and locate source
- Check filters and by-passes in tuning indicator circuits
- Determine signal level directly at tube grid or plate
- Determine I. F. signal leakage in A.V.C. circuits
- Determine presence of distortion in second detector
- Determine I. F. leakage into audio circuits

VOLTMETER

5,15,50,150,500 Volts



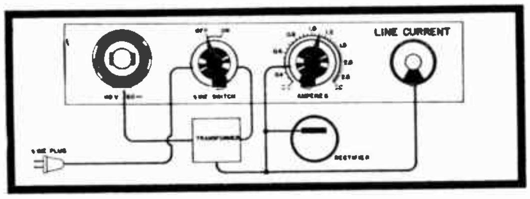
The Electronic Voltmeter channel incorporates a tube (6F5G), a voltage divider system and an electronic indicator tube. No meter of the ordinary type is employed, as the voltage readings are taken directly from the calibrated scale of the central control. This scale is over twice the length of that which would be available on a meter occupying the same or even more space on the panel. Thus more accurate readings may be made. Five voltage ranges are provided: 0 to ±5, ±15, ±50, ±150 and ±500 volts D.C. A five-position switch located at the right side of the voltage scale selects the range required. The fact that positive and negative readings are available will facilitate taking voltage readings at any point in the receiver with a single probe, regardless of polarity. The ground connection which is clipped to the chassis provides the return circuit for the voltmeter. The input resistance of this instrument on all ranges is 10,000,000 ohms so that on the five-volt scale we have 2,000,000 ohms per volt. Thus all D.C. operating and control voltages may be measured directly at the tube elements while the receiver is in operation without such operation being at all affected by the measuring device.

Among the hundreds of applications that will be found for this very versatile portion of the ANALYST are the following:

- Measurement of bias voltages during operation.
- Measurement of A.V.C. voltages directly at grid of controlled tubes with signal present in circuit.
- Measure D.C. voltage in diode circuits
- Locate leaky A.V.C. by-pass condensers
- Measure A.V.C. voltages at any point along A.V.C. bus
- Determine leakage in coupling condensers
- Measure all D.C. power supply voltages
- Bias-cell voltage measurements
- Determine audio overload by check of D.C. grid voltage
- Determine operation of oscillator tubes
- Alignment of discriminator transformer in A.F.C. circuits
- Determine level and characteristic of discriminator output voltage
- Complete and accurate determination of operating potentials upon all vacuum tube elements without affecting operation of the receiver.

LINE CURRENT

0.3 to 3.0 Amp.



The Line Current Channel is automatically placed in operation when the receiver under test is plugged into the 110-volt A.C. receptacle at the left side of the panel. A step-up current transformer is used with a diode rectifier to supply a direct-current voltage to the actuating grid of the electronic indicator tube. A calibrated resistive control provides the current reading directly when the control is set to just close the shadow on the indicator. The current range is from 0.3 to 3.0 amperes which will cover the current input to practically any type of receiver.

A simultaneous measurement of the D.C. voltages in the receiver together with the Line Current indication will be of great assistance in solving many of the problems connected with power supply faults, especially when they are of an intermittent nature.

Solving the Tough Ones

Actual case histories presented to show the ease and speed with which the Analyst locates the point of trouble on tricky service jobs.

CASE 1—

A customer complained that the new set of output tubes installed in his receiver gave poor quality and low output. The service man found this hard to believe since he had personally tested them before selling them and suspected something else had happened to the set. He traced the signal from the antenna with good quality and satisfactory gain per stage showing up at each grid until he reached the grids of the push-pull output stage. The signal here was distorted and the electron ray tube indicated an abnormally large signal. This voltage was present even with the audio control set to zero. Pulling out either one of the output tubes would drop the voltage to zero on both the inoperative grid and the grid of the tube left operating. It was obvious that the output amplifier was oscillating. The customer confessed he had asked for glass output tubes in place of the metal tubes previously used. When a 1000-ohm resistor was connected in series with each grid, the trouble was eliminated. The time required to locate the fault was only six minutes.

CASE 2—

A new receiver gave a peculiar kind of buzzing distortion at moderate volume. The service man could not decide whether the trouble was in the speaker or the chassis. Used the audio section of the Analyst and a head set to check the quality of the signal to the speaker. Quality was found O. K. at speaker transformer therefore the trouble was not in the receiver. He removed only the speaker and found a small sliver of wood that touched the cone of the speaker causing a buzz. The trouble of removing the entire set, which was a big one, was avoided. The time required to find the trouble was only five minutes, the time to repair only ten minutes.

CASE 3—

An intermittent set was analyzed in the following manner: Prods were attached to oscillator grid, 1st I. F. grid, 1st A. F. grid, plus B and the input was measured through the Line Current unit. At irregular intervals the receiver, tuned to one of the local stations, would cut in and out of operation. The probes on the first I. F. grid, the 1st A. F. and the oscillator showed no signal. The voltmeter prod touched to the grid of the oscillator showed no voltage from grid to ground, yet there was normal voltage on the plate of the tube. The tube had a cathode resistor and showed a reasonable cathode bias. Reconnecting the oscillator section it was found by tuning the frequency control of the oscillator section, that an R. F. voltage was found at a frequency several hundred kc above the place where the oscillator had formerly been working. The shift in frequency was traced to a faulty padding condenser in which one of the leaves was making intermittent contact. Time to localize the fault in oscillator section, seven minutes, after the first fade.

CASE 4—

A set with low and distorted output on all signals was analyzed as follows: Signal traced through from antenna to the grid of the 1st A. F. tube with good quality and satisfactory gain per stage. At the grid of the output stage the quality was very poor. The Electronic voltmeter was connected to the grid of the output tube and indicated a positive bias on the grid. The output tube was pulled out and the grid circuit became more positive. This was conclusive evidence of a leaky coupling condenser from the plate of the 1st audio to the grid of the output stage. Time consumed in testing five minutes.

CASE 5—

A set overloaded and distorted badly on strong local stations. The signal was traced through from the antenna to grid of the last I. F. transformer with good quality and satisfactory gain per stage. At the diode load resistance, the quality was poor. On weaker stations the quality was good at this point. The electronic voltmeter applied to the A. V. C. string showed conventional A. V. C. action. It was suspected that the output I. F. amplifier tube was being overloaded when listening to the strong local station. The A. V. C. circuit was rearranged to apply to the output I. F. tube only one-half of the A. V. C. voltage available. Quality then became satisfactory. The total time for diagnosis was only ten minutes. The time for correction was even less.

REVIEW QUESTIONS

1. What advantage is there in servicing a radio in the home?

2. On what principle do modern tube testers operate?

3. What use would a serviceman find for an A.C. voltmeter?

4. What is the difference between an analyzer and a simple meter with several scales and a selector switch?

5. How does a meter of poor sensitivity give the wrong voltage reading?

6. A 1000 ohm/volt meter has what basic movement? (How many ma.)

7. How can a D.C. voltmeter range be extended?

8. What frequencies should a good signal generator (oscillator) cover?

9. What is the process of "flat topping" mean?

10. What main advantage does a vacuum tube voltmeter have over the regular meter type?

11. How can the power output of an audio amplifier be measured with a vacuum tube voltmeter?

12. Name three tests that require the sensitivity of at least 20,000 ohms/volt?

13. Recalling the work performed on a radio receiver you or some other radio serviceman once has repaired, try to picture how the same problem could be solved with a new "signal tracing" analyzer.

WHAT SERVICING EQUIPMENT TO GET FIRST

The radio serviceman first getting started, must obtain his test equipment in bits. The question, "What unit should I purchase first," always comes up. The volt-ohm-milliameter of the D.C. type should be the first unit. The quality and sensitivity should be determined by the available funds. But do not get too cheap a unit, for you will have to trade it in when you realize the need for better equipment. A signal generator should come next and then an analyzer.

The many more advanced test units are helpful. They not only save time on the tough jobs, but will enable to charge more on the job.

LESSON 13

HOW TO USE AN OSCILLOSCOPE

THE CONTROLS

The big tube at the top of the panel is the Cathode Ray Tube. That is where you will get your "picture." To the left of this tube is the "intensity" control. This is a potentiometer which you will use to vary the brilliance of the scope's picture. It also has the power line supply "On-Off" switch attached - just like on the average radio receiver The "Focus" control to the right of the cathode ray tube is used to focus the picture to a sharp, bright image, just like you do with a telescope or binoculars, or a moving picture projector.

Much of this practical information on the use of the oscilloscope is due to the courtesy of SUPREME INSTRUMENTS CORPORATION of Greenwood, Mississippi. The data given is for Model 546, but in general it is applicable to other models and makes.

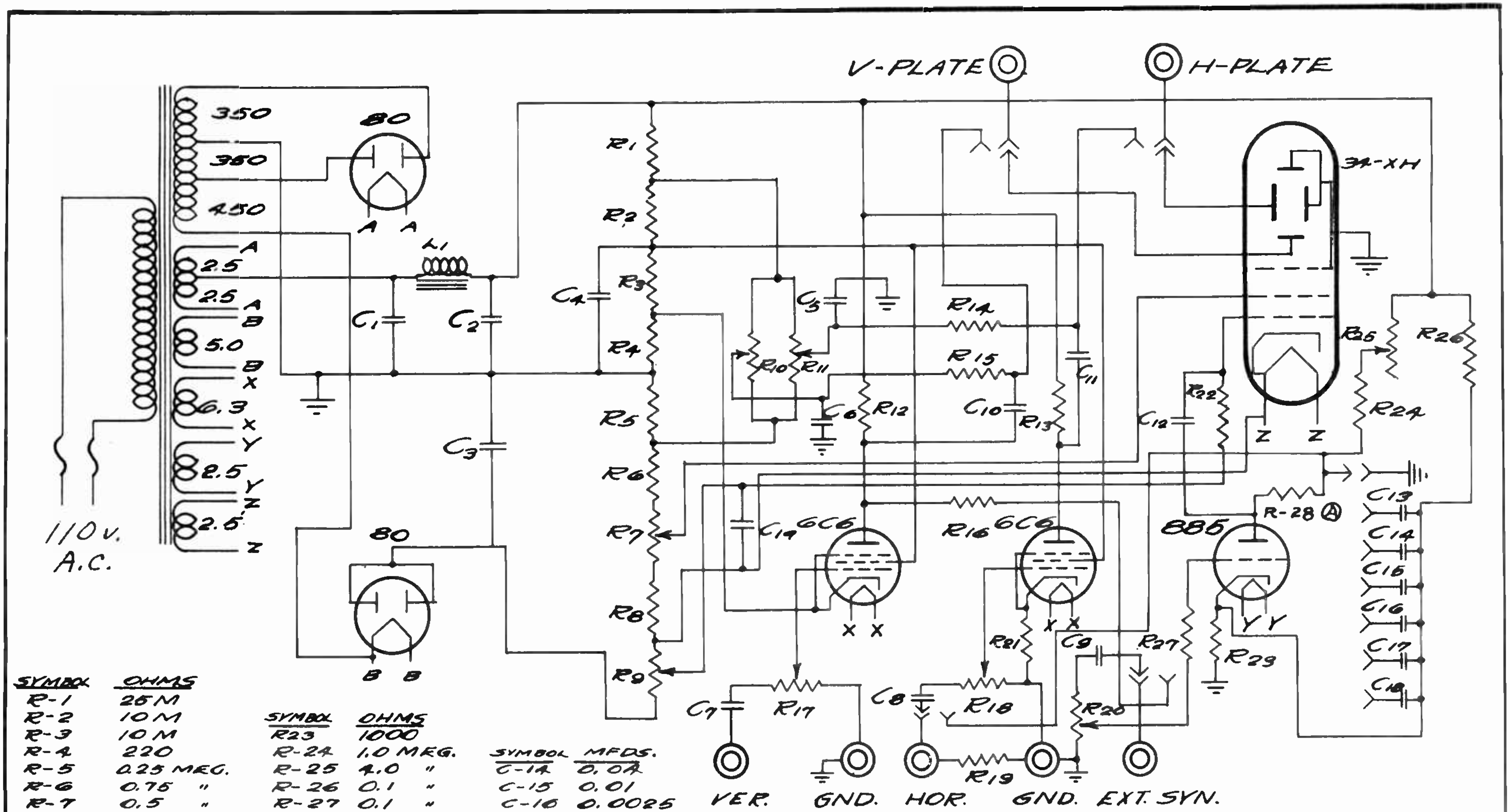
Remember, regardless of what kind of a picture you get on the screen, it is actually only a dot of light which is moving so fast that it forms a picture.

Sometimes we desire to shift the position of the dot or the complete picture. For this, we have the "Vert. Position" and the "Hor. Position" controls. To shift the picture upwards, we turn the "Vert. Position" control in a clockwise direction and to shift the picture downward, we turn this control in a counter-clockwise direction. To move the picture to the right, we turn the "Hor. Position" control in a clockwise direction and to shift the picture to the left, we turn this control in a counter-clockwise direction. These controls are not connected to the cathode ray tube unless their respective amplifier "gain" controls are "on."

The "Vert. Gain" control acts as a volume control on the vertical amplifier and to feed a signal into the vertical amplifier, we use the pin jack marked "Ver." and any "Gnd." pin jack. When this control is in the "off" position the "Vert. postiion" control and the vertical amplifier are eliminated from the circuit and the signal can be fed directly to the vertical deflecting plates.

PANEL LAYOUT OF MODEL 546 THREE-INCH CATHODE RAY OSCILLOSCOPE

PROPER PART NAME (USED IN INSTRUCTIONS)	FUNCTION	LOCATION ON PANEL
CATHODE RAY TUBE	3" SCREEN TUBE	TOP CENTER
"INTENSITY" CONTROL	CATHODE RAY BEAM INTENSITY CONTROL AND POWER SUPPLY "ON-OFF" SWITCH	TO LEFT OF CATHODE RAY TUBE
"FOCUS" CONTROL	CATHODE RAY BEAM FOCUS SONTROL	TO RIGHT OF CATHODE RAY TUBE
"VERT. POSITION"SPOT CONTROL	CONTROLS PLACEMENT OF SPOT IN A VERTICAL PLANE ("VERT. GAIN" CONTROL MUST BE TURNED ON).	TO LEFT OF WORDS "MODEL 546".
"HOR. POSITION" SPOT CONTROL.	CONTROLS PLACEMENT OF SPOT IN A HORIZONTAL PLANE ("HOR. GAIN" CONTROL MUST BE TURNED ON).	TO RIGHT OF WORDS "MODEL 546."
"VERT. GAIN." CONTROL	(1) GAIN CONTROL FOR VERTICAL AMPLIFIER. (2) VERTICAL INPUT SWITCH (IN "OFF POSITION, SIGNAL FED DIRECT TO VERT. DEFLECTING PLATES).	BELOW "VERT. POSITION" SPOT CONTROL
"HOR. GAIN" CONTROL	(1) GAIN CONTROL FOR HORIZONTAL AMPLIFIER (2) HORIZONTAL INPUT SWITCH. (IN "OFF" POSITION, SIGNAL FED DIRECT TO HOR. DEFLECTING PLATES.	BELOW "HOR. POSITION" SPOT CONTROL
"SYNC. CONTROL".	SYNCHRONIZING CONTROL FOR VARYING THE AMOUNT OF INPUT POTENTIAL APPLIED TO THE CONTROL GRID OF THE 885 SAW TOOTH OSCILLATOR TUBE TO SYNCHRONIZE SAW TOOTH OSCILLATOR WITH SIGNAL UNDER STUDY.	BELOW WORDS "MODEL 546"
"FINE FREQ." CONTROL	VERNIER FREQUENCY CONTROL FOR SAW TOOTH OSCILLATOR	BELOW "SYNC. CONTROL."
"SWEEP FREQUENCY" CONTROL	ROUGH RANGE SELECTOR FOR SAW TOOTH OSCILLATOR — IN "OFF" POSITION, OSCILLATOR IS DISCONNECTED.	BELOW "FINE FREQ." ADJUSTER
"EXT. SYN."—"INT. SYN." SWITCH	FOR CHOOSING EITHER AN INTERNAL OR AN EXTERNAL MEANS FOR SYNCHRONIZATION	TO LEFT OF "FINE FREQ." AND "SWEEP FREQ." CONTROLS
"EXT. SWEEP" — "INT. SWEEP" SWITCH	FOR CHOOSING EITHER AN EXTERNAL OR AN INTERNAL SWEEP FREQUENCY	TO RIGHT OF "FINE FREQ." AND "SWEEP FREQ." CONTROLS
"EXT. SYN." PIN JACK	INPUT TO SYNCHRONIZING CIRCUIT FOR EXTERNAL SYNCHRONIZING SIGNALS	LEFT LOWER CORNER OF PANEL
"VERT." PIN JACK	INPUT TO VERTICAL AMPLIFIER	BELOW "EXT. SYN." PIN JACK
"HOR." PIN JACK	INPUT TO HORIZONTAL AMPLIFIER	RIGHT LOWER CORNER OF PANEL
"V-PLATE" PIN JACK	DIRECT INPUT TO VERTICAL PLATE OF TUBE	LEFT LOWER CORNER OF PANEL
"H-PLATE" PIN JACK	DIRECT INPUT TO HORIZONTAL PLATE OF TUBE	RIGHT LOWER CORNER OF PANEL
"GND." PIN JACK	ALL LEAD BACK TO COMMON GROUND	ABOVE AND BELOW "HOR." PIN JACK AND BELOW "VER." PIN JACK



SYMBOL	OHMS
R-1	25 M
R-2	10 M
R-3	10 M
R-4	220
R-5	0.25 MEG.
R-6	0.75 "
R-7	0.5 "
R-8	0.1 "
R-9	0.2 "
R-10	4.0 "
R-11	4.0 "
R-12	0.13 "
R-13	0.1 "
R-14	5.0 "
R-15	0.5 "
R-16	1.0 "
R-17	1.0 "
R-18	4.0 "
R-19	1.0 "
R-20	15 M
R-21	1000
R-22	0.5 MEG.

SYMBOL	OHMS
R23	1000
R-24	1.0 MEG.
R-25	4.0 "
R-26	0.1 "
R-27	0.1 "
R-28	500 OHMS
SYMBOL	**MFDS.**
C-1	4.0
C-2	4.0
C-3	0.5
C-4	8.0
C-5	0.05
C-6	0.05
C-7	0.1
C-8	0.1
C-9	0.05
C-10	0.05
C-11	0.05
C-12	50 MMFd.
C-13	0.2

SYMBOL	MFDS.
C-14	0.04
C-15	0.01
C-16	0.0025
C-17	600.0 MMFd
C-18	200.0 "
C-19	0.5 MFd.

The "Hor. Gain" control acts as a volume control on the horizontal amplifier and to feed an external signal into the horizontal amplifier, we use the pin jack marked "Hor." and any "Gnd." pin jack, also we throw the "Ext. Sweep"- "Int. Sweep" to the "External Sweep" position. When this control is in the "off" position, the "Hor. Position" control and the Horizontal amplifier are eliminated from the circuit and the signal can be fed directly to the horizontal deflecting plates. We also have a circuit, internally, which is always used in connection with the horizontal amplifier and plates. This is called the saw tooth or linear time base oscillator and, in this case. we throw the "Ext. Sweep- Int. Sweep" position.

This linear time base or saw tooth oscillator uses two controls on the panel. If you will liken this oscillator to any all wave receiver oscillator circuit, you will more easily understand the use of the two controls. While the radio receiver's oscillator generates radio frequencies, the saw tooth oscillator generates low frequencies and, instead of being sine wave in shape, resemble the teeth of a saw. This saw tooth oscillator generates frequencies from about 115 to 30,000 cycles and, as in a radio receiver, all these frequencies cannot be accommodated on one band. Hence the "Sweep Freq." switch which corresponds to a band change switch on the receiver. In the "off" position, the oscillator is disconnected. The approximate frequencies covered by the balance of the six ranges are as follows:

(1) 15-65, (2) 65-230, (3) 230-950, (4) 950-3000, (5)3000-10,000) and(6) 10,000 to 30,000 cycles.

Please remember that these are only approximate frequency limits and that in each case, the bands actually overlap the frequency limits.

The "Fine Freq." control might be compared to the variable capacitor used in the radio receiver's oscillator circuit to vary the radio frequency. Actually, the "Fine Freq." control is a potentiometer, but it serves as a vernier frequency control on each range of the saw tooth oscillator.

Many times we desire to synchronize the signal being applied to the horizontal and vertical plates of the Cathode Ray tube. For this purpose, we either introduce some external synchronizing signal through the pin jack marked "Ext. Syn." (with the Ext. Sync-Int. Syn." switch in the "Ext. Syn." position), or we use the internal synchronizing circuit that has been provided and, in this case, throw the "Ext. Syn."-"Int. Syn." switch to the "Int. Syn." switch position. To control the amount of synchronizing voltage applied to the circuit, we vary the "Sync. Control" for the best results as will be explained later.

The only other item on the panel, not previously explained are the "V-Plate" and the "H-Plate" pin jacks. It is sometimes very helpful to be able to apply the voltages directly to the horizontal and vertical deflecting plates without going through either amplifiers or capacitors. This is true particularly in D. C. voltage measurements. The pin jacks marked "V-Plate and "H-Plate" tie directly to their respective sets of deflecting plates without using series capacitors.

PRELIMINARY ADJUSTMENTS

We are now ready to make some actual tests and see how easy it actually is to operate this instrument. First, make sure that the "Sweep Freq." control is in the "Off" position and the "Ext. Sweep-Int. Sweep" switch in the "Ext. Sweep" position. See that the "Vert. Gain" and the "Hor. Gain" controls are rotated to about "15" or just enough to trip their switches. Place the A. C. plug in a convenient power supply outlet and set the "Focus" control at about half rotation. Rotate the "Intensity" Control only enough to trip the power switch. Allow about thirty seconds for the tube to properly heat. By advancing the "Intensity" control, a spot of light will be noted on the screen. Do not allow a brilliant spot of light to appear on the screen as it will burn it. Vary the "Focus" and "Intensity" controls until you get a nice, clean spot, as small in diameter as possible and JUST VISIBLE! If the "Intensity" control is advanced beyond this point the spot will burn a hole in the screen, so be very careful. We will give you a better way to adjust the "Focus" and "Intensity", later on, but first we want you to see the actual spot.

You will probably find that the spot is not in the center of the screen and to move it, it is only necessary to vary the "Vert. Position" and the "Hor. Position" controls until the spot is properly positioned. In the majority of tests, the spot should rest in the center of the screen and you should now place it there.

PLACING THE SPOT IN MOTION

The spot can be caused to move horizontally, vertically, or, if both sets of plates are used, the spot can be made to move at an angle, in an elipse. In a circle or in a wide variety of directions making up the "Pattern" or picture which the operator desires to view. Let's first make it move vertically.

MOVING THE SPOT VERTICALLY

First, make sure that both the "Vert. Gain" and the "Hor. Gain" are rotated sufficiently to turn their switches on (to about 10). Obtain a set of test leads and connect one end of each to the "Vert." pin jack and one to the Gnd. pin jacks. Apply the other ends to your A. C. supply by plugging them into a convenient A. C. outlet. Be careful that they do not short and that you do not get across them. See that the "Sweep Freq." control is "Off." You will note that the spot will now become a short vertical line. By increasing the rotation of the control, you will increase the length of the line. Adjust the "Vert. Gain" until the line is about 2" long. You can now increase the brilliance of the pattern by advancing the "Intensity" control somewhat. Do not increase the "Intensity" control past a position which will give you reasonable brilliance.

The spot is now rapidly travelling back and forth past its normal center position at a frequency equal to the frequency of the power supply. The spot, starting at center, moves upward an inch then as the polarity of the supply changes, it moves downward 2 inches through center to its lowest point and then returns to Zero as the polarity changes again. This occurs sixty times a second for sixty cycle supplies, etc. As a matter of fact, we can apply an alternating voltage of any frequency (up to the frequency limit of the vertical amplifier) in the same way and the spot will oscillate up and down at the frequency of the applied voltage.

If we were to apply one half the potential, the line would be only half as long. A quarter the voltage would result in a line only a quarter as long, etc. Therefore, we can establish the fact that the resulting line will depend directly upon the VOLTAGE applied-more voltage, longer LINE--less voltage, shorter line. This makes this test ideal for comparing the potential of a known voltage with an unknown voltage and for output measurements of radio receivers.

MOVING THE SPOT HORIZONTALLY

We are now going to move the spot in a horizontal direction. This can be accomplished by using either an external voltage (as we did in the case of the Vertical Amplifier) or the internal saw tooth oscillator may be used. We will use the external voltage first.

Apply one end each of two test leads to the "Hor." pin jack and one of the "Gnd." pin jacks. Apply the other ends to the A. C. base plus or outlet as explained in the previous test. The "Ext. Sweep - In. Sweep" switch should be in the "Ext. Sweep" position. The "Hor. Gain" and "Vert. Gain" controls should be rotated sufficiently to snap on their attached switches. Advance the "Intensity" control until a short horizontal line may be seen on the screen. Always keep the "Intensity" control at a position which results in the lowest brilliance for a satisfactory image. Adjust the "Hor. Gain" until the line is about 2" long.

We now have, on the horizontal plates, exactly the same type of signal which we previously had on the vertical plates, the only difference being that the dot is now moving to left and right of its "Zero" or "At Rest" position rather than up and down. Look at this line, because in a number of tests this is referred to as the "Zero Reference" line or "Zero Axis" above which is considered "plus" and below which is considered "minus." This is also called the "Timing Axis" or "Time Base" line because it will be used as a standard against which the frequency of the potential applied to the vertical plates will be measured.

Inasmuch as we have applied a sine wave to these plates, the spot will not move from side to side with the same speed, as it will actually move faster at some points than at others. This is not hard to visualize. A sine wave does increase and decrease linearly with respect to time, that is, its rate of voltage change is more rapid during some portions of the cycle than at others. If such were not the case, and the voltage increased and decreased linearly with respect to time, the resulting wave shape would have to look like the following illustration.

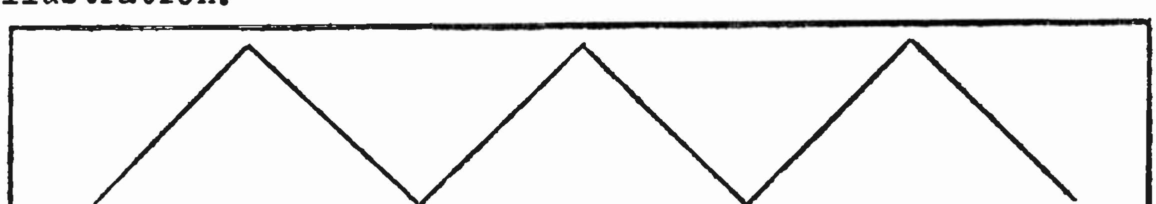


FIG. 1

INSTEAD OF THIS, THE WAVE ACTUALLY LOOKS SOMEWHAT LIKE THE FOLLOWING ILLUSTRATION:

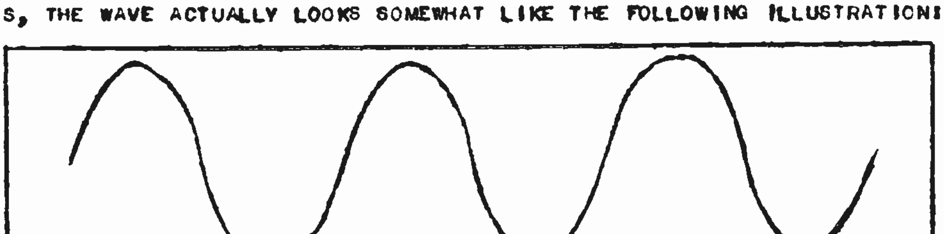


FIG. 2

You can see that when the voltage is passing through "Zero" in either direction its rate of chance is greater than when it approaches either maximum point. Now turn this book on its side so that in the above picture, maximum voltage points on the sine wave will be to the left and right. Now imagine this sine wave compressed from the top and bottom until it is merely a straight horizontal line. This is what we now see on the cathode ray screen. Incidentally, this is what we saw in the first test except the sine wave maximum points were at top and bottom. From this, you can see that the spot will decrease in speed as it moves to both the left and right of center. Therefore, it may be used as a non-linear time base.

There are few applications or tests where an unknown A. C. potential is applied to the horizontal plates circuit except where phase measurements or other special tests are made. As stated previously, the horizontal plates circuit is usually used as a time base against which the frequency of an unknown voltage is measured or, by which we can "spread out" this applied voltage to examine its wave form.

LET'S CONSIDER THE LINEAR TIME BASE

To examine the wave form of an A. C. voltage, it is necessary to use a time base which is linear with respect to time. In other words, the spot must be caused to move from left to right at a constant rate of speed from the left side of the screen to the right side. We then require the spot to return to the original starting point almost instantaneously, so that it will repeat its constant movement from left to right.

Here is where the "saw tooth" or "linear" oscillator enters the picture. This saw tooth oscillator is built into majority of oscilliscopes and has the "Sweep Freq." and Fine Freq." adjusters as its controls. This oscillator generates a wave which looks very much like a saw's tooth as the following picture shows: it starts at zero potential, increases linearly in voltage output until it reaches a maximum voltage and then almost instantaneously drops to zero and repeats the cycle.

FIG. 3

When this is applied to the scope's horizontal plates circuit, it causes the spot to travel linearly from left to right and then snap back to the original left position so it may start over. Let us connect the internal linear sweep in place of the external non-linear sweep which we were just using. First disconnect the test leads from the A. C. supply outlet and then from the pin jacks on the panel. Reduce the intensity of the spot.

See that the "Fine Freq" control is at about "50" and the "Sweep Freq." control is "off." Place the "Ext. Sweep - Int. Sweep" switch in the "Int. Sweep" position. See that the "Hor. Gain" and "Vert. Gain" controls are advanced sufficiently to snap on their respective switches. Turn the "Sweep Freq." switch to the first position past "Off." Advance the "Intensity" control and "Hor. Gain" until a short horizontal line is noted on the tube's screen. Adjust for minimum brilliance with satisfactory visibility. Rotate "Hor. Gain" until line is about 2" long. Vary the "Fine Freq." Adjust from "Zero" to "100" and vary the "Sweep Freq." switch from range to range. You will note that at zero on the "Fine Freq." control and the first position past "Off" on the "Sweep Freq." switch, the line will appear to have a decided "flicker." This is due to the extreme slow speed at which the spot is travelling. By varying the "Fine Freq." adjuster, this flicker increases in rapidity until it disappears completely. This is due to what is termed "Persistancy of Vision" which merely means that above a certain frequency the eye cannot follow the spot and a line results. "Flicker" is the result of an effort by the eye to keep up with the individual spot. At very low frequencies the line may appear slightly jagged, due to small induced voltages, but this will not effect any test which you may desire to make.

USING THE LINEAR TIME BASE

Let us now put this "saw tooth" linear time base to practical use. Let us examine the wave shape of the A. C. supply voltage. Leave the controls on the scope as is, with the "Fine Freq." control at about "50" and the "Sweep Freq." control at the first position past "off." Place the "Ext. Syn. - Int. Syn." switch in the "Ext. Syn." position.

Connect the ends of the two test leads to the "Ver" pin jack and one of the "Gnd." pin jacks. Connect their other ends to your A. C. supply outlet or base plug. Rotate the "Vert. Gain" to about "20". You will now see a series of wavy lines moving rapidly across the screen. Adjust the "Vert. Gain" until this picture is about 2" high. Vary the "Fine Freq." adjuster until you get an image resembling the following picture.

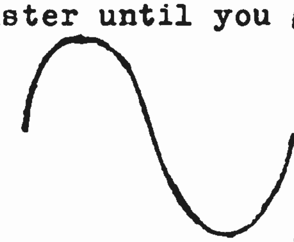


FIG. A

As most power supplies are 60 cycle in frequency, we are going to use this as our basis of discussion, however, any other supply frequency will react in the same manner.

Assume a 60 cycle power supply frequency, we then know that this is the frequency of the potential applied to the vertical plates. By adjusting the linear time base to the same frequency, we get a picture of the wave shape of one complete cycle. This test is used to determine the wave shape of the voltage applied to the vertical plates circuit although it is better to adjust the circuit so that there are several standing waves on the screen because no linear time base in commercial oscilloscopes is absolutely linear.

We have not, as yet, mentioned the synchronizing circuit or its use. You probably found that the 60 cycle wave would not "stay put" on the screen, but wandering off the screen either to the left or the right. This occurred due to the fact that you could not exactly tune the linear time base to the applied voltage's frequency. The synchronizing circuit does this for you by applying a very small amount of the applied voltage across the grid of the saw tooth oscillator tube, making it "trigger" in exact synchronization with the frequency of the applied voltage. The amount of synchronizing voltage used will depend upon the setting of the "Sync. Control." To obtain synchronization between the applied potential and the linear time base, throw the "Ext. Syn. - Int. Syn." switch to the "Int. Syn." position. This allows the synchronization circuit to function between the applied voltage and the linear time base. After varying the "Fine Freq." adjust until the image wanders the least, advance the "Sync. Control" until the image "Locks in" and remains stationary. Never over-synchronize because this will distort the image. Advance the "Sync. Control" only enough to allow "Locking in."

If it were desired to synchronize the time base, not with the frequency of the applied voltage, but with the frequency of some other voltage, the "Ext. Sync. - Int. Sync." switch should be thrown to the "Ext. Sync." position and the synchronizing voltage applied between the "Ext. Syn." pin jack and one of the "Gnd." pin jacks.

To obtain more than one standing wave on the screen of the frequency under study, the linear time base should be adjusted to some sub-multiple of the frequency of the applied voltage. In our previous tests, we set the time base at 60 cycles so that we could obtain one standing wave of the applied potential, which had a frequency of 60 cycles so that we could obtain one standing wave of the applied potential, which had a frequency of 60 cycles. By reducing the frequency of the time base to 30 cycles, a 60 cycle frequency applied voltage would result in two standing waves on the screen. Decreasing the linear time base frequency to 20 cycles results in three standing waves on the screen, and decreasing it to 15 cycles results in four standing waves on the screen.

This arrangement offers many possibilities for tests. A potential of unknown frequency could be applied to the vertical plates circuit and the linear time base adjusted until one or more standing waves appeared on the screen. A variable audio signal generator could then be applied in place of the unknown voltage and the signal generator varied until the same number of standing waves appeared. By reading the dial of the signal generator, the frequency of the unknown potential could be directly determined.

This test is good for frequencies up to about 75 to 100 k.c. as the amplifiers will pass sufficient voltage up to these limits for a practical test.

WHY USE A SIGNAL GENERATOR?

Back in the early days of radio, we did not have to worry about I. F. (Intermediate Frequency) stages, receiver acceptance curves, hair-line selectivity, high fidelity response, etc. Usually, a receiver either worked or did not work and that was that.

With the advent of superhets, multiple tuned stages and ganged controls, the need arose to peak each stage properly and to maintain maximum selectivity over the receiver's complete tuneable range.

The first method of alignment was to tune in a local broadcast station and wiggle the condenser plates and adjust the trimming and padder condensers while listening to the results in the set's speaker. The serviceman adjusted the set as best he could to play the loudest. The ear is a poor judge of sound level as it barely distinguishes a change in sound level double the original. Therefore, the next step was to use an indicating meter across the set's output in place of its loudspeaker. However, the audio signal (radio program) varied greatly in sound level from second to second and this was still not a satisfactory answer to the problem.

This led to the design of the "R. F. Oscillator," forerunner to the modern signal generator. This oscillator took the place of the radio station and its program, as it was a miniature transmitter usually was tuneable over the complete broadcast band. In place of the radio program, a steady audio note was used to modulate the transmitter and as this allowed a steady volume of modulated R. F. to be fed the receiver, any change in the receiver's circuit adjustments could be noted on a meter. If the set was badly in need of tuning, a large R. F. output was required to push through the set's circuits and as the set was brought into line, less and less input signal was required to obtain the same relitive signal strength at the receiver's output.

Then, out of the introduction of high fidelity reproduction and a better understanding of receiver acceptance curves arose the need for a different type of modulation. Something that, when used with a cathode ray 'scope, could give the serviceman an instantaneous picture of the ability of the receiver to accept a band of R. F.'s above and below the wanted carrier frequency and also show its ability to reject other frequencies.

The original signal generator when used with a motor employed amplitude modulation just the same as radio stations use when sending out voice or music. The transmitted R. F. wave of the signal generator is constant in frequency and its amplitude varied by means of an audio note -- usually 400 cycles. This, then allows the serviceman to peak an I. F. stage at, let us say, 175 K. C., but -- what happens each side of this frequency? When a radio station broadcasts a program, it emits "side bands" as well as the R. F. carrior. Let's assume a station is broadcasting on 600 K. C. and it is sending a 3000 cycle note. Besides the 600 K. C. signal, the receiver must also receive the upper and lower side bands (3 K. C. plus 600 K. C. and 3 K. C. minus 600 K. C. or 603 K. C. and 597 K. C.) Thus, when these R. F. signals are beat with the super-het's oscillator, we would get 175 K. C. (if this if I. F. peak) 178 K. C. and 172 K. C. Now let's assume the station sent out a 5000 cycle signal. This would result in a 170 K. C. and a 180 K. C. I. F. signal in addition to the 175 K. C. frequency. Now, the question arises, if both the 3000 cycle note and the 5000 cycle note were originally the same relative intensity, what would their relative intensities be when they reached the set's second detector?

As each radio station in the broadcast band is placed 10 K. C. apart, each sends side bands up to approximately 5 K. C. each side of its carrier frequency. Thus, a perfect response curve on a receiver would look like Fig. 1 where the horizontal lines represented relative "set acceptability" and the vertical lines represented frequency. You can see that such a set, when tuned to 600 K. C., would accept all side bands between 595 K. C. and 605 K. C. with equal intensity, but would completely reject all other signals.

Unfortunately no set has ever been built with such an acceptability curve and the best would be as shown in Figure 2. A poorly designed receiver (such as many of the cheaper sets) would have an acceptability curve like Figure 3.

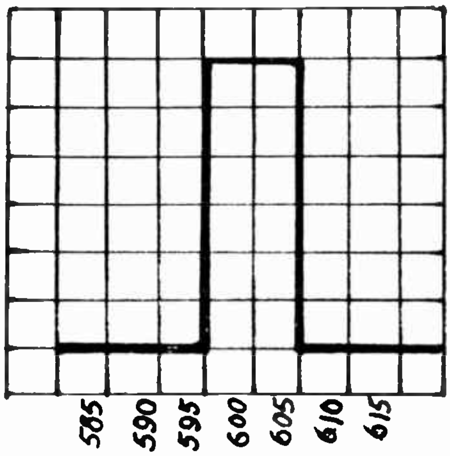


FIG. 1 PERFECT RESPONSE CURVE

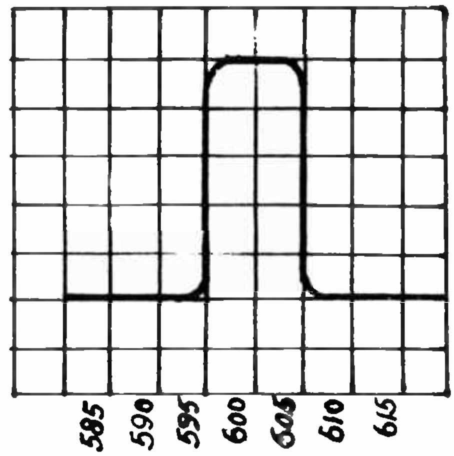


FIG. 2 BEST PRACTICAL RESPONSE CURVE

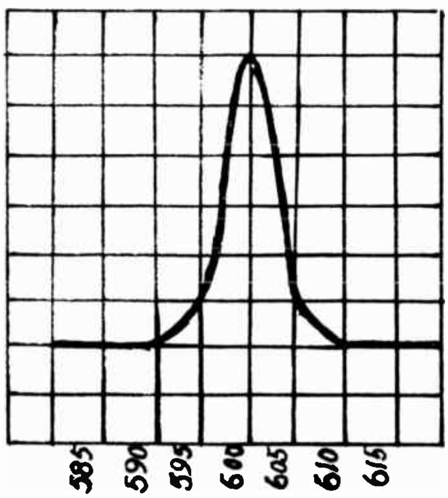


FIG. 3 POOR RESPONSE CURVE

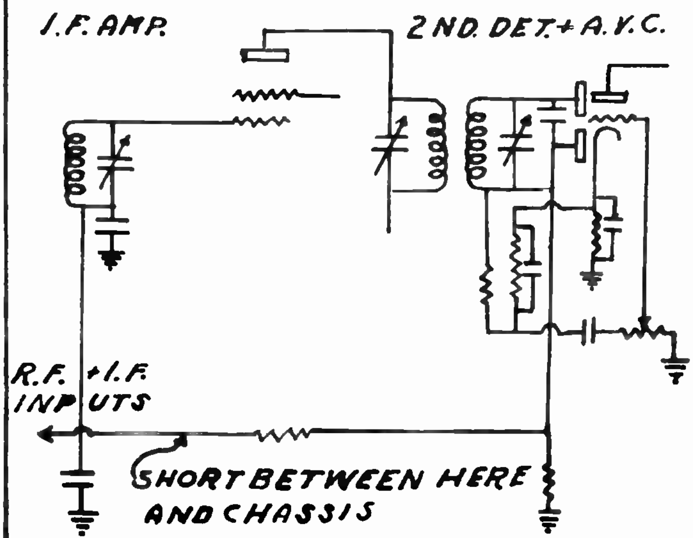


FIG. 4

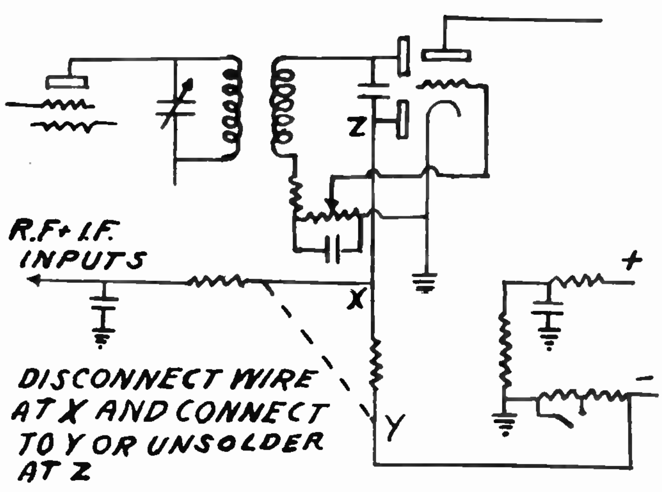


FIG. 5

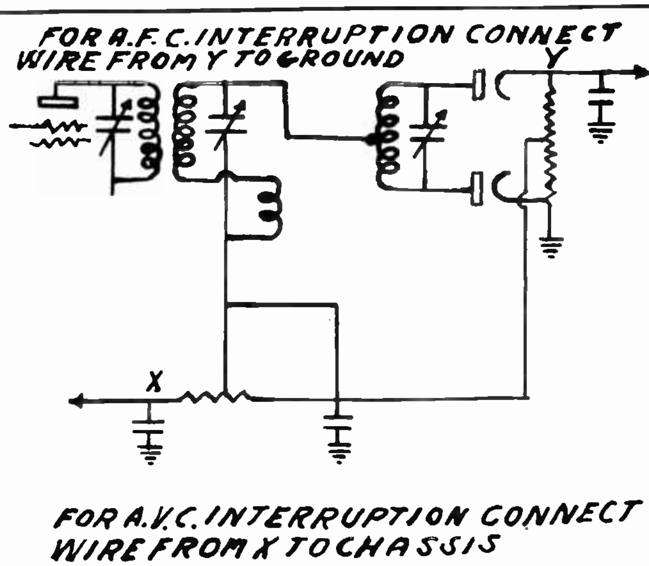


FIG. 6

Therefore, it is important that the serviceman know not only (1) that the set is working at peak sensitivity of I. F.'s and R. F.'s, but (2) its relative side-band acceptability because, if the set is tuned too sharply, it will cut off most of the radio program high audio frequencies. If it is tuned too wide, it will result in "side-band chatter" because it will also receive the high-frequency side bands of the adjacent radio channels.

To solve this problem, visual alignment was developed. This is a system of varying the R. F. frequency over a predetermined band width while keeping the amplitude of the signal constant. Thus, after peaking the receiver using the amplitude modulation method, we swing over to frequency modulation and finish the job by adjusting the set's acceptability curve to optimum. Remember, visual alignment is not a "cure-all." It will not make a set with poor I. F. design work like a high fidelity receiver. It will and does allow you to adjust each set to its maximum ability to perform properly.

For visual alignment work, you need a cathode ray oscilloscope as well as a signal generator. This relatively new service help will be mighty useful to not only in visual alingment but for (1) tracing hum, (2) checking I. F. amplifier overload, (3) checking second detector troubles, (4) checking A. F. distortion, (5) automatic frequency control adjustment, and (6) dozens of other uses.

The cathode ray scope is connected to the output of the receiver (usually in the second detector circuit) and takes the place of the output meter. The acceptability curve of the receiver is shown on the scope's screen and any adjustment of the receiver is reflected in a corresponding change in the scope's image.

PUTTING THE SIGNAL GENERATOR IN OPERATION

We will now explain the test procedure in using the signal generator for alignment work and will include as much explanation of theoretical background as we feel might be necessary.

First, connect the A. C. plug to a convenient A. C. socket and turn the power switch to the "ON" position. Allow the signal generator about 15 minutes to one-half hour to heat up before attempting to use. This is necessary to allow the tubes and parts to assume their stable operating temperature.

Many complaints of frequency drift are due to using the signal generator during its "worm-up" period. All test instruments are designed for a nominal room temperature of about 70 degrees and a normal humidity. When used in those section having abnormal temperatures or humidity conditions some consideration must be given to keep temperature and humidity as even and close to normal as possible. After the signal generator has "warmed up," plug the shielded lead into the "Output" jack and you are ready to align a receiver.

Most servicemen slip up in alignment work because they do not prepare the receiver correctly. The following hints should prove helpful.

First, we must stop the receiver's oscillator and to do this we connect a 0.5-mfd. capacitor between the oscillator grid and ground (or, this may be connected between stator of the oscillator tuning condenser and ground).

Next, if the set has A. V. C. action, this should also be temporarily disconnected or the signal generator's output held below the A. V. C. point. However, in some receivers which do not have delayed A. V. C. action, A. V. C. is present at any signal level and this may result in limiting the rectified voltage (at the 2nd dotoctor) to a value below that which will give a satisfactory scope image.

Due to the numerous types of A. V. C. circuits, no fixed ruling can apply. However, in sets having a separate A. V. C. tube, the tube can be removed during alignment. In most other circuits it is possible to connect a temporary shorting wire between ground and some part of the A. V. C. circuit. Other methods are shown in Figures 4, 5 and 6.

Where receivers incorporate other special control circuits (R. F. noise suppressors, automatic frequency control, etc.) this circuit should also be interrupted. See examples in Figures 6 and 7. In some models, a switching arrangement is included to change over from A. F. C. to manual tuning and in those cases, just place the switch in "manual." Also, in some models a "Q" on-off switch is included and this should be in open position.

It should always be remembered that when shorting out portions of radio receiver circuits, care should be exercised that D. C. set voltages are not changed or interupted.

CONNECTING THE GENERATOR FOR PEAKING THE I.F.'s

Our first problem is to peak the I.F. stages of the receiver under test. To do this, find the I.F. frequency and assuming it is 175 K.C., set the "Range Selector" switch on the oscilloscope to "A" and turn the dial knob until the "175" marker is right over the hair line shadow. The next step is to turn the "Output Selector" switch to "Amp." which results in a 400 cycle audio modulated 175 K.C. signal being available at the "Output" jack. (Similar instructions apply to other make signal generators.)

Connect the output of the generator to the receiver's first detector grid circuit. Be sure to remove any connections to this grid circuit from the previous R.F. coil because its low impedance might act as a shunt. Also, any radio signals received through the R.F. stages might beat with the test oscillator to produce spurious beat notes if this is not done.

Care must be exercised when aligning AC-DC receivers, as the chassis is very seldom at ground potential and it is quite possible, when connecting the oscillator to the first detector circuit, to damage the attenuator resistor. This possibility can be eliminated by including 0.5 mfd. condensers in series with both the inner lead and the outer shield lead from the oscillator and a 100,000 ohm resistor connected across the condensers as shown in Figure 10.

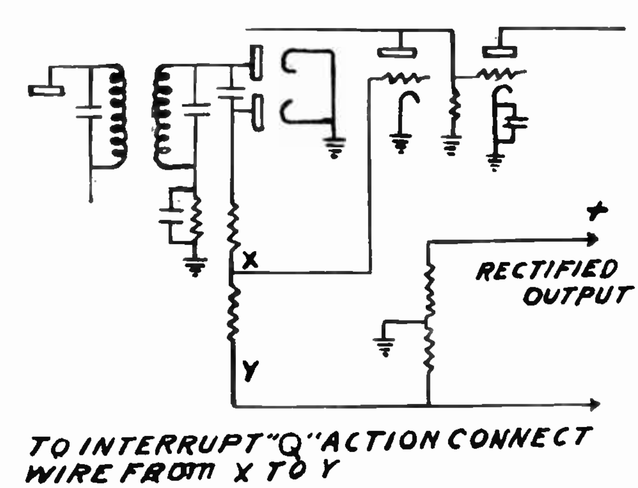


FIG.7

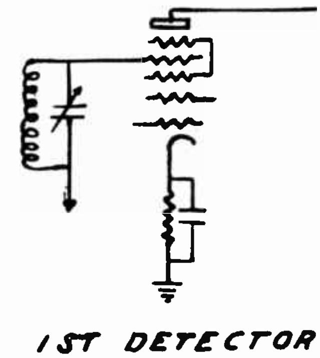


FIG.8

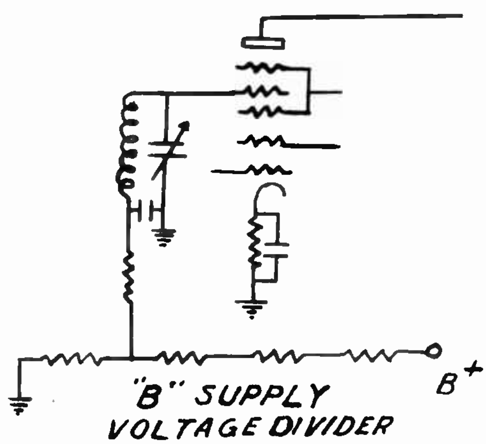


FIG.9

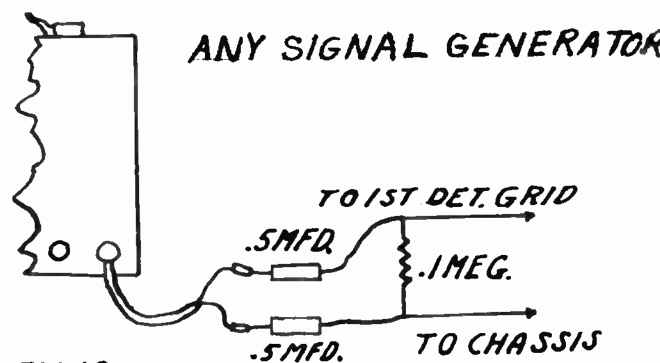


FIG.10

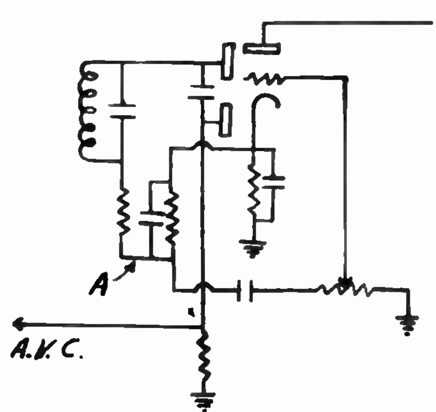


FIG.11

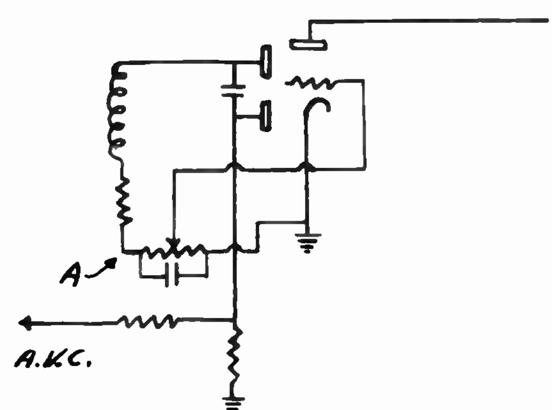


FIG.12

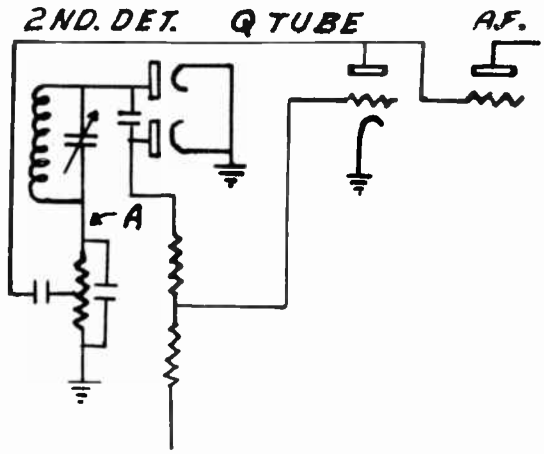


FIG. 13

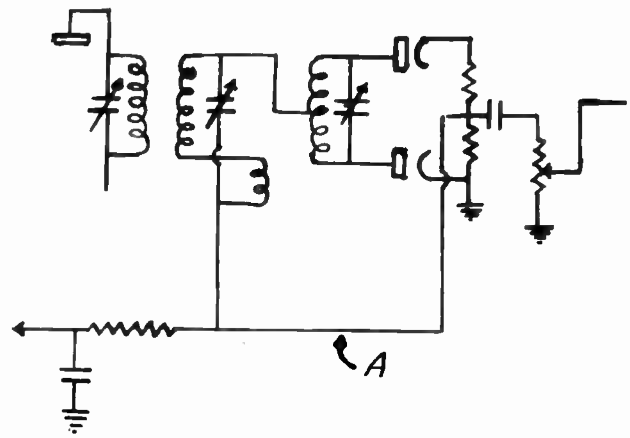


FIG. 14

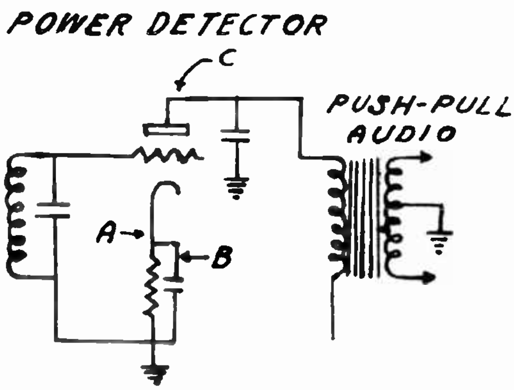


FIG. 15

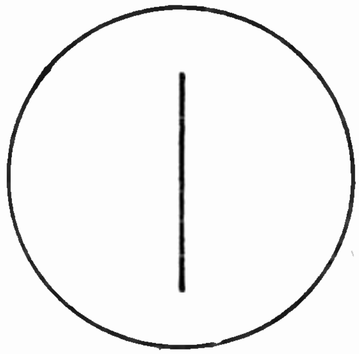


FIG. 16

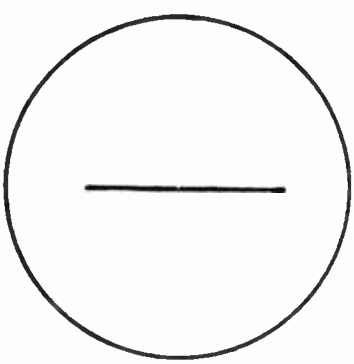


FIG. 17

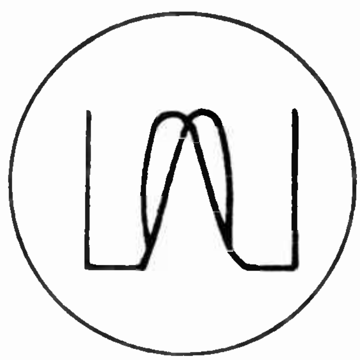


FIG. 18

CONNECTING THE SCOPE TO THE RECEIVER

Next, the scope should be connected to the A. C. supply, turned on and its vertical amplifier circuit connected to the proper place in the receiver's 2nd detector circuit. The exact connections once more depend on the receiver to be aligned and several types of connections are shown in Figures 11, 12, 12 and 14. The ground of the scope is connected to the receiver's chassis and the scope's vertical input jack connected to "A" in the various circuits shown.

In receivers using power detection (where the tube is biased to cut-off), a somewhat different arrangement must be made. (See Figure 15.) First, the wire running from the detector plate to the audio transformer should be disconnected ("C" in Figure 15.) Then, the capacitor across the cathode resistor should be disconnected at "B" and finally, the vertical amplifier connection made to "A." This, temporarily, converts the second detector from a biased to a diode detector.

The last connection is to run two leads between the "Time Base" pin jacks on the scope and the horizontal amplifier pin jacks on the scope. The vertical gain on any scope should be rotated wide open for alignment. All radio receiver controls which may affect the gain of the signal should also be left full on as the only proper place to control gain during any visual alignment test is at the signal generator.

If the signal generator is tuned to the I.F. frequency with all connections correctly made and the I.F. stages are not too much off, a 400 cycle audio tone will be heard in the speaker. At the same time you should have a vertical line on the scope such as in Figure 16. Next peak the I.F. transformers for maximum length of the line on the screen. If this line goes off screen during the adjustments, retard the signal generator multiplier and attenuator controls untill the line is again about 1 inch long.

Next change the output selector switch of the generator to "Freq." This will produce a 120 cycle note in the speaker. Rotate the horizontal gain control on the scope untill a 2 inch line results. See Figure 17. With all connections made, the alignment curve should appear on the screen without having to change anything else. Re-adjust the I.F. controls for the best possible band-pass working from the second detector backward

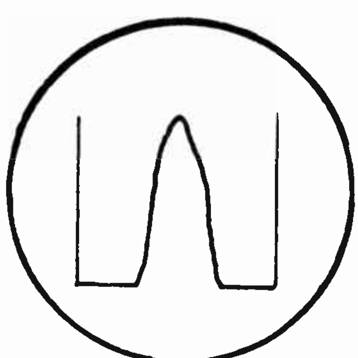


FIG. 19

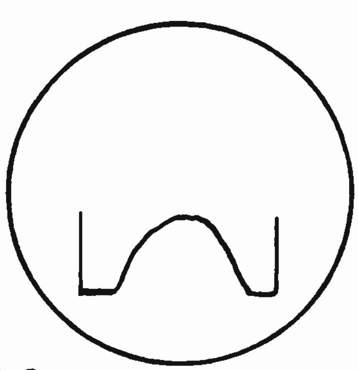


FIG. 20

REVIEW QUESTIONS

1. What area does a three inch cathode ray tube have?

2. Why is an amplifier included in the oscilloscope?

3. What happens to the electron beam when the focus control is turned?

4. Why must the oscilloscope be synchronized externally at times?

5. What happens if the spot is left in one position?

6. Name the different kinds of sweep circuits?

7. How can an unknown voltage be measured on the oscilloscope?
   If an A.C. voltage is being measured, will the peak or R.M.S. voltage be indicated?

8. How was alignment performed in the early days of radio?

9. What is an ideal response curve?

10. Why is it easier to align a set properly with a scope than with just an output meter?

11. What is the purpose of the audio tone in the signal generator?

12. Name as many applications of the oscilloscope as you can?

On the left is illustrated a Triplett signal generator. Below is the photograph of Weston recent model. This unit has been prepared to serve all regular needs as well as for television.

LESSON 14

Audio Amplification
Public Address
Loudspeakers
Microphones

Principles of PUBLIC ADDRESS SYSTEMS

When a large group of people is to be served with a common program, public address equipment finds its application. Most often a speaker's voice is amplified to a suitable volume to make him audible to all present. Radio programs and phonograph records also serve as a means of the input. If the program originates some distance from the amplifier a line is used to connect it to the input. In talking picture work a photo-cell serves as a means of input and requires a special amplifier.

Essentially a P. A. system consists of one or more of the sources of input mentioned above, the amplifier or any pre-amplifiers necessary, and the output in the form of one or more loud speakers so placed as to take the greatest advantage of the acoustics. These various parts of P. A. systems will be taken up in detail with additional data on volume controls and measurements of related factors.

CARBON MICROPHONES

A microphone is a machine for transforming the sound waves into corresponding electrical energy. How truthfully it performs this task is the test of its excellency. By far the most common microphone in P. A. use is the two-button type. Being a carbon microphone it depends for its operation on the varying resistance of the carbon granules with the pressure of the wave produced by sound which strikes the diaphragm. As the diaphragm fluctuates, corresponding fluctuations in the resistance of the carbon occur and vary the current passing through. In the two-button microphone, one button is placed on each side of the diaphragm and so operate exactly out of phase. This electro-acoustical push-pull arrangement cancels out the even order harmonics.

The thin metal diaphragm will resonate at a certain frequency and cause an increased output at this frequency. The better grade microphones have their diaphragm stretched so that resonance occurs at the upper end of the audible frequency range. This may be further reduced by air damping. The output of a two-button microphone is in the order of -40 DB, and the impedance is commonly 200 ohms per button and a transformer is used to couple the microphone to the load.

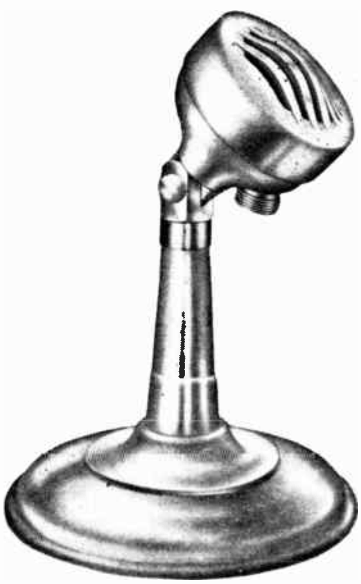
CONDENSER MICROPHONES

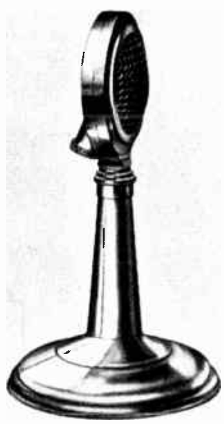
Somewhat superior response characteristics are possessed by a condenser microphone. If a variable condenser is connected to a source of potential, the charging current will vary with changes in capacity. The diaphram of a condenser microphone constitutes one of the plates of the condenser, while the back plate acts as the other plate. The capacity so formed is in the order of 200 micro-microfarads, and the maximum variation in capacity is only 0.01 per cent.

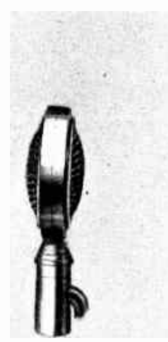
Into the head of the condenser microphone is built-in a two stage resistance coupled amplifier to bring the output signal strength up to that of a two-button microphone. Batteries are usually employed as the source of condenser potential and for filament and plate supply of the pre-amplifier.

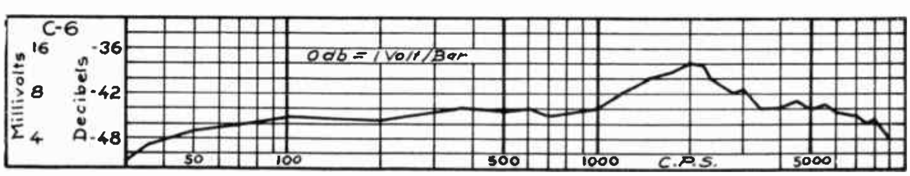
CRYSTAL MICROPHONE

The crystal microphone employs a piezo-electric crystal as a generating element. A crystal when subjected to stresses of sound waves produces corresponding electrical changes in current generated by the crystal element. The output level of a crystal microphone is, of course, much lower than that of a carbon microphone, usually in the order of -60 db., and requires either a suitable pre-amplifier or a main amplifier of a high gain type. The crystal microphone has absolutely no background noise and the response is not effected by the position of the microphone not by reason of moving it about while in use.







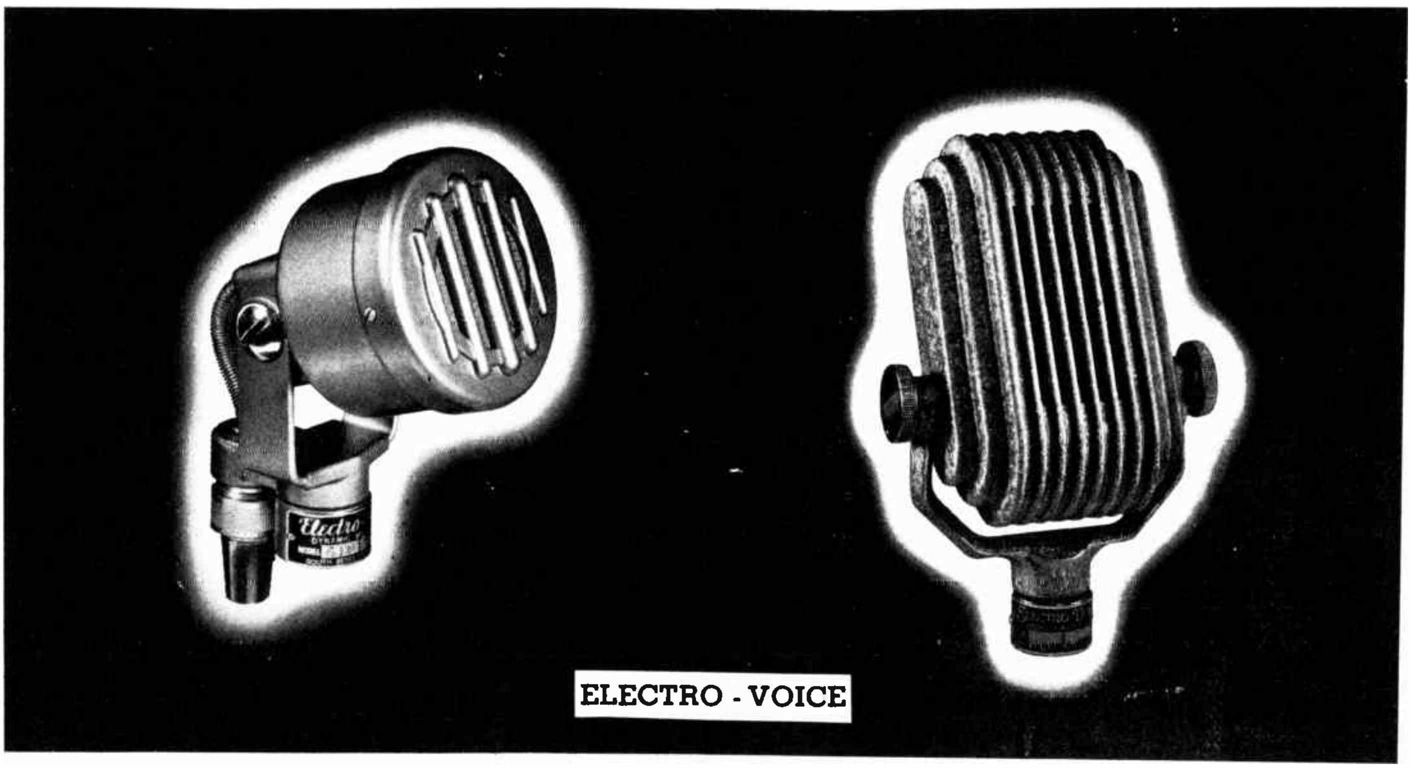


American Microphone units

VELOCITY MICROPHONES

The velocity microphone has been but recently developed and because of its excellency over the other types is finding extensive application in better public address equipment. Velocity microphones have an output of about the same value as the output of crystal type and may be obtained in high impedance types for direct coupling to the control grid of vacuum tubes.

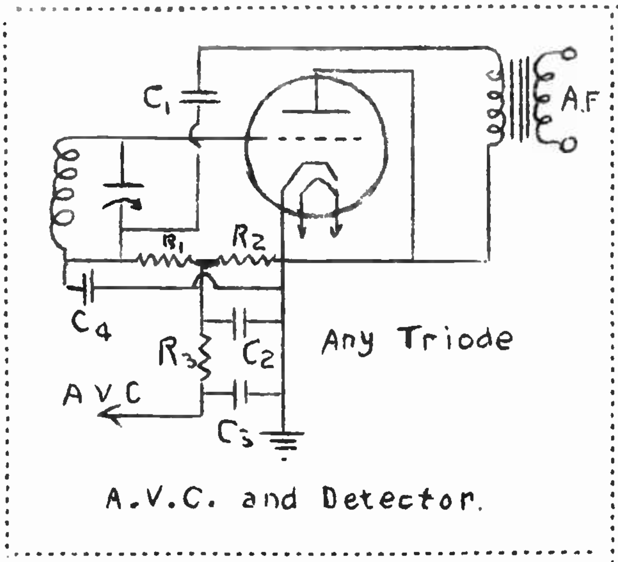
The velocity microphone has highly directional qualities and will not pick up background noises. This greatly assists in reducing the possibility of reproducing undesireable noises. This type of microphone further has no internal "hiss noises" and possesses quite flat response characteristics over a wide audio frequency band.

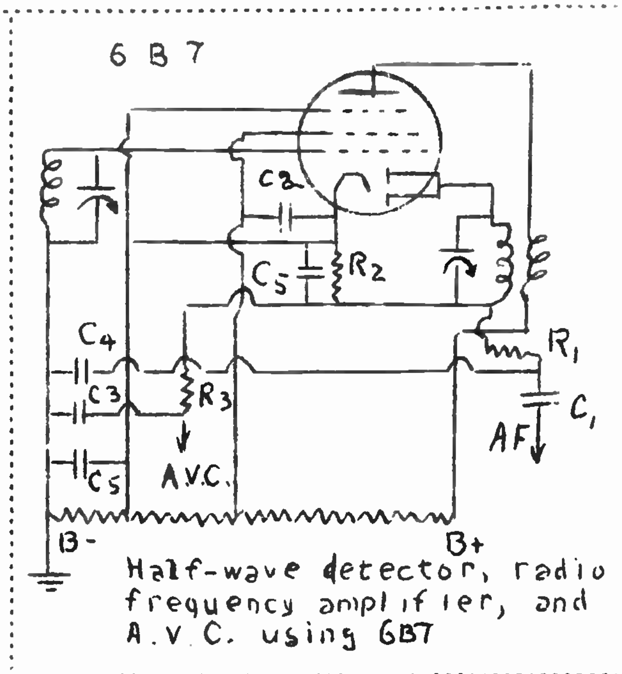


Microphones in general are mounted on suitable floor or table stands. Ring and spring mounting is used for carbon microphones while other types screw directly on the stand.

RADIO INPUT

As a means of radio input an ordinary tuner is utilized. This may be of the tuned radio frequency type or a superheterodyne. The latter is preferred because of its better selectivity. An automatic volume control is essential as a powerful local may literary blow the people out of the hall before the manual control is adjusted. The second detector should be of the diode type as no further audio frequency amplification outside of the final P. A. amplifier is needed. If a triode tube is used the plate should be connected to the cathode for diode operation. Two A.V.C. circuits are illustrated below.



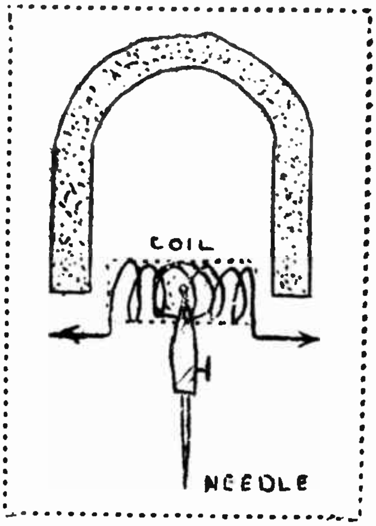


Parts used:

R_1 = 150,000 ohms
R_2 = 250,000 ohms
R_3 = 500,000 ohms
C_1 = 0.25 mfd.
C_2 = 0.5 mfd.
C_3 = 0.1 mfd.
C_4 = 0.0001 mfd.
C_5 = 0.00015 mfd.

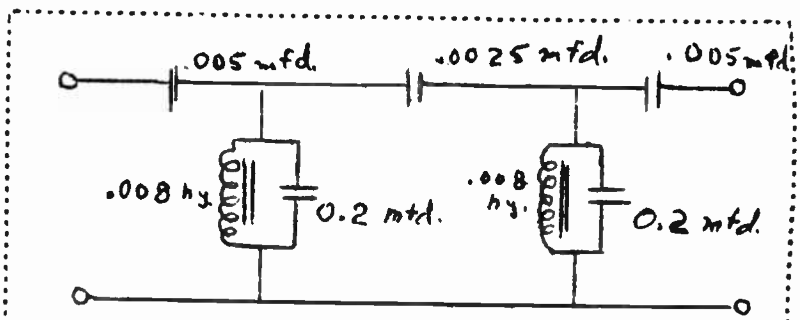
PHONOGRAPH INPUT

Phonograph records are of two varieties depending on the speed they are to be revolved. The 33 1/3 R.P.M. records are longer playing than the 78 R. P. M. Motors are obtainable that rotate at the two speeds mentioned. This with a pickup for the two types makes an ideal combination, serving any record requirement that may come up. The difference in pressure may be made up by a removable counter-balance. Impedance of the pick-up arms vary considerably, some of the more common sizes being: 200, 2,000, and 9,000 ohms. The practice is to match this impedance to the load by means of a suitable transformer.



A pickup arm may consist of a permanent magnet within which is pivoted a coil of wire directly connected to the needle. As the needle works along the groove of a record, the uneveness of the grooves sets the needle in vibration. The needle being connected to the coil by mechanical means, the motion is transformed to the coil which in moving cuts the lines of force of the permanent magnet. A current is set up in the coil. This current corresponds to the recorded sound. Crystal pickups working on a different principle are also used.

One of the difficulties encountered in phonograph reproduction is needle-noise. This may be removed to an extent where it may be considered negligent by means of a band filter. This is possible because the noise is of a limited frequency, usually about 4,000 cycles per second. A suitable filter for this frequency is show schematically below. One must bear in mind that this filter will not only reduce the needle-noise, but will also reduce amplification at this frequency. However, this fault is less noticeable; the human ear being less critical for what is missing than for what is present.

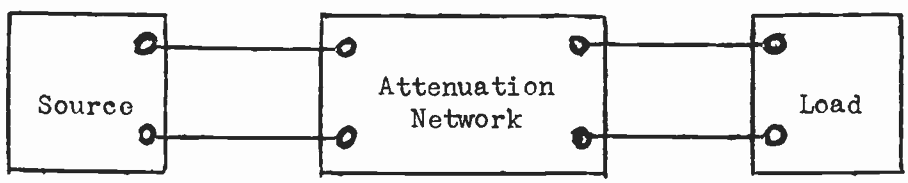


Band Filter. 3,950 - 4,050 cycle range.
Input and load impedance 17,000 ohms.

If the source of input is some distance from the amplifier a line is used for transmission purposes. It is advisable to use shielded cable for this purpose, thereby reducing the chance of picking up stray currents. Usually by means of transformers the impedance of the connecting line is made equal to 500 ohms.

VOLUME CONTROL and MIXING

Where the audio power must be reduced in the audio amplifier, this is accomplished with the aid of attenuation networks built up of resistive branches. All circuits possess capacity, inductance, and resistance. Of these three only resistance does not change over wide limits of frequency and, therefore, must be adapted in the circuit for the purpose of reducing the volume. With this in mind we may consider for practical purposes an attenuation network to consist of a combination of resistance elements, with one or more variable units. These resistance elements are used to introduce a power loss of value between certain limits when placed in the circuit between some fixed values of input and output impedances. Occasionally circuits are encountered where either or both the input and output impedances are in such a relation to the circuit that variations over wide limits in their impedances will not make a material difference in the operation. Under such conditions one or both of the impedances may be neglected in designing the volume control.



Relation of Attenuation Network to Source and Load

Irrespective of its application, an audio amplifier is used to amplify the frequencies of the audible range. It is possible without imposing too drastic complications to design public address amplifiers to reproduce faithfully to a marked degree audio frequencies between approximately 50 and 10,000 cycles.

USE OF VACUUM TUBES

Audio amplifiers are entirely dependant upon the use of the vacuum tube as an amplifier. This use falls into two classes (1) where voltage amplification is the object, and (2) where power output with little distortion is desired. Power tubes used in the last stage of an amplifier are of this latter type. Tubes preceding the power stage are primarily voltage amplifiers, with the exception of the driver stage in class "B" type amplifier which must also supply power to the grids of the last stage. The transformer connected between these must be design carefully and possess high efficiency.

The amplification ability of the tube is due to the nature of the construction which causes a small grid potential change to have the same effect upon the plate current as a much larger plate potential change. The ratio of the change in the plate voltage (E_p) to the change in grid voltage that will vary the plate current (I_p), by an equal amount is called the amplification factor, or the Greek letter μ.

INTERSTAGE COUPLING

The current change in the plate circuit may produce a voltage variation across a resistance, a high impedance, or the impedance of the primary of an audio transformer. With a transformer it is possible to step up the voltage by a small ratio in the order of 3 to 1, or less. Higher ratios will demand a great deal of inductance for the secondary which will result in large capacity between the turns. This capacity would act as a shunt for high frequencies. Transformers at best can only give partially true reproduction, but may be designed to give only negligent variations in the needed audio range.

With the advent of high gain amplifiers, use of resistance coupling between stages is becoming more and more in vogue, while impedance coupling finds but little present day application. The advantage of direct coupling has been surpassed by the high gain tubes. If the plate current is passed through a high resistance connected between the plate and the positive side of the "B" supply, voltage variations are produced in proportion to the changes in the plate current. The voltage drop distributes itself in proportion to the resistance of the tube (r), and the load (R). The voltage amplification is a fraction of μ expressed by the relation:

$$\text{Voltage Amplification} = \frac{\mu R}{R + r}$$

From the above relation it is seen that as the load increases, voltage amplification will approach the amplification factor. The value for best results is usually suggested by the tube manufacturer. The voltage variations are coupled to the grid of the next tube through a condenser of suitable size. This size may be found approximately from the formula below, where R_g is the grid coupling resistor of the following tube. All resistances are in ohms.

$$C = \frac{0.04(R + r)}{R_g(R + r) + rR} \text{ farads}$$

The grid resistor serves to release the electrons that may have accumulated on the grid. If this resistor is made small very little voltage will be impressed upon the grid, if unreasonably large, it will not free the electrons and cause blocking. A suitable value is suggested by tube manufacturers.

The grid of a tube is biased sufficiently negative that from the practical point of view no current flows in the grid circuit and no power is consumed there. The grid resistor does use some power which may be calculated.

Although a certain amount of power amplification always takes place, our primary consideration until now was in regards to voltage amplification. However, the last stage of the P. A. amplifier must transmit power and not merely voltage to the loud speaker. Usually power tubes are used for this purpose.

POWER AMPLIFIERS

A tube of the triode type is used in the output stage as a class "A" power amplifier to supply large power with little distortion to the loud speaker. To accomplish this power sensitivity is sacrificed. The pentodes have comparatively high power sensitivity, but add considerably to the distortion.

Distortion arises from operating the tube over the curved part of its characteristics. It usually resolves itself into harmonics. Of all the harmonics the second are of the greatest magnitude. The push-pull amplifier by cancellation reduces the even order harmonics to a very negligable figure, requires less filtering of its plate supply, and permits somewhat larger input voltage without causing distortion due to overloading.

In class "B" operation the tubes are biased or designed with a sufficiently high amplification factor to cut off the plate current with no input signal. When a signal sufficient to swing the grid is introduced, the negative portion of the cycle will add only to the bias and, therefore, plate current will flow only during the positive half of the cycle. A large amount of even order harmonics will of course be produced. However, by using two similar tubes in a balanced circuit the harmonics may be eliminated from the output. Since at times the grids are driven positive, the preceding stage must be capable of supplying the power drawn by the grids under this condition. This is accomplished by using for a driver stage a class "A" power amplifier of suitable size, coupled by a transformer possessing the proper characteristics. The transformer is usually of the step down type.

With class "B" it is possible to obtain high power output with comparatively small tubes operating at ordinary plate potential. Since very little power is consumed with no signal, economy is another advantage. To offset these, the distortion present is always somewhat larger than for the same power for class "A" operation and the power supply must have very good regulations to maintain proper operating voltage with considerable current variations.

Many modern amplifiers employ output stages using tubes in an arrangement intermediary between class "A" and class "B" commonly called Class "A prime", or Class "AB". On low signals the circuit behaves as a class "A", while on powerful signals the class "B" action allows the handling of large power. In this manner the advantage of both classes are combined in a happy medium.

ADVANTAGES OF INVERSE FEEDBACK

A beam power amplifier to be truly modern should incorporate inverse feedback. It is a commonly recognized fact that low plate resistance tubes such as the 2A3 are superior from the standpoint of low distortion and good quality. With inverse feedback the high plate resistance beam power tube may be made to take on the characteristics of the low-mu triode, yet retain most of its high power sensitivity. The important advantages obtained by the use of inverse feedback are fourfold: first, reduction of wave form distortion; second, improvement of frequency response; third, reduction of hum; and fourth, reduction of "hangover" effect. The only disadvantage of inverse feedback lies in the fact that the gain is considerably reduced.

EXPLANATION OF INVERSE FEEDBACK

In the circuit of Fig. 1, a certain amount of the voltage developed in the plate circuit is fed back out of phase with the signal in the grid circuit. If without inverse feedback a certain voltage E_0 is developed across the output circuit with an input voltage E_1 the gain of the stage is E_0 divided by E_1. If now a certain percentage N of the voltage E_0 is fed back to the grid circuit in such a way that the voltage is out of phase with the input voltage E_1 the total input voltage to obtain an output voltage of E_0 is $(N E_0 + E_1)$ and the gain of the stage is $\frac{E_0}{(N E_0 + E_1)}$. The ratio N is the percentage of the output voltage which is fed back to the input circuit. It may be readily seen that if N is large the gain of the stage depends more upon N than upon the circuit constants.

The ratio reduction in gain by the addition of inverse feedback may be readily determined by dividing the gain without feedback by the gain with feedback.

REDUCTION OF DISTORTION

As was pointed out in the above paragraph, an inverse feedback circuit feeds back a certain portion of the output voltage to the grid circuit. If distortion is introduced in the amplifier stage a certain amount of the distorted voltage will be fed back into the grid circuit and this will tend to cancel out the distortion developed in the amplifier stage. If in the circuit of Fig. 1 a certain amount of distortion voltage B is present in the output circuit the distortion voltage fed into the grid circuit will be N x B and this quantity multiplied by the gain of the stage will give the cancelling effect of the inverse feedback. The total distortion present in the output is then equal to the sum of the distortion without inverse feedback and the distortion cancelled by the inverse feedback. In other words, if b is the distortion without inverse feedback, the total distortion, B, with inverse feedback is equal to (b + B) x N x A, where A is the gain of the stage. Evaluating B gives the quantity $\frac{b}{1 + NA}$. In other words the distortion is reduced by the ratio of $\frac{1}{1 + NA}$.

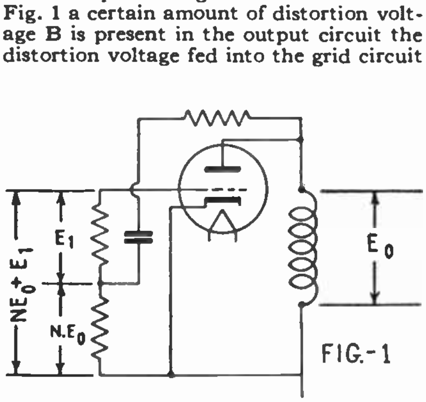


FIG.-1

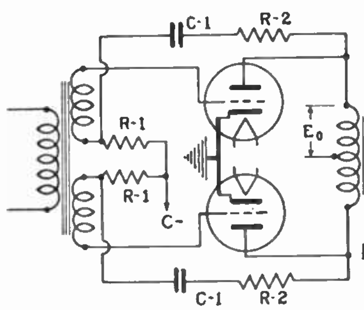


FIG. 2

Fig. 2 shows the ordinary method of obtaining inverse feedback with the resistor-condenser method. The amount of inverse feedback is equal to $\frac{R_1}{R_1 + R_2}$ assuming that the reactance of the condenser C_1 is negligible over the operating frequencies. However, this assumption is not necessarily true especially at the lower frequencies and the circuit of Fig. 3 is much more efficient from this standpoint. In Fig. 3 the feedback voltage is obtained from a tertiary winding on the output transformer. This method also provides a much better overload characteristic since the resistance in the grid circuit is negligible and it is quite possible to operate the tubes in the grid current region.

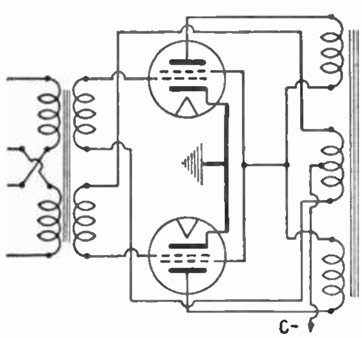


FIG. 3

REDUCTION OF PLATE RESISTANCE

In addition to the reduction in distortion obtained by inverse feedback, there is also a reduction in the plate resistance of the tubes. A high plate resistance is a definite disadvantage in the case of a power tube which operates into a speaker load which is more or less variable depending upon the impedance of the voice coil. In the circuit of Fig. 4, it may be easily seen that the voltage E developed across the load depends a great deal upon the actual value of R_L which is the reflected impedance of the voice coil. This is due to the fact that the signal current depends almost entirely upon the high plate resistance of the tube. Since the load resistance is low in comparison to the plate resistance, the voltage developed across the load is almost directly proportional to the impedance of the load which varies appreciably with change in frequency. In Fig. 5 it may be seen that the voltage across the load does not vary so much since the signal current depends both upon the load and upon the plate resistance of the tube. If the voice coil has an appreciable amount of reactance the impedance rises with the frequency causing distortion and giving an unnatural amount of "highs." The high plate resistance is unsuitable from another view point, that of the amount of low frequency distortion which may be tolerated. This low frequency distortion is not

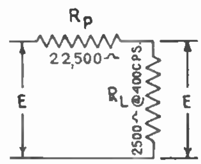


FIG. 4

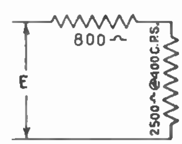


FIG 5

due to the characteristics of the tubes which remain unchanged regardless of the frequency, but depends upon the magnetizing current in the output transformer. The magnetizing current is a distorted non-sinusoidal wave and this current, on flowing through the high plate resistance of the tube, develops a nonsinusoidal voltage drop across the tube which, when subtracted from the input signal, results in a distorted wave across the output. Unfortunately, most amplifiers today are measured for distortion at 400 c.p.s. where the magnetizing current is practically negligible. It is not uncommon to find beam power amplifiers without inverse feedback which have only 25 per cent of the rated power at 40 or 50 cycles. This low frequency distortion is particularly objectionable since all harmonics fall within the audible range. Inverse feedback effectively reduces the plate resistance so that the distorted voltage drop caused by the magnetizing current is exceedingly small with the result that there is very little distortion across the output circuit. With a poor output transformer it is quite possible for the distortion to be as high as 30 per cent at 40 cycles without inverse feedback.

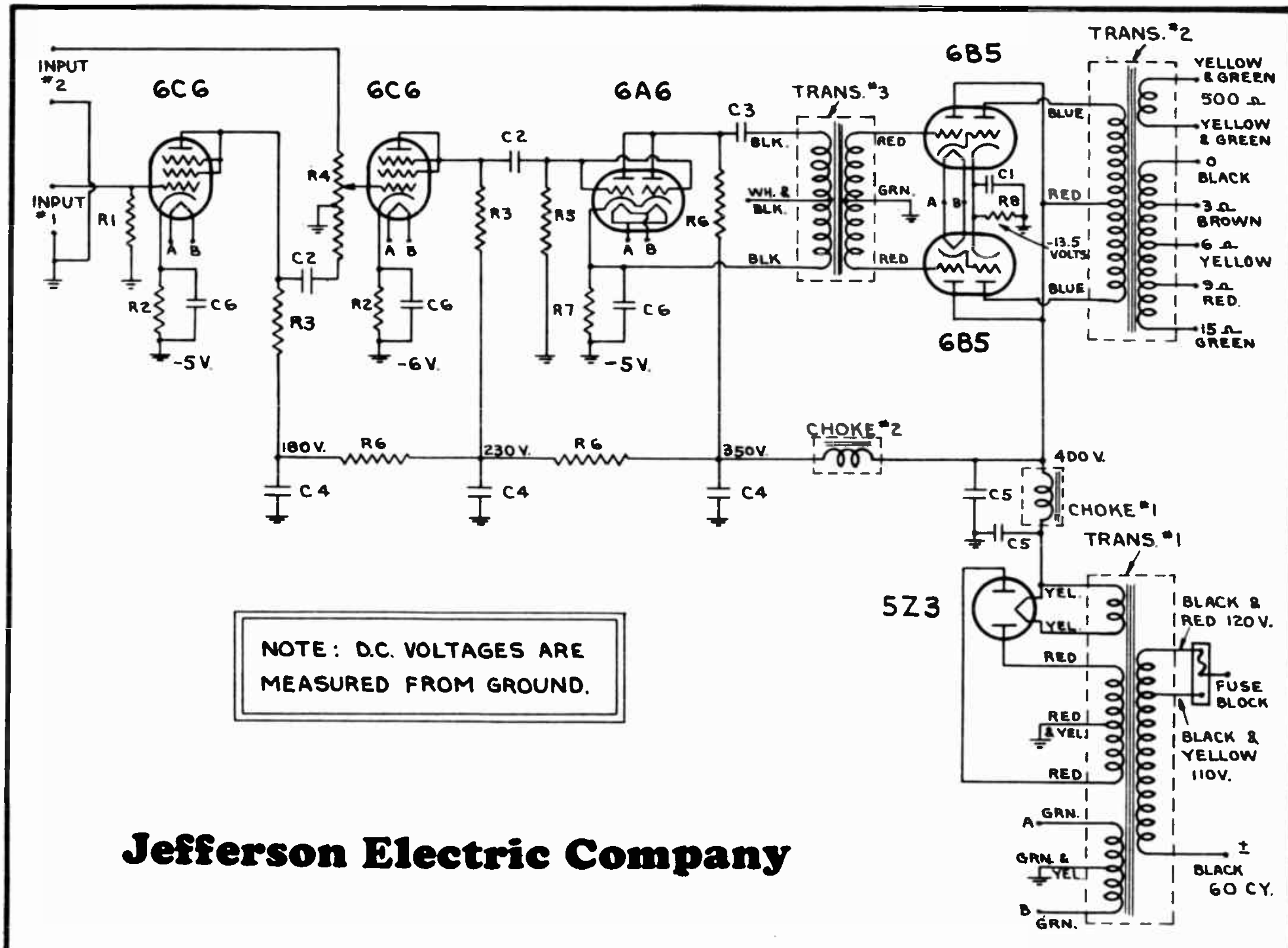
"HANGOVER" EFFECT

"Hangover effects," or transients caused by the loud speaker cone vibrating at its natural period when shock excited, are greatly reduced by the use of inverse feedback. The lower plate resistance provides a considerable amount of damping so that the oscillations or transients are reduced. With regular beam power tubes the shunting effect of the tube is exceedingly small with the result that the damping is negligible. As a result, unnatural "boominess" may result when the speaker is shock excited and the cone vibrates at its own natural period. The natural period depends upon the physical construction of the speaker and is usually in the neighborhood of 50 to 150 cycles.

HUM

Hum in the output stage is cancelled out in much the same way as distortion, since the hum developed in the stage and the voltage fed into the grid circuit are out of phase and tend to cancel. It must be remembered, however, that distortion not appearing in the stage or hum from a previous stage will not be cancelled by inverse feedback in the output stage. Great reductions in plate circuit distortion and plate resistance may be obtained by the use of large amounts of inverse feedback. However, the limiting factor in inverse feedback is the amount of desired gain from the stage in question. In actual design the amount of inverse feedback is a compromise between the gain and the desired reduction in distortion. If there is enough gain in the previous stages and if the driver tube can supply the necessary peak voltage, it will be advisable to increase the amount of inverse feedback in order to reduce the plate resistance and the plate circuit distortion. However, if the plate resistance is fairly low and if the plate circuit distortion is a reasonable value, there is not much advantage gained in further reducing the gain by the addition of more inverse feedback.

JEFFERSON 20 WATT P.P. 6B5 AMPLIFIER CIRCUIT



JEFFERSON PRODUCTS

TRF. #1	Cat. No. 463-501	Power	1 Reqd.
TRF. #2	Cat. No. 467-460	Output	1 Reqd.
TRF. #3	Cat. No. 467-454	Input	1 Reqd.
CH. #1	Cat. No. 466-300	Choke	1 Reqd.
CH. #2	Cat. No. 466-380	Choke	1 Reqd.
Base	Cat. No. 469-109	Chassis	1 Reqd.

RESISTORS

R1	5 Megohm 1 Watt	1 Reqd.
R2	3,000 ohm 1 Watt	2 Reqd.
R3	50,000 ohm 1 Watt	2 Reqd.
R4	1 Megohm center tapped potentiometer	1 Reqd.
R5	500,000 ohm 1 Watt	1 Reqd.
R6	30,000 ohm 1 Watt	3 Reqd.
R7	1,000 ohm 1 Watt	1 Reqd.
R8	140 ohm 3 Watt	1 Reqd.

CAPACITORS

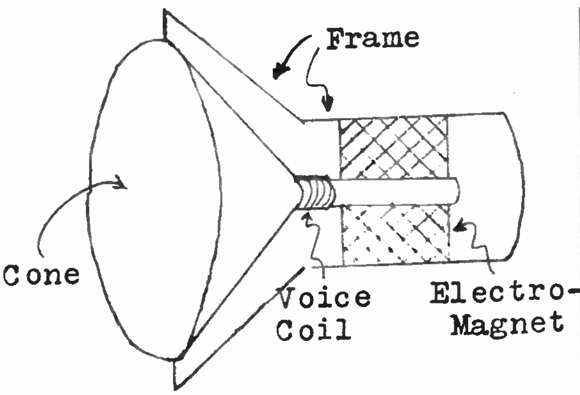
C1	25 MFD.	50 V.	Electrolytic	1 Reqd.
C2	0.05 MFD.	400 V.	Paper	2 Reqd.
C3	0.25 MFD.	400 V.	Paper	1 Reqd.
C4	2 MFD.	400 V.	Paper	3 Reqd.
C5	8 MFD.	500 V.	Electrolytic	2 Reqd.
C6	10 MFD.	30 V.	Electrolytic	3 Reqd.

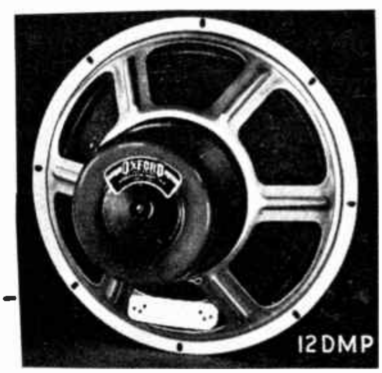
Electrodynamic & Magnetic Speakers

After the audio signal in electrical form is amplified, it must be changed to sound. It is the task of the loudspeaker to change electrical energy to acoustical energy. At the present time loudspeakers commonly employed are: Magnetic types, Permanent Magnet (P.M.) types, and electro-dynamic types. The electro-dynamic type may be of the D.C. excited type or may be A.C. operated.

In a magnetic type speaker, the cone which sets up the sound waves is attached to a coil by means of a mechanical rod. This coil is in the field of a powerful permanent magnet and is connected to the source of the audio output. Electrical impulses cause this coil to move and the motion is transmitted to the cone.

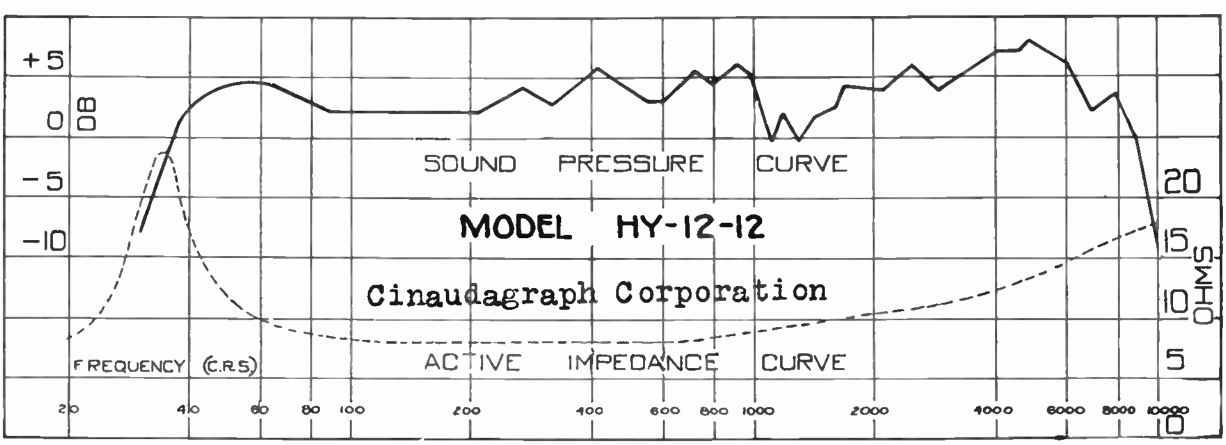
The magnetic speakers have coils of correct impedance for directly matching the output tubes and, therefore, do not require any matching transformers. Such speakers find application in battery operated sets and extension speaker use.





In the dynamic speaker a small cylindrical coil (voice coil) is attached to a paper cone. The coil is suspended in a strong magnetic field and carries the impulses from the radio setb or amplifier's output. The voice coil will move in accordance with the signal and will vibrate.

The chart below will give you an idea of the response of a good quality 12 inch speaker. Also notice the dotted curve which indicates the change of the voice coil impedance.



LOUDSPEAKER SELECTION AND PLACEMENT

In all Public Address installations, loudspeakers are more than just an accessory of the system; they must be considered as the all important devices used to convert the electrical audio output to the needed acoustical energy -- sound. The speakers of any well matched sound system are selected with care so that the response characteristics and power handling ability will give the desired results with the associated equipment. But the proper placement of the speakers and the use of correct baffles or directional horns is necessary to permit the P.A. engineer to secure the best results from the sound system in any particular installation. Just as poor placement of speakers may ruin the response from the highest quality equipment, so can moderate cost equipment be made to perform wonders when the speaker placement is correctly made along scientific lines.

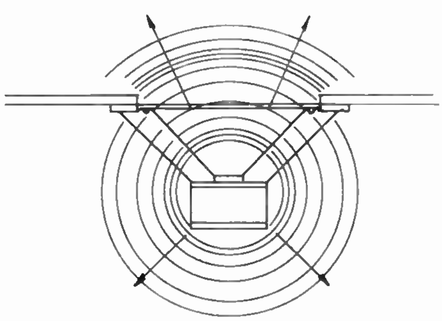


Figure 1. A cross section of a speaker mounted in a baffle. Note how the baffle prevents the inter-action of the waves set up by the front and rear of the cone.

The speakers must always be used with some form of baffle to prevent the tendency of the front and rear sound waves from cancelling-out each other. (Fig. 1) If the baffle were omitted, sound compression produced in front of the speaker cone, when the cone moves forward, would cause the air to rush around the edges and relieve the rarefaction in the rear. To be equally effective to the middle and lower frequencies a baffle must be fairly large. In practice a 6" or 8" speaker will require a baffle with 40 inch sides.

A speaker mounted in a flat baffle made of ply-wood, celotex, or masonite will radiate sound almost uniformly in all directions. If the installation requires the projection of the sound forward, directional flares or special horn baffles must be employed. The Oxford Exponential Horn XA22 is ideal for this purpose. It gives the desirable directional effect, and has great volume-handling ability. (These exponential horns are supplied with either Permag or electrodynamic trumpets).

NUMBER OF SPEAKERS TO USE

In average installations it is best to use one or two speakers. A single speaker such as Oxford type 110C or 11WMP will serve in class rooms, hallways, small stores, and in almost all other installations requiring less than 10 watts of power. For auditoriums, churches, gymnasiums, dance halls, two speakers of good quality should be able to handle the audio volume from amplifiers supplying 15 to 35 watts. These speakers must have a conservative power handling capacity of at least 18 watts each. For use with amplifiers supplying greater power, employ directional trumpet speakers or at least four well made 12 or 14 inch dynamics (such as Oxford types 12D or 14D).

PLACEMENT FOR NATURAL RESPONSE

The speaker location is selected with two objectives in mind: (1) to make the program sound natural to all present, and (2) to reduce the possibility of acoustical feedback. The loudspeakers should be placed so that sound originating from the actual source (be it a singer or a complete orchestra) and the sound emitted by the loudspeakers should reach the majority of the audience at the same instance. (Fig. 2) This is why two speakers are used in auditoriums and dance halls,

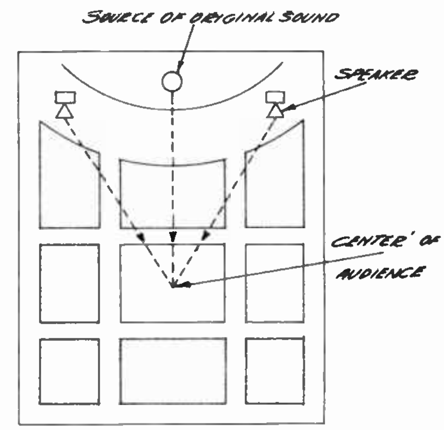


Figure 2. The speakers should be placed so that the majority of the listeners will hear the original and reinforced sound at the same instance.

one on each side of the stage. This type of installation permits the original sound to be supplemented or reinforced by the amplified output. It certainly would not do to have a single speaker in the back section of a long and narrow hall. Under such a condition, the listeners sitting in the first front rows and those in the extreme rear would hear the original sound and the amplified sound at a considerable time interval.

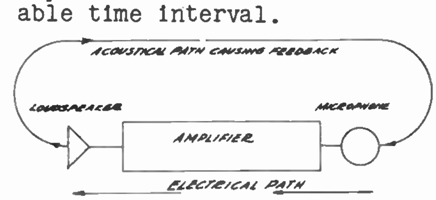


Figure 3. The acoustical return of sound causes feedback.

FEEDBACK PROBLEM

In all installations, some of the sound emitted by the loudspeakers will reach the microphone of the system. Feedback will result if the sound reaching the microphone is greater in intensity than the original sound input. (Fig. 3) Consider for example a typical auditorium with an orchestra playing. A definite sound level produced by the instruments of the orchestra is picked up by the microphone. After amplification, a correspondingly higher power level of sound is emitted by the

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loudspeakers. Of course, the actual ratio of the input to the output power is the net gain of the amplifying equipment at the volume control setting employed. Now if the sound coming back to the microphone, either through direct radiation or by reflection from walls, is about equal in intensity to the original input, twice as much output will result. This larger output will in turn cause twice as much sound energy to be returned to the microphone and again the output level will be doubled. This doubling process will continue, under such condition, at a rate equal to the time required for the sound to pass acoustically from loudspeaker to microphone and electrically through the amplifying equipment. In several seconds the amplifier will be overloaded, and a continuous loud whistle will be the only output present.

Should the sound returning to the microphone be greater in intensity than the original, the feedback action will start just so much faster. If the sound intensity is but a little less than the original input, a hang-over effect or echo will be present. All these conditions are equally bad and can successfully be eliminated.

SOLUTION OF FEEDBACK PROBLEM

Reduction of amplification will always solve the feedback problem. But this is a poor solution, since the output in majority of cases must be reduced to so low a point that the sound system no longer serves its purpose. In some installations certain groups of frequencies are the only cause of feedback. Perhaps this is due to greater amplification at these frequencies or to the resonant effect of the room. Tone control adjusted to reduce the gain at these frequencies will eliminate the feedback due to this cause. But this, too, is a make-shift solution, for the tone control adjustment not only may solve the feedback problem, but also may distort the natural qualities of the program.

The way to eliminate feedback is to prevent sound from the speakers reaching the microphone of the system. If the speakers are focused in a direction away from the microphone, direct feedback will be

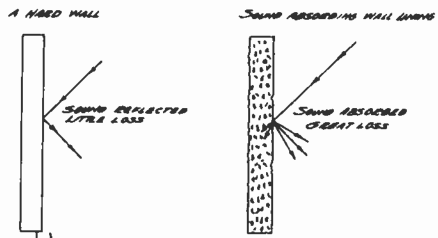


Figure 4. To prevent sound emitted by the speakers from reaching the microphone, sound absorbing materials are used.

eliminated. However, sound reflected from walls, ceiling, and floor will reach the microphone. The sound in being reflected, loses some of its energy, so that in striking several walls in its return path to the microphone, the sound intensity may be reduced to a low value where it will no longer create any feedback. (Fig. 4) Since sound-absorbing materials deaden the sound and absorb its energy, the use of carpets, heavy curtains and drapes, and special sound-absorbing materials strategically placed will permit the use of the Public Address system at the required volume level without encountering feedback.

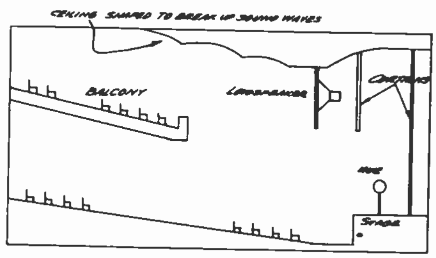


Figure 5. In an auditorium the speakers should be above and in front of the microphone. The curtains should be down as much as possible to serve as sound traps.

PRACTICAL EXAMPLES

Practically every school auditorium is or soon will be equipped with sound amplifying equipment. Here the correct placement of speakers is a simple matter. Two speakers of the 12 inch size should be used. Oxford type 12DMP will work well in such installation. These speakers should be placed on the two sides of the stage, and directed outwards. The speakers should be well in front of the microphone and should be enclosed in suitable baffles. (Fig. 5) The sound should be emitted in front only. If the auditorium is small, non-directional baffles will serve. The curtain in back of the stage should be lowered to eliminate sound reflection. If the walls are of hard material and this type of installation does not completely eliminate the feedback problem, a directional microphone may be used or the speakers may be moved a little more forward and the front curtain lowered a little.

A well decorated square shaped room, 40 by 60 feet, serves as a dine-and-dance club. On a stage placed alongside one of the longer walls is the orchestra. When the orchestra plays softly, the

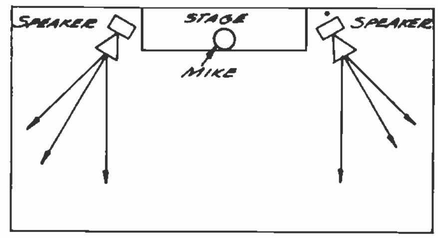


Figure 6. This simple but correct installation solved the problem of the night-club.

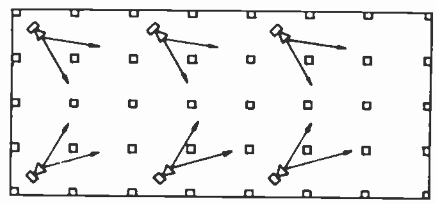


Figure 7. Even a factory paging system can present difficulties unless the speakers are correctly placed.

music cannot be heard in the extreme corners away from the stage. Loud playing proves uncomfortable for the patrons near the stage. (Fig. 6) Experimentation with a small 8 watt sound system shows that speakers placed in the far corners facing the stage create feedback. By using two semi-directional speakers placed above the stage and faced towards the extreme opposite corners, the problem is solved.

In a large factory located on a single floor, speakers used in a paging system were spread out at random. Difficulty was experienced in understanding the calls and announcements. This was caused by the sound from several of the speakers reaching the same individuals. By using directional speakers, and facing them in such directions that the sound from any two did not interfere, the difficulty was eliminated. (Fig. 7)

Servicemen and P.A. Engineers should bear in mind that the correct placement of speakers will prevent feedback difficulties and will permit the system to sound "natural":

MATCHING SPEAKERS TO THE P. A. INSTALLATION

The correct selection of the speakers for any public address installation depends on the equipment used, results required, and the acoustics and size of the location. These determining factors are closely inter-connected and must be considered together in selecting the type and number of loud speakers to be employed.

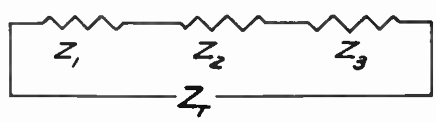
The number of speakers used will depend primarily on the installation; perhaps only two speakers will be needed in a school auditorium, but several dozen may be used in a complex paging system. In any one enclosed hall or room, as few speakers as practical should be used. This suggestion, however, cannot always be followed, since the speaker efficiency is highest when the speaker is operated well under its maximum rating. Also, at times the installation calls for so much power that a great many speakers must be used. Bearing in mind that no one rule will really serve in all cases, the P.A. specialist may depend on the table given for correct information for every regular installation. (See Table 1.)

No matter if you use a single speaker or have a complicated network, the speaker load should be correctly matched to the amplifier output. For maximum power transfer and minimum added distortion, the load impedance, Z, must equal the output impedance of the amplifying system. Two forms of mismatch may occur -- the load may be higher in value, or the load may be lower. In both instances a power loss will occur -- less than the maximum amplifier power output will reach the speakers, and there will also be a loss of quality.

Small errors in matching are not important as is evident from the table below. (See Table 2.)

The commercial amplifiers provide several different output impedances in the most commonly required ranges. For example, one unit may have taps at 4, 8, 16, and 500 ohms. When speakers are used at a distance from the amplifier, the speaker line is usually connected to the 500 ohm tap, and the speakers with line transformers are connected together to match this impedance. If the speaker is near by, within 50 feet, the voice coil may be directly connected to the nearest value tap. Let us now consider the problem where several similar speakers are to be connected together.

In connecting impedances in series, the individual impedance values are simply added. (See Chart 1.)

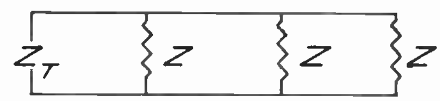


$$Z_T = Z_1 + Z_2 + Z_3 + \text{----} +$$

Chart No. 1.

In connecting several equal impedances in parallel, the resulting impedance is found from the formula (See Chart 2.) where Z is the value of one of the impedances used and X is the number of impedances in parallel.

In using two 8 ohm voice coil speakers, the connections



$$Z_T = \frac{Z}{X}$$

Chart No. 2.

may be made in series or in parallel. In the series circuit the resulting impedance is 16 ohms; in parallel, 4 ohms. It is better to use parallel connection, as an open voice coil in a single speaker in the series circuit will stop the entire service of all speakers.

TABLE 1.

Type Of Application	Room Size Cu. Ft.	People Present	Noise Level	Power Needed (Watts)	Number Of Speakers Needed	Size Of Speakers	Oxford Type	Type Of Baffel
Hospital Room-Paging	4,000	6	Very Quiet	1/4	1	6½"	6XMC	Cabinet
School Room	8,000	48	Quiet	1	1	8"	8WMC	Cabinet
Office Inter-Comm.		1	Average	1	1	5"	5XMP	Cabinet
Small Restaurant	10,000	25	Noisy	3	1	12"	12WMP	In Grill Work
Funeral Home	25,000	100	Quiet	3	2	12"	12WMP	Flat Baffels
Window Ballyhoo	Open Air	25	Noisy	8	1	12"	12DMP	Semi-Directional
Factory Paging	150,000	50	Noisy	25	4	8"	8WMC	Cabinets
Auditorium	150,000	600	Quiet	25	2	14"	14DMP	Semi-Directional
Street Advertising	Open Air		Very Noisy	30	2	Horn	6DMP	Directional Horns
Large Stadium		10,000	Noisy	60 to 100	8	14"	14DMP	Direction Horn and Baffels

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Speakers may also be connected in series-parallel arrangement, so that the resulting impedance will match one of the output taps. For example, four 8 ohm voice coil speakers may be connected in a fashion to give the equivalent impedance of 8 ohms. (See Chart 3.)

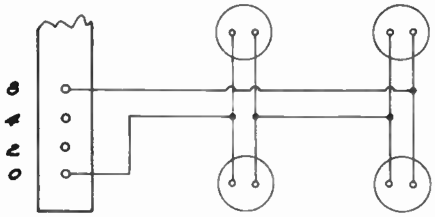
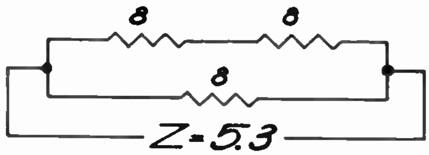


Chart No. 3.

So far, we were mainly interested in properly matching the output to the speakers employed and we assumed that the volume level at all speakers was to be the same. There are installations, however, that, while using speakers of one type, must have the speakers operate at different volume levels. For example, the speakers of a paging system must have their volume level of intensity to serve the different locations -- and probably every place has a different noise level. Just how can this variation of sound intensity be accomplished and yet match the network to the amplifier output?

The first important rule to remember is that it is immaterial how the speakers are connected; if the equivalent impedance is correct, good matching will result. As an example, we may consider a food market installation with two 8 ohm voice coil speakers inside, and another similar speaker outside. The outside speaker is to be operated at about four times the power level of either inside speaker. To accomplish this the speakers may be connected in the following manner. The speakers used indoors are connected in series, giving the equivalent 16 ohms. This combination in turn is connected in parallel with the 8 ohm speaker placed outside, and gives the equivalent 5.3 ohms. The 4 ohm impedance tap of the amplifier used will give good results as there will be only a trivial loss. (See Chart 4.)



$$\frac{16\times8}{16+8}=\frac{128}{24}=5.3$$

Chart No. 4.

It is evident that the voltage across each branch is the same, but the current through the single speaker will be twice as great as the current present in the branch having two similar speakers. Therefore, the single speaker placed outside of the store will have twice the power of the two other speakers combined -- or four times the power of each speaker placed inside.

The speakers used, of course, need not be all the same and may be employed with Oxford-Tartak universal line transformers for still greater versatility. For another example, consider the school installation with 8 inch speakers in eight different school rooms, two 14 inch Oxford 14DS-TLL speakers in the auditorium, and one exponential horn in the gymnasium -- all speakers equipped with Universal 500-1000 ohm transformers. The sound level needed in each of the rooms is $1\frac{1}{4}$ watts, in the auditorium 20 watts total, and in the gymnasium 10 watts where the exponential horn trumpet will serve. The units may be hooked-up in the manner shown, and a study of the circuit will show that the right match with the required power at each point is obtained. The amplifier, of course, must supply 40 watts.

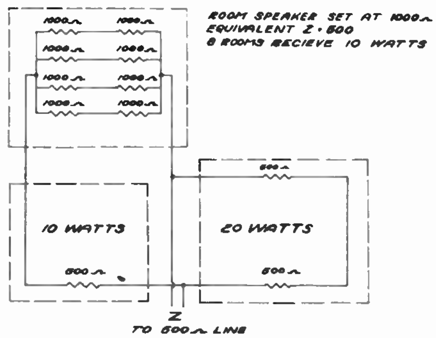


Chart No. 5.

In a similar manner any complex speaker installation may be designed to give optimum results and produce just the right amount of audio power at each speaker.

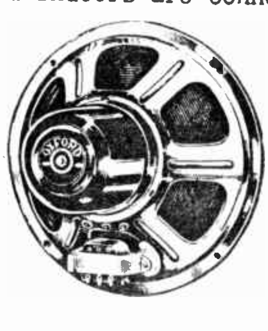


TABLE 2

ERROR IN MATCHING OUTPUT Z / LOAD Z	APPROXIMATE LOSS OF POWER IN DB	APPROXIMATE LOSS OF POWER IN %	APPROXIMATE EFFECT ON QUALITY AND SENSITIVITY
.5	.5	11	NOTICEABLE
.6	.35	7	SLIGHTLY NOTICEABLE
.7	.2	4	BARELY NOTICEABLE
.8	.1	2	BARELY NOTICEABLE
.9	.05	1	NEGLIGABLE
1.0	0	0	NONE
1.25	.05	1.5	NEGLIGABLE
1.50	.2	4	BARELY NOTICEABLE
1.75	.35	7	SLIGHTLY NOTICEABLE
2.0	.5	11	NOTICEABLE

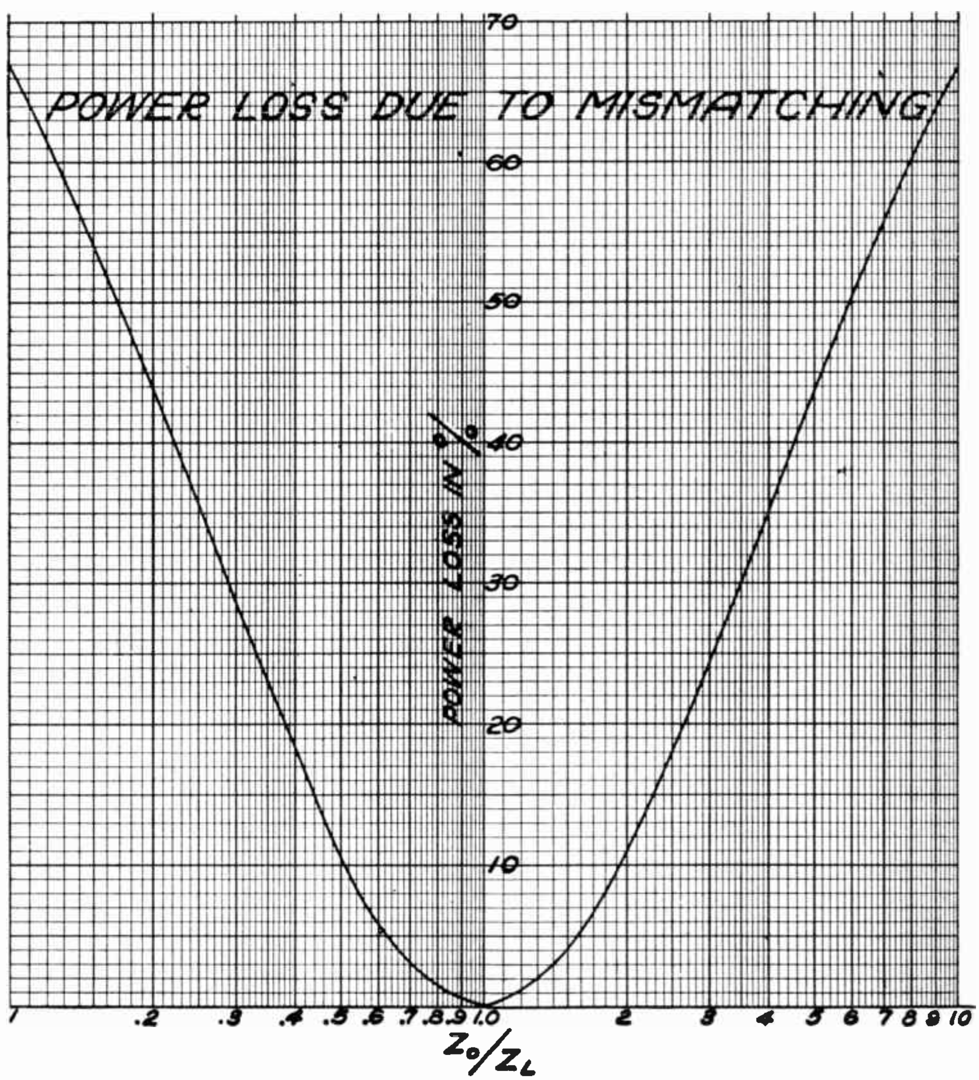
EFFECT OF MISMATCHING SPEAKERS TO AMPLIFIER OUTPUT

A great deal of stress has been placed on the necessity of exact matching from source to load. While this generally holds true when the mismatching is considerable, a slight mismatch is not serious. This is quite obvious by referring to the chart.

In order to properly determine correct matching, the impedance of the voice coil must be known. This impedance is not a constant figure, but varies with frequency. For all general applications, however, the impedance is measured at 400 cycles. In the event that the impedance of a speaker is not known, the approximate value can be obtained by multiplying the DC resistance by a factor of 1.25.

To consider the usefulness of the graph, let us take the problem where the only speaker available is one with a 6 ohm voice coil, and the amplifier output is available in either a 4 ohm or 8 ohm tap. The question in this case is what tap on the amplifier will give the best results. The ratio of $\frac{Z \text{ output}}{Z \text{ load}}$ in the case of the 4 ohm tap is .666, and in the case of the 8 ohm tap is 1.33. In checking these figures on the graph, we find that in the case of the 4 ohm tap where the ratio is .666, the loss is approximately 4%, and similarly, on the 8 ohm tap, the loss is only 2½%. It is quite obvious that the best results will be obtained if the speaker is connected to the 8 ohm tap. Generally, the results are better if the speaker is mismatched to a higher rather than a lower impedance.

However, if the speaker has only a 2 ohm voice coil, and the only tap available on the amplifier is 8 ohms, the ratio of the two impedances is 4. From observation on the graph, the loss is 35%, which is quite serious and this mismatching is not recommended.



T H E   D E C I B E L

Of all units in radio the least understood and most often misused is the decibel. The decibel, abbreviated as DB, is a unit of comparison of two powers and under proper consideration may be used to compare currents and voltages. It is the transmission unit uded to measure power related in some way to the auditory sense. The DB is a logarithmic unit in so much as it varies as the log of the ratio of the two powers in comparison.

$$DB = 10 \log_{10} \frac{P_1}{P_2}$$

The formula on the previous page states the relation that the log to the base ten of the ratio of the two powers multiplied by ten will give the difference between the two powers in decibels.

The difference in decibels may also be found from the table below if the ratio of the two powers' under consideration is known.

Gain in DB.	Power Ratio P_1/P_2	Gain in DB.	Power Ratio P_1/P_2
40	10000	0	1.
35	3162	- 1	.8
30	1000	- 2	.6
29	800	- 3	.5
26	400	- 4	.4
23	200	- 5	.32
20	100	- 6	.25
15	32	- 7	.2
12	16	- 8	.16
10	10	- 9	.12
9	8	- 10	.1
8	6.3	- 11	.08
7	5	- 13	.05
6	4	- 15	.03
5	3.2	- 17	.02
4	2.5	- 20	.01
3	2	- 25	.003
2	1.6	- 30	.001
1	1.3	- 35	.0003
0	1	- 40	.0001

Since DB is always a ratio, when we speak of an amplifier as having so many decibels gain, we assign an arbitrary level of comparison. Usually 0.006 watts is taken as this figure. If one amplifier has a gain of 75 decibels in comparison with a given arbitrary level, while another has 60 decibels when compared to the same level, the first has (75 - 60) or 15 DB more gain.

The transmission unit is employed to express any ratio of power, mechanical loss or gain, etc. related in some way to the auditory sense.

TESTING AMPLIFIERS

Practically nothing is said concerning the testing of amplifiers in the constructional articles in this guide. This subject is too broad to be covered in such limited space. The following ideas and suggestions will be of great help to the Sound Man who builds or repairs his own amplifiers. They are the results of long experience in the laboratory and in answering letters on this subject from our many friends and customers.

There are certain basic test instruments that should be available to every sound man and certain routines in their use that should be known and followed, if the full benefit is to be secured from them. These instruments include a good audio oscillator, a cathode ray oscilloscope, a selection of 50 or 75 watt resistors with values of 500 ohms or equal to output impedances to be used (these are to be used as substitute voice coil and line loads when measuring the output of an amplifier), and a vacuum tube voltmeter with a high range. For accurate overall gain measurements an accurate micro-volt meter is needed to measure the audio voltage applied to the input of the amplifier, and an output meter with no frequency discrimination.

CHECKING HUM

One of the first problems encountered by the constructor is the elimination of Hum from an amplifier. The oscilloscope is very useful in determining the frequency of the Hum, its location, and when it has been reduced to a negligible quantity.

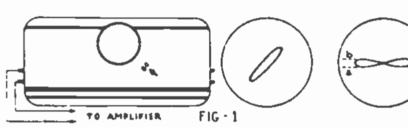


FIG. 1

To determine the frequency of HUM, feed a portion of the output of the amplifier to the vertical input of the oscilloscope. Turn the sweep selector switch to "60 cycle". A 120 cycle HUM will produce some form of a figure eight on the screen of the cathode ray tube as shown in Fig. 1. This indicates that the hum is coming through the power supply circuit, and is caused by lack of filtering or isolation of the different stages. On the other hand, a 60 cycle HUM, usually picked up by induction in the wiring, transformers or chokes will produce some form of circle — no crossing of lines. (Fig. 1).

The best procedure in checking HUM is to pull all tubes but the outputs and clear up any HUM that originates in that stage. Next insert the correct tubes and proceed to the driver stage, the interstage and the inputs successively. It will usually be found that HUM is picked up most often in the input stages. For this reason they must be well shielded. Notice that the resistors and leads associated with this portion of the circuit are always shown as being shielded in the diagrams. This is important in the elimination of HUM and cross talk between inputs. Such simple things as the placement of leads, transformers, tone control chokes, etc., will affect the amount of HUM present in the amplifier. Any defective condensers in the filter circuit will usually be shown at the first of the test and of course should be replaced with perfect units.

On the oscilloscope the height of the image on the screen is a measure of the amount of HUM. This is shown in Fig. 1 as the distance "a" — "b". Note: This height is affected by the voice coil impedance across which the tests are made. The greater the impedance, the easier it is to detect HUM on the oscilloscope. The ear will of course tell when HUM is no longer noticeable, but will not aid sufficiently in the location and elimination of the source. Tube hiss, which will appear after a gain of approximately 100 db has been reached, should not be confused with HUM.

OSCILLATION

Another source of trouble, especially in modern high gain amplifiers and those using an inverse feedback circuit, is parasitic oscillation.

If the transformers shown on the parts lists in this guide are used, and the circuit diagrams and various constants are followed, there can be but one main reason for oscillations. This is the reversal of the tertiary winding of the output transformers. All other sources of oscillation have been carefully eliminated.

The following suggestions for the curing of oscillation are given for the benefit of those building their own amplifiers from parts other than those recommended in this guide.

1. Complete shielding of the entire wiring of the final stage including the tertiary center tap.

2. Insert a 200 ohm ½ watt resistor in each output tube grid lead.

3. Connect .001 Mfd., or smaller, condensers from the output stage grid leads to ground, or the junction of the above mentioned 200 ohm resistors to ground.

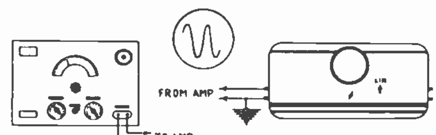


FIG. 2

4. Connect a by-bass condenser across the self bias resistor.

5. Connect a 25 ohm 10 watt resistor in series with each plate of push-pull parallel output tubes.

6. Insert 10,000 ohm or larger resistors across each half of the secondary of the driver transformer.

7. Connect a resistor across the total secondary of the driver transformer, the value to be as high as possible and still stop the oscillations.

A simple test procedure for the source of oscillation is as follows: First, reverse the tertiary winding of the output transformer. Second, remove the inverse feedback system entirely to make certain this part of the circuit is or is not responsible. Third, try the various circuit changes as previously outlined.

DISTORTION MEASUREMENTS

The most popular way to check the distortion in an amplifier is shown in Fig. 2. The output of the amplifier is fed to the vertical input of the scope and an audio signal with a sine wave characteristic is fed to the input of the amplifier. Since a sine wave is uniform, any deviation from it is easily recognized.

It is not possible to distinguish distortion on the oscilloscope below 5 or 6 per cent. The only distortion which may be readily seen with this method is the flat top wave. This flat top may be caused by operating into the curved portion of the tube characteristic in the case of triodes or by using too high a plate load in the case of a pentode. Driving a class A or AB power stage so heavily as to draw grid current will also cause this form of distortion.

Where distortion is present the leads from the vertical input of the oscilloscope should be moved to the output and input of each successive stage, beginning with the final, until the defective one is located.

OUTPUT MEASUREMENTS

Output measurements are usually taken across a resistor, substituted for the impedance which would usually be connected to the secondary. Use an accurate output meter when making these measurements. From the formula Power (Watts) equals $\frac{E^2}{R}$, it is then easy to compute the output of the amplifier.

An oscilloscope is almost a necessity in measuring power output if usable output is to be considered. Most amplifiers are capable of considerably higher output than their usual rating but with high distortion. An output with a maximum distortion of less than 8% is all that is really useful.

Connect the vertical input of the oscilloscope across the same load resistor that is used for the output voltage measurements. Increase the output, through the use of the gain control, until the sine wave form begins to distort. Back the gain down until no noticeable distortion is present, then take the output voltage reading. The oscilloscope will begin to show distortion when about 6% is present.

A point often forgotten is that an amplifier passes many frequencies, thus the watts output should be fairly constant over the entire frequency range if the amplifier has any quality at all. An amplifier with 25 watts output at 400 cycles should also deliver 25 watts with no noticeable distortion at 50 c.p.s. and to at least 8,000 c.p.s. These measurements are not possible unless the laboratory equipment previously mentioned is available.

OVERALL GAIN

No rating can be so abused as the db gain of an amplifier. This is true because of the nature of the measurements involved. The decibel is a unit of power measurement so the resistance across which the voltage measurements are computed will influence the mathematical, not the actual, result.

To compute the overall gain, a carefully measured input voltage is applied to the input of the amplifier and the output voltage measured. The gain is figured in decibels through the use of the formula $db = 10 \log. \frac{Po}{Pi}$, where Po is the power output and Pi is the power input.

The output voltage is usually read across the load resistor mentioned at the beginning of this article. The input voltage is fed into the regular input, which is usually a 5 megohm resistor.

It is this input resistor that can play havoc with the gain measurements. Although its value is 5 megohm, purposely a large value to prevent loading of the microphone, such a value is never encountered as an actual grid load. When shunted by the microphone or other input source the resultant impedance is much less. For this reason the secondary impedance of the usual transformer, 100,000 ohms, is the generally accepted figure used in gain computations. An actual input impedance of 5 megohms would obviously ruin the high frequency response of the stage involved. The calculated db gain will be less with 100,000 ohms but it will be more indicative of the usable gain. You will notice that in the technical data on each amplifier in this guide the figure of 100,000 ohms is given as the value used. Without this statement the db value would be meaningless. ***Always state the constants used when speaking of db gain.*** Although a higher db gain will be shown by using a value of 5 megohms rather than 100,000 ohms in the computations, the actual gain from microphone to speaker will be the same under either condition.

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GROUP HEARING AID INSTALLATION

Within the past few years Group Hearing Aids have become more and more popular, and theatres and churches are finding it greatly to their benefit to install this equipment. In the Trimm line, ever ahead of the trend, will be found the finest equipment of its kind ever built. A complete installation consists of a Trimm Custom-Built Amplifier, Featherweight earphones or Trimm Oscillators, phone plugs, individual volume controls, a microphone, and a small amount of wiring. Installation is very simple as illustrated in the wiring chart, Fig. 1.

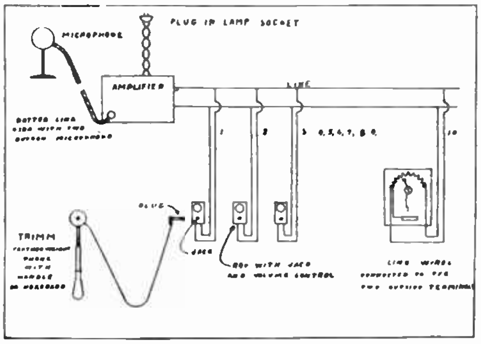


Fig. 1

We urge the purchase of a complete Trimm installation as combining parts not perfectly matched electrically will result in inefficient operation and expensive repair work.

The earphones used are the famous Trimm Featherweights built especially for this service. They are very light-weight, sturdy and able to supply ample volume without distortion. The headband set is usually preferred in the theatre; while churches and funeral chapels find the lorgnette handle type most satisfactory. In addition to earphones, the Trimm Oscillator can be supplied and is very popular among those who prefer a bone conduction unit.

Because the loss of hearing differs for each individual, a volume control for each phone is provided. The Trimm outlet box which includes the volume control is very generally used. This box, made with all edges and corners rounded off, is attached to the back of a church pew, or to the frame of a theatre chair as shown in Fig. 2.

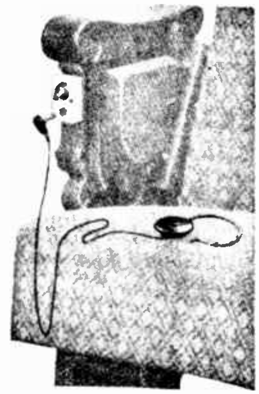


Fig. 2

REVIEW QUESTIONS

1. Name several bad features of a carbon microphone?

2. How can needle-noise be removed?

3. Can the gain per stage be as great as the amplification factor of the tube used? Why?

4. What are some advantages of class B tubes?

5. How does inverse feedback improve the quality?

6. Why must a baffle be used for good reproduction?

7. How does audio feed-back originate?

8. How can four speakers of the same type be connected to an amplifier, so that one pair has four times the output of the remaining pair? Assume the speakers have universal line transformers.

9. If a speaker having a 6 ohm voice is connected to the 8 ohm tap of an amplifier, how much power is lost because the mismatch?

10. An audio stage requires 2 milliwats input and produces .6 watts of power. What is the gain in decibels?

LESSON 15

RECORDING

The entire recording process is based on a few simple principles of electrical and acoustical sciences. Briefly, the sound be it conversation, music or singing, is changed from sound energy to electrical energy by means of the microphone. This sound is then amplified in a suitable high fidelity amplifier of ten or more watts output. The output of the amplifier is fed to a recording head usually of the screw feed type.

For semi-professional use blank aluminum or composition discs give better results than the pre-grooved type. As the disc revolves, the cutting head cuts a groove and at the same time the needle moves from side to side responding to the original sound characteristics. In this manner a record of the sound is made on the disc, as a means for future reproduction. In playing back from the recorded disc the same method is used as for commercial records. In order to preserve the record, a fibre or cactus needle should be used.

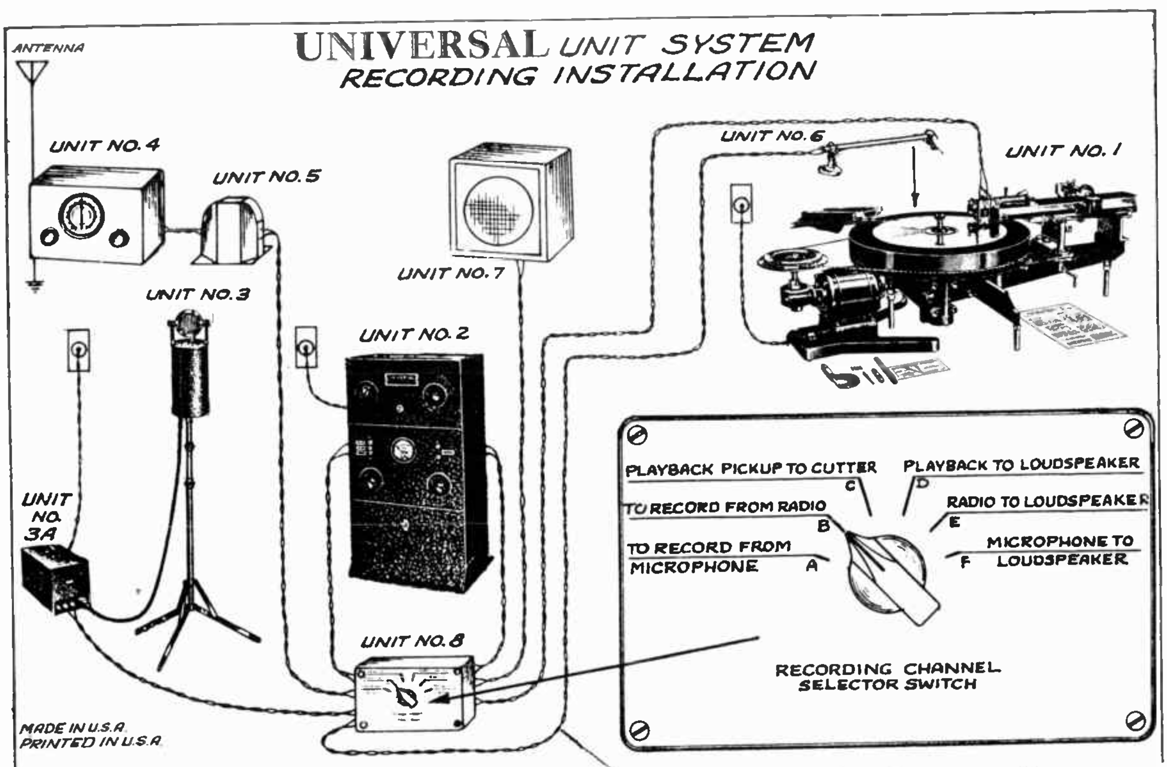


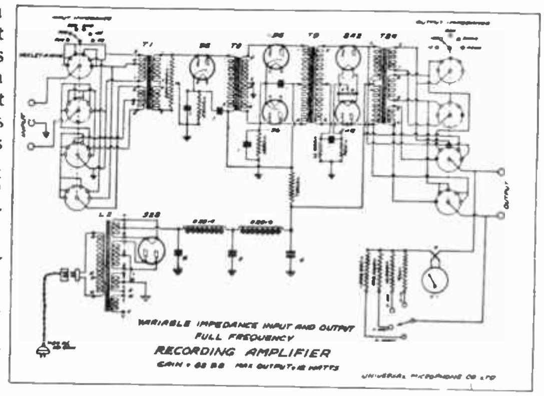
Illustration above shows the various elements of a recording system, connected to the Universal Recording Channel Selector Switch, which allows all combinations of connections shown, any one of which can be instantly made by simply turning indicator knob.

Professional Recording Amplifier

A three-stage Class "A" amplifier having an over-all gain of 82 D.B. Frequency range substantially rising from 40 to 14000 cycles; output 12 watts with harmonic distortion of less than 2%. Entirely free from hum—which is of utmost importance if clear recordings are desired. Uses large high quality coupling transformers which are shielded first in copper, then in heavy cast iron. Laminated iron shelving separates various stages and further eliminates hum. Amplifier is completely mounted on panels in rack form. Power consumption from 110 volts A.C. is 75 watts. Copper oxide type of rectifier output meter provided, with multiplier switch, allowing ranges of 0-.1, 0-1, 0-10 and 0-100 volts.

Variable input and output impedance combinations instantly available for use in impedance matching and tone regulation.

Also incorporates a high and low pass filter system, arranged on a single control knob, allowing adjustment of the frequency response from normal to either a rising or falling characteristic; thus allowing the recording operator to compensate for any discrepancies in the incoming program, an absolute necessity when recording studio broadcasts or air checks where the incoming program is not under complete control of the recordist.



P.A. BUSINESS The P.A. business resolves itself into two phases: rental and sales. Usually it will be found best to carry on business in both phases. In either case, however, the consumer must be found and correctly approached.

The average user will ultimately prove to be a buyer of sound equipment. At first the user of sound equipment may prefer to rent because he may want a trial under actual conditions, or he may have only occasional use for sound amplification. Most prospects approached, therefore, will find some early or later occasion to buy or rent. In case of rental an operator must usually be furnished to control the system. Rental also necessitates temporary improvised setup. A permanent installation, on the other hand, is properly placed and the owner or some other individual is instructed in the control operation of the system.

PERSONAL CALL RECOMMENDED The users of public address equipment lie in almost all fields of human endeavor. Club houses, parks, churches, stores, schools, advertising cars are large users of sound equipment. Coal yards use small systems to speed up the weighing of trucks. Movies need hard-of-hearing sound equipment. Factories need call systems to quickly locate employes. And you yourself probably have in mind a dozen more excellent applications of sound systems and amplification equipment.

The best possible contact can be made by means of a personal call. At every rental the operator will be asked many questions. Usually many of the curious individuals will prove excellent prospects and should be followed up. When calling on any prospect have a small sample system along. By quickly setting up this system you will be able to give the prospect a real idea of what he may expect from a sound system. Public Address is the money making field and we urge you to be a Sound specialist as well as a radio serviceman. We have given you here a real good background for sound work.

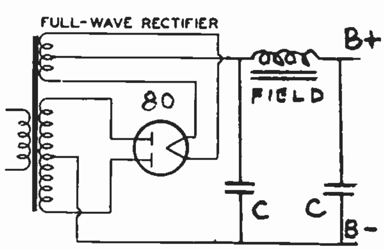
LESSON 16

Power Supplies

Automobile sets & installation

A radio receiver requires a source of power for heating the filaments and for supplying the plate potential and grid bias. In a battery operated radio the power required is obtained from batteries of the correct voltages and capacities. The majority of the present day sets, however, are operated from power lines and require a special power supply unit incorporated into the radio chassis.

The primary function of a power supply is to furnish the required A.C. and D.C. voltages to the tubes' filaments, and properly filter the plate supply so as to avoid hum and have satisfactory regulation. Usually the power supply also provides the necessary current for one or more speaker fields. There are power supplies for A.C. only and designed to be operated at the voltage and frequency of the supply, others for D.C. only, and still others for A.C. and D.C.

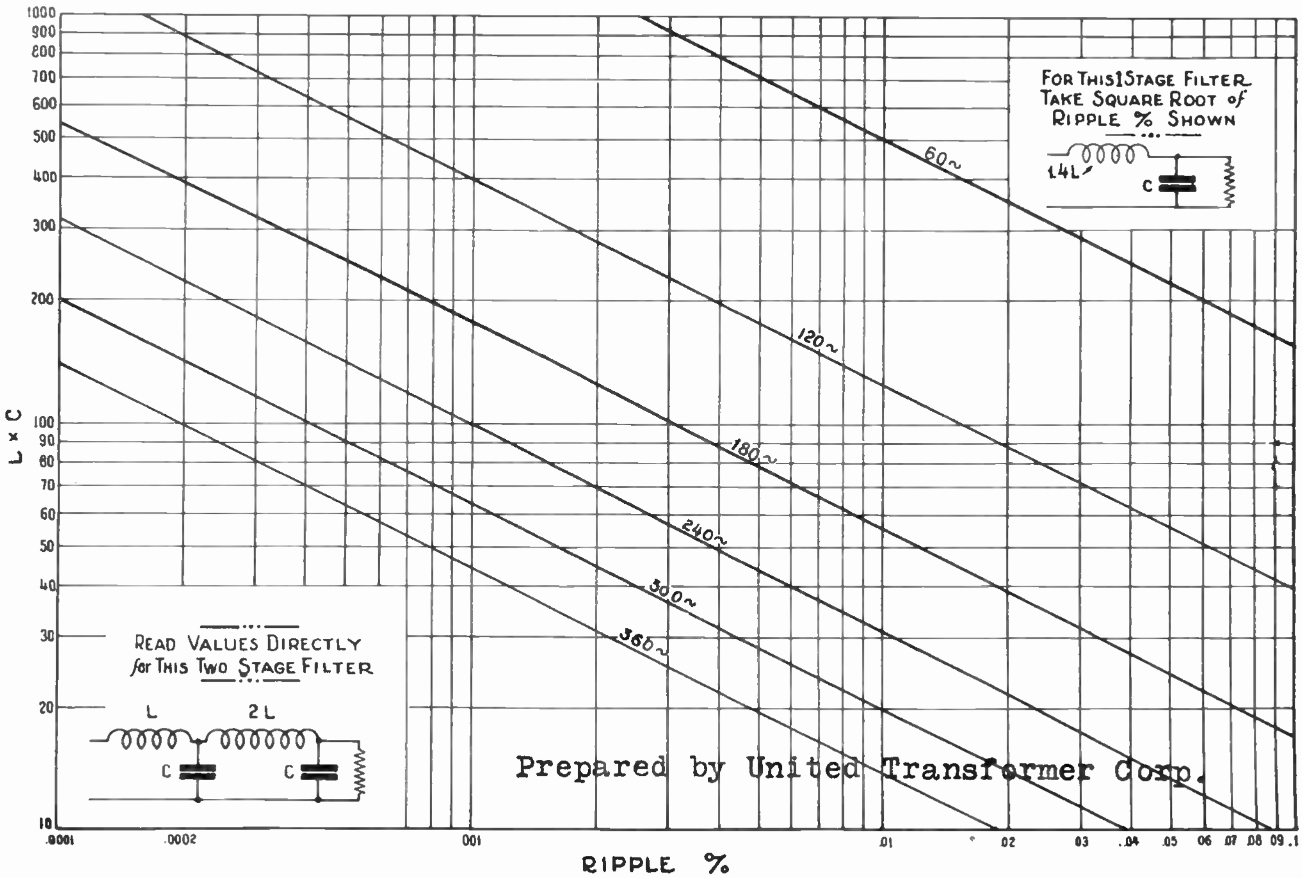


The essential parts that are employed in the simplest A.C. operated power supply are a power transformer to step the voltage up or down as needed, a rectifier tube, and one filter section consisting of a choke and two electrolytic condensers. Generally the choke can be the speaker field. The figure shows such a circuit which has become very popular. The resistance of the choke must be correctly chosen so that the total current drawn by the receiver is just sufficient to produce the required excitation in the electromagnetic field of the speaker.

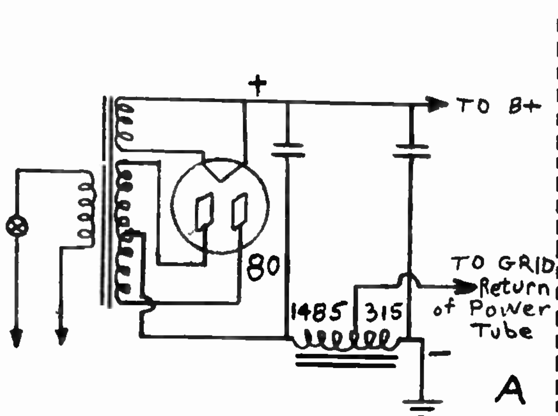
This arrangement is nearly the most economical one for small receivers. It is generally used with sets of relatively low sensitivity because there is only one filter section and any hum which reaches any of the early amplifying stages has only a limited amount of audio amplification. So, if this amplification is not too much the hum in the speaker can be kept at a negligible level. Some small receivers will also be found to employ some form of hum-bucking coil in the voice coil circuit.

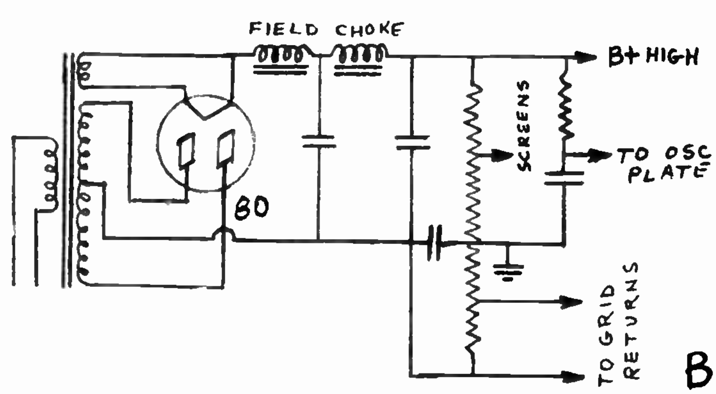
Note that a voltage divider consisting of high resistance units of the carbon type is used. The heavy bleeder of a few years ago is very little used now days. It is, of course, well known that in cases where a heavy bleeder is absent, the voltage of the B supply will vary considerably with the current drain.

The largest variation in drain is usually caused by the A.V.C. circuit which changes the bias on several tubes. In one case the plate voltage on the R.F. amplifier was 240 volts with a strong signal coming in, but dropped to 225 volts without signal. The result may be a slight shift in the oscillator frequency. Servicemen should keep these facts in mind when servicing such a receiver.



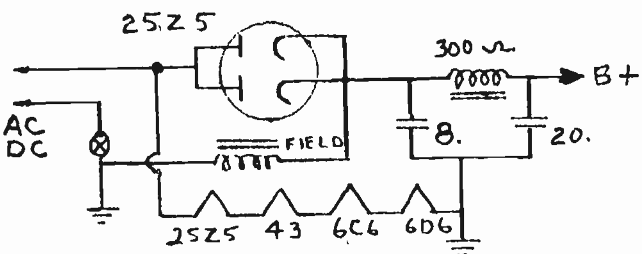
It is seen that there is a drop of 105 volts across the speaker field; consequently when the specifications for the power transformer are made up, 105 volts must be added to the required plate voltage. This voltage drop can be utilized by placing the choke in the negative leg of the power supply and using a part of the supply for C bias. This is illustrated below. A tap on the field coil has been so chosen as to provide the correct voltage drop for the grid bias of the power tube. Additional filtering for the bias supply is easily provided since practically no current is taken. A high resistance and a condenser serve well for this purpose.





In B a typical power supply for larger receivers employing two filter sections and with the speaker field used in the second section is illustrated. The filter stage ahead of the speaker field greatly reduces the hum introduced by the field itself besides lowering the hum level of the plate supply. The voltage divider serves as a bleeder to deliver semi-fixed bias to the driver stage. The output stage, however, as well as all other tubes are self biased.

A.C. - D.C. CIRCUITS The A.C.-D.C. receivers offer some new problems to our considerations. As far as the circuit is concerned, very little variation is possible. Let us take the problems up one by one, beginning with the filaments.



A series of tubes is available which is suitable for this service because all members of the series require the same filament current (0.3 amperes). The voltages vary, however, some are of the 6.3 volt type others of the 25 volt, etc. The tubes are connected in series and a resistor is added so as to provide the required additional voltage drop. This resistor may be placed in the power cord so as to remove the heat from the chassis.

When placing the filaments in series it makes quite a difference in which order they follow each other in order to keep hum to an absolute minimum. The hum is introduced due to leakage between the cathode and the filament; this leakage will in turn depend on the potential difference between these two elements. Since all cathodes are connected to the negative side of the power supply, it follows that the most critical tube should be placed at the negative end. This tube is generally the detector. Starting from that side one encounters first the detector, then the R.F. and I.F. stages, then the A.F. stages, and finally the rectifier.

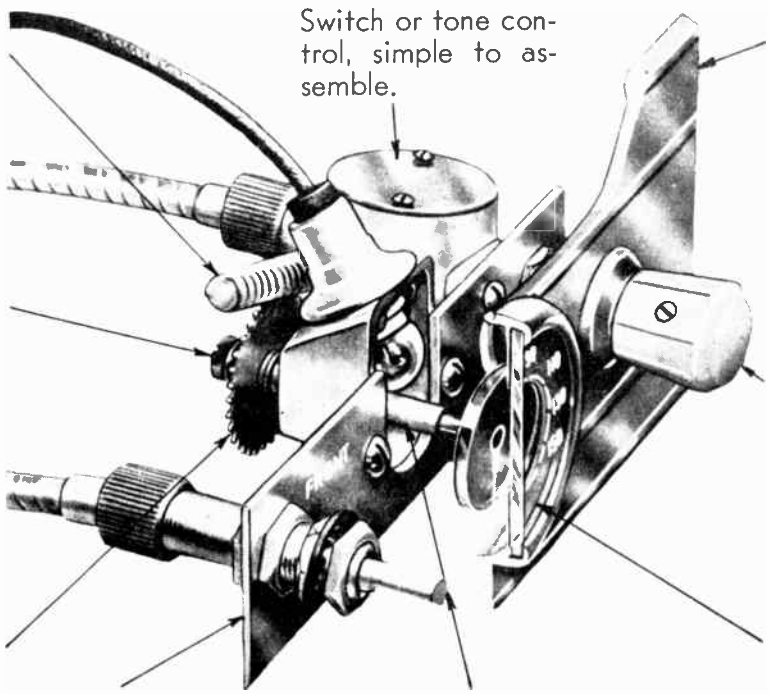
The B supply has only about 120 volts A.C. to start, so it is not possible to employ high resistance chokes. Consequently, the speaker field (if a dynamic speaker is used) cannot serve as a filter choke and is connected across the B supply. Filtering a 60 cycle supply is twice as hard as removing a 120 cycle ripple in full wave rectifiers. Reactances of the chokes are only half as much as for 120 cycles and reactances of condensers are twice as high offering a poorer path for the ripple voltage. One filter section is usually employed; large condensers are used and the choke can have larger inductance due to a relatively lower current.

Another problem with A.C.-D.C. sets is the fact that the chassis, if tied to the B- side becomes one side of the line and this may be side that is not grounded. Accidental grounding of the chassis or the antenna wire would result in a short circuit. The last danger is circumvented by placing a series condenser in the antenna lead and making no provisions for a ground connection.

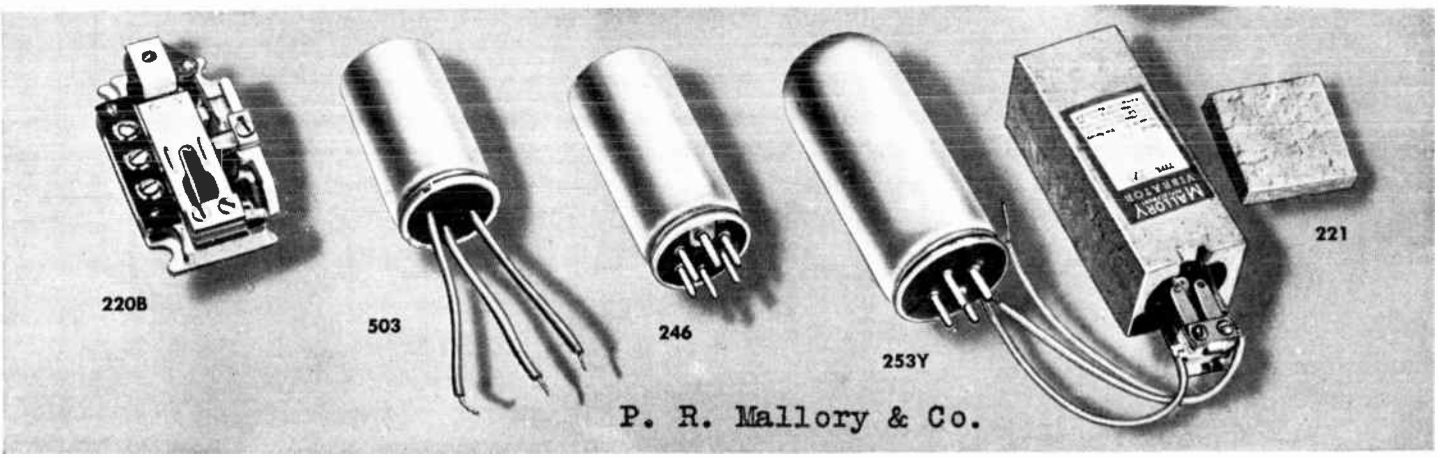
AUTOMOBILE RADIO SETS AND INSTALLATION

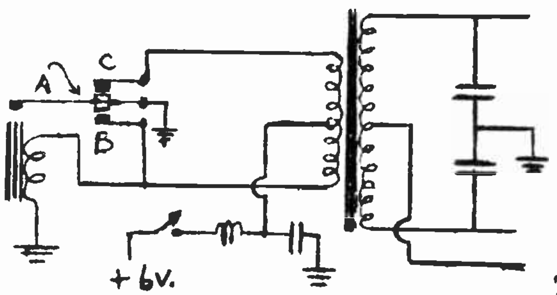
Radio receivers for automobiles are now considered standard accessories. Auto sets present a number of special installation problems and must be correctly installed by the radio servicemen. Since the total operating power must be obtained from the automobile's regular 6 volt storage battery, the set must be designed with power economy in view. An average radio will have a current drain from 6 to about 10 amperes. Vacuum tubes of the 6.3 volt series are employed and obtain the filament current directly from the 6 volt battery. The high B voltage and C voltage, if required separately, are obtained by means of a vibrator power supply. The genemotor supplies popular a few years back are not used in late type radio sets.

The auto radio set must be extremely sensitive since a very small antenna placed relatively near the ground is used. Essentially the average auto set is a superhet using 6, 7, or 8 tubes and obtaining the B power from a vibrator type unit. Usually a number of special chokes and by-pass condensers are used in the circuit to suppress ignition interference. The tuning condenser and volume control are mounted in a metal cabinet housing the complete chassis and the speaker, but these are controlled externally by means of drive shafts and remote control units. In older radios mounted in cars prior to 1935, the remote control unit was placed on the steering column, but present day sets have custom fitting controls placed in spaces provided on the dash boards. There is also need for the servicemen to move the radios when cars are traded-in for new models.



Star Machine Mfgs., Inc.

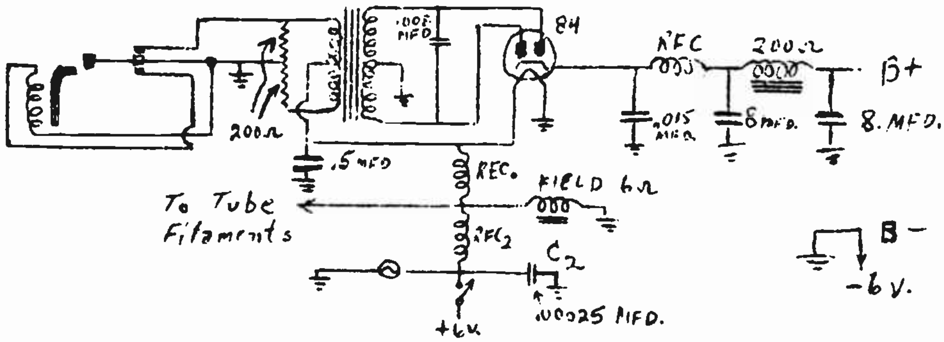




In connection with the operation of auto sets' power supplies we must carefully study the action of vibrators. The non-synchronous vibrator consists of an armature which is kept in vibration by an electromagnet on the same principle as the buzzer.

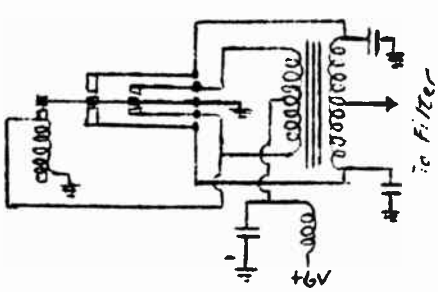
This diagram shows only the vibrator itself with the transformer and R.F. filter. When the switch is closed current will flow through the lower half of the transformer primary and then through the magnet windings. The armature is then attracted and contact A will touch contact B, thereby short circuiting the electromagnet. The armature is then released again and swings back until contact A touches contact C. Meanwhile the electromagnet is attracting it again so that it keeps on vibrating at its own natural frequency and alternately touching contacts B and C. Now when contacts A and B are closed, the lower half of the primary is directly across the battery, which will result in a heavy current from the center tap downwards. When A touches C, the upper half of the primary is across the battery and a heavy current will flow from the center tap upwards. These two impulses may be considered an alternating current although not of a perfect sine wave form. An alternating voltage will be induced in the secondary. Becsuse of the turn ratio, the secondary voltage may be made of any required value.

There are some special precautions to be taken in the design of vibrator systems. When the contacts A and B close there is such a sudden increase of current that a high voltage peak is induced in the secondary. The same is true when the other contacts close. Furthermore, sparks are likely to appear at the contacts. Various ways have been devised to eliminate the interference caused by the vibrator. Buffer condensers are generally placed across the secondary and simetimes across the primary. Other manufacturers connect a center-tapped resistor across the primary. The buffer condensers will absorb the sudden charges and thereby improve the waveform. Yet this alone is not sufficient to insure noise-free reception. The B supply filter may contain an R.F. filter in addition to the regular A.F. filter and the filament circuit may be filtered too. Also the filament circuit should not have any part in common with the vibrator circuit -- except the battery of course. A typical circuit of an automobile power supply using a non-synchronous vibrator is shown below. This circuit includes the center-tapped resistor across the primary and the usual buffer condenser across the secondary. Sometimes two condensers are connected across the secondary with the center tap grounded. The values of these condensers should be about .01 mfd. They must also have high voltage rating.



Note the R.F. filter in the B supply. There are also two filters in the filament supply. The first consisting of RFC_1 and C_1, serves to eliminate the interference caused by the vibrator, while the other section consisting of RFC_2 and C_2 is intended to eliminate ignition interference. In addition to these precautions, the vibrator and power supply must be shielded.

SYNCHRONOUS VIBRATORS The armature of a synchronous vibrator closes another set of contacts which serve to rectify the current in the secondary. The figure shows this principle. When the armature moves downwards it not only closes the primary circuit but also the secondary; when it moves up, the other halves of both the primary and secondary are closed. Buffer condensers are again employed in the secondary to improve the wave form. The usual R.F. filters and A.F. filter are used like in the other vibrator system.



The most common fault with auto radio sets and with house sets employing vibrators, is vibrator trouble. The best procedure is to replace the unit with an exact duplicate.

Usually the vibrators are of the plug in type may be easily replaced.

IGNITION INTERFERENCE The high tension ignition wires of an engine may be considered a small antenna system, grounded at the spark plug end and oscillating at a frequency dependent upon the distributed inductance and capacity. The passage of the sparks excite this antenna and power is rediated. Owing to high resistance, the waves are highly damped. Each time a spark plug fires a damped wave train is started and quickly dies away. This difficulty can be practically eliminated by using a resistance in the distributor circuit and by-passing the generator and low voltage side of the spark coil. In real stubborn cases or where out of date cars and radios are envolved, spark plug suppressors may be needed. These are carbon high resistances connected into the spark plug leads.

The ordinary auto radio installation will simply call for mounting the radio with the single bolt provided, connecting the cables, drive shafts, and antenna, and collecting the money. However, when slight interference results on a new car job, place a distributor suppressor and condenser The Ford V-8 requires special units of this type. If interference still persists other parts of the automobiles electrical system should be by-passed with condensers available for this purpose. All parts of the frame of the car should make good electrical contact. Additional instructions are commonly supplied with the radio set itself.

At this point we must point out to the student that a radio serviceman just like the doctor does not know it all. A physician will come across many cases completely new and baffling to him, but be will undertake to handle them by additional study and consultation with other men of his profession. The serviceman should do likewise. If the problem puzzles you, simply take the set to the shop or point out that there are a number of facts you must look up and that you will be back next day.

REVIEW QUESTIONS

1. Name several important reasons why batteries are not used for radio power in localities where electrical power is available.

2. What is the function of the power transformer? On what factors does the size of the transformer depends?

3. Why is the field coil of a dynamic speaker often used as the filter choke?

4. What advantage does an A.C. transformer type set have over the AC-DC radio?

5. Why are buffer condensers used in a vibrator power supply circuit? Notice that these condensers are placed in the secondary circuit at times, or sometimes connected in the primary circuit.

6. What advantage does a synchronous vibrator give?

7. Why is it better to connect the power lead from the auto set to a source of power in the automobile, so that the current drain will always register on the ammeter?

8. What happens to the radio's response and the function of the different circuits, when the vibrator points become badly worn?

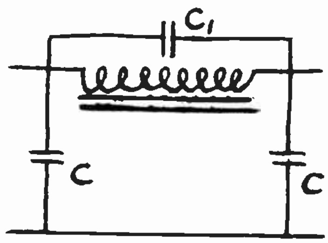
9. What special precautions must be taken in making a repair in an auto radio set?

LESSON 17

In this lesson you will find a great many really helpful service hints and suggestions. These ideas will prove time - savers and money-makers for you.

If hum develops only on strong local stations, it may be removed by connecting a 0.1 mfd. 600 volt paper condenser from one side of the transformer primary to the chassis of the radio set. This keeps the radio set from being modulated by A.C. when tuning in a strong carrier and many new sets are supplied with such condenser arrangement.

Electrolytic condensers sometimes fail to properly filter the circuit and under test will show only a fraction of the original capacity. If electrolytics do not appear in good shape and the radio has a loud hum, it is best to replace these units.



Tuned-Filter Arrangement

In "All American" Models 70 73, 75 and other sets using a tuned-filter as illustrated, the parallel condenser C_1 sometimes blows shorting the choke. This choke and condenser form an anti-resonant circuit and the voltage under such conditions may rise to a very high value. Replacement should be made if a direct short from one side of the choke to the other does not give any change in volume or hum present. A 0.1 mfd. condenser should be tried as a replacement. If the result obtained is not satisfactory, two or more such units should be tried connected in parallel across the choke. Paper units rated at 600 volts or more should be used.

If the complaint of hum really has no bearing, but is due to a critical listener, a 8 mfd. or larger electrolytic condenser placed across the filter circuit will solve this problem.

TUNING MECHANISM OUT OF ORDER

On practically every job, where the radio employs a cable drive, the servicemen have an opportunity to perform an extra service and earn a little additional amount. Since the failure of the tuning mechanism to operate properly comes about slowly, the people using the radio fail to realize how the tuning control once properly operated. Also although many do realize that the tuning mechanism is in error, they continue to use the radio as is since "the radio plays all right". A repair job here nets a quick profit and builds real good will.

Replacement cables may be obtained for almost all radios, but it is another story to find replacement cast parts, gears pulleys, etc. for any radios except a few popular makes. Where a replacement cannot be obtained, a superior repair may be made by replacing the dial assembly with a modern high ratio airplane dial. In the eyes of the radio owner an airplane completely modernizes the set and the set becomes "just as good" as Brown's 1939 model.

Obviously no dial replacement or repair requires any testing instruments. A quick inspection should show the trouble and this should be followed with a quick neat repair job. Remember that a dial cable replacement does not call for a re-alignment of the set except in early Atwater Kent and other models where the variable condensers are coupled by means of cables.

In case a knob needs replacement and the exact type is not available, a complete new set should be obtained. The price of knobs is so low, and the actual appearance to the owner is so important that this will pay dividends in the long run.

Occasionally condensers are found that do not test bad, but which do not operate properly. If such a unit is suspected a replacement should be made for in such case a 10¢ investment may save hours of repair time. For example low volume and poor quality reception is often caused by defective coupling condenser between the detector and the first audio tube. This condenser may develop a high resistance when in operation and will test right when outside of the set.

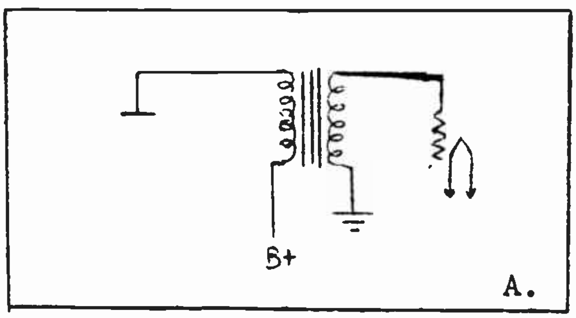
SIMPLE HINTS FOR IMPROVING SELECTIVITY

Without exception the selectivity of old TRF sets can be greatly improved by the use of a good antenna and coupling this to the set through a .00025 mfd. mica condenser. A ground will also prove helpful and should be used with the older sets where such a connection is provided.

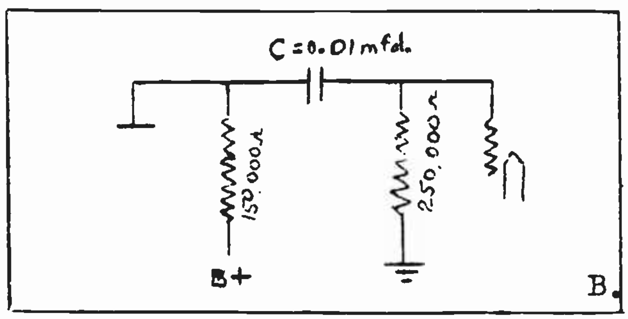
In servicing any old set be sure to test and examine all tubes even if the set appears to be operating correctly. In a radio set using four R.F. stages of 26's, a bad 26 would simply act as a coupling capacity between adjacent stages reducing the over all gain and volume but a small amount. New tubes do real wonders to such radio sets.

REPLACEMENT OF AUDIO TRANSFORMERS

Audio transformers do not often actually fail, but in years of service particularly in moist climates they become noise because of insulation break down. An audio transformer that is noisy or is completely burned out should be replaced. Exact audio replacements are scarce and standard units will serve the purpose just as well and should be employed. In mounting the audio transformer care should be exercised to eliminate any possibility of hum. It is good practice to connect the audio with long leads and locate the most advantageous position in this manner.



A.



B.

Audio transformers coupling single tube stages can be replaced with resistor coupling, usually with an improvement of quality. And what is more the job can be done at a saving of parts. This type of substitution is of especial advantage where space is at a premium. This type of installation is shown schematically above.

SERVICE HINTS

COMPILED AND PUBLISHED BY

Hygrade Sylvania CORPORATION

The following Service Hints have been contributed by servicemen as the result of practical experience. Each hint has been carefully considered before being accepted, and we believe them to be correct and authentic. However, we assume no responsibility with respect to results.

Acratone 9A. Oscillation which is traced to the second r-f circuit is easily remedied by turning the second r-f coil at right angles to the antenna coil, or vice versa.—Geo. G. Baptiste, Howard, R. I.

Admiral 6 Volt Farm Set. A terrible vibrator noise which at times may drown out all reception may be caused by the following condition: The negative lead to the battery is composed of three wires in a cable, a heavy shield which goes to set ground and two small rubber covered wires. These two wires had parted in the covering and were not touching the shield wire. Resoldering these three wires together eliminates the noise. This set is also made by Continental Radio and sold under several well known trade names such as Knight, Mantola, Admiral, etc.—Bernard Greene, Petersburg. Va.

Airline 62-14. Signals at one end of the band only, usually means that the 40,000 ohm resistor from grid of the 27 oscillator tube to ground has changed resistance. Replace with a good metallized resistor and the trouble will be solved —Wayne Storch, Beecher, Ill.

Airline 62-98. The volume control may be improved by using a 5000 ohm unit instead of 10,000 ohms and moving the .001 input blocking condenser to the rear of the chassis away from the antenna coil. To reduce hum and increase efficiency connect the cathodes of the 25Z5 rectifier together and bypass with an 8 mfd. 200 volt tubular electrolytic condenser. For better tone replace the .006 condenser from the 43 plate to ground with a .05 unit.—Lap Radio Laboratory, Plainfield, N. J.

Airline 62-98, 62-104. The filter block and the .25 mfd. bypass in the control grid return of the 43 output tube often gives trouble. In early sets the detector screen was connected to the positive supply. Later a 100,000 ohm resistor was added in series with the screen and bypassed with a .25 mfd., 200 volt condenser at the screen end to prevent overloading and oscillation. Check to be sure these are present.—Henry Berg, Pittsburgh, Pa.

Airline 62-154. The 13,000 ohm series section of the candohm resistor opens and a one watt **carbon** unit is a satisfactory replacement. When the one antenna choke is burned out and no replacement is at hand, check the small shunt condenser for leakage and, if OK use it across the remaining choke, if not OK, use a .005 to .001 mfd. unit across the choke with the antenna connected to the high end.—Henry Berg, Pittsburgh, Pa.

Airline 62-160. To eliminate distortion and improve the tone quality on local stations, replace the 2 megohm bias resistor connected between the control grid and the positive filament contact of the 34 second detector tube with a 750,000 ohm resistor This distortion will be found to be quite severe on local stations when about three-fourths of the B battery's life has been used.—Clarence Camper, Bristol, Tenn.

Airline 62-226. When this set is found with no a-v-c action and an inoperative "tuning eye," check the blocking condenser C5, .05 mfd. in the 6K7 r-f tube grid return. To improve the a-v-c action and for sharper operation on the 6E5 indication, change resistor R21 to a 2.0 megohm unit.—A B. Chismar, Streator, Ill.

Airline 62-249. When the tuning eye (6G5) on these sets does not operate (no control of shadow angle) check the one megohm resistor between the target and plate circuit. This resistor is mounted on the socket of the tuning eye, between the target and plate pin holes. As the space is somewhat small. there is quite a tension on the resistor. This tension often causes the resistor to break. Replace the broken resistor with a new ¼ watt, one megohm unit.—M. Margossian, Oakland, Calif.

Airline 62-316. If this set will pick up short wave stations but no standard broadcast stations. try paralleling a new .0034 or .003 condenser across the C-6 condenser. It is one of the units next to the front of the chassis, of the pair from the waveband change-over switch of the 600 Kc. padding condenser. A condenser of near value will not restore reception.—Warren J. Dougherty, Kincaid, Kans.

American Bosch 670C. This set may cut off due to the wave band switch. Wiggling the switch will indicate the defect. Turn the set upside down and remove the entire coil unit, being careful to note how to reassemble. Clean the round movable plate and flow solder evenly over the entire surface on both sides. Since the contacts cannot be tightened, this remedy, which is a sure one, saves the price of a new switch.—Francis J. Kmetz, Allentown, Pa.

Ansley Universal AC-DC. These sets are often found inoperative with no B voltage on the r-f tubes. After having checked all bypass filter condensers for shorts and still not locating the trouble, check the shielded wire from the plate of the 39/44 tube to the first r-f coil for a short to the shielding. I have run across this condition several times in this particular model.—John H. Bloomer, Philadelphia, Pa.

Arvin 27. This radio has what seemed to be a high pitched audio squeal on all stations. The trouble was not found in the audio circuit, however, but in the twin .05 condenser, bypassing the grid return from the r-f coil to the 78 tube and the grid return to the 6A7 oscillator circuit. These two condensers are used as bypass condensers and are known as C17A andC17B. The one in the oscillator circuit opened up, hence the trouble. Replace the twin condenser with two separate high efficiency condensers with good stout leads. Anchor them down tightly.—Keith Howard, Santa Ana, Calif.

Arvin 7, 17, 27, 37. Intermittent oscillation is often caused by a defective a-v-c condenser between the 78 tube and the antenna coil. Replace with a new condenser. In the Model 7, the condenser is located between the 6F7 tube socket and the antenna coil.—Doran's Radio Service, Martinsville, Ill.

Arvin Radios (All 1935 Models). Oscillation and motorboating in these sets is usually caused by the condenser located between the antenna coil and r-f tube. The capacity of this dual condenser is .05 and .05 mfd. at 160 volts. The voltage rating of the original is apparently too low. In replacing use a 400 volt unit. This condenser is used as an a-v-c bypass and is Arvin part No. 17-4731. Orvil W. Carter, Coffeyville, Kans.

Atwater Kent 2. These receivers or any other battery models having the off-on switch controlling A and B voltages, will eventually give trouble until the jinx is found.

The set will work fine then suddenly quit, appearing to have gone out of oscillation. Simply change the double pole double throw toggle switch with a new one and your troubles will be over. Almost all of these models develop this trouble sooner or later.—V. M. Moen, Tracy, Minn.

Atwater Kent 72. I often find these models completely dead or just loud enough to be heard with the volume on full. The first thing to examine is the first audio filter resistor, located directly under and a little to the right of the first audio transformer This resistor is white with a grey band around it. Replace with a 30,000 ohm, 1 watt unit. Due to the age of these resistors, some test open. others have a very high resistance and pass little or no plate voltage to the first audio tube.—H. L. Fornoff, Buffalo, N. Y.

Atwater Kent 89, 89F, 89P. Intermittent operation in these models is sometimes caused by the failing of the 800 ohm flexible bleeder resistor between screen and cathode of the 24A a-v-c control tube. You are usually able to make the set come on loud if you provide a. path for grid return to ground on the control tube by touching your hand to the grid cap and the chassis. This kind of trouble is usually hard to locate as the resistor will check all right with the set turned on.—V. L. Crawford, Texarkana, Tex.

Atwater Kent 165. We have had several cases of severe distortion and loud hum in this receiver and have corrected it by the following method: Install a filter consisting of a 3000 ohm resistor and a 0.2 mfd. condenser in series with the B plus lead of the i-f transformer in the plate circuit of the 58 i-f amplifier tube. In severe cases it will be necessary to use a larger condenser. One set of this model which we repaired was so severe that it was necessary to use an 8 mfd. electrolytic condenser. However, this method cleared it up nicely, whereas before the slightest increase in volume made reception unbearable.—Clarence C. Fuller, Loxley, Ala.

Atwater Kent 480. When this set is dead on the low frequency end of the broadcast band, check the bypass on the plate circuit of the 58 r-f tube. Often it shows high leakage and replacing it will cure the trouble. It is best to replace the oscillator tube with a Sylvania 56 as the circuit seems to be critical as to tubes. —Donald G. Buck, N. Tonawanda, N. Y.

Atwater Kent 812. Erratic reception, sometimes accompanied with noise and oscillation may be due to broken or loose connections to the .00145 mfd. condenser located inside the oscillator coil shield. Replace with a mica .0015 unit. Do not attempt to place the new unit in some other section of the set as it must be within the shield. Henry Burlington, Abington, Pa.

Audiola 23-S-10. This receiver has a neon tuning indicator which sometimes goes out of commission. There are two probable causes of such trouble; one is the resistor connected to the tuning indicator changing its value, and the other is a defective 1 mfd. condenser connecting to same. This condenser is often overlooked and it is always advisable to replace. The proper value of the tuning indicator resistor is 10,000 ohms.—Geo. F. Baptiste, Howard, R. I.

Balkeit 41A. Oscillation, which sometimes occurs in these receivers after they have been in operation a short time, can usually be traced to tube shields working loose or not fitting properly. A good kink is to solder flexible wire leads to all tube shields and ground each one to the chassis.—Geo. F. Baptiste, Howard, R. I.

Belmont 550. When plate voltage in these sets drops from around 300 volts to about 80 volts shortly after being turned on, look for a shorted i-f input transformer. The lugs inside the can sometimes short to the wire of the coils, providing a direct short from the 2A7 plate coil to the 58 grid coil. Remedy: Bend each lug away from the coil or snip off the ends of the lugs.—J. E. Lephart, Arcanum, Ohio

Belmont 685, 686A, 686B, 786A. If this set will pick up short wave stations but no standard broadcast stations, try paralleling a new .0034 or .003 condenser across the C-6 condenser. It is one of the units next to the front of the chassis, of the pair from the waveband change-over switch of the 600 Kc. padding condenser. A condenser of near value will not restore reception. This hint also applies to the Airline Model 62-316.—Warren J. Dougherty, Kincaid, Kans.

Belmont Gamble 770 Series A, 777 Series B-C. In a few cases, difficulty has been experienced with intermittent hum. This hum usually appears only after the receiver has been allowed to operate for some time and temporarily disappears upon snapping the line switch off and on. The difficulty is generally due to the opening of the common lead of the dual condenser (.1—.25 part No. 118-12), at the point of attachment to the condenser coil.

This dual condenser is indicated as C-18 and C-14 on the circuit diagram C-14 being the .1 mfd. 200 volt screen bypass of the 6B7, while C-18 is a .25 mfd. 200 volt unit acting as a filter for the bias voltage of the type 42 tube. Examination of the circuit will show that when this occurs, the entire hum voltage of the filter is impressed on the screen of the type 6B7 tube. It is generally advisable to replace the entire unit with two separate units having ratings identical with the original unit.—Sidney E. Keepers, Pierre, S. D.

Belmont 777 Series B. Bad distortion and poor a-v-c action can be cured by replacing the 250,000 ohm, ½ watt, 6B7 plate load resistor even though it appears A-1 in value.

Improved tone and performance can be obtained by replacing the 180 ohm cathode resistor for the two 6D6 tubes with a ½ watt 300 ohm resistor. Oscillation and hum in these models is usually due to an open in the dual unit condenser #P-118-12 (0.1 mfd. and .25 mfd. C14 and C18 on the diagram). Replace these units with single section 0.1 mfd., 600 volt units.—N. E. Nelson, Mayville, N. D.

Belmont 778 Series B. If the set is intermittent or inoperative over lower portion of dial at about 1200 Kc. the bakelite condenser across the terminals of the low frequency trimmer may be open. The capacity of this condenser is .0005 mfd.—Tim W. Shaw, Vernon, Texas.

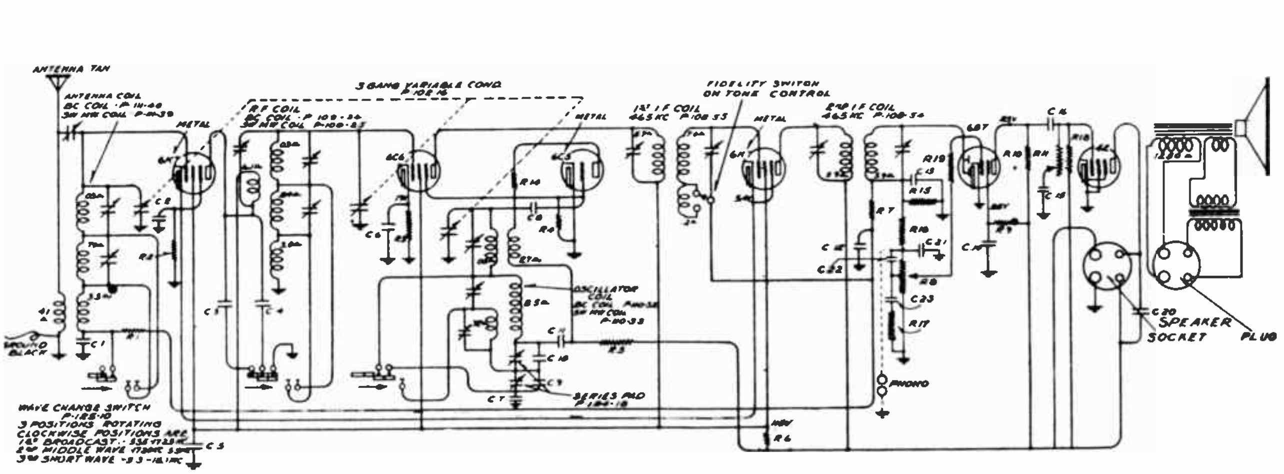
Bosch 48 Modernization. Replace the 24A sockets with standard 6 prong sockets for type 58 tubes. Connect the suppressor directly to the cathode of the socket. The type 27 tube is replaced by a type 56. The biasing and screen resistors remain the same due to the similarity of the tubes. The trimmers should then be rebalanced. This change results in higher sensitivity, better selectivity, clearer tone, and better control of volume.—Louis Freedman, Brooklyn, N. Y.

Bosch 58. Complaint: inoperative. Try touching the antenna or oscillator lead to the control grid of the first r-f (24A) on the right hand side next to the 27. If a signal comes through, check the variable condenser No. 1, for shorted plates. The rotor plates of the condenser are held to the shaft by small cap screws. These screws work off center until the rotor plates touch part or all of the stator plates.—Herbert Hass, Chicago, Ill.

Bosch 236. When distortion is the trouble in this model, replace the cathode resistor in the 57 second detector tube circuit with a 25,000 ohm resistor in place of the 250,000 ohm unit useb in some sets.—Ray Chandler, Delake, Ore.

Bosch 440C. Erratic and weak reception after set plays a few minutes. The lug on the L. F. broadcast oscillator padder condenser C39, is arranged in such a way as to short out the condenser very easily.—A. B. Chismar, Streator, Ill.

BELMONT GAMBLE 770



Clarion Jr. A tone control and built-in antenna may be added to this receiver with very little difficulty. The control consists of a 50,000 ohm variable resistor and a 0.1, 600 volt condenser. The 0.1 condenser is connected from the plate of the 47 to ground with the variable resistor in series with the grounded side of the condenser.

The built-in antenna consists of two 0.1, 200 volt condensers connected to either side of the 110 volt line. One of the condensers is directly grounded while the other one is connected to the antenna post on the antenna coil.—Stoddard Radio Lab., Oak Park, Ill.

Clarion 80, 81. Models AC 80 and 81 Clarion Receivers manufactured by Transformer Corporation of America may have a-v-c added by replacing the type 24A second Detector tube with a type 2A6. This necessitates changing the socket for this stage from a five to a six prong socket and making the following circuit alterations. Connect the diodes of the type 2A6 together and connect to the former grid terminal of the second i-f transformer. Replace the tone control and on-off switch with a .5 megohm potentiometer having an on-off switch. The potentiometer to be used as the diode coil return to the 2A6 cathode, and supply for a-v-c voltage. The control grid of the Type 2A6 should go direct to ground through a .5 megohm resistor and is coupled to the variable arm of the new volume control potentiometer through a .02 condenser. An additional 150,000 ohm resistor should be added to the plate load of the 2A6. The 40,000 ohm bias resistor of the original 24A tube should be replaced with a 3,000 ohm resistor.

To complete the a-v-c circuit the grid inductances of the r-f and first detector stages must be removed from ground. This necessitates the removal of both these coils from the chassis as they are grounded within the shield cans. A 1 megohm resistor is connected from the high side of the new volume control potentiometer to the low side of the first detector grid coil. This point is bypassed to ground through a .01 condenser, and is also connected to the low side of the r-f coil through a .1 megohm resistor where a .005 condenser may be used as a bypass. The 230 ohm bias resistor is disconnected from the variable arm of the old volume control and connected directly to ground. The old volume control is now connected from ground to the .02 condenser which is connected to the plate circuit of the type 47 output tube and serves as the new tone control. The installation of this circuit prevents fading on weak signals and overloading on very strong signals.—E. E. Overmier.

Clarion 240 (All Wave). Low volume may be due to an open bypass condenser inside the i-f can located at the right rear of the set looking from the back. Replace with a .05 mfd. tubular condenser. It is necessary, when aligning these models, to make certain the bottom chassis plate is in place and making good connection to the chassis proper, otherwise the alignment will change when the receiver is bolted in the cabinet.—D. A. Brown, Marion, Ohio.

Clarion 470. If all parts check O. K. but choppy reception, distortion and low sensitivity persists, change the 2A6 tube bias resistor to 5000 ohms. The original value was 10,000 ohms.—A. H. Kohnert, Millbrook, N. Y.

Colonial 62. Operation failure in this model may be due to the type 56 oscillator tube not oscillating. If replacing the tube has no results, check the grid resistor and grid condenser of this tube and if values have changed replace the proper units, (value 30,000 ohms—.00025 mfd.). If this is not the trouble or if the set still lacks tone quality, and the power output is distorted, check the 8 mfd. input condenser going to speaker field as this often shows leakage.—Geo. F. Baptiste, Howard, R. I.

Coronado 575. If the complaint is fading look for a poor ground on the battery switch. The ground is obtained through a wire running from the switch to one of the i-f can lugs. This has a habit of working loose. The switch is usually OK, but if in doubt ground the shaft with a pigtail.—Vere L. Henning, Montevideo, Minn.

Courier 65. The volume of this set can be increased 25 per cent by removing the cathode resistor ahead of the variable resistor used as a volume control. A smaller resistor can be put in its place. The volume control should be replaced with a tapering type to reduce the critical adjustments in varying volume.—Walter Gazowsky, Detroit Mich.

Courier 65. When this set oscillates and all remedies fail try an 0.1 mfd. condenser from contact of volume control (opposite the contact ground) to ground on chassis. This will remedy the trouble.—Clarence Bierkamp, Jr., Youngstown, Ohio.

Crosley 143. Symptoms:—Poor control of volume and also extremely difficult to tune in stations at the high frequency end of the dial. Replace the 300,000 ohm second detector 34 tube plate load resistor with one of 250,000 ohms. Improved punch and better control of volume can be obtained by changing the negative 22½ volt lead to the minus 16½ volt tap on the "C" battery. This will increase "B" drain only slightly. The 2.0 mfd. condenser across the "B" supply usually develops leakage so be sure to replace. Improved tone can be had by replacing the Class "B" input transformer.—N. E. Nelson, Mayville, N. D.

Crosley 148. In many of these radios the first i-f plate trimmer will short, killing all "B" voltages and acting like a shorted filter condenser. The short usually occurs next to the ground plate of the trimmer, several plates being in the trimmer. Re-insulate with larger pieces of mica.—Barrett Radio Service, Sulphur Springs, Texas.

Crosley 148 (Fiver). Elimination of modulation hum, increased volume and improved tone may be obtained in these models by merely adding a .02 mfd., 600 volt condenser from the low side of the a-c switch to the chassis.—N. E. Nelson, Mayville, N. D.

Crosley 148, 167, 169. When these radios come in with a complaint of no reception and a steady low pitched shrill whistle, replace the dual condensers .03, .006, serving as coupling condenser and detector plate bypass. This trouble is very hard to locate as it sometimes takes days and even weeks to act up, and when it does start to whistle the slightest electrical disturbance in testing restores normal operation.—Fred B. Honchock, Monessen, Pa.

Crosley 163. Bad distortion after the set warms up with all resistors okey and the filter condensers perfect, can be cured by making the following change: Replace the 150,000 ohm resistor in the cathode circuit of the 77 tube with a 100,000 ohm unit and the set will be okey.—N. E. Nelson, Mayville, N. D.

Crosley 168. Loud 60 cycle hum on strong stations. To remedy, it is necessary to install an 0.1 mfd. condenser between one side of the a-c line and chassis.—Paul Grayson, Gastonia, N. C.

Crosley 636. A complaint of intermittent oscillation, squeals and howls was very difficult to locate. The trouble was eliminated by the replacement of the class "B" input transformer part No. 24628, a unit we did not suspect. We found this trouble in several of these models.—Joseph S. Napora, Uniontown, Pa.

Crosley 716. A complaint of no reception or of excessive noise, is often caused by an open or intermittent oscillator plate resistor. This resistor is wire wound and is a frequent offender. Replacement should be made with a high grade carbon resistor of reputable make.—Joseph S. Napora, Uniontown, Pa.

Crosley 816. In this receiver and other Crosley models using the special sound diffuser baffle, a complaint of rattles is often traced to loose sections of the ply wood of which the baffle is made. Take the speaker off the baffle board and recement any particles of the plywood.—Joseph S. Napora, Uniontown, Pa.

Delco 1936-37 Home Sets. When these sets have been in use for some time they may develop loud crackles and roars. You will likely find that the wave band switch when turned from one band to another has quite a bit of mechanical movement that causes the socket of the 6C5 tube, located to the right and next to the dial, to become internally shorted. Replace the socket, but be sure to solder a small piece of flexible wire from the external connection to the part which makes contact with the tube prong. We have had several of the above cases in our shop and have found that the grid prong always shorts first.—Red's Radio Shop, Birmingham, Mich.

Delco 628. When this set will not bring in weak signals, make sure that the receiver is in normal operating condition and make the following change: Locate a black lead protruding from the bottom of the second i-f coil. This lead connects to the inside end-lug of the five lug terminal strip located on the side of the vibrator shield partition. Disconnect this lead from the terminal strip and connect it directly to the 85 tube cathode. This will improve reception in remote districts, but will give very noisy reception if used in cities where local interference is bad.—Orvil W. Carter, Coffeyville, Kans.

Delco 3201, 3202—32 Volt Radios. These sets often motorboat between stations although they are properly balanced. The trouble is that the line voltage is too high. Install an automatic voltage control tube to keep the voltage at 32 volts. This set draws 1.5 ampere at 32 volts.—John L. Freling, Hannibal, Mo.

Detrola 5-B. For very choppy tone starting about 10 minutes after the set is turned on, look for an open section of the candohm resistor located on the right of the ground connections on the candohm. Replace with a 100 ohm, 5 watt resistor. The value is very critical. This trouble is hard to locate because of the parallel circuit.—Al's Radio Service, Tonawanda, N. Y.

Detrola 6-W. The resistors used in this model tend to increase in value after a period of time. On cases where the set is weak, particularly check the 7500 ohm plate resistor in the i-f stage. If the trouble is distortion, check for shorted or leaky 25 mfd. electrolytic across 42 bias section of candohm bleeder.—F. Reisdorf, Detroit, Mich.

Emerson H-5. Bad hum when the condensers and tubes check perfect, may be due to the following. If the line ballast is the type where the resistance element is clamped in a metal holder with asbestos as an insulator between the two, place the set in operation and check for a-c leakage from any tap on the ballast to chassis. If an indication is present insulate the ballast from the chassis or replace same.—A. H. Urbansky, Newark, N. J.

Emerson U6D. A common complaint from this receiver is frequency drift necessitating constant retuning in order to hold any certain station on the broadcast range. On the short wave range this trouble is not so noticeable. The peculiar problem is that when this receiver is removed from the cabinet, all signs of drift or frequency change disappears. The trouble will be found in a small midget type compensating condenser in series with the broadcast oscillator coil. This condenser being of a composition fibre and mica construction will not hold calibration with changes in temperature. There are two possible remedies—one is to replace the condenser with a small air tuned walnut type. However, a much simpler method is to control the temperature change in the receiver by providing ventilation. This can be done by drilling several ⅝ inch holes in the cabinet base in the vicinity of the compensating condenser, making sure that one of the holes falls directly opposite the condenser. This not only provides ventilation but also makes the condenser accessible for adjustment without removing the chassis from the cabinet. The above procedure completely eliminates drift and frequency change, and also improves reception greatly since poor ventilation also has a tendency to throw the i-f transformers out of line. The above trouble does not manifest itself on the S. W. band due to the fact that the compensating condenser controlling the oscillator coil for S. W. is in parallel and therefore not as critical. C. C. Richelieu, Milwaukee, Wis.

Emerson 103. A loud pitched whistle which is much stronger than any station can be cured by using a lower value resistor in the grid of the 33. Use the highest value that will stop the noise. Daniels Bros., Everett, Pa.

Emerson L135 or 2 MN Series. When these sets come in dead and all voltages are normal, look for corrosion in the oscillator coil primary. A continuity test will show the coil to be ok. Many of these coils absorb moisture in damp climates, particularly in the Gulf States Area. The corrosion is sometimes barely noticeable. It is best to replace the coil as repairing of the wire is difficult.—Barrett Radio Service, Sulphur Springs, Texas.

Erla-Sentinel 60BT. In several of these radios, I have found the following trouble: The volume is very low on all stations, although all voltages test all right. I have found this trouble to be caused by a partial short in the volume control. The center terminal tests about 500 ohms to ground. Sometimes the short disappears during the testing process, but it is safer to replace the volume control anyway. This is the first thing to look for in this and similar models. —Robert Smith, Olds, Iowa.

Erla 6200, 7700. To stop oscillation in these models, replace the .01 mfd. condenser, used to bypass the grid return, with an .02 mfd. on the i-f transformer. To improve the tone quality and eliminate background noise in the Model 6200, install a 10,000 ohm resistor in series with a .005 mfd. condenser from plate to ground on the last audio tube.—Geo. A Lewis, Storm Lake, Iowa.

Fada K. U. This set uses a system of screen bleeder and cathode variation for a volume control giving poor control at low volume. To remedy this proceed as follows: Remove old volume control, installing new 15,000 ohm control with taper for antenna and cathode bias. Ground center arm of new control, left arm goes to antenna post, right arm goes to cathode bias resistor, then ground old wire leading from screen series resistor through 5,000 to 8,000 ohm, 2 watt resistor. This completes the job and the volume control is now smoother. This can be used on other sets using the same method of volume controlling.—Al's Radio Service, Tonawanda, N. Y.

Fairbanks Morse 8AT8, 8AC2, 8AC3. When these sets are normal on police and foreign stations, but completely dead on standard broadcast, look at the resistor mounted directly on the 6C5G oscillator socket and connected to terminals #1 and #5. Unless the resistor is open the application of a hot iron to the joints will cause normal reception. We have had several of these sets with exactly the same trouble.—Bernard Greene, Petersburg, Va.

Fairbanks Morse 42 Series. If you are having trouble keeping "B" and "C" batteries on this receiver, trace out and remove entirely from the set, the 20,000 ohm ¼ watt resistor that goes from minus 16½ volts C direct to ground. We have found this on several of these sets and have noticed no drop in the performance of the set, but have increased our battery life more than 100% in most cases.

Explanation: The switch in this set is on the negative lead, A, B and C plus and as this resistor is from C minus 16½ volts to ground, there is a direct lead from "B" through to the "C" battery through the 20,000 ohm resistor to ground even though the switch is open, and as the "B" minus circuit is returned to ground through a filter condenser and a high resistance resistor circuit, the circuit is therefore complete enough to allow from 1 Ma. to 2½ Ma. of "B" and "C" current to drain at all times which will shorten the life of the "B" and "C" batteries considerably. Before we started to remove this resistor our batteries were only lasting a few days for the Eveready No. 772, to a few weeks for the Eveready No. 486's. We now actually get months of operation from the No. 772 "B" batteries.—O. M. Haire, Hagerstown, Md.

Fairbanks Morse 42T5-B. Steady drain on B's when set is turned off. The drain is as high as 1½ mills. For satisfactory service, remove the 20,000 ohm resistor from minus 16½ C to ground. —Harold Gillogly, Bonners Ferry, Idaho.

Freshman 400. A type 56 with the grid tied to the plate is used as a rectifier. The grid of this tube often shorts to the cathode thus shorting the transformer. This fault can be remedied by replacing the 56 with a Sylvania 84. The filament terminals are disconnected from the 2.5 volt supply and are connected in parallel to the 6 volt supply of the 41 output. The two plates of the 84 should be connected together at the socket.—Stanley Baronowski, Bayonne, N. J.

Gable 1937. If you have a call on a Gable '37 job and you find it dead with an unusual blue glow in the 83—don't dive for the filters. Examine the wire on the low side of the choke. You no doubt will find that the insulation has broken down and the wire is shorting to ground. Clip the wire and run it through a piece of spaghetti, resolder and the job is OK. We have serviced several of these machines for the same trouble.—B. Greene, Petersburg, Va.

General Electric Pilot Light Failures. A cure for pilot lights burning out in 1937 G. E. with colorama lights is the placing of a 150 ohm resistor in the center tap of the high voltage winding. Also a 15 ohm resistor should be used with the colored lamps. This will offset high line voltages.—Alvin Morgan, Somerset, Ky.

General Electric A-64, A-67. Distortion may be cleared by raising the 6J7 audio plate voltage to 78 volts. The plate dropping resistor often increases in value from its original 500,000 ohms, thus reducing the voltage.—F. W. Johnston, Gainesville, Fla.

General Electric A-82, A-86, A-87. Failure on any particular band may frequently be traced to a shorted permaliner trimmer condenser. The permaliners are located in the Sentry Box, thus it is necessary to remove one of the shield cans. This may be done by removing the dial cylinder and band-change-switch assembly and sliding the switch shaft out the front. With the switch shaft removed all parts are easily accessible.—F. W. Johnston, Gainesville, Fla.

General Electric A-86. In this receiver and others with the Sentry Box assembly, it is a complicated job to remove the Sentry Box shield cans to get at the source of trouble when located in that unit. After I have the Sentry Box cans off for the first time, I cut a slot from the wave band switch hole to the edge of the can so that on future jobs on the same set, it will be possible to remove the cans without touching the dial assembly. This saves considerable time on any subsequent servicing of that set. —Oscar Carlson, Seaside Park,

General Electric C-41. On this model a short between the open end of the i-f trimmer and the primary soldering lug will ruin the 6B7 tube. This occurs when the set warms up just enough to cause this trimmer plate to warp over and touch any solder that has run down the lug on the trimmer side. Remove the solder in the trimmer side and replace the tube with a new Sylvania 6B7.—Geo. Baer, Roslindale, Mass.

General Electric E-91, E-95, E-101, E-105, E-106. Failure of the Colorama Dial to change or sluggish changing may be traced to a defective 0.5 mfd. condenser across the high resistance side of the Colorama reactor, part #RC156 schematic part C52. Colorama changing may also be pepped up by replacing the Colorama tube with a Sylvania tube of the same type.—F. W. Johnston, Gainesville.

General Electric F-63. When the antenna coil in this receiver burns up, don't suspect the set of having been struck with lightning. The wave band switch, in which the rotation stop arm becomes defective, will rotate beyond its proper point and place 98 volts on the antenna winding, subsequently burning it out.

General Electric J-100, J-105, J-107, J-109. Each of these sets use a type 82 mercury vapor rectifier which radiates noise on weak signals. This 82 tube may be changed to a Sylvania 5Z3 rectifier by the following directions: The power transformer on this set has a separate 2.5 volt winding for the 56 a-v-c tube. Disconnect this from the a-v-c tube and connect in series with the rectifier winding, thus giving the necessary 5 volts for the 5Z3 tube. Next connect the a-v-c heaters to the winding supplying the other 2.5 volt tubes. The wire connecting the a-v-c heater to the cathode should be removed.—Al's Radio Service, Tonawanda, N. Y.

General Electric J-125. Intermittent, erratic reception and oscillation or motorboating between stations is often caused by dirty wiping contacts on the variable condensers. Cleaning these usually remedies this situation.—George Springmeier, Jr., Cincinnati, Ohio.

General Electric K-51. When all voltages test all right and the set has low volume the trouble is usually a defective series padding condenser in the 2A7 circuit. The oscillator and i-f adjustment and the series padding condenser should be checked carefully.—Geo. F. Baptiste, Howard, R. I.

General Electric K-62, RCA R-11. To cure motorboating connect an 0.1 mfd. condenser across the resistor mounted inside the antenna coil.—Roy E. Busse, Mankato, Minn.

General Electric M 51. A fading hard to find is often caused by the coupling condenser from the plate of the 6B7 to the grid of the 42 opening up. Replace with a .01 mfd., 600 volt unit.—Al's Radio Service, Tonawanda, N. Y.

General Motors A. Models with serial numbers below 62100A have a metal encased 0.1 mfd. condenser across the first choke coil in the filter supply. Hum will result if this condenser shorts. This condenser is under five connection terminal strips in the rear left hand corner when the set is turned bottom side up. Models with serial numbers above 62100A do not use this condenser and it does not seem to make any noticeable difference when not used.—Clifton S. Krumling, Spencer, Iowa.

General Motors 120, 130, 140. Several cases of intermittent reception were caused by the condenser which by-passes the cathode voltage on the first r-f tube. I replace this condenser with a tubular unit and have no more trouble. While I have the sets in for repair I solder a pigtail from the condenser rotor to ground to suppress oscillation on the high frequencies.—Harold B. Cook, Wichita, Kans.

General Motors 251. To prevent cross-modulation from very strong nearby stations, install a shielded lead from the antenna post to the antenna coil. Also switch the lead from the antenna coil to the lug next to the coil, and use the old antenna coil lug for connecting the oscillator condenser.—Anderson Radio Hospital, Seattle, Wash.

Gloritone 26. Better all around performance of this set can be had by removing the black bypass condenser that goes from the r-f assembly to ground on back of chassis. This will result in better quality and an increase in frequency range.—David Williams, Peabody, Mass.

Gloritone or Carlton 27 Chassis. To increase sensitivity and volume on these models, remove the wire on the shunt resistor from the terminal next to the B plus at the right hand end, resolder to extreme end. This will increase plate voltages and will result in pick-up on volume. In all high gain receivers employing cathode bias volume control, you can try connecting a 1 to 4 mfd. condenser from cathode to ground to end oscillation.—Geo. Baer, Roslindale, Mass.

Gloritone 27. The simplest way to squelch inductive hum originating in the audio section is to insert a resistance of about one-half megohm between the grid of the power tube and ground. Too high a value will have no effect; too low a value will stop the hum but will also impair tone. Don't connect the resistor across the audio transformer secondary. When it becomes necessary to replace the power tube bias resistor in this model, use one with a 20-watt rating as this resistor carries the total output of the power supply.—B. E. Wenstrom, Ashtabula, Ohio.

Graybar 100. When this set has poor or no reception with the type 27 a-v-c tube in the socket, but good reception when the tube is removed, check the cathode by-pass condenser. The heater and cathode of the a-v-c tube are tied together and by-passed to the grid. An 0.5 mfd. condenser will work very nicely.—Geo. Baer, Roslindale, Mass.

Grunow Super Teledial (Any Model). When this set cuts off and the trouble cannot be located, slip off the dial and check the reeds on the station stop. Careful inspection of the reeds and moving them with an insulated rod will show up the trouble as defective mica spacers. Replace with new spacers.—Francis J. Kmetz, Allentown, Pa.

Grunow 12W. The 0.1 mfd. condenser from B plus on the third i-f transformer to ground gives quite a lot of trouble in these sets. It often shorts and burns up the 2200 ohm dropping resistor in series with the second i-f tube plate circuit. It is a good practice when working on these sets to replace this condenser whether it is shorted or not.—D. H. Prewitt, Artesia, Calif.

Grunow 622. Audio distortion is usually caused by lack of grid bias on 42 output tube with plate current of about 65 milliamperes. All resistor and condenser values correct. Insert a 400 ohm. five or ten watt resistor between the black wire from the speaker field coil and the negative end of the wire wound C resistor increasing the bias to proper value.—R. L. Bonsteel, Asheville, N. Y.

Grunow 660 Chassis 6C. A frequent trouble in this receiver is mushy reception. The set will pick up stations but the reception will be distorted. We have found in every case of this kind that the .01 coupling condenser between the plate of the 75 tube and the grid of the 42 was leaky. Even if this condenser has a leakage of from 5 to 10 megohms, it will cause trouble. This unit is part No. 29453, mounted on the inside and at the bottom of the small terminal board which is on the left side of the chassis looking at the set bottom side up from the front. Replace with a 600 volt type and you won't have any call backs. Be sure to disconnect one end of this condenser to test for leakage.—J. S. Kreutz, Ansonia, Conn.

Grunow 750, 751, 752. No reception in these models on part of band "C" from about 2000 to 1500 kc., even though set checks OK and is otherwise normal, is due to the oscillator refusing to function over that portion of the band. Remove 50,000 ohm oscillator grid resistor (Part #23853) and replace with a higher value; about 150,000 ohms seems satisfactory.—Anthony Piatti, Northville, Mich.

Grunow 1067 (Teledial). If this set cuts off, check the mica bodied resistor connected from the 6F6 tubes to ground as it often opens. If shorted, the set will motorboat on strong locals at normal gain. The value of this unit being very critical makes it best to use a resistance indicator to obtain good overall sensitivity.—Francis J. Kmetz, Allentown, Pa.

Grunow (1937). A peculiar hum which develops on some of the Grunow 15 tube models after the set has played a few minutes can be eliminated by connecting the shell of the large speaker to ground.—Oliver F. Klein, Milwaukee, Wisc.

International Kadette. Hissing and intermittent oscillation at the high frequency end of the dial can usually be overcome by cleaning the condenser plates and adjusting the trimmers. If noises are present, either replace KR-1 rectifier with a Sylvania type 1V or place a small r-f choke between cathode of rectifier and the filter choke. This choke will filter out the disturbances which are so common with mercury-vapor rectifiers. The type 1V is a vacuum type rectifier and does not cause such disturbances.—Henry Burlingame, Abington, Pa.

International Kadette. A common trouble with these sets is due to the line dropping resistor becoming quite hot and causing disintegration of the parts. The failure is usually that of the dual 0.5, 0.5 mfd. bypass condenser to the cathodes of the 36 and 38 tubes. Remove the line dropping resistor from the set and replace with a 290 ohm line resistor cord.—William R. Benedt, Chicago, Ill.

Kennedy 62D. When the tuning meter is jumpy, accompanied by erratic action of the set, the trouble may be traced to intermittent opening of the 4200 ohm section of the Candohm voltage divider. This will check okey with the switch off.—Clarence M. Doyle, Utica, N. Y.

Kolster 110, 120, 130, 140. Perfect alignment of these models is usually difficult because the tuning condensers are enclosed in a shield that cannot be taken off. Often the condenser plates need altering and the only way to do this is to take a screw driver and a pair of pliers, bending the fore part of the shield out and upward. At first it looks as if you are tearing the set up, but it's really easy to put back when once torn apart. Altering the plates and adjustment of the trimmers will give a perfect balance job.—Harold B. Cook, Wichita, Kans.

Lafayette 24. If the signal detunes when the automatic frequency control is turned on, readjust the discriminator transformer which controls this action. A low range (0-5V or 0-10V) high resistance voltmeter or preferably a microammeter is inserted in series with the diode load resistor at the grounded end, which will indicate maximum when a signal is tuned to exact resonance. The 0.5 megohm load resistor is located directly under the discriminator transformer. A 0-10 milliammeter is inserted in the cathode circuit of the a-f-c tube. An r-f signal (any frequency in the broadcast band) is fed into the receiver and is tuned as accurately as possible (with a-f-c off). Now throw the secondary trimmer of the discriminator off resonance. Tune by the meter maximum output of the primary side. Turn a-f-c on and tune secondary in the same manner. Then turn a-f-c switch on and off, there should be no meter deflection.—Herbert Hass, Chicago, Ill.

L'Tatro 6-Volt Farm Radio H465-I465. The early sets of these models go dead with no apparent reason; voltages test normal; vibrator sounds all right and the tubes light. Holding the aerial wire on the cap of the Type 15 oscillator tube generally brings in stations. The reason for this is that the oscillator tube does not oscillate properly. A sure cure is to replace the 5000 ohm resistor, shunted across the .0015 condenser from the cathode of the 15 oscillator tube to center tap of the oscillator coil. Replace the resistor with one of about 3800 ohms resistance. These parts will be found on the end of the radio where the aerial wire enters. In the later models of this set, the resistor was changed at the factory.—Raymond Feldman, Little Rock, Iowa.

L'Tatro K54, M54, NH44, (32 V.). Lack of volume and poor quality in these models, providing the 45 volt "B" battery is good, is generally due to lost capacity in the 10 mfd. 25 volt electrolytic condenser in the 75 tube cathode circuit.

Incidentally, these sets can be stepped up in volume considerably by merely removing the dial lamp. No danger to the tubes, in so doing, unless the 32 volt supply runs well up above 35 volts most of the time.—N. E. Nelson, Mayville, N. D.

L'Tatro UP36, ZP36 (32 V.). Very weak reception which is isolated to the 75 tube grid circuit may be a short across the ground and center tap terminals (center tap goes to 75 grid). The trouble is that the 75 grid lead is grounded to the shield. This trouble may eventually develop in many of these models due to the thin insulation between the wire and the shield.—N. E. Nelson, Mayville, N. D.

Lyric LA-6. Symptoms:—Intermittent reception, crackling noises, or set completely dead. The 80 rectifier tube is usually damaged. A continuity check does not reveal the trouble. The trouble lies in the speaker field insulation breaking down and shorting to the speaker frame which is grounded. If the coil is not extensively damaged, a permanent repair may be effected by insulating same, and reassembling the speaker. Install a new Sylvania type 80 as the rectifier is probably weakened or otherwise damaged due to the load on it.—Al Kiszewski, Milwaukee, Wisc.

Majestic Receivers. In the Majestic receivers that use spray-shield tubes, I had oscillation trouble that was difficult to locate. This was usually of an intermittent nature. The oscillation was found to be due to the spray-shield not making contact with the cathode pin. The wire connected from the pin to the shield was broken or was not making good contact on the shield. The cure is to replace with a Sylvania shielded tube of the same type number. The 6F7S usually causes the trouble.—F. Sikonski, Pawtucket, R. I.

Majestic 15. Failure to operate below 800 Kc. can be overcome by changing the autodyne 24A cathode bias resistor to 8000 ohms. To improve, change the autodyne 24A to a 57 tube using a 7,500 ohm bias resistor.—Bill Eslick, Norwich, Kans.

Majestic 20. The oscillator 0.1 megohm grid resistor that usually opens can be replaced without removing the bottom cover and unsoldering wires. Remove the horseshoe washer from the shaft and take off the dial. The resistor can be reached by using long nose pliers. Carefully grip the resistor with pliers and raise it up causing the pigtail lead to unwind from the resistor. Solder a new resistor lead to the old pigtail and ground the other side of the resistor to the most convenient place on the chassis. By removing the right end plate (facing front of the set) the old resistor can be cut from the chassis with diagonal cutters. This will save considerable time.—E. Bintliff, Riverside Park, N. J.

Majestic 50. This set would play for a while then click and the volume would drop so that the set could hardly be heard. All voltages checked normal, and turning on or off electric lights or appliances did not affect operation. The trouble was found to be a defective .04 mfd. condenser between the center tap of the oscillator coil and cathode of the type 24A first detector tube. Replacing this part solves the problem.—G. F. Kinkade, Elk Mills, Md.

Majestic 66. Choked and distorted signals with weak reception may be caused by an open 10 mfd. condenser in cathode circuit of the 6C7. This is condenser #C12 in Rider's Manual.—Tim W. Shaw, Vernon, Texas.

Majestic 70. This set came in with low volume and distorted reproduction. All voltages were considerably below normal. I dismantled the power supply and could find nothing wrong. Finally afters hours of work, I discovered that the leads to the pilot lamp pass through a metal sheath on the end of the gang condenser and that too much strain on the shield had caused the sharp metal edge to short out one side of the pilot lamp lead. I taped the wire at this point and all voltages jumped back to normal and the set played 100%.—Edwin Levinson, Perth Amboy, N. J.

Majestic 95, 105 (2 V. Sets.). Symptoms:—Lack of volume and poor tone. To remedy be sure to replace the 1B5-25S grid coupling condenser (2 blue leads from metal can #11245) with a .02 mfd., 600 volt unit. Both these condensers are usually very leaky. Generally too, the unit with a white rubber lead from the condenser can to the r-f coil can will be found leaky. Replace it with a .05 mfd., 600 volt unit and ground to can. Bad oscillation from 550 Kc to 650 Kc can be eliminated by increasing this unit to a 0.25 or 0.5 mfd., 600 volt unit.

Added pep can be had by replacing the 1A6 with a Sylvania 1C6. Be sure to realign all circuits after doing this. When using a 2 volt "A" battery the Candohm resistor section in series with negative blue lead and filament of 34 r-f tube should be shorted out or poor volume may result. —N.E. Nelson, Mayville, N. D.

Majestic Chassis 300. Low volume and volume controlled on about 1/5 of the manual volume control. This action is not due to any defective part in the set, but is due to the 57 tube located directly above the manual volume control. Replace this tube with a shielded Sylvania 57S or 58S tube. Preferably type 58S, as it gives smoother volume control action to this particular chassis.—John H. Bloomer, Philadelphia, Pa.

Majestic 310-B. This hint applies to all sets using i-f plate feed for automatic volume control. A very slight leakage will bias the controlled grids positive, causing them to block, killing reception. Some cases are so slight as to require a vacuum tube voltmeter to detect. Replace defective unit with 50 to 100 micromicrofarad mica condenser.—Harl O. Piety, Georgetown, Texas.

Majestic 330. This model uses a type 59B output tube which is not made by Sylvania. Change to a 2A5 Sylvania tube by taking out the 7 prong socket and replacing with a 6 prong socket. Rewire the new socket by fastening the original lead wires to the respective terminals with the suppressor grid lead to the cathode terminal.—Clive W. Keemer, Dayton, Ohio.

Majestic 800, 850. The Model 800 receiver is of the AC-DC design with traveling pilot lights which often short to chassis, burning out all three pilots and often damaging the #A-16037 ballast tube. Always check the pilot and traveling light circuit when the pilots and ballast need replacement. The flexible indoor insulated antenna wire may be used for re-wiring the traveling pilot light.

The heater wires leading to the traveling light assembly in the Model 850 are a frequent source of trouble, in that the insulation wears causing the wires to short to the chassis, opening the dial light circuit. For a permanent repair use a high grade flexible wire as outlined above.—J. S. Napora, Uniontown, Pa.

Majestic 850 (1937). The Hi-fidelity switch is a frequent offender in this model. Very low sensitivity results. Use a good S.P.D.T. rotary switch as a replacement.—Joseph S. Napora, Uniontown, Pa.

Midwest 18-36. This and other models employing a large size bell shaped speaker cone, instead of the regulation shaped cone, develop a very annoying buzz on the deep bass notes. This is due to fatigue of the cone and voice coil form. Re-centering and re-shaping of the voice coil will not cure the trouble, due to the fact that the heavy downward pull of the voice coil on the deep bass tones causes the bell shaped part of the cone around the voice coil to be drawn out of shape. This in turn also causes the voice coil to momentarily lose its trueness resulting in the latter rubbing against the center magnet (on the inside) and outer centering hole. This defect can only be detected by removing field coil and housing and observing how bad the voice coil sags when the cone is pressed downward.

To effect a permanent cure first make sure that the voice coil is properly centered. Then, having the correct speaker shims in place between the voice coil and center magnet, apply several coats of speaker cement to the cone, front and rear for about 2 or 4 inches starting at the voice coil, allowing each application to dry thoroughly with shims in place.—Fred B. Honchock, Monessen, Pa.

Midwest 1938 20 Tube Models. The dial lamp and bull's eye wiring becomes worn or broken very easily, causing cut-outs and grounds. Replace completely with a D.C.C. stranded wire for greater strength.—Lester H. Davison, Alameda, Calif.

Norco 160. These receivers in the 71000 series often develop faulty volume controls. The volume control has too much carbon on the high end and as this wears it deposits on the moving contact causing a 1000 ohm loop to ground. This causes the set to operate at extremely low volume although all voltages check ok. To remedy, use a new .5 megohm control or take the old one apart, clean it and then shellac the carbon The new control is the best bet.

Norco 160, Remler 45, 60, 71. It is not an easy job to take the volume controls of these sets apart and put them back without causing damage. If shellac is applied improperly, it may seal some almost invisible granules which would cause permanent injury to the volume control. I suggest these two easy methods to remedy the fault. 1. Blow air through the small holes behind the connecting lugs which will cure the fault permanently. 2. Charge a 4 mfd. paper condenser from the filter section of any set and discharge it through the volume control. This will burn the fine loose carbon granules in the faulty volume control without damage, as the time of discharge is only a fraction of a second. However, no direct current should be sent through the volume control as it will burn the carbon paper immediately.—M. Margossian, Oakland, Calif.

Philco (All Models). It is the practice of some servicemen to bridge across an open condenser with a new unit leaving the original in the circuit This practice affords the serviceman a convenient mounting, but this is a poor practice. An open condenser may function abnormally at times, causing a "plop" to come in the set with a loss of volume. Always remove the defective units. This hint also applies to other receivers.—E. B. DeWell, Petersburg, Va.

Philco Receivers. A simple service tool which I call a "jiggler" really speeds up the checking of the bakelite condensers causing intermittent trouble in Philco receivers. It can be made easily from an ordinary straight pin with the head clipped off and a small wooden handle. Insert the blunt end of the pin into one end of the handle and fasten securely.

To use the jiggler, insert the sharp end into the openings in these bakelite units through which the lead wires enter the condenser and "jiggle" it around. The intermittent contact in the condenser is almost always where the lead joins the condenser inside. With the jiggler, you can cause the condenser to open, determining which unit is causing the trouble.

The above method will not apply to Philco receivers of the last two years or so as the holes are filled with solder to keep out moisture and thus prevent this trouble.—S. W. Ferrell, Jr., Greenville, Ala.

Philco 20. When oscillation starts on this set, instead of by-passing the 71 bias to ground as has been suggested, use a small unit of .05 to 0.1 mfd. and connect across the entire voltage divider (from 45 to plus 135) and the same results will be obtained without the hum.

Of course, this same applies to all sets where it is desirable to by-pass the output bias resistor—less oscillation and a notable improvement in tone generally results.—C. O. Barnhart, Walhalla, Mich.

Philco 37-610. No short wave reception may be due to the small condenser (mica) soldered to tuning condenser being loose. Resolder and bend to clear plates of the variable condenser.—Wm. Hickey, South Norwalk, Conn.

Philco 38. Distortion on low volume only may be overcome by changing the 32 second detector tube even though it tests good. The 1A6 det-osc. used in some of these models may be replaced with a 1C6 for better oscillator performance. The set should be realigned. The correct volume control replacement is very important. Two different controls are used on these models. Part No. 33-5017 is used on the early 38 and part No. 33-5154 is used on the 38 code 123. —Joseph S. Napora, Uniontown, Pa.

Philco Model 38-7. To reduce extreme bass response in these models change the following parts:—Remove condenser No. 24, .01 mfd. replace with condenser .001 mfd. Remove resistor No. 32, 51,000 ohms ½ watt. Replace with 40,000 ohm ½ watt resistor. Remove condenser No. 38, .006 mfd., replace with condenser .01 mfd. This change results in better all-round response.—M. J. Planovsky, Cleveland, Ohio.

Philco 38-116 Code 125 and 38-690. To prevent parasitic oscillations and improve performance of the oscillator circuit at 180 Mc. in Model 38-116 Code 125, connect a 100 ohm resistor between the 6A8G oscillator anode and the 6N7G plate. This resistor replaces the original brown wire which should be removed.

To prevent oscillation and improve performance at 118 Mc. in Model 38-690, use same procedure as given for Model 38-116 Code 125.—M. J. Planovsky, Cleveland, Ohio.

Philco 59. When you find it necessary to replace the dial gearing on this model, which generally requires the removal of the old tension spring cup and ball bearings; drill a ¼ inch hole directly above the screw that holds this unit in place. This screw is at once accessible and the rest of the work—removing and replacing of old parts—is then a matter of a few minutes work and the set is then ready for further service of the same kind at any future time.—Berlin Radio Service, Buffalo, N. Y.

Philco 60. When any of these sets come in with an intermittent a-c hum that ruins reception, look at the condenser from the last filter to ground. This is a small paper condenser about .25 mfd. in capacity and housed in a tin container with several other by-pass condensers.—J. E. Lephart, Arcanum, Ohio.

Philco 65. When you service this model, check the plate voltage of the 45's. If the voltage is approximately 100 to 115 volts, reverse leads listed as C and D in the manuals. This will bring the plate voltage up to normal and your customer will say it works better than when new.—M. W. Vavrek, Cleveland, Ohio.

Philco 70. If this set fades on low volume, the chances are that the coupling condensers need replacing. Sometimes resoldering the connections will repair it for awhile. When this set gives a hum on stations tuned in at about the middle of the dial, look for trouble in the double condenser across the primary of the power transformer.—Harold B. Cook, Wichita, Kans.

Philco 70. These sets use a special volume control which is often difficult to obtain. To change to a different control the following changes should be made. The control we use is a 10,000 ohm unit. First take off the old control and install a new 10,000 to 15,000 ohm control tapered for antenna and cathode bias. Center arm to ground, left arm to cathode, right arm to antenna and coil. Now the connection marked "F" in the Philco schematic diagram, is connected in series with a 1,000 ohm, 1 watt resistor and goes to the cathode of the 24A tubes. The other connection marked "G" in the Philco schematic goes to the cathode of the 27 oscillator tube. This completes the wiring. If any fringe howl is noticed an 0.5 mfd. condenser across the main plate supply will remove it.—Al's Radio Service, Tonawanda, N. Y.

Philco 71. A frequent complaint is that this set cuts out on strong local stations and lower powered stations can be heard weakly in the background. The trouble is usually in the oscillator of the set. Changing the autodyne oscillator bias resistor from 15,000 to 10,000 ohms is the cure.—Al Sorgenfrei, St. Louis, Mo.

Philco 71 Code 221. This receiver sometimes has intermittent reception and distorts during the momentary break down. Change part #32 in the parts diagram and replace with a .05 mfd. 400 volt tubular condenser. Make sure you cut out the old bakelite condenser, the center lug is a dummy and used only to connect the resistor and lead from the volume control.—H. Evangelista, Jr., Philadelphia, Pa.

Philco 80-81. If volume drops and quality is mushy accompanied by a sputtering sound, or the volume varies, check the coupling condenser between the detector and the 42 audio tube for very high resistance short. The 1 megohm scale on an ohmmeter will generally show a slight deflection. Quite often the 42 tube will be weak since a high positive voltage is on the grid when this condenser shorts.—Donald G. Buck, N. Tonawanda, N. Y.

Philco 89. The cause for no plate or screen voltage on all tubes has been traced to a grounded primary in the second i-f transformer and compensating condenser assembly. Due to vibrations in the set, the stationary plate of this condenser has a tendency to shift and short to ground through the mounting screw to chassis. This trouble is easily remedied by loosening the mounting screw and shifting the assembly slightly until the short is removed. A replacement should be made to assure a foolproof job.—Fred B. Honchock, Monessen, Pa.

Philco 89-19. When the oscillator section won't work satisfactorily, try decreasing the 15,000 ohm cathode resistor of the 36 tube to 8,000 ohms. If it still refuses to work on low frequencies, change the type 36 socket to a six prong for a 77 tube. Wire up the same as the 36, tying suppressor grid to cathode and decrease the cathode resistor to 8,000 ohms.—James Rush, Greenwood, S. C.

Philco 90 With One 47. This set often does not work properly after being aligned. Strong stations come in extremely weak and far from their correct dial settings. Although the Philco instructions give the i-f of this set as 260 Kc. some were built to align at 175 Kc. The i-f's will align at either frequency but the gang condenser will not. Realign at 175 Kc. and the set works fine.—Tom J. Davis, Cave Spring, Ga.

EDITOR'S NOTE: Refer to the Sylvania Tube Complement Book for the differences in i-f peaks for this set.

Philco 116 Code 122. Complaint:—Intermittent howling and squeals. Remedy: The coil shields on these sets are fastened to the chassis by means of lugs which do not bolt but simply spread to make contact. By making good grounds for these shields the trouble is immediately cured. This is sometimes difficult to find because when the chassis is moved, a good ground may be made and the set may play for some time before the trouble reappears.—G. W. McLean, Big Timber, Mont.

Philco 118. When the trouble is intermittent volume, check the by-pass condenser connected from the top on the volume control to ground through the 10,000 ohm resistor. In these sets I have found high resistance grounds on the bakelite cased condenser.—Barrett Radio Service, Sulphur Springs, Texas.

Philco 118. Cutting off of about 25% of the normal volume may be caused by an intermittent a-v-c filter condenser 0.05 mfd. We find it a good practice to replace all a-v-c condensers in this model even though they test good. The condenser mentioned above is a No. 11 in the Philco diagram.—Joseph S. Napora, Uniontown, Pa.

Philco 630, 635. Often there is a high pitched whistle when the volume is more than half way on. This trouble can easily be remedied by moving the wire leading to the grid cap of the 75 tube inside the insulating can of the 75 tube.—D. J. Spittel, Staten Island, N. Y.

Philco Chassis 650 Code 121. Weak and distorted signal from only a few powerful stations is found in these sets. The condenser part #3615-SU connecting the control grid on one of the 42 tubes is usually at fault. The condenser does not register open nor short as the leak is hardly noticeable on a meter.—L. A. Chamberland, Forestdale, R. I.

Pilot Dragon 10. If the set has an a-c hum which is hard to find, look for a ground at the reflector mounted behind the pilot light. There is a small piece of fiber insulation between the reflector and the dial. Sometimes the sharp corners of the reflector pierce the insulation and ground the filament.—James F. Cochran, Westfield, N. Y.

Radiola 20 Air Cell Conversion. The following notes will be of assistance in installing type 30's for air cell operation of Radiola Model 20. It was found necessary to shunt a 1,000 ohm resistor across the primary of the second radio-frequency transformer. It was also necessary to remove four turns from the secondaries in order to get down to 1500 Kc. Remove turns one at a time until the trimmers peak sharply at the centers of their dials.—Harold B. Cook, Wichita, Kans.

RCA 6BK6, 8BK6. In wind charger installations where charger ground point is too close to the set ground point, (inside a radius of 10 feet), there is a chance of a voltage increase on the filament unless an 0.1 mfd., 400 volt condenser is connected from chassis to ground post, i.e., in series with ground and chassis. Never ground the negative side of charger to the same ground point of the set, as an increase of from 2 to 4 volts will result because of the wiring arrangement to supply 4 volts to vibrator and only 2 volts to filament. This will paralyze all tubes except the 30's and 49's. When the 8BK6 set fails to function, look for bad a-v-c tube. This tube seems to short easily.—Stockers, Ridgeway, Wisc.

RCA 6K, 6T. When servicing these models the .065 ohm heater resistor, R15 in the schematic, should be removed and a jumper used in its place. This resistor is omitted in later production of these sets. —E. W. Jacquet, Shreveport, La.

RCA D9-19. This model, as well as others using the magic eye, often becomes defective after the set has played for a short time. Remedy: Try replacing 1 megohm resistor between plate and target of 6E5. Replacing the 6E5 with a 6G5 tube, will often improve the operation of the eye.—Oliver F. Klein, Milwaukee, Wisc.

RCA 9K1, 9K2. These sets may play on powerful locals, but with low volume and distortion. By removing the second detector 6H6, the set will pick up. Check the first detector, screen condenser. This condenser is a 4700 mmfd. unit and usually the leakage is not large enough to cause a large screen voltage drop.—Robert Geller, Egg Harbor, N. J.

RCA 38-P. This set often lacks power after it is in use for some time, has a habit of developing oscillation and the input condenser usually goes bad by short circuiting. This condenser is rated at 10 mfd. and should be replaced by one with a slightly higher voltage rating, capacity rating the same. The oscillator trouble is quite odd and is usually traced to the second detector a-v-c, 2B7 tube. One will note that when the receiver is operating, oscillation may take place which can be controlled by the volume control. This is caused by the shielded lead running to the cap of the second detector not fitting into the slot in the tube shield. The shielded lead **must** be grounded to the chassis.—Geo. F. Baptiste, Howard, R. I.

RCA 44. This Radiola model often developes a very strong oscillation over the entire dial. By removing the two copper stage shields housing the second r-f and detector, you will see a copper clip on each one which fits over the condenser shaft when the shields are in place. By bending these clips so they wil make a tight fit over the condenser shaft, and applying a little sandpaper if it is necessary this trouble will be overcome entirely. These models have a rather annoying hum which can be reduced considerably by placing a 4 mfd. paper condenser across the rectifier output. This also increases the pep of the receiver some.—Anthony Piatti, Northville, Mich.

RCA 48. Intermittent operation and loud crackling noise is caused in some of these sets when an output coupling condenser breaks down. The way to find out if this is the trouble is to pull out one of the power tubes. If the radio plays better with one out, the coupling condenser is letting B voltage into the grids of the 45 power tubes. To make replacements, cut the two green wires that go to the grids of the 45 tubes, then connect two .025 mfd., 600 volt units from the grids of the 45 tubes to condenser bank number 5 and 7 (number 7 has no wire connected to it). It is best to replace both condensers. If the transformer gets hot, look at the rectifier tube socket for shorted contact connection.—Earl S. Daniel, Los Angeles, Calif.

RCA 80, G. E. H-31, Westinghouse WR-5. Distortion on low volume is quite common. Check the 110 ohm resistor going from cathode of the second detector to B plus. This resistor will be found to have changed its value. Replacing this unit will cure the trouble. —John Beisiadecki, Brooklyn, N. Y.

RCA 82, G. E., Westinghouse. Fading and scratching can often be traced to one of the intermediate transformers, the primary of which will show a higher resistance than the other (39 ohms is correct). Examination of the winding may show corrosion under the piece of tape used to keep the wire from unwinding. Replacement of the transformer of course, is the best solution, but in case of emergency unwind two turns from the coil and reconnect to the lugs. In case of noisy reception and fading, examine all windings where tape of any kind is used to hold down the wire as corrosion may have broken the connections.—Lester C. Doerr, Edgerton, Wisc.

RCA 86T. I find that by connecting a .0001 condenser, or larger, from the antenna connection to the oscillator tuning condenser stator plates, there is a very marked increased in volume; about 25%.—J. S. Jackson, Jr., Bowling Green, Ky.

RCA R99. Weak and distorted output in this model may be due to the failure of the insulation on the bushings of C23 and C24, causing the speaker field to be shorted out removing the bias on the 2A3's. If set is dead, it might be the speaker field shield cover, touching the voice coil, causing a short. For best adjustment of the expander circuit in this model, set the plate current of the 6L7 at 2.2 mils.—F. U. Dillion, W. Hollywood, Calif.

RCA 118. When these sets fail to work satisfactorily on the 25 and 49 meter bands, check the condenser that by-passes the oscillator anode voltage dropping resistor for leakage. Noises in these sets when on the short wave bands, can be diminished by disconnecting the 6A7 grid lead from the wave changing switch and connecting it directly to the stator of the first tuning condenser. However, the set must be realigned after this change is made.—Chas. Marusak, Cleveland, Ohio.

RCA R-118, R-211. Abrupt fading may be due to opening a-f coupling condensers (.02 mfd.) located on resistor board and connected between the 6B7 and 41 tubes.—Bernard Krinsky, Brooklyn, N. Y.

RCA 120. If these sets oscillate as resonance is approached when attempting to align the r-f stages, replace the tubular condenser from cathode of 58 first r-f tube to ground with one of higher value. Some sets require as much as 0.25 mfd. capacity to stop oscillation.—Tim W. Shaw, Vernon, Texas.

RCA Victor T5. Since these phono-pickups have a needle pressure of about 6 oz. as compared to a modern pickup having only 2½ to 3 oz., the record life will be comparatively short before defects will occur in the grooves. I have reduced the needle pressure from 6 oz. to 3 oz. by removing the two weights, each 1½ oz., from the arm of the pickup. This doubles the record life and the reproduction is better.—Matthew J. Socha, Brooklyn, N. Y.

RCA Victor R-10. This set has both the input and output transformers located in the same can. When the input transformer primary burns out, instead of replacing it, connect a 40,000 ohm resistor from the B plus to the plate of the 27 and a .02 condenser from the plate to the grid of the 47. The set plays as well as ever and the job is done cheaper and faster.—Larry Bowers, N. Uxbridge, Mass.

RCA Victor RE-39, R-55, RE-57. A common trouble encountered in these sets is low volume which will usually be found in the detector stage. The resistor R5 in the screen of the detector is usually open or changed to a very high value, probably around 30 megohms. The screen bypass C11 may check okey, but it often gives trouble and should be replaced. To permanently remedy the above trouble, change the detector screen as follows: Remove 1.5 megohm resistor R5 from the circuit, connect two 0.1 megohm resistors in series from B plus end of R17 to B minus end of this resistor. At junctions of the two 0.1 megohm resistors, connect another 0.1 megohm unit and connect detector screen to B minus end of this last resistor. Connect condenser C11, screen to cathode, as before. After this change, the set will have better sensitivity and will handle more volume than before. This change has been made on several sets and they have given no trouble of this nature in more than two years operation.—R. L. Foster, Sciotoville, Ohio.

RCA Victor R50, R55. When these sets are inoperative until the a-v-c tube is withdrawn, the trouble is usually a shorted 0.1 mfd. condenser from the a-v-c grid coil to ground. This is the blue lead from the capacitor pack in S. P. U. unit. Replace pack or disconnect blue wire and install a new 0.1 mfd. by-pass condenser. William Doty. New York, N. Y.

RCA Victor RE52. Distortion is often caused by a defective .001 mfd. bypass condenser in the plate circuit of the detector. Jesse Beczak, Pittsburgh, Pa.

RCA Victor; Westinghouse; G. E. Models:—80, 82, R15, R7, 86; WR5, WR6, WR8, WR7; H31, H61, H71. If confronted with a loud hum, try taking the output tubes out of the circuit one at a time, being sure that one is in the circuit while the other is out. Usually with these particular sets the opening of one side of the secondary of the input transformer with both power output tubes in the circuit will cause the loud hum. By taking the tube out of the open circuit the hum will disappear and the set will sound almost normal. Knowing the above will often facilitate the quoting of a job price in the home and will add to one's good reputation.—Keith Howard, Santa Ana, Calif.

RCA Victor 280. Lack of volume in this set may be due to an open in the reactor coil L-16 of 3,200 ohms. One end of this coil is connected inconspicuously to the volume control. The leads from the coil are very fine and should be checked.—Baer Radio Service, Roslindale, Mass.

Remler 28, 46, 47, 60, 71, 72, 54 and Norco 140, 170, 171, 178. The coils used in these sets either have an extremely thin layer of varnish for protection or none at all. In damp weather the coils in these sets absorb moisture, creating a high resistance leakage path between various lugs on the coil-form, causing cross modulation (monkey chatter) or weakening the signal strength. To remedy the fault, heat the coils (after taking them out of the set) in an oven at a temperature around 150 degrees for about ten minutes, then dip the end of the coil-form with the lugs into a pot with melted commercial wax, thus giving a protective coating against humidity. If the wax is not available, a layer of shellac or varnish or a similar protective coating will do. The leakage path has been known to range from 50,000 ohms to 42 megohms. The same leakage will be observed on coils used by other manufacturers if the coil-forms are not protected properly against dampness.—M. Margossian, Oakland, Calif.

Remler 28 AC-DC "Scottie." When set breaks into motorboating, with no signal anywhere on the dial, check the insulating fibre washers on screws holding the dial plate on metal baffle. The dial plate is insulated from chassis with these fibre washers. Quite often when screws are too tight, these washers break and thus short the insulated dial plate to ground. To remedy the situation simply replace fibre washers.—M. Margossian, Oakland, Calif.

Remler 45. The set becomes dead intermittently when shaken or jarred. Check the tone control condenser (.05 mfd. 600 volt) and you will find it shorting intermittently when shaken. thus shorting the plate of the 6F6 to ground. Replace this condenser to cure trouble.—M. Margossian, Oakland, Calif.

Remler 45, 71, 72, 89, 89C. When any of these sets prove to be very weak or dead on the high end (16 to 18 megacycles) of the short wave band, replace the 6C5 with a new Sylvania 6J5 tube and realign the set. The pickup of shortwave signals will be amazing. No changes in the circuit will be necessary. Because of its low interelectrode capacities, 6J5 is a better tube than the 6C5 in the oscillator stage. The earlier model 72 receivers as well as all the models listed above have the 6C5 as an oscillator. However, the later Remler model 72 receivers use the 6J5 for the oscillator.—M. Margossian, Oakland, Calif.

Remler "Scottie" 46. To reduce the hum in these sets, do the following: First check to see if the speaker has a bucking coil. If it does, simply add a .05 mfd. 200 volt paper condenser across the speaker field coil connections. If the speaker does not have a hum bucking coil (due to the insufficient filter of the 4-4 mfd. dry electrolytic condenser the hum will be fairly prominent) replace the 4-4 mfd. 450 volt dry electrolytic with another of similar construction, but with 8-4 mfd. 450 volt capacity. Be sure to place the 8 mfd. section first (condenser input) as filtering of hum will be more effective. A 8-8 mfd. 450 volt condenser cannot be used because of space limitations. —M. Margossian, Oakland, Calif.

Remler 52, Norco 178, Tot 178, Sky Raider 178. These sets originally had the plate condenser on the 42 output tube connected from plate to ground. In this position the condenser was subject to high voltage at certain times. In the later models the condenser is across the output transformer primary, namely from plate to screen of the 42. This produces the same tone quality and the condenser is subject to less overload. This is also true of the Remler Scottie Model 46, which uses a 6F6 output tube. The condenser under discussion is .01 mfd. A change to this new arrangement is recommended.—Walter T. Walsh, San Francisco, Calif.

Remler 64. When the set breaks into high pitch oscillation at the high end of the short wave band, change the 100,000 ohms (No. 8 resistor-Rider) resistor on the oscillator input control grid prong of the 6A8 tube to 50,000 ohms. If oscillations persist reduce said resistance to 25,000 ohms and all such painful-to-ear oscillations will disappear improving the short wave band of the set considerably. Incidentally, if you happen to have the Rider Manual No. 7, make the following correction in the diagram of this set: Interchange the wiring connections (on your diagram) of 6A8 Nos. 6 and 7 prongs.—M. Margossian, Oakland, Calif.

Remler 71 (1936-37). When this set whistles on the lower end of the broadcast band, check to see if the plate by-pass .0003 mfd. condenser on the audio 6K7 is there. Rider's Manual Volume VII shows that this condenser is not in the original diagram and it is missing on some sets marketed. Adding such a condenser (from the plate of audio 6K7 to ground) on the audio stage 6K7 plate will make all whistles disappear.—M. Margossian, Oakland, Calif.

Remler 71. When the set is noisy on short wave band, or subject to microphonic noises, ground thoroughly the braided flexible wire which connects the rear end plates of all the three sections of the tuning variable condenser (ganged) to ground. This will provide a positive direct connection from the rotor section to ground. A complete soldering job, several places along the braided wire is necessary in all short wave sets. A poorly grounded rotor will always cause microphonic noises, particularly on short wave. M. Margossian, Oakland, Calif.

Remler 89, 89C. The earlier receivers of these two models used a .05 mfd. 200 volt type 244 paper condenser. These condensers showed leakages of various degrees. When such condensers are found in these two models or in other receivers, replace them by an equivalent unit carrying different type numbers such as Aerovox .05 mfd. 200 volts type 284.—M. Margossian, Oakland, Calif.

Remler-Norco 180. These receivers have a tendency to motorboat strongly on the low end (550 to 700 Kc) of the broadcast band. To remedy this fault remove the cathode by-pass to ground 0.1 mfd. 200 volt condenser from the 6D6 socket and replace it with an 0.25 mfd. 200 volt condenser. The earlier models marketed, did not have this change.—M. Margossian, Oakland, Calif.

Sentinel 39B. A fuzzy sound in the speaker of this set is common. In some it is very slight and in others, very annoying. At times the speaker sounds as if it were rattling. It is more noticeable at high volume. To correct, place a .003 mfd. condenser from each plate of the 19 output direct to the chassis. Each plate must have a separate condenser. This value will have no effect on the high notes, yet the capacity is high enough to cut out the fuzzy sound.

Another trouble is no reception on lower short wave band and in extreme cases, dead spots on other bands or possibly no reception at all. Try replacing the type 1C6 tube with a Sylvania 1C6. Another source of annoyance is a slightly microphonic 34 first audio tube. This is more noticeable on the short wave bands when the set is tuned to a station that is fading badly. A new Sylvania 34 will cure this.—Robert J. Ridenour, Fredericktown, Ohio.

Serenader 10 Tube, Airline 1955. Intermittent cutting out of signals: Oscillator plate to grid .01 mfd. coupling condenser opens up intermittently thus stopping oscillation. Easily traced by testing for the oscillator signal. A. B. Chismar, Streator, Ill.

Silver Marshall Chassis 60. This model uses a 1 megohm grid resistor in series with a bias cell to ground on the 6F5 audio tube. Due to the high grid resistor and small bias, the grid draws current on large signals and lowers the voltage of the bias cell. Distortion results. Change the 1 megohm to ¼ megohm, 1/5 watt unit. There is very little loss in volume.—L. W. Krizan, Chicago, Ill.

Silvertone Battery Receivers. We dealers in small towns and rural communities find that people who own Sears battery sets are disappointed to learn that the A battery is a large flat type and that some tubes are of an odd type that are not sold by us dealers.

I have found that the flat type of A battery used on some of these battery sets, can be replaced very easily and profitably by removing the cardboard container surrounding the old battery and place in it 8 regular type or radio type dry cells. These must be connected in two banks, of four in parallel and these two banks in series. All connections should be soldered. This gives the 3 volts which is the same as the original. In considering the life of this replacement most dry cells are rated at 35 ampere hours. The total life can be figured after determining the total filament drain.

Another kink on these sets is that the type 951 tube can be replaced with a Sylvania type 32 or 34 by changing the tube shield. The performance of the set seems much better with this type than with the original.—George W. Nikolai, Kissimee, Fla.

Silvertone 1722. When complaint of insufficient short wave sensitivity is received try a new 56 tube. If this doesn't help try increasing the coupling of the short wave antenna coil. The single turn of green silk covered wire should be moved as close as possible to the other windings on the coil. An additional ground connection from the coil should be made to the low side of the trimmer condenser mounted on the wave changing switch frame. There is one ground connection from the coil to the variable tuning condenser frame but this should not be disturbed. A hum which cannot be eliminated with the hum balancing adjustment is due to poorly matched 2A3H tubes. The plate current of these tubes must be nearly equal in order to obtain this balance. Two new Sylvania 2A3 tubes will do wonders in this respect.—Steve Pochiber, Jr., Leechburg, Pa.

Silvertone 1831. When replacing i-f transformers in this model, do not put too much confidence in your service notes. All service notes that I have seen give the i-f as 480, but I find in this particular model that some of the sets are tuned to 175 Kc.

Editor's Note: The Sylvania Tube Complement Book gives this set a 445 Kc. listing, which is that supplied by the manufacturer.—E. W. Wood, Jasper, Ala.

Silvertone 1850, 1851, 1862, 1868, 1870. All available data for these sets states the i-f at 480 Kc. In working on two different sets of these models we could not align at 480, but found alignment easy at 175 Kc.—G. W. McLean, Big Timber, Mont.

Simplex AC-DC Models. To eliminate unable hum; reconnect the condenser which is now between B minus and one side of the power line, so that it is directly across the line.—Anderson Radio Hospital, N. B. Anderson, Seattle, Wash.

Simplex Model D A. I have found a number of these sets with the i-f coils open from moisture. To repair, carefully remove coil, unwind about two layers of the inside winding holding wire in either hand. Pull gently and insulation will part at break. Repair, cement, replace coil and realign set.

Simplex V. When tubes, condensers resistors, and wiring all check perfect yet the set will fail at times without voltage change, look for bad connections to the insulated posts supporting the common wiring junction points. The rosin core solder used isn't always sweated out and under heat forms an occasional insulator which disappears under the load of testing.—Henry Berg, Pittsburgh, Pa.

Skyrover 224. This set may develop an oscillation whistle after several minutes of operation. To cure, replace the .25 mfd. plate by-pass condenser of the third r-f tube with an 0.5 mfd. unit.—A. B. Chismar, Streator, Ill.

Sonora 70S. If set hums and the volume control does not reduce the volume correctly, look for an open 8 mfd. electrolytic condenser located under the resistor-condenser bank. This condenser should be replaced with one having a rated voltage of 300 volts.—Lee White, Jr., New Orleans, La.

Sparton 9, 420. Increasing the value of the voltage divider to 100,000 ohms from the old style low resistance type will raise the sensitivity of these sets. Use two 50,000 ohm 1 watt carbon resistors in series. Connect one from high positive to screen and one from screen to low end of volume control; the cathode bias resistor in series with center volume control connection and maximum end of volume control to ground.—Henry Berg, Pittsburgh, Pa.

Sparton 14. Distortion and intermittent hum may be due to the speaker field coil shorting. The best way to locate this is to hold a screw driver to the speaker—Al's Radio Service, Tonawanda, N. Y.

Sparton 16. If this set has a tendency to drift off the station, becomes weak in volume and whistles, check the connections on the oscillator coil which is under a shield. One connection is made with a small bolt and in time is apt to work loose. It is a good idea to solder this bolt.—George Curtis, Chicago, Ill.

Sparton 61, 62. The grid lead with metal shield is placed between and very close to the 25Z5 and 43 tubes. The heat often ruins the insulation and the movement of the grid wire crumbles the insulation thus shorting the lead to ground. Replace with a well insulated, shielded wire.—C. A. Vaughn, Los Angeles, Calif.

Sparton 111A, 301. If hum still remains after everything checks OK, clean and tighten the ground connection of the large wirewound 7,000 ohm resistor located back of the two 50 tubes on the power converter.—S. Wiesenberger, Cleveland, Ohio.

Sparton 930. When this set goes in and out of oscillation sometimes as often as ten times a second and at the same time the detector voltage respectively changes, look for the trouble at the connections to the r-f coils near the sub panel. Through corrosion the solder connections come loose from two grid leads and one plate lead and will make and break contact. Cleaning and resoldering eliminates the trouble.

This particular model will in time develop a violent high frequency howl at a low point on the volume control. The trouble has been found in the series plate choke to the detector tube. Through corrosion part of the choke winding shorts out leaving too little reactance in the circuit. Replace with a new choke to remedy the trouble.—Keith Howard, Santa Ana, Calif.

Sparton (All Models Using 485's). Bad motorboating, particularly true when replacing old tubes with new ones. Before realigning at 1200 Kc., clean thoroughly all wiper contacts on rotor of the condenser gang and apply carbona. This will eliminate motorboating and results in greater sensitivity.—Vito F. Daidone, Newark, N. J.

Stewart-Warner 111, 115. Tunable hum may be caused by condenser No. 15 opening. If you change condenser No. 34 in Stewart-Warner 111, be sure it is not wax or tar filled. This chassis stands on end and heat from the 43 will cause wax or tar to run down and mess up the gang condenser and might mean a replacement of the gang.—Ivan L. Crowe, Chicago, Ill.

Stewart Warner 123-123A. These models may have condenser trouble in the fixed tone control circuit consisting of a .01 mfd. 600 volt condenser from the plate of the 41 output tube to the chassis. When installing a new condenser, connect a .01 mfd. 400 volt unit from plate to suppressor grid of the 41 to eliminate future trouble. This puts the condenser across the transformer primary.—D. A. Brown, Marion, Ohio.

Stewart Warner R-180-A. This set may lack pep with the dial off calibration and will be impossible to realign at the low frequency end of the dial, below 570 Kc. If the set checks okey, add a .0025 mfd. condenser to the .0054 mfd. condenser which is already across the padder and the set will align perfectly over the entire broadcast band. A great increase in volume will also be obtained.—N. E. Nelson, Mayville, N. D.

Stewart Warner Converter 301A. If this converter does not work satisfactorily make the following changes. The plate voltage of the broadcast receiver to the converter type 27 oscillator is regularly dropped through a 50,000 ohm resistor, giving a no-load potential at the plate of 90 volts, dropping to half this under load. This voltage is further dropped through a 100,000 ohm resistor to the plate and screen of the 24A second detector tube, providing about 20 volts. These voltages are much too low. Substitute a 10,000 resistor for the 50,000 ohm unit, and a variable 50,000 ohm resistor for the 100,000 ohm unit. Adjust the 50,000 ohm resistor for best results. The improvement is remarkable.—Harold B. Cook, Wichita, Kans.

Stewart Warner 1261. When the broadcast band is okey, but the short wave band is weak, try raising the oscillator plate voltage by shunting a 10,000 ohm resistor across the oscillator plate supply resistor.—Al's Radio Service, Tonawanda, N. Y.

Stromberg Carlson 64. The power transformer on this set may overheat and smoke. Don't suspect the windings but check the first electrolytic condenser. This is often leaky and causes such trouble.—Al's Radio Service, Tonawanda, N. Y.

Stromberg Carlson 345. More bass response on the 345 receivers can be obtained by making the simple change outlined below. This change is incorporated in all receivers manufactured after September 1, 1938.

Remove the 4700 ohm resistor (R-17) from the volume control tap and replace with a 10,000 ohm resistor, Pc. 26345.

Remove the .15 mf. capacitor (C-37) from the volume control tap and replace with a .1 mf. capacitor, Pc. 24402.

Remove the .001 mf. capacitor (C-42) from the high side of the volume control and replace with a .04 mf. capacitor, Pc. 24405.

Caution: Do not mistake capacitor C-38 for one of the capacitors to be changed.—Stromberg Carlson, Rochester, N. Y.

Tiffany Tone 157. The airplane type dial may work hard and slip, causing much annoyance. The calibration will possibly have shifted. The remedy is to remove the chassis and slightly bend the dial bracket back. A lock washer at the point where the tuning condenser shaft goes through binds and causes the shaft to turn hard. Another general hint about airplane dials:—when the calibration seems high or low for any station, it may be remedied by checking up on the alignment of the holes where the chassis is held in place in the cabinet. If these holes are out of line, the chassis may not fit perfectly in place. The escutcheon may press one side of the dial back, causing the entire tuning assembly to be pushed back resulting in a change in frequency.—John C. Gill, San Diego, Calif.

Trav-Ler 51. Noisy operation frequently shows up, especially if the set is jarred. The shield on the grid lead of the 75 tube may be shorting to the can of the electrolytic condenser. The can of the condenser is at negative potential with respect to the chassis.—Tim W. Shaw, Vernon, Texas.

Truetone 667. Background hiss on local stations in which the trouble seems to be a defective r-f tube. Look for lead broken on r-f section of tuning condenser between condenser and grid cap of 6K7 r-f tube.—H. Plouf, Springfield, Mass.

U. S. Gloritone 99A. Intermittent operation in this model is often caused by the .002 mfd. condenser connected between the plate of the first 24A and the first i-f transformer. Another trouble often found is non-operation due to two open resistors, both located in what is known as a Candohm unit, located in the rear of the chassis. These are 11,000 and 10,000 ohms feeding the plate of the 35/51 and the screen grid of the first 24A and the 35/51, respectively.—Wesley Carpenter, Edwardsville, Pa.

Wells Gardner 0C. The oscillator tube of this set is a 76 triode. By changing the socket to an octal type and using a Sylvania metal 6J5 improved oscillator performance is obtained and the set is improved considerably on the short wave band. Through this change the receiver will pull in stations that were never heard before and will also clear up spotty reception on the shortwave band. The only circuit change necessary in some of the early models is the oscillator plate load resistor. If the oscillator plate resistor is above 30,000 ohm for 100 volt operation, change to 30,000 ohms with a cathode resistor of 1500 ohms. For higher voltage use higher values, double the voltage, double the load resistor. This same job can be performed on many superheterodynes. Be sure to use the Sylvania metal 6J5.—Geo. F. Baptiste, Howard, R. I.

Wells-Gardner 5E Series. If this set is noisy replace the 50 mmf. condenser between the plate of the 34 i-f tube and the grid of the second detector. This is not a regular condenser but is a special capacity wire type that can be replaced with a .001 mica condenser.—D. Gordon, DeLand, Fla.

Wells Gardner 052. This particular model is often found inoperative with screen voltage and cathode voltage high. This is all caused by the two 40,000 ohm resistors changing values. These two resistors are in the same can with the i-f transformers and are mounted on the terminal strip in same. Replace both resistors and the volume control if necessary.—C. DeWall, San Antonio, Texas.

Wilcox-Gay 50-A. On this model the dirt will sift in and get down between the voice coil and the pole piece with the result that it sounds terrible. To remedy this, remove the speaker and cut a piece of soft felt or soft leather just a little larger than the diameter of the voice coil and glue it over the voice coil opening. When it gets dry you can put a handful of sand on it and the tone will not be affected. I have used this a number of times and it gives excellent results, especially on the horizontal type mounted speaker. It may be used on all dynamic speakers but shows the best results on the speakers that are mounted horizontally or speaker shooting the voice and music upwards.—Tommie Birdwell, Iowa Park, Texas.

Zenith 12S265, 15U269 (1938). Microphonic noises, accompanied by a low rumbling with the volume at a minimum is usually caused by a microphonic 6J5G first a-f tube. Use a Sylvania 6J5G. Shielding of this tube with a loose fitting shield may or may not be necessary.—J. S. Napora, Uniontown, Pa.

Zenith 15U269 (1938). To reduce the number of complaints on the split-dial mechanism, carefully lubricate all bearings and tighten all set screws, especially the two that hold the lever on the wave band switch. If these screws work loose, the whole dial assembly will "jam."

Weak reception accompanied by a high noise level was caused by an open in the 6K7G r-f plate choke, Zenith Part #20-135. This choke has opened in several cases and the defect was usually found at the choke terminals.—J. S. Napora, Uniontown, Pa.

Zenith 39A. Set weak or dead:—Look for a corroded wire connection on terminal strip plugging into power pack.

Zenith 55-127, 55-150. A common complaint on these sets is that after a few minutes of operation they begin to fade until finally only the locals are audible. Sometimes it may take as long as half an hour to fade completely out. In either case, a repair can be effected by replacing the 6A8G cathode resistor. This unit is mounted directly at the tube socket toward the front of the chassis. Replace with 400 ohm ½ watt. resistor.—Bernard Greene, Petersburg, Va.

Zenith 91, 92. Many of these sets suffer from lack of volume and poor tone. When the a-v-c tube (24A) is removed the sensitivity comes up, but the set overloads badly on strong signals. The trouble is caused by the resistor in the screen-cathode and audio transformer CT circuit. These resistors generally deteriorate with age. The CT to cathode portion should check 2500 ohms and the cathode-screen section should check 10,000 ohms. In later series of the same model the screen to cathode checks 15,000 ohms.

Tuning meters on this model often open which results in no plate voltage on the first r-f tube. Temporary repair can be made by shorting out the meter.

Another type of trouble in these sets is poor bass response and apparently poor sensitivity. This is caused by an open in the 0.5 mfd. condenser part #22-113 in the cathode of the second detector tube.—Donald G. Buck, N. Tonawanda, N. Y.

Zenith 230. This receiver often has an intermittent trouble that is very hard to find. All voltages will check the same when the set is in operation or completely dead and the coupling condensers will all check ok. The last i-f transformer is usually at fault. Inspection of the i-f unit will disclose a rosin joint on the secondary. All joints should be resoldered.—Harold B. Cook, Wichita, Kans.

Zenith 755. Watch these sets for two defects; a short circuit in the tuning meter leads and an intermittent short between primary and secondary of the i-f transformers. The cure for the first is a good doping with lacquer type radio cement and the second requires disassembling the i-f transformers and insulating the lower coil where the leads from the upper coil pass it. The second condition is attended by a sharp rasping buzz in the speaker during the operation of the set, similar to the interference set up by a leaking power transformer on the electric lines.—Henry Berg, Pittsburgh, Pa.

Zenith Chassis 1004. A comprehensive survey of repair jobs on this type of receiver reveals the following trouble spots. If the receiver is noisy in spots on the "C" band, check the dial pulley—move it away from dial pan, tone and sensitivity switches, volume control and 16 mmf. condenser, C21 is schematic diagram. If hum is experienced check tubes, open filter, or open electrostatic shields on power transformer. The latter can be remedied by by-passing the a-c line with a .001 mica-condenser. If the stations ride in, check the alignment and the .0012 mf. condenser in oscillator plate circuit.—Herbert Hass, Chicago, Ill.

MISCELLANEOUS HINTS

All Radios Using A.F.C. On most radios using automatic frequency control, a 6H6G is used as the discriminator and a 6N7G as the oscillator control voltage amplifier. When the 6H6G needs replacing check each cathode current of the new tube. To retain a balanced bridge circuit without needing to retrim the a.f.c. trimmer, it is absolutely necessary to have a tube in which the diode currents are nearly the same. Unless this is observed, the a.f.c. will not function properly. Sylvania 6H6G's will usually be found satisfactory.—Vito F. Daidone, Newark, N. J.

Battery Charger Interference. Several times a persistent noise covering an area of several blocks has been traced to tungar battery chargers with bulbs. Although performing satisfactorily, they generate a very annoying interference. New bulbs will remedy the trouble. One offender is the 3 ampere twin bulb type, but the worst offenders are the 6 ampere single bulb type.

Cabinet Protector. I use cellophane to protect the fine finish on my sets that I sell or rent out. The sheet of cellophane is shaped according to the layout of the controls on the set. A small amount of cement placed in each corner of the cellophane holds it firmly in place. An arrangement of this type prevents finger nail scratches around the knobs and does not detract from the appearance of the radio. Scotch tape may be used instead of cement.—Richard Dawson, The Dalles, Oregon.

Don'ts on Installing Battery Sets. 1. Don't fail to use a filament current limiting resistor when installing an air cell battery. Failure to use the resistor results in short tube life, increased "B" current drain, frequent call backs, and a dissatisfied customer. The resistor costs only a few cents, yet it may cost you many dollars by your negligence. If a ballast tube is used, the resistor, of course, will not be necessary.

2. Don't fail to observe the polarity of the "A" connections. Improper polarity often means an increase of 10 ma. in B current drain with resultant short B battery life.

3. Don't fail to use a good ground connection on any battery set, it means as much as 50% of good reception in some cases.—Joseph S. Napora, Uniontown, Pa.

Farm Receivers. Many farm sets use a 6 volt storage battery and 2 volt tubes. Some of these sets have the 2 volt leads coming from the set in the cable with the 6 volt leads. If the owner hooked the lead wire to the wrong post the tubes would be damaged. We get around this by painting the posts red, blue and yellow and the clips on the cable to match. Thus, all that is necessary is to match colors which saves a lot of grief.—Bernard Greene, Petersburg, Va.

Frozen Electrolytics. During the cold months when a low hum is encountered in a receiver that has been in a cold place, look for a frozen electrolytic condenser. The best thing to do in such a case is to leave the condenser thaw out gradually in a warm place. I have encountered this trouble in delivering and in servicing receivers located in rooms that were shut off from the rest of the house.—Harry Farber, Syracuse, N. Y.

Hum. In older sets, tunable hum is experienced and in most cases this can be eliminated by connecting a small condenser not larger than .01 mfd. from each plate of the rectifier to the filament of the same tube. This is a sure-fire way of eliminating hum that is experienced when a station is properly tuned in.—William F. Howard, Cincinnati, Ohio.

Insulating Aerials. Common copper gasoline tubing makes a good shield for auto aerial and similar lead-ins. Simply push in ordinary insulated wire before bending the tubing, then install. You don't have to worry about dampness in the insulation if you heat the end of this tubing with your soldering iron and run a little parafin into it.—O. T. Bolick, Davidson, N. C.

Intermittent Cut-Off. Some time ago I had a set in for intermittent cut-off. It was one of those cases where touching any part restored operation for awhile. I tried the old stunt of heating the under side of the chassis quickly with an electric heater but with no success. I then took a spot light with a 32 CP bulb, adjusted it for a sharp focus at two feet and shot the light on various condensers for several minutes each. Eventually the fifth unit opened under the heat of the lamp. I have used this scheme several times since with the same good results.—Harold A. Duvall, Los Angeles, Calif.

Label For Stolen Radios. No doubt many servicemen have had trouble with stolen rental radios. In our location, which is a summer resort, we lost quite a few sets until we used stickers on the bottom of the cabinet where only a serviceman could see them. If all servicemen would use this method and cooperate in the return of stolen sets the individual serviceman would suffer much less than in the past. Our stickers read: "Fellow Servicemen; this is a rental set stolen from PARK RADIO CENTER, Seaside Park, N. J., Phone 265, please communicate with above."—Park Radio Center, Seaside Park, N. J.

Mirror For Servicing. If there is a place in the radio set where it is hard to check for loose connections or to see the code of a resistor a dentist's mirror makes a valuable tool for use in these places.—Carl Flor, Milwaukee, Wis.

Noisy Transformers. To eliminate the buzz in transformers, loosen the screws which hold the laminations in place. Then with a brush apply enough varnish to soak the core. Let it stand for about an hour and then tighten. Do not use shellac because it will damage the enamel covering of the wire.—Frank Kreiger, Chicago, Ill.

PZH Tube. This tube is not directly interchangeable with type 2A5 as specified in several interchangeable tube charts. The 2A5 is a six prong tube, whereas the PZH has seven pins. In the PZH the suppressor is brought out to a separate pin. This necessitates a change in socket.—Clarence M. Doyle, Utica, N. Y.

Push Button Tuning. If you have trouble with the push buttons sticking in an automatic tuning radio, it's because the radio is kept where there is too much sun or heat. The heat swells the buttons so that they stick on the sides. Also the springs often lose their tension. Remove the buttons that stick and sand the high spots down. If the springs cause the trouble, stretch them for better tension or replace with new ones. If the buttons are replaced they should be of some material other than bone or rubber then they will not warp. New springs should be of stronger steel for better tension.—George Baer, Roslindale Park, Mass.

Push Pull Magnetic Speaker Repair. When one half of a magnetic speaker from a push-pull output stage burns out, a temporary repair may be effected by using a resistor of d-c resistance value equal to the remaining half. While the volume may not be as great as the original the result is usually a satisfied customer until a new speaker can be obtained. This is not recommended when a new speaker is in stock and can be sold, but if the customer cannot afford it the foregoing answers a problem.—Henry Berg, Pittsburgh, Pa.

Replacing Octal Tubes. In servicing sets using the octal base tubes, I occasionally find that they motorboat or may be dead. The cause is often traced to some of the tubes being in the wrong socket. The owner usually takes out some or all of the tubes and in putting them back, puts some in the wrong sockets. Always check the tubes with the service diagram to make sure the correct sockets are being used.—Edmond Falconbury, Kings Mountain, Ky.

12Z3 Rectifiers. Several sets using the 12Z3 as a rectifier have a current drain exceeding or approaching too closely the maximum (60 Ma.) output of this tube. By changing the rectifier socket and changing the series dropping resistor to the correct resistance value a 25Z5 may be substituted with better results. The 25Z5 may be used with both plates and cathodes paralleled or may be used with the one cathode to supply plate current and the other to supply speaker field current. In the latter connection, an extra filter capacitor is required across the speaker field supply.—Roesch Radio Service, Cleveland, Ohio.

Receiver Whistles. A considerable number of cheap radio sets of different models and makes that use a single type 43 output tube give trouble in the form of an audio whistle. If one looks over such a set he may find no resistor in the screen grid lead, the lead being connected directly with the plate supply of the 43 tube. The trouble may be overcome by cutting the lead going to the screen grid terminal and inserting a 1000 ohm resistor in series. Also, keep the plate lead from the 43 tube away from all other grid leads as far as possible.—George F. Baptiste, Howard, R. I.

Refrigerator Interference. Annoying interference from electrical refrigerators can often be overcome by connecting metal braid from the frame of the motor to the frame of the refrigerator. This provides a path for the leakage of the static electricity generated by the belt. I believe that most of the new refrigerators are now bonded this way.—G. W. McLean, Big Timber, Mont.

Screw Holder. A service tool that I have found indispensable is made from a six inch piece of ¼ inch copper tubing and two pieces of clock spring about 1 inch long. Pinch one end of the tubing in a vise until it is almost closed. Insert the two pieces of spring leaving about ½ inch extended being sure that the two pieces spread away from each other, then pinch the end of the tubing slightly. This makes a useful tool for holding split head screws.—Richard Dawson, The Dalles, Ore.

Service Light. An unusually handy servicing light can be made by removing the batteries from a fountain pen type of flashlight and connecting a flexible cord from a small filament transformer to the light bulb. This small handy light makes it convenient to test in the darkest and most inaccessible parts of a radio chassis. Eliminating the batteries cuts operating costs to a fraction since such a light is used so much.—Manuel Holtzman, Portland, Ore.

Slipping Cable, Open Grid, Glass Jar Hints. The "fish cord" type of dial cable may be remedied for slipping by brushing with a solution of gasoline and rosin. The gasoline will evaporate and leave the rosin in the cable.

Symptoms of an open grid many times leads to an open or "rosin joint" in the control grid cap. This cap should be examined first as it will sometimes save hours of work.

If you have a number of screw cap jars around the shop to keep your small parts in, but which seem to always be getting in the way, fasten the lids to the under side of a shelf. You can then hang the jars and make them convenient.—Eugene Kingrey, Dayton, Ohio.

Soldering Iron Holder. A good soldering iron holder can be made from a piece of asbestos pipe covering such as is used on steam pipes. A piece about a foot long, closed at one end, and supported under the edge of the bench (or on top if preferred) enables you to keep the iron where it can do no damage.—R. C. Wyann, Medford

LESSON 18

Elements of Radio Transmission

The radio frequency radiations occupy a large part of the electro-magnetic radiation spectrum. Light and X-rays occupy the higher frequency end of the spectrum, while sound waves are at the lower end of the frequency range. Radio radiations may be produced by a number of different methods, but at the present time vacuum tube oscillators are almost exclusively employed. The oscillations are amplified and are coupled to the transmitting antenna. The radiations produce electro-magnetic and electro-static fields.

The intensity of the electro-magnetic field diminishes as the square of the distance. This means that a signal at twice a given distance will be but ¼ in intensity; at three times the distance only 1/9 the intensity, etc. The electro-static field diminishes directly as the distance from the radiating antenna.

The intensity is also dependent on the frequency of the signal. Higher frequencies cover greater distances. This is why a low power short wave station may be received a great distance away.

Any transmitter must contain an oscillator. Ordinarily a triode vacuum tube is so connected that some plate energy is fed back to the grid circuit, and the circuit oscillates according to the natural period of the inductance-capacity present. The stability of such self-excited oscillator, however, is poor and the frequency produced has a tendency to drift. To overcome this difficulty the oscillator is excited with a quarts crystal of suitable dimensions to produce the frequency. Beginning at the right we see the crystal subjected to mechanical stress and producing oscillations of its natural period. These impulses excite the 6L6 oscillator, which in turn is coupled to a somewhat larger type 10 tube as a power amplifier. The transmitting antenna may be loosely coupled to the L_2 coil. The power supply to provide plate and filament current is also included, so that the complete unit operates from 110 v. A.C. This transmitter is designed primarily for code transmission or C.W. as it is called by the amateurs.

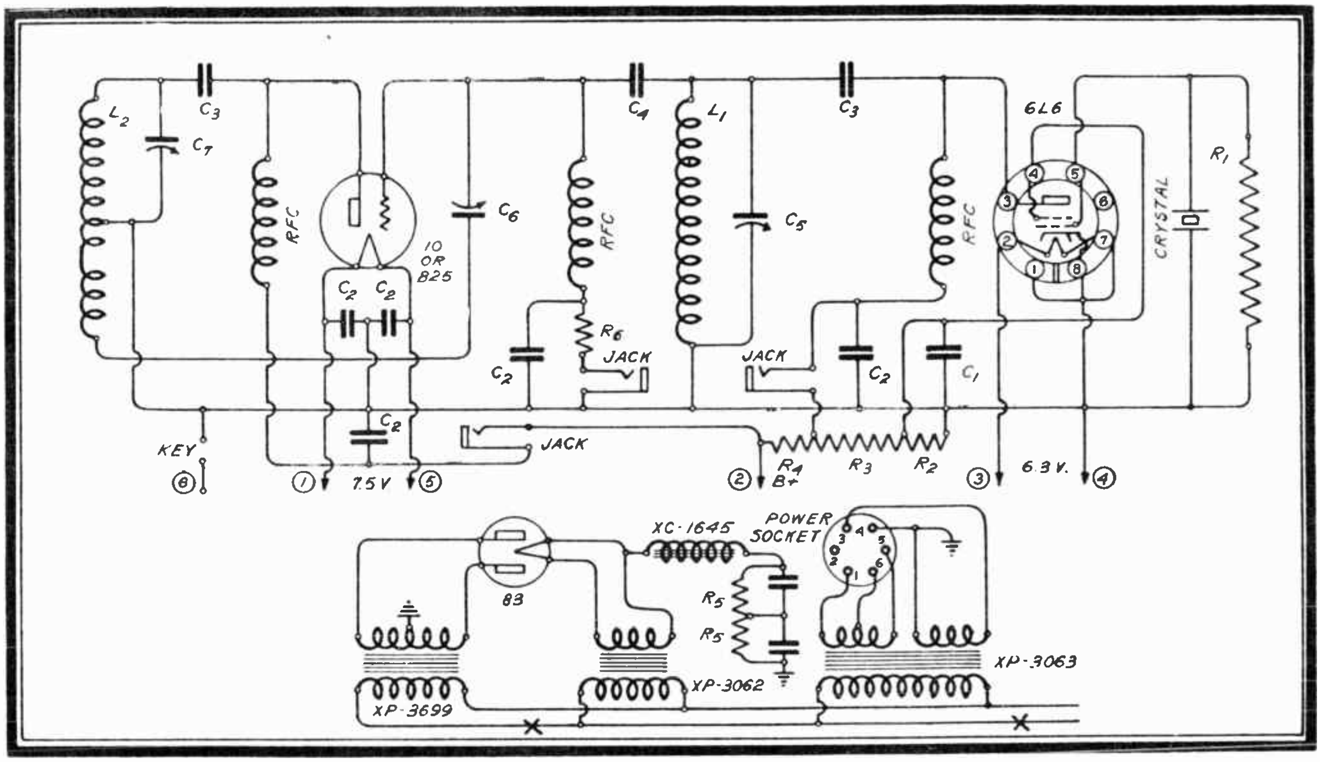
For phone (voice or music) operation, the R.F. signal produced must be properly modulated and the transmitter should be used with a modulator. Note that the modulator is simply a P.A. amplifier of the correct size and correctly connected to the equipment with a modulation transformer.

Follow through and study carefully the other transmitter described. Essentially these units are the same as the larger units employed by commercial broadcasting stations. By following the action in the circuits and applying your knowledge of radio receivers you will easily grasp the important features of transmitters. Ordinarily servicemen are not called to service transmitters, but servicemen are employed by the stations.

A Modern Simple Crystal Controlled Transmitter

The transmitter shown here is simple, yet all the fine features of a large transmitter are incorporated. The 6L6 tube makes an excellent oscillator, having high output, good efficiency and being easy on the crystal. The layout is symmetrical as well as electrically correct. There is enough room on the R. F. chassis for a buffer stage should it be desired for phone operation.

The power supply is mounted on a chassis 4½"x17"x1¼" and uses Standard 5¼" panel. The R. F. section is mounted on a chassis 7½"x17"x2½" and uses Standard 7" panel.



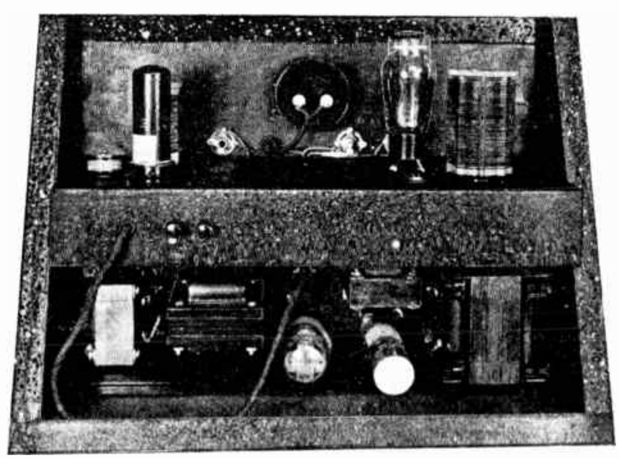
From "Stancor Amateur Transmitter Circuits", Second Edition.

C—8 MFD. Electrolytic.
C_1—.01 Mica Cond.
C_2—.002 Mica Cond.
C_3—.0005 Mica Cond.
C_4—.00005 Mica Cond.
C_5—150 MMFD. Variable.
C_6—30 MMFD. Double-spaced Midget.
C_7—100 MMFD. Variable.
RFC—2.5 M.H. RF choke.
L_1—30 t No. 20 E spaced wire, dia. 1½ form.
L_2—50 t No. 20 E spaced wire, dia. 2½ form tapped at 25 turns.
Crystal—80 meter crystal.

Tuning and Neutralization of a Crystal Oscillator, Amplifier Type Transmitter Commonly Known as M.O.P.A.

With all the filaments turned on, insert a dummy plug in the amplifier plate jack, and the meter plugged in the oscillator plate jack, apply the plate voltage to the transmitter.

Tune the oscillator tank condenser for sharp dip in the plate current of the oscillator. This indicates that the crystal is oscillating. The plate current should be between 20 and 30 milliamperes. Oscillation can be checked with a Neon bulb or a tuning lamp (one turn of wire to fit over the coil and a small flash light bulb). Remove the meter plug from the oscillator plate jack and insert it in the amplifier grid jack. The key is closed for these adjustments. Readjust the oscillator for maximum grid current as indicated by the meter. With the oscillator working properly tune the amplifier tank condenser to resonance (the oscillator will stop oscillating if the amplifier is not properly neutralized). Then tune the amplifier tank condenser so that the oscillator is still oscillating, its condenser being tuned slightly to the high frequency side of resonance. This will cause the oscillator to draw slightly more plate current, but it must be kept oscillating. Oscillation may be checked by the presence of grid current in the amplifier grid circuit. Then turn the neutalizing condenser until the lamp loop dims, retune the amplifier tank slightly, readjust the oscillator for maximum grid current to make the lamp light brighter; dim the light in the loop with the neutralizing condenser, repeat until the lamp does not light when the amplifier is in resonance. Then remove the dummy plate plug, insert the meter plug in the amplifier plate circuit and apply the amplifier plate voltage. Then the amplifier tank condenser is retuned for minimum plate current.



Fundamental Circuits

Essential information about transmitter circuits is presented below. Practical application of these circuits will be found in the explanations of complete transmitters given later on. This data has been originally published in Thordarson's Manual and is reproduced here through the courtesy of this company. For more detailed discussion of transmitters the student is referred to the American Radio Relay League "Handbook" or to the "Radio Handbook" published by Radio, Ltd.

Although self controlled oscillators were quite generally used a few years ago, better frequency stability is demanded today and practically all modern transmitters are crystal controlled. One exception is the electron-coupled oscillator (Figure 1) in which the screen, cathode and control grid

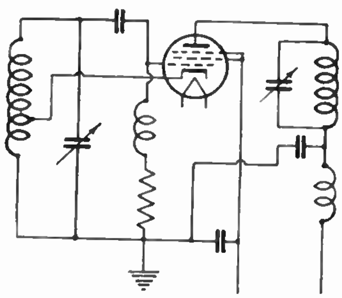


Figure 1

are connected in a Hartley circuit to generate oscillations, and the R.F. energy is taken from the plate tank circuit. By using the grounded screen grid as the anode in the oscillatory circuit, the other elements in the tube are electrostatically shielded from the plate, and the output load has very little effect on the frequency of the oscillator. The circuit has been named Tri-tet, and its operation has been fully described in the "Radio Amateur's Handbook" and "Q.S.T." One feature of the circuit is that very strong harmonics are generated in the plate circuit and by using crystal control (Figure 2), good outputs can be obtained at harmonics of the crystal frequency.

A high power Tri-tet circuit is illustrated in Figure 3.

Tubes designed for audio power work make good crystal oscillator tubes. The power

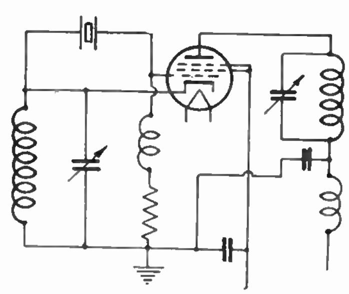


Figure 2

output obtainable will depend upon the plate voltage and the amount of feedback voltage which the crystal will stand without cracking. Tubes with a low amplification factor require a relatively large exciting voltage so must be operated at a lower plate voltage than tubes with a high amplification factor. More output can be obtained by using one of the pentode power tubes such as the 41, 42, 47, 2A5, 59, etc. These tubes require only a small exciting grid voltage for a fairly large power output, so higher plate voltages can be used (See Figure 4).

Crystal oscillators are quite simple to adjust. The plate tank circuit should be designed to tune to the crystal frequency or with the Tri-tet to a harmonic of the crystal frequency. With proper voltages applied the condenser is adjusted for a sharp drop in plate current, indicating oscillation. The proper setting will be slightly on the high frequency side of that which gives a minimum value of plate current.

Amplifiers

As the power output of crystal oscillators is limited, radio frequency power amplifiers are used

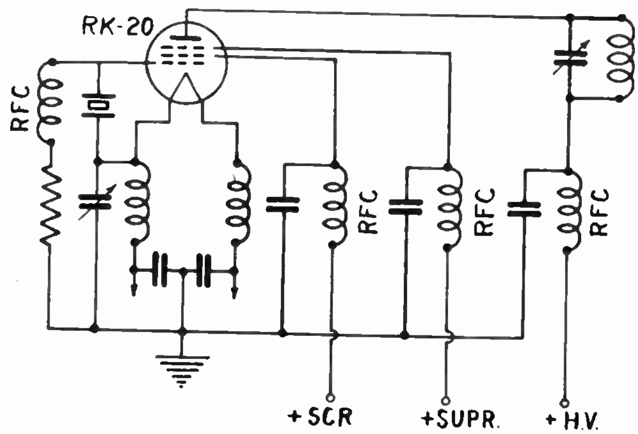


Figure 3

to build up the power output to the desired point. These are of two general types, usually called straight amplifiers and doublers, or frequency multipliers. The first are those which are tuned to the exciting frequency, the second those which are tuned to a harmonic of the exciting frequency.

The circuits for both are identical, the difference being the conditions under which the tubes are operated. For a straight amplifier the grid bias voltage should be about twice the value required to reduce the plate current to zero with no excitation, and the excitation voltage must be great enough to drive the grid positive during part of the cycle.

Triode tubes used as straight amplifiers must be neutralized, otherwise the feedback through the grid-plate capacity will cause oscillation.

Neutralization is accomplished by introducing enough voltage from one side of the circuit to

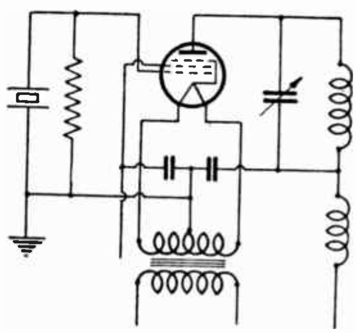


Figure 4

equal that operating through the grid plate capacity of the tube. The methods most commonly used are illustrated in Figures 5, 6, 7, 8 and 9. Figures 5 and 9 are to be preferred as the circuits will remain neutralized with different coils.

Screen grid tubes, of course, require no neutralization, but these should not be confused with the 2A5, 59 and similar types in which the shielding is not complete.

The neutralizing procedure is the same regardless of the circuit or tube used. With the plate voltage disconnected, but with the filament lighted and the excitation from the preceding stage applied to the grid, the neutralizing condenser is adjusted until no R.F. remains in the plate circuit when the plate tank condenser is tuned to resonance. Some indicating device is necessary, the simplest

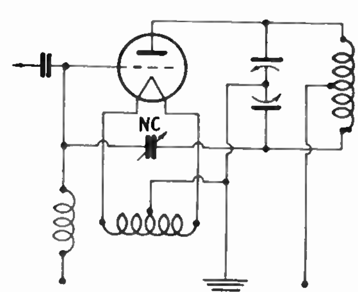


Figure 5

being a flashlight lamp connected to a one or two turn loop, which can be loosely coupled to the plate tank coil.

Coupling

Capacity coupling, in which the R.F. power generated by the oscillator or driver is fed into the

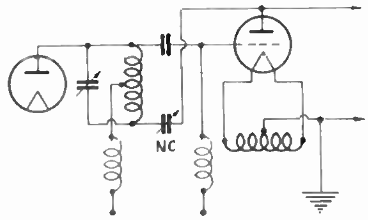


Figure 6

amplifier grid, consists of a coupling condenser connected between the driver plate and the am-

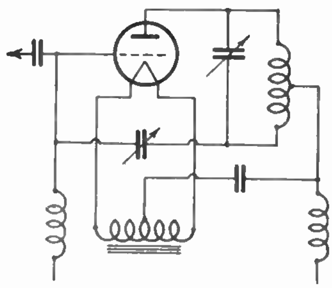


Figure 7

plifier grid. The amplifier bias is fed to the grid through an R.F. choke. This method is quite satis-

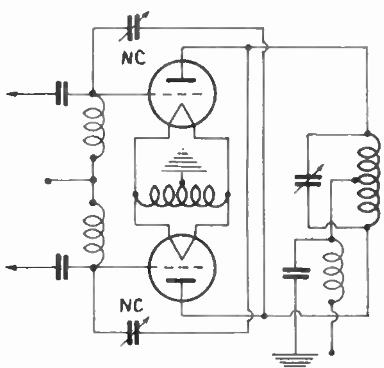


Figure 8

factory for the lower frequencies and for tubes having a low amplification factor. See Figure 10.

For tubes with a high amplification factor, inductive coupling is more efficient. A coil, preferably tuned, is connected to the amplifier grid and inductively coupled to the driver stage. Bias is fed to the grid through the coil, Figure 11. If the amplifier is located some distance from the driver, an untuned line or link, can be used as in Figure 12, or the coils may be tapped and coupling condensers used, Figure 13. This method permits closer matching than the others and was used in most of the experimental transmitters shown in this book.

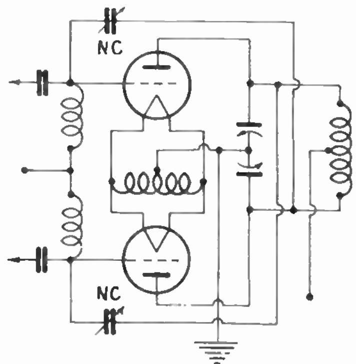


Figure 9

Amplifier Tuning

The tuning of amplifiers and frequency multipliers is much the same. A D-C milliammeter in the grid return circuit will greatly assist in making proper

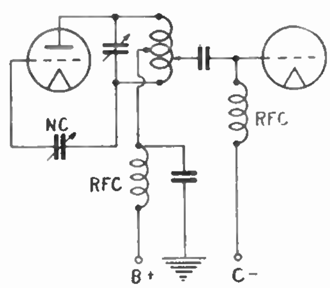


Figure 10

adjustments. Without applying plate voltage to the amplifier, the driver tuning and coupling should be adjusted to give maximum rectified grid current. Apply reduced plate voltage to the amplifier and tune the amplifier tank for minimum plate current. This should be about 10% of the rated value for straight amplifiers, but will be somewhat higher for frequency multipliers. When proper adjustments have been made full plate voltage may be applied. The amplifier is next connected to the

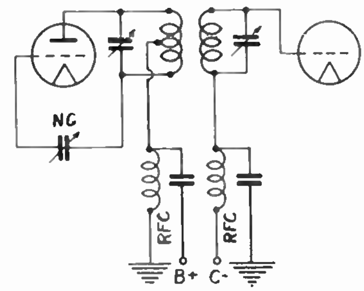


Figure 11

load, which can be another amplifier or the antenna. When the load is connected the amplifier tank circuit must be retuned for minimum plate

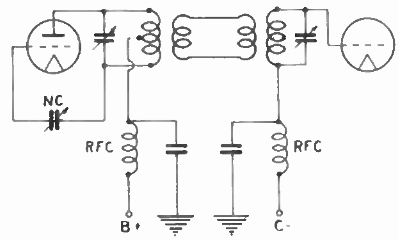


Figure 12

current, which should now be near the rated value. Coupling must be adjusted to give rated plate current. If coupled to another amplifier, proceed

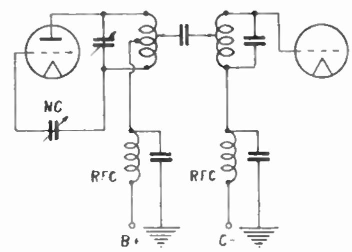


Figure 13

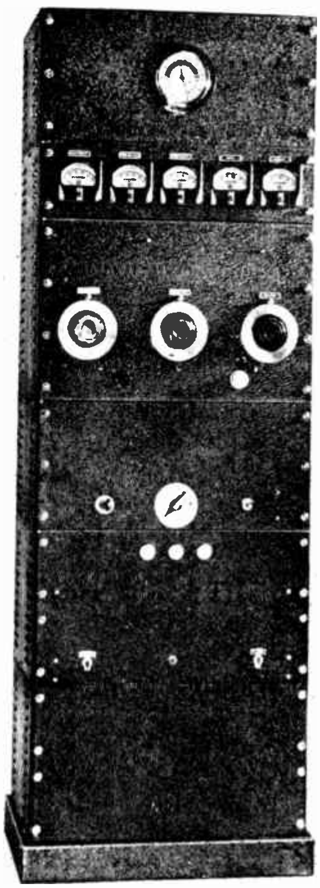
as before; if to an antenna, adjust antenna coupling and tuning for proper load.

400 Watt Transmitter

THORDARSON

This transmitter has been developed by Thordarson Electric Mfg. Co. for amateur use. By carefully studying the material included and following out the circuit diagram you will gain valuable facts about transmitters. The modulator action will be clearer after you review the additional information about modulation given at the end of the lesson.

Try to see the reason for the use of the definite size condensers and resistors. Reason out the application of each condenser and the current passing in resistors. Notice in the design the logical location of parts. For example, power supplies at the bottom. Compare the illustrations with the schematic diagram.



← R. F. Unit →

← Speech Amplifier and Driver →

← Class B Modulator and Low Voltage Power Supply →

← High Voltage Power Supply →

Photos courtesy of Popular Mechanics Magazine

The compact construction of this transmitter will lend itself to those conditions where operating space is at a premium, and where neat appearance and attractiveness are important features. Although small in size, the power input is conservatively rated at 400 watts, and an additional panel is provided for the addition of extra equipment. The transmitter as originally designed was intended for 10 and 20 meter operation; however, efficient operation on other bands may be obtained simply by changing coils.

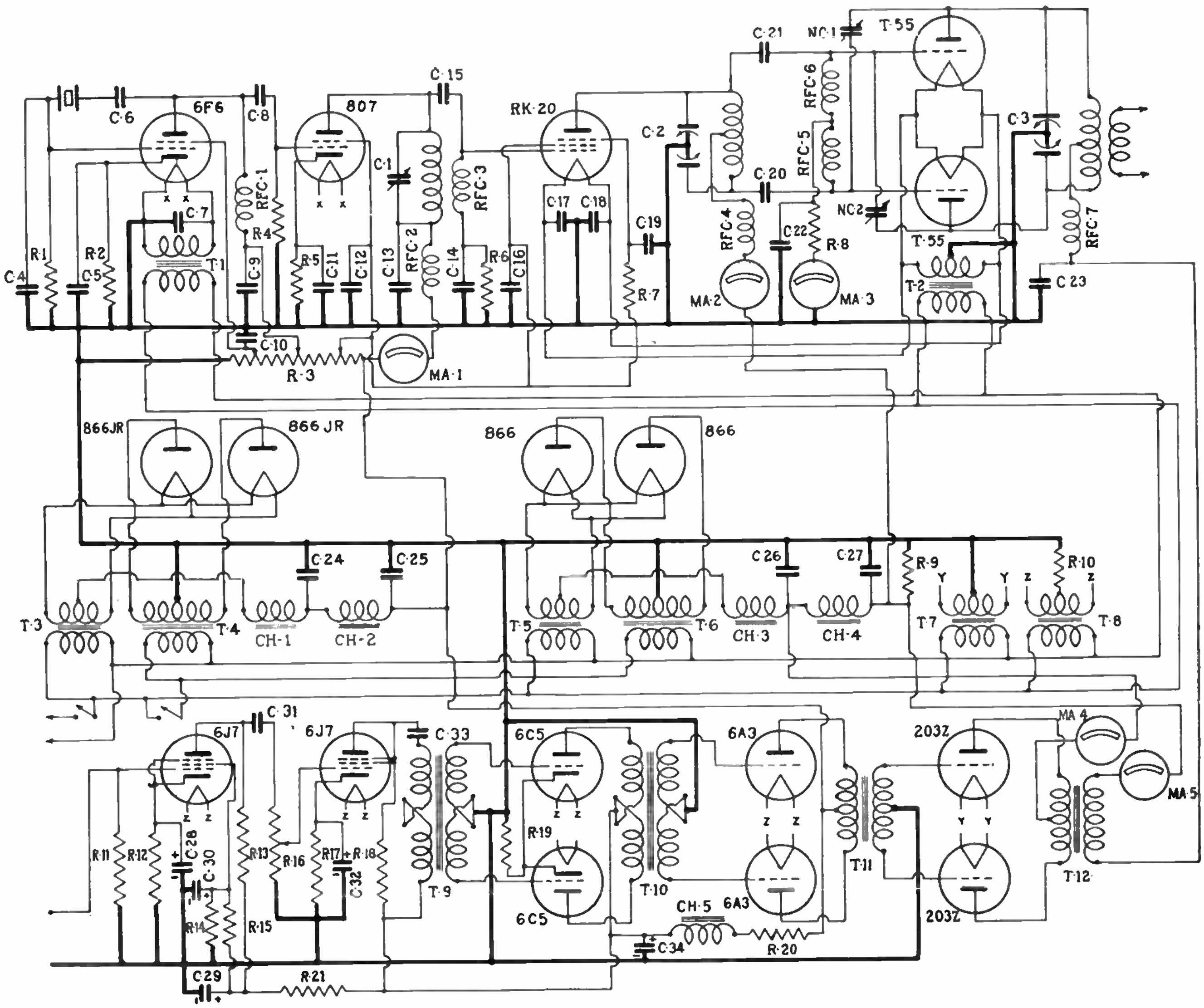
A 40 meter crystal is recommended for both 20 and 10 meters and in both cases the 807 doubler tank is tuned to 20 meters; the RK-20 is used as a doubler for 10 meters only. Since sufficient final grid current was obtained with capacity coupling, it was deemed unnecessary to use link coupling which, due to the small size of the R.F. unit would tend to complicate the layout.

The crystal oscillator utilizes the Pierce circuit. If this transmitter is used on bands other than 20 and 10 so that the 807 tank is tuned to the crystal frequency, the 807 should be neutralized to reduce the crystal current at resonance. The neutralizing voltage may be obtained from a tapped coil or by means of a split stator condenser. The latter method is recommended since reneutralizing is unnecessary in changing bands. However, even with split stator, especially if the tube has a high plate to cathode capacity, it is sometimes necessary to reneutralize. This is noticeable if the setting of the split stator is different for different bands. Complete neutralization for any setting of the tank condenser may be obtained by placing a small variable condenser across the half of the split stator unit opposite the plate connection. This additional condenser compensates for the unbalance caused by the plate to filament capacity of the tube. When capacity coupling is used, the additional grid to filament capacity of the following tube must be compensated for also.

Two power supplies are used for the entire transmitter, this further tends toward compactness. The 1250 volt supply handles the RK-20 buffer, and the T-55 final stage, as well as the 203Z modulators. The 400 volt unit supplies the 6F6 oscillator, the 807, and the speech amplifier. The driver transformer is a T-15D78 with a ratio of 3.8:1. The modulation transformer is a T-11M77. The correct connections are as follows:

For the primary: The modulator plates connect to No. 2 and No. 5; B+ connects to No. 3 and No. 4.

For the secondary: No. 7 and No. 11 are joined, also No. 8 and No. 12; the secondary load connects to No. 7 and No. 8.



400 Watt Transmitter

PARTS LIST

RESISTORS

R-1 50,000 ohms, 10 watts
R-2 250 ohms, 10 watts
R-3 25,000 ohms, 50 watts
R-4 50,000 ohms, 10 watts
R-5 100 ohms, 10 watts
R-6 15,000 ohms, 10 watts
R-7 50,000 ohms, 10 watts
R-8 5,000 ohms, 50 watts
R-9 50,000 ohms, 100 watts
R-10 750 ohms, 10 watts
R-11 5 MEG. 1/4 watt
R-12 2,250 ohms, 1 watt
R-13 250,000 ohms, 1 watt
R-14 20,000 ohms, 1 watt
R-15 100,000 ohms, 1 watt
R-16 500,000 ohm, vol. control
R-17 2,250 ohms, 1 watt
R-18 50,000 ohms, 1 watt
R-19 500 ohms, 1 watt
R-20 5,000 ohms, 10 watts
R-21 20,000 ohms, 1 watt

VARIABLE CONDENSERS

C-1 100 mmfd., 1,000 volt spacing
C-2 *250 mmfd., 1,000 volt spacing
C-3 *50 mmfd., 7,000 volt spacing
NC-1 NC-2* 8 mmfd., 5,000 volt spacing

*DUAL TYPE: CAPACITY AND VOLTAGE RATING PER SECTION

THORDARSON COMPONENTS

Transformers:	Chokes:
T-1 T-19F97 or T-16F17	CH-1 T-15C36
T-2 T-19F94 or T-16F14	CH-2 T-15C45
T-3 T-19F88 or T-16F08	CH-3 T-15C39
T-4 T-15P11	CH-4 T-15C48
T-5 T-19F90 or T-16F10	CH-5 T-74C30
T-6 T-15P16	
T-7 T-19F96 or T-16F16	
T-8 T-19F97 or T-16F17	
T-9 T-15A74	
T-10 T-15A75	
T-11 T-15D77	
T-12 T-11M77	

METERS

MA-1 150 M.A.
MA-2 250 M.A.
MA-3 150 M.A.
MA-4 500 M.A.
MA-5 750 M.A.

R.F. CHOKES

RFC-1 125 M.A.
RFC-2 125 M.A.
RFC-3 125 M.A.
RFC-4 125 M.A.
RFC-5 125 M.A.
RFC-6 125 M.A.
RFC-7 600 M.A.

FIXED CONDENSERS

C-4 00015 MFD., 1000 volt mica
C-5 .01 MFD., 1000 volt mica
C-6 .01 MFD., 1000 volt mica
C-7 .001 MFD., 1000 volt mica
C-8 .01 MFD., 1000 volt mica
C-9 .001 MFD., 1000 volt mica
C-10 .001 MFD., 1000 volt mica
C-11 .001 MFD., 1000 volt mica
C-12 .001 MFD., 1000 volt mica
C-13 .001 MFD., 1000 volt mica
C-14 .0001 MFD., 1000 volt mica
C-15 .0001 MFD., 1000 volt mica
C-16 .001 MFD., 1000 volt mica
C-17 .006 MFD., 1000 volt mica
C-18 .006 MFD., 1000 volt mica
C-19 .001 MFD., 1000 volt mica
C-20 .0001 MFD., 1000 volt mica
C-21 .0001 MFD., 1000 volt mica
C-22 .0001 MFD., 1000 volt mica
C-23 .001 MFD., 5000 volt mica
C-24 2 MFD., 600 volts
C-25 2 MFD., 600 volts
C-26 2 MFD., 2000 volts
C-27 2 MFD., 2000 volts
C-28 10 MFD., 25 volts Elect.
C-29 8 MFD., 450 volts Elect.
C-30 8 MFD., 200 volts Elect.
C-31 .1 MFD., 400 volts Paper
C-32 10 MFD., 25 volts Elect.
C-33 .1 MFD., 400 volts Paper
C-34 8 MFD., 450 volts Elect.

NTX-30 Transmitter

General Description: The National NTX-30 is an extremely flexible crystal-controlled transmitter having an RF output of 30 watts on the 10-, 20-, 40- and 80-meter amateur bands. It is complete and self-contained for c.w. operation, and terminals are provided for connecting an external modulator for phone use.

The output stage, which consists of two 6L6G's connected in parallel, is operated at 300 volts, and the normal power input under load is approximately 60 watts. The 30-watt output rating is, therefore, very conservative, and if the output circuit is properly loaded, maximum RF power will be as much as 35 or 40 watts. Excitation to the final amplifier is supplied by any one of the four 6L6 tubes. Three of these tubes are employed as doublers following a crystal-controlled oscillator which normally operates in the 3.5- to 4-Mc. band. The doublers will, therefore, provide excitation in the 7-, 14- and 28-Mc. bands, and the desired excitation frequency is selected and is automatically applied to the final amplifier by means of a low-loss push-button type switch. This arrangement will be discussed more in detail under "Circuit Description."

Frequency Control: The crystal oscillator is a conventional circuit wherein the crystal current does not normally exceed a few milliamperes. Under such conditions, there is no possibility of injuring the crystals themselves, but as a further safeguard a 2-volt 60-ma. pilot light is connected in series with the crystal holder. Normally, this lamp does not light, but if for any reason the crystal current should become excessively high, the lamp will burn out before the crystal could become overheated.

A special National type 4-in-1 crystal holder is supplied as standard equipment. This unit is plugged in horizontally on the front panel, so that the crystal selector switch is in the same position as the other panel controls. Any crystal holder which is built to fit in a five-prong tube socket can, if the operator desires, be used in place of the 4-in-1 holder, and the arrangement of the circuit is such that a simple tuned circuit can be plugged into the crystal socket if a self-excited oscillator is desired. Such an oscillator will, however, be subject to slight changes in frequency with variation of line voltage since the circuit is of the tuned-plate-tuned-grid type.

Band Selection: As outlined above, three 6L6 doubler stages follow the crystal oscillator. The outputs of these doublers are on 40, 20 and 10 meters. By simply switching the grid circuit of the final amplifier to the proper tank circuit in the exciter line, and by plugging in the proper output coil, the transmitter, as a whole, may be put on any desired frequency depending, of course, upon the frequency of the crystals.

The tank condenser of the final amplifier is tuned from the front panel by means of a type "0" dial; it is not necessary to retune the various doubler stages when changing to different frequencies within any of the amateur bands.

Metering: A dual range, illuminated meter, used in conjunction with a five-position switch, serves to check the plate current and excitation of all stages. The meter itself has a 1-ma. movement and is connected through suitable multiplier resistors to any of the cathode circuits. The multipliers are chosen so that the full scale deflection of the meter is 100 ma. when it is connected to the crystal oscillator, or to any of the doublers; when it is connected to the final amplifier cathode circuit, full scale reading is 500 ma.

The meter switch positions are numbered from 1 to 5 corresponding with the oscillator, first, second and third doublers and final amplifier respectively. It should be noted that measurement of cathode potential does not provide a direct reading of plate current, since the current in the cathode circuit is a combination of control grid, screen and plate currents. Of these, control grid current is comparatively small, but the screen current may, under certain conditions, be quite large, and it so happens that, in general, screen current will decrease with increasing plate current. For instance, when the final tank circuit is tuned to resonance, unloaded, the plate current is minimum, but at the same time screen current will be maximum. When the output circuit is loaded, as it would be in normal operation, plate current is comparatively high, while the screen current drops to a minimum value. These facts are mentioned only because the experienced operator may expect to find a greater "dip" in current than actually occurs when any tank circuits are tuned to resonance.

The cathode potential method of measurement has, however, several important advantages; if, for instance, a short should occur in any of the plate circuits, the meter will not be harmed. Incidentally, the cathode resistors have a very definite stabilizing effect and protect the various tubes against overload when excitation is removed.

Keying: Two key jacks are provided; one in the cathode circuit of the crystal oscillator and one in the cathode circuit of the final amplifier. Keying the final will provide the cleanest signal and is recommended for this reason. Where break operation is desired, it is necessary to key the crystal oscillator, and the panel control of oscillator tuning will be found very convenient in obtaining the exact adjustment necessary to eliminate keying chirps. The operator should remember that it is quite impossible to obtain good oscillator keying in any transmitter if the crystal is the least bit sluggish, or if the holder is improperly adjusted.

Power Supply: The NTX-30 is designed to operate on line voltages between 105 and 125 at frequencies of either 50 or 60 cycles. Even at a line voltage of 100 volts an RF output of 30 watts is still available. The total power input at 115 volts is about 240 watts. Special models of the NTX-30 are available for 220 volts 50- to 60-cycle operation, but 25-cycle models cannot be supplied nor can the transmitter be supplied for operation from DC line supplies.

Two switches are provided; one is the AC line switch, while the other is connected in the rectifier output and is used to disconnect all plate voltages while allowing the heaters of all tubes to remain turned on. This is the stand-by switch and it is wired to a terminal panel at the rear of the cabinet marked BSW. This terminal panel provides a convenient means of connecting a relay, as may be required in any particular installation.

The B-supply circuits deliver 500 ma. at 300 volts, and are quite conventional except for the use of parallel rectifier tubes, which are required to rectify the comparatively high current. 600-volt oil impregnated condensers are used in a two section filter, which supplies the oscillator and doubler stages. The final amplifier, which requires less filtering, is connected at the junction of the two chokes. It may be of interest to point out that in the event of the failure of one rectifier tube, the remaining tube is still capable of operating the transmitter even though it will be considerably overloaded. Such operation is not recommended, of course, but may be used in case of emergency.

The primary circuit of the power transformer is fitted with a type 3AG fuse having a rating of five amperes. It is mounted underneath the chassis.

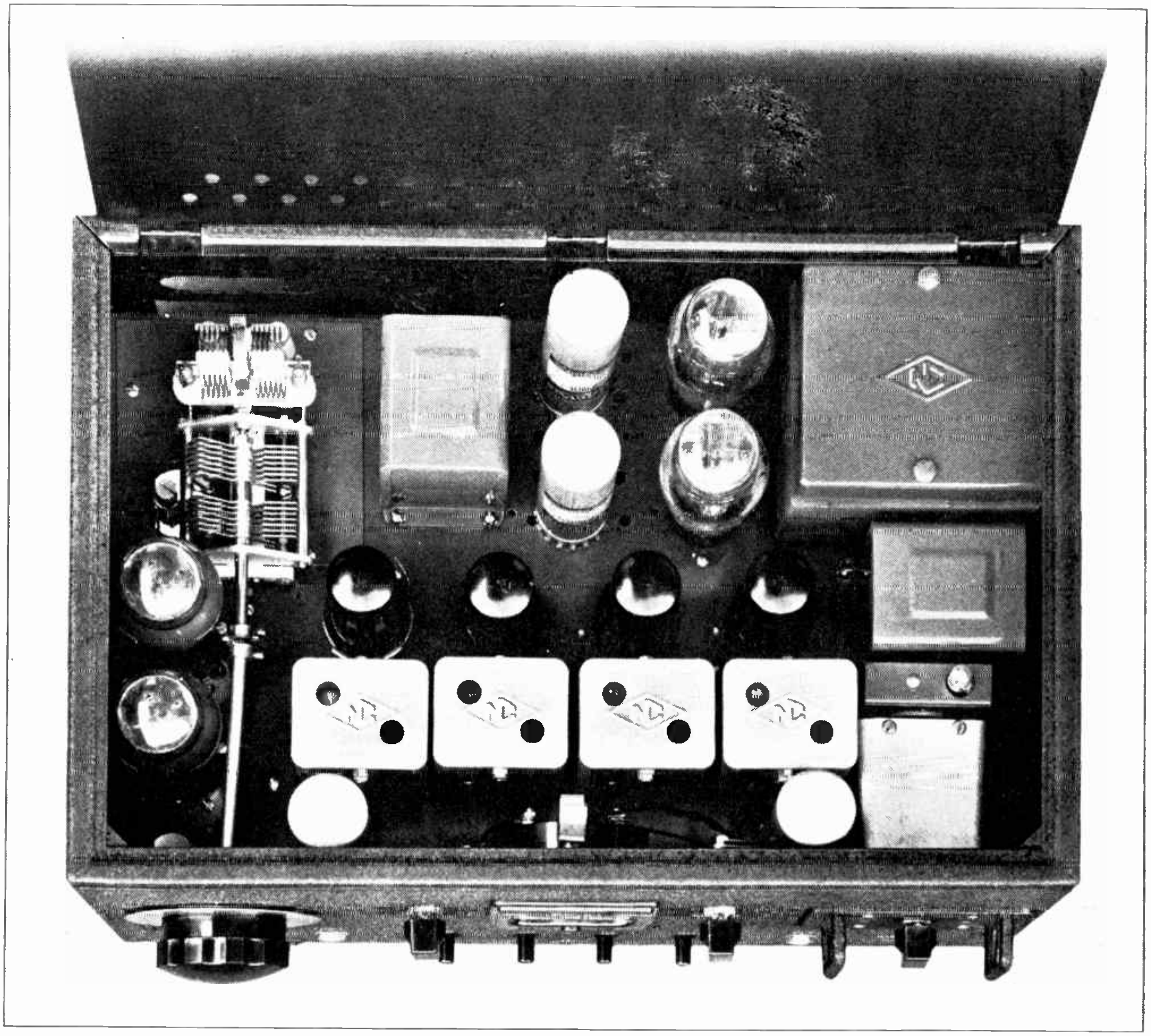
Circuit Description

Much of the material which might properly be presented here has been covered in the previous section, and it remains, therefore, to comment upon the unusual design features with which the reader may not be familiar.

The Exciter: As previously indicated, the fundamental circuit of the NTX-30 is quite conventional. The method of band-switching is unique, however, and may be described briefly as follows: Reference to the circuit diagram will show a four-section push-button switch. Each section of this switch has two positions and all sections are inter-connected mechanically by an automatic tripping mechanism. For instance, suppose the 20-meter button is pushed in to provide 20-meter excitation to the final amplifier, inspection of the diagram will show that excitation to the 10-meter doubler is now disconnected, the compensation condenser C-24 being switched in. The grid circuit of the output tubes is connected to a tap at the proper point on the 20-meter tank coil. Suppose that it is now desired to shift to the 40-meter band, it is only necessary to push the 40-meter button. When this is done, the 20-meter button will be automatically released, disconnecting the final amplifier excitation lead from the 20-meter tank. The 40-meter button will connect 40-meter excitation to the final and will, at the same time, disconnect the grid of the 20-meter doubler. In order to compensate for the detuning effect caused by the decrease in circuit capacity when the doubler grid is removed, compensating condenser C-23 is switched in. The 40-meter tank circuit will, therefore, remain in tune and will supply the correct amount of excitation to the final amplifier.

Possibly the reader has wondered about fixed tuning in the various doubler stages, and its effect upon output when changing frequency within the limits of any band. Actually, no such difficulty arises since panel controls are provided for the two critical circuits, i.e., the crystal oscillator and final amplifier output tanks. The 6L6 doublers do not require precise adjustment of excitation and since they are normally somewhat over-excited the tuning of the various circuits is not at all fussy. There is only one precaution that should be observed: the 10-meter doubler plate circuit should be tuned to within 500 kc. of the operating frequency. For instance, if this circuit is tuned to 29 Mc. the operating frequency should be between 28.5 and 29.5 Mc.; if the deviation is greater than this, there will be a slight drop in the output of the final amplifier.

Final Amplifier: There are several points of interest in connection with the final amplifier, which, as previously stated, consists of two 6L6G tubes connected in parallel. The parallel arrangement was chosen in preference to push-pull for a number of reasons. To begin with, only half of the excitation voltage is required and, furthermore, the excitation can be obtained directly from the various exciter plate circuits with no intermediate link circuits or grid tuning required. The most important point, however, is that the parallel connected tubes have comparatively low plate impedance, making it possible to maintain constant output from 80 to 10 meters, in spite of unavoidable losses which would normally decrease output considerably at the high frequencies. These losses tend to reduce the impedance of the final tank circuit and would, in the case of a push-pull amplifier, impair plate circuit efficiency. The parallel tubes, on the other hand, are much less critical in regard to the tank circuit into which they operate, and the output will, therefore, remain essentially the same over the entire range.



The amateur is apt to regard parallel operation of tubes with disfavor because his experience has shown such a circuit to have tendencies toward parasitic oscillation. It is not difficult, however, to eliminate these spurious oscillations, and in the NTX-30 complete stability is obtained by simply connecting two very small chokes close to the two plate terminals of the 6L6G tubes. They are indicated in the circuit diagram a L_7 and L_8.

Output Coupling: Each of the plug-in coils used in the final amplifier is provided with a semi-adjustable pick-up coil, designed primarily for coupling the final amplifier to a 72-ohm transmission line. The pick-up coil can be adjusted to provide varying degrees of coupling as may be required for any particular antenna or feeder system. The same coil can, of course, be used for a link pick-up where the NTX-30 is used as a driver for a high power final amplifier.

If the NTX-30 is to be used with a Zepp antenna, the conventional variable series condensers must be connected in the feeders. In the installations where the antenna feeders are of high impedance, or where voltage feed is used, it will be necessary to employ a pi-section matching network. For complete data on various types of antennae, coupling systems, etc., the reader is referred to the A.R.R.L. Handbook.

Operating and Alignment Instructions

The Exciter Section: Tank circuits and compensators in the exciter section of the NTX-30 are aligned in the laboratory before shipment, but it is quite possible that the alignment may require checking, particularly in the case of the 10-meter doubler tank, which, as stated above, should be tuned to within 500 kc. of the operating frequency. The complete alignment procedure is, therefore, given below and may be accomplished without difficulty if the instructions are carefully followed.

Looking at the NTX-30 from the front, each tank shield in the exciter line will be seen to have two adjustment holes; of these, the ones on the left-hand side of each shield are the main tank condensers, while those on the right are the compensators described above, except in the case of the 10-meter doubler where both trimmers are in parallel and act as tank condensers.

First turn on the AC switch and allow the rectifier tubes to heat for ten or fifteen seconds before turning on the B-supply switch. Push the 10-meter button and set the meter switch at No. 1, and with the desired 80-meter crystal connected in the oscillator, adjust the crystal tuning control on the front panel for a dip in current. In normal operation, the off-resonance current will be in the neighborhood of 45 to 50 ma. and the meter will dip down to about 30 ma. when the crystal is oscillating. Turn the meter switch to position No. 2 and tune the 40-meter tank condenser for minimum meter reading. Off-resonance current will be 60 or 70 ma., while the current at resonance is from 30 to 40 ma. Proceed to the next tank, switching the meter to position No. 3, and tune it to resonance in the same manner; then check the 10-meter tank with the meter in the No. 4 position. Now push the 20-meter selector-switch button and set the 20-meter compensating condenser for minimum reading, the meter switch being in the No. 3 position. Proceed to the next lower frequency range by pushing the 40-meter button and set the 40-meter compensator for minimum reading of the meter with meter switch in position No. 2. Repeating this operation on the 80-meter range with the meter in the No. 1 position will complete the alignment.

The adjusting screws of the various tank condensers are at B+ potential so reasonable care must be taken not to short the screw driver against the shield can. Such a short will not, however, harm the meter, since it is connected in the cathode circuit.

When the NTX-30 is to be used on several different frequencies, it is best, of course (although not especially important), to align the various circuits to the middle frequency of the group. As stated previously, however, the tuning of the 20- and 40-meter tanks is not at all fussy as far as excitation of the final amplifier is concerned, and if the crystal frequencies cover a wide range, it is best to favor those circuit adjustments which give correct alignment on the principal 10-meter frequency.

Neutralization: The design of the final amplifier is such that when it is neutralized on one frequency it remains neutralized at all other frequencies in any of the amateur bands. Naturally, this makes neutralization simple, and the recommended procedure is as follows: Push the 10-meter selector switch to provide excitation to the final at that frequency; plug-in the 10-meter coil and remove the wire connecting the modulation input terminals at the rear of the chassis; connect a 2-volt 60-ma. dial lamp (as used in 2-volt battery receivers) directly across the antenna terminals. The coupling coil should be set to provide maximum coupling. Carefully tuning the final tank circuit to resonance at about 25 to 30 on the dial should not show any indication of light in the 2-volt lamp. If it does, the neutralizing condenser, which is located just to the left of the split stator tank condenser, should be adjusted with a screw driver made of insulating material. When finally set, the adjusting screw should be locked in place by means of the lock nut which screws down against the molded end piece of the neutralizing condenser. The adjustment which gives correct neutralization is quite critical and it is necessary to set the screw to within ¼ of a turn. Care should be taken when locking the screw in its final position as the action of the lock nut tends to reduce the capacity slightly.

The 2-volt lamp, when used in the manner outlined above, constitutes a very sensitive indicator and through its use the final stage can be neutralized very accurately. As a matter of fact, the lamp is very apt to burn out if the final stage is exactly tuned to resonance at any time when the neutralizing condenser is incorrectly adjusted. In order to avoid this possibility, the final tank circuit should be tuned towards the point of resonance slowly (from either side), the neutralizing condenser being adjusted as may be required to keep the indicator lamp from lighting.

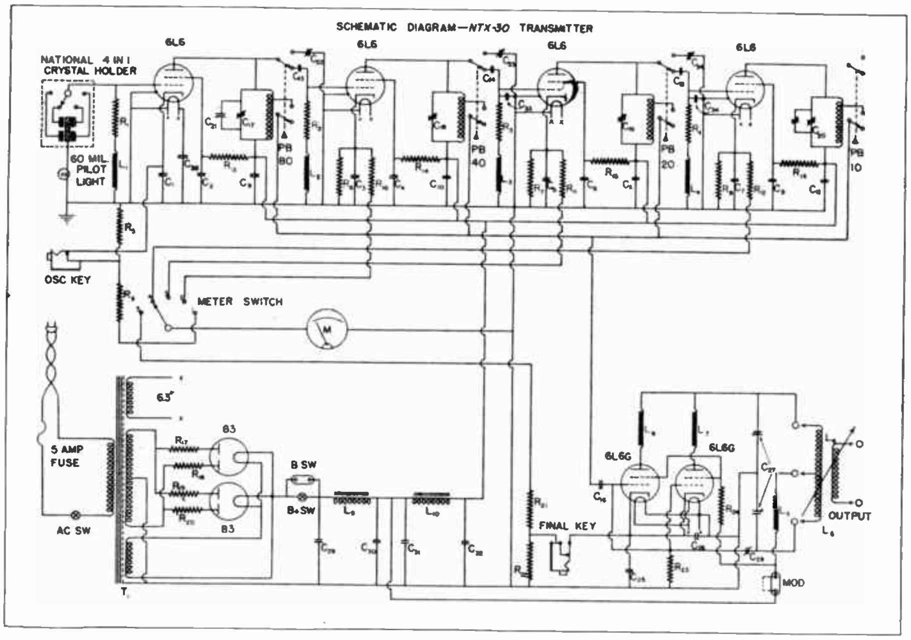
In common with other circuit adjustments of a permanent nature, the neutralizing condenser is set at the factory to correctly neutralize the particular tubes which are furnished with the transmitter.

Final Amplifier Tuning: After the final amplifier is properly neutralized, B-supply voltage may be applied to the plate and screen circuits by replacing the bridge wire connecting the two modulation supply terminals. The various amateur bands will be found at the approximate dial readings listed below:

80	meters	65–70
40	"	55–60
20	"	40–45
10	"	25–30

The plate current drawn by the final stage will vary with the band in use and will, in general, be considerably higher on 10 and 20 meters than it is on 40 and 80 meters. The meter reading will be made with the switch in position No. 5. When the final tank circuit is off-resonance, the final plate and screen currents on 10 and 20 meters will be around 320 ma., and when the circuit is tuned to resonance, as indicated by minimum meter reading, the current will be about 190 ma. Corresponding readings for 40 and 80 meters are 220 ma. off-resonance, and 60 ma. at resonance. When fully loaded and delivering from 30 to 40 watts of RF power, the meter will read about 290 ma. on the 10- and 20-meter bands, and about 190 ma. on 40 and 80 meters.

There is one more point which should be mentioned concerning tuning of the final amplifier. When the 80-meter coil is plugged in, it will be



PARTS LIST

R_1 to R_4, inclusive — 50,000-ohm, 2-watt
R_5 to R_8, inclusive — 300-ohm, 2-watt
R_9 to R_{12}, inclusive — 30,000-ohm, ½-watt
R_{13} — 20,000-ohm, 2-watt
R_{23} and R_{14} to R_{16}, inclusive — 7500-ohm, 10-watt
R_{17} to R_{20}, inclusive — 30-ohm, 2-watt
R_{21} — 5000-ohm, ½-watt
R_{22} — 10-ohm, 2-watt
R_{24} — 2500-ohm, 10-watt
C_1 to C_8, inclusive C_{25} and C_{35} — .01-mfd., 400-volt
C_9 to C_{12}, inclusive — .003-mfd. mica
C_{13} to C_{15}, inclusive — .001-mfd. mica
C_{16} — .00025-mfd. mica
C_{17} to C_{20} — 25-mmf. tank condensers
C_{21} — "Crystal tuning" National STE60
C_{22} to C_{24}, inclusive — 15-mmf. compensators
C_{26} — .001-mfd. mica
C_{27} — Final tank condenser National TMC-150D
C_{28} — Neutralizing condenser National NC-600
C_{29} to C_{32}, inclusive — 4-mfd., 600-volt (oil)
C_{33}, C_{34} — 10-mmf. mica
L_1 to L_4, inclusive — National R-100 RF Chokes
L_5 — National R-200 RF Choke
L_6 — National AR-16S Tank Coils
L_7, L_8 — Parasitic Chokes
L_9, L_{10} — National Filter Chokes (Special)
PB — National Push Switch ACS-4

possible to tune it to 40 meters by setting the dial at about 10, and considerable output is available even though the amplifier is, in this case, acting as a doubler. Such operation is not recommended, however, since the tuned circuit has a high ratio of inductance to capacity which will result in excessive harmonic radiation. It may also be possible to tune the 40-meter tank coil to 20 meters in a manner similar to that outlined above, but here again the L/C ratio cannot provide adequate harmonic suppression.

Antenna Coupling: The output pick-up coil is designed primarily to match a 72-ohm untuned transmission line. For further data on this subject refer to the last paragraph under "Circuit Description."

In general, the output coupling coil should be adjusted to fully load the final amplifier, this condition being indicated when the meter reading is about nine-tenths of the "off resonance" value. The output coupling coil should be set to provide the correct loading condition by bending the mounting leads and, when once adjusted, need not be changed unless some alteration is made in the antenna system. It is obviously impossible to give exact directions for adjusting and tuning all of the various types of antennae to which the NTX-30 may be connected, and it will be necessary for the operator to do a certain amount of experimental work in order to obtain maximum antenna power. The operator should realize that the performance of the transmitter depends largely upon the efficiency of the antenna system, and it is well worthwhile, therefore, to take considerable pains to see that all parts of the radiating system are working efficiently.

'Phone Operation: The final amplifier of the NTX-30 may be modulated for 'phone operation and suitable terminals are provided at the rear of the chassis for connecting the modulator. Reference to the circuit diagram will show that these terminals are connected in series with the B-supply to both plate and screen circuits, and both circuits will, therefore, be modulated. This system of modulating the final is very satisfactory and an oscilloscope will show negligible distortion up to 100% modulation.

When the final amplifier is fully loaded, about 30 watts of audio power will be required to modulate the carrier completely.

The load impedance of the Class C amlpifier, looking into the modulation terminals, will vary with the current drawn by the plate and screen circuits, and the modulator must of course be designed to work efficiently into the Class C load. The 10- and 20-meter impedance is approximately 1000 ohms, while on 40 and 80 meters it is about 1500 ohms. These values are somewhat lower than those ordinarily encountered in a Class C amplifier, but the actual impedance is unimportant as long as the modulator tubes are properly loaded.

National NSM Modulator

General Description: The NSM Modulator is a complete speech amplifier and modulator unit having a maximum undistorted output of 35 watts. It is designed primarily to be used in conjunction with the NTX-30 Transmitter, but can, of course, be used with other transmitters and, to this end, has been fitted with suitable switches, terminal panels, etc., as well as other features which will be described in detail in the following pages.

Nine tubes are employed as follows:

Input Amplifier	6C6
Voltage Amplifier and Compressor Control	6D6
Phase Inverter and Driver	6F8G
Power Output (2)	6L6G
Compressor Rectifier	6X5
Meter Amplifier	6C5
Rectifier	83
Voltage Regulator	VR150

Although the fundamental circuit is quite conventional, there are a number of unusual features which merit a complete description and while this booklet is intended as an instruction manual, it is felt that the operator of the NSM will appreciate information concerning the design and operation of this equipment.

Frequency Characteristic: The normal frequency characteristic of the NSM has been selected to favor the particular characteristics of voice transmission. This subject has been covered thoroughly in the various periodicals devoted to amateur transmitters so that in this booklet it will only be said that the frequency characteristic of the NSM is down 10 db. at 25 cycles, 6 db. at 50 cycles and is flat within 2 db. between 100 and 10,000 cycles.

A four-position tone control is provided which may be used as follows:

In position No. 4, the normal characteristic, as outlined above, is obtained.

In position No. 3, the high frequency response is attenuated in such a way that the gain at 5000 cycles is down 10 db.

In position No. 2, low frequency response is attenuated in such a way that the gain is down 10 db. at 100 cycles.

In position No. 1, both high and low frequencies are attenuated.

Position No. 2 will be found particularly useful when the operator is attempting to work through bad interference, since the effective or "intelligibility modulation" may be increased about 8 db. without actually exceeding 100% modulation.

Input Circuits: Two input circuits are provided. A high gain circuit starts at the microphone jack on the front panel and from this point the overall gain to the modulator output is 140 db. Full output is obtainable with an input of about one-half of one millivolt at the microphone jack. This amplification is sufficient for any conventional low level microphone and it will be seldom necessary to fully advance the gain control.

A relatively low gain input circuit (90 db. gain) is brought out to terminals at the left-hand side of the chassis, as viewed from the rear. This channel may be used in conjunction with sound equipment having fairly high level, such as would be obtained from a carbon microphone or a phonograph pick-up.

Both input circuits utilize the same audio gain control or fader. The gain control is located just to the right of the meter on the front panel and is of such design that with the pointer in the vertical position both channels are dead. As the control is rotated counter-clockwise from the central position, the amplification of the low gain channel increases and, conversely, when the control is rotated clockwise from mid-position, the amplification of the high gain channel increases.

Output Circuit: The output of the 6L6G's is brought to a terminal panel at the upper right-hand side of the chassis at the rear. The impedance of the load circuit should be in the neighborhood of 1400 ohms and the NTX-30 may, therefore, be connected directly as covered under "Installation and Operation."

The output transformer is designed to carry the full current drawn by both plate and screen circuits of the Class C amplifier and, as indicated above, will deliver 35 watts under these conditions. In certain applications where the NSM is to be used with a transmitter having markedly different characteristics than those of the NTX-30, or in Public Address work, etc., it may be advisable to connect directly to the plates of the 6L6G's, either directly or through a special coupling transformer. In such cases, the maximum undistorted output will be about 45 watts. The output transformer must, however, be carefully designed and have excellent power efficiency or a large percentage of available power will be lost. The standard 1400-ohm transformer furnished has a power efficiency of about 81%; in other words, the loss is less than 1 db.

Volume Compression: It is doubtful if the average amateur operator realizes that it is practically impossible to operate his transmitter within the limits of 90% and 100% modulation. In order to fulfill this requirement, it would be necessary for him to talk at a uniform level which would not vary more than about one-half of 1 db.

Obviously, this cannot be done and since it is usually necessary to maintain modulation at an average level of at least 80% or 90%, in order to cope with interference and heterodynes, it is no wonder that the majority of phones are considerably over-modulated most of the time. The practical solution to the over-modulation problem lies either in an accurate indicating device, or in volume compression.

Of course, the Federal Communications Commission requires some form of modulation indicator but even though it is used conscientiously, continuous vigilance on the part of the operator is required and the mere fact that an indicator is in use is no assurance that 100% modulation will not be exceeded during a QSO when the operator is trying to think of several things at the same time. The volume compressor, on the other hand, works automatically and will maintain a uniformly high percentage of modulation, even though the output of the microphone varies over a range of about 8 to 1. Study of the NSM diagram will show how the volume compressor works.

The high end of the modulation transformer secondary is connected to the cathode of the 6 × 5 rectifier, the plate circuit of which is grounded through a resistance of 100,000 ohms shunted with a 10-mfd. condenser. The plate end of this network is connected through a suitable filter to the control grid of the 6D6 amplifier tube. It should be noted that the rectifier cathode is supplied with a higher audio voltage than that connected to the Class C amplifier. Inasmuch as the tap on the transformer secondary is connected directly to the Class C amplifier, modulation voltage which is sufficient to produce about 90% modulation will, at the same time, produce enough excess voltage, in that portion of the secondary winding connected to the rectifier cathode, to cause rectification of negative audio peaks. At modulation percentages over 90, the carrier envelope during the negative portion of the cycle is very close to zero since, by definition, 100% modulation occurs when the peak modulator voltage equals the DC supply voltage of the Class C amplifier. Obviously, the extra turns on the modulation transformer secondary will couple an additional modulator voltage to the 6 × 5 rectifier and as soon as the cathode becomes negative, with respect to ground, current flows in the plate circuit and the resulting voltage drop is impressed upon the grid of the 6D6. This voltage cuts down the amplification of the tube in such a way that the output of the modulator is held essentially constant and it is practically impossible, therefore, to operate the Class C amplifier beyond its modulation capability of 100%.

This type of compressor "takes hold" very quickly; in other words, the volume compressor action is almost instantaneous. The action continues, however, until the condenser in the plate circuit of the rectifier discharges through the 100,000-ohm load resistance. Since this action is relatively slow, there is no audio degeneration or distortion in the audio cycle and the compressor simply rides along on the modulation peaks.

Inasmuch as the compressor is a voltage actuated device, it will work exactly as outlined above on any transmitter provided, of course, that the standard modulation transformer is used.

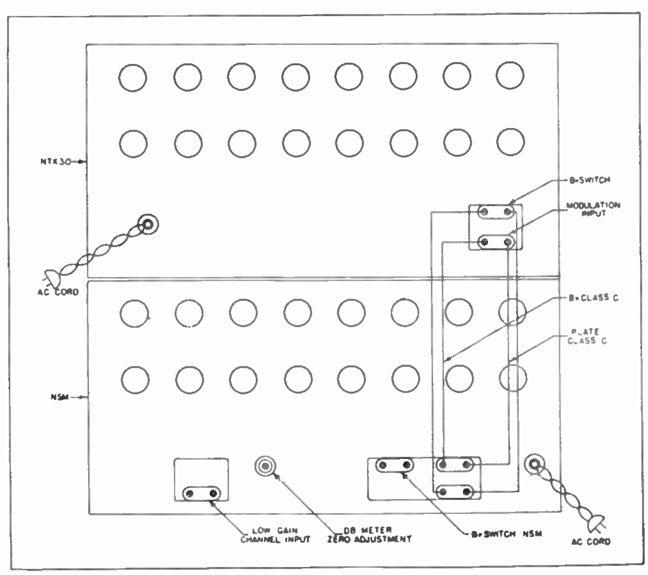
The volume compression meter employs a special scale and reads directly the decrease in overall gain of the speech amplifier when the compressor is in operation. For instance, assume that a given input from the microphone is just sufficient to produce 90% modulation. At this level there will be no compressor action and the meter will read zero. If, however, the input to the amplifier is increased by 6 db., for example, compressor action starts and cuts down the gain of the amplifier by almost exactly 6 db. so that output and percentage modulation remain about the same as before. The meter will now read 6 db. When it is remembered that a 6 db. increase means a power change of 400% and that this increase would result in 180% modulation (if the modulator tubes could handle it), it is evident that the 17 db. range of the compression meter is ample and in use the meter seldom reads over 10 db.

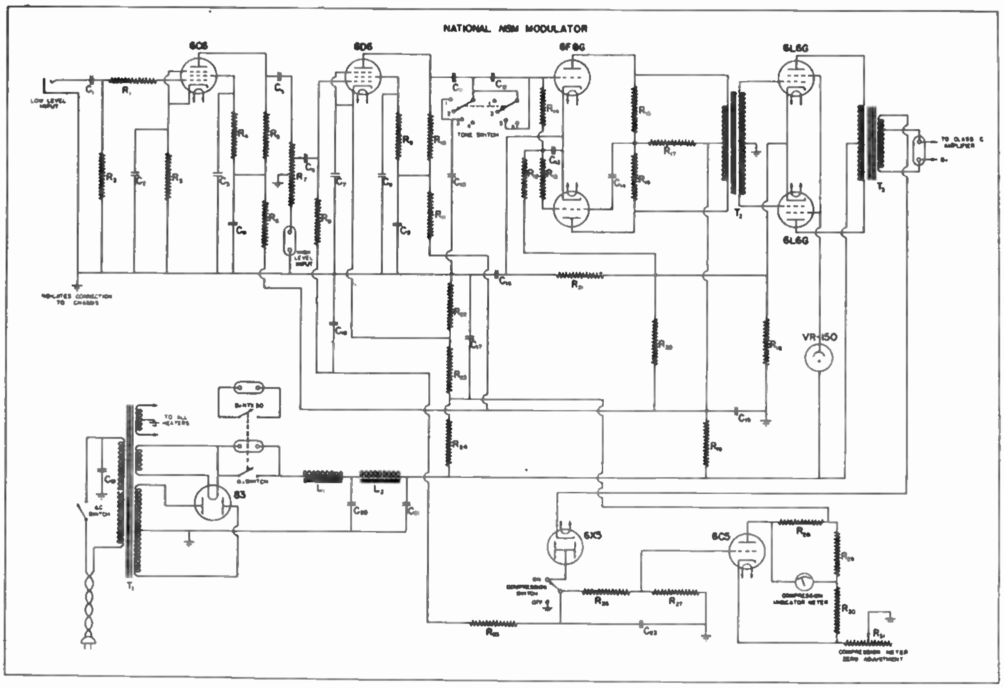
Phase Inverter: Another unusual feature of the NSM is the manner in which the 6F8G is used as a phase inverter. Referring again to the circuit diagram, it will be seen that the upper triode has a voltage divider network connected between the plate and B+ with the grid of the lower triode fed from a tap. This part of the circuit is quite conventional but a self-balancing effect is obtained by connecting a resistor between the plate of the lower triode and the tap which feeds its grid. Briefly, the action is as follows: The resistor network of the upper triode supplies the grid of the lower unit with more audio voltage than is actually needed to obtain balanced output. This excess voltage is, of course, amplified by the lower triode and appears in its plate circuit. Since the plate resistor previously mentioned is connected to the grid excitation tap and since a portion of the total resistance (between B+ and the grid tap) is common to both grid and plate circuits, there will be a bucking action which will equalize the excess grid voltage and will keep the circuit as a whole very closely balanced. The self-balancing action is very desirable since it will accurately compensate for any slight differences between the two triode sections of the 6F8G tube and will assure good push-pull action, correct balance in the transformer primary, etc., with negligible distortion.

Installation and Operation: The accompanying sketch shows the recommended interconnections between the NSM and the NTX-30. It will be seen that only four leads are required, two for the modulator output and two for the B+ switch circuit of the NTX-30. The B+ switch of the NSM is a double-pole single-throw type and, when wired as shown, will control both the R.F. and modulator power supplies simultaneously. An additional B switch panel is also provided and is connected in parallel with the NSM B+ switch for those installations where it is desired to employ a relay associated with the controls of the receiver. This panel will not, however, be used ordinarily with the NTX-30.

When connecting the two units, it is very important that the modulator output terminals be correctly wired to the corresponding terminals of the Class C amplifier. If they are not, or if polarity is reversed, the volume compressor will be inoperative. If there is any doubt on this point, the wiring of both units should be checked in accordance with the circuit diagram.

After the two units are wired together with the R.F. portion of the transmitter properly adjusted, the modulator AC switch should be turned on and the tubes allowed to warm up for about one minute. The B switch may now be turned on and with the audio gain control off (in mid-position), the compressor switch should be turned on and the compression meter reading checked. If the meter does not read zero, it will be necessary to adjust the compensating resistor located on the back of the chassis. This adjustment is of the semi-permanent type and is made with a screwdriver. When once set it need not be readjusted except at infrequent intervals, as the 6C5 tube changes its characteristics. The micro-





RESISTOR AND CONDENSER LIST

R_1	50,000 ohms	½ watt	
R_2	5 megohm	½ watt	
R_3	1,000 ohms	½ watt	
R_4	1 megohm	½ watt	
R_5	250,000 ohms	½ watt	
R_6	100,000 ohms	½ watt	
R_7	1 megohm tapped Fader		
R_8	500,000 ohms	½ watt	
R_9	1 megohm	½ watt	
R_{10}	250,000 ohms	½ watt	
R_{11}	40,000 ohms	½ watt	
R_{12}	250,000 ohms	½ watt	
R_{13}	500,000 ohms	½ watt	
R_{14}	500,000 ohms	½ watt	
R_{15}	50,000 ohms	½ watt	
R_{16}	50,000 ohms	½ watt	
R_{17}	20,000 ohms	½ watt	
R_{18}	155 ohms	4 watts	
R_{19}	5,300 ohms	5 watts	
R_{20}	20,000 ohms	2 watts	
R_{21}	430 ohms	½ watt	
R_{22}	140 ohms	½ watt	
R_{23}	15,000 ohms	3 watts	
R_{24}	15,000 ohms	5 watts	
R_{25}	250,000 ohms	½ watt	
R_{26}	80,000 ohms	½ watt	
R_{27}	20,000 ohms	½ watt	
R_{28}	2,500 ohms	½ watt	
R_{29}	350 ohms	½ watt	
R_{30}	20,000 ohms	2 watts	
R_{31}	1,000 ohms	wire-wound rheostat	
C_1	.1 mfd.	400 volt	tubular
C_2	25 mfd.	25 volt	electrolytic
C_3	.25 mfd.	400 volt	tubular
C_4	8 mfd.	450 volt	electrolytic
C_5	.1 mfd.	400 volt	tubular
C_6	.1 mfd.	400 volt	tubular
C_7	25 mfd.	25 volt	electrolytic
C_8	.25 mfd.	400 volt	tubular
C_9	8 mfd.	450 volt	electrolytic
C_{10}	.005 mfd.	400 volt	tubular
C_{11}	.025 mfd.	400 volt	tubular
C_{12}	.001 mfd.	mica	
C_{13}	.1 mfd.	400 volt	tubular
C_{14}	.1 mfd.	400 volt	tubular
C_{15}	24 mfd.	450 volt	electrolytic
C_{16}	10 mfd.	50 volt	electrolytic
C_{17}	8 mfd.	450 volt	electrolytic
C_{18}	.1 mfd.	400 volt	tubular
C_{19}	.1 mfd.	400 volt	tubular
C_{20}	4 mfd.	600 volt	oil
C_{21}	4 mfd.	600 volt	oil
C_{22}	10 mfd.	50 volt	electrolytic

phone may now be plugged in and the volume control advanced to the right. The operator must, of course, adjust the gain control to provide sufficient sensitivity but it should not be advanced to the point where the compression meter reads over 6 on the ordinary peaks encountered in voice modulation.

Do *not* try to operate the transmitter with the meter reading above mid-scale, as such operation may cause over-modulation even though the compressor control circuits are capable of holding the modulator output uniform within a few per-cent. It must be remembered that the carrier is modulated over 90% as soon as the compression meter starts to read and that an increase in the modulator output voltage of only 10% (approximately .5 db.) will produce over-modulation with distortion and side-band splatter.

If the NSM is used for Public Address work, or any similar application not directly associated with the modulation of the Class C amplifier of a transmitter, the compressor switch should always be turned off; otherwise the amplifier circuits cannot function properly.

MODULATION PRINCIPLES

Modulation of an R.F. carrier may be accomplished in a number of different ways: plate modulation, grid modulation, and screen or suppressor modulation. By far the most popular is plate modulation; and with the merits of class B audio accepted facts, the trend of even the largest broadcast stations, which in the past used low level modulation, is toward the use of plate modulation in the final stage.

Plate modulation is accomplished by varying the plate voltage on the class C stage in accordance with the wave shape of the signal from the modulators. If the normal class C plate voltage is 1000 volts, for 100 per cent modulation the plate voltage (due to the voltage from the modulators) will swing from zero to 2000 volts.

In Figure 1 is shown a carrier which is 100 per cent modulated by a sine wave.

The unmodulated carrier is shown from A to B; the modulated portion, from B to C. The distances a and b represent either voltage or current amplitudes; and for 100

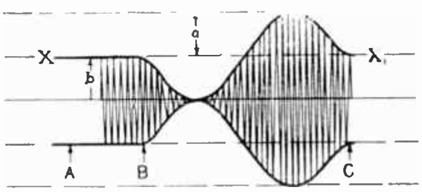


FIG. 1

per cent modulation, they are equal. This modulated wave may be thought of as the regular carrier surmounted by a sine wave, the axis of which (X-X') is placed along the top of the carrier. This sine wave signal and the power represented in it must be supplied by the modulators. The amplitude of the carrier is b, and the carrier power is thus equal to Kb^2, where K is a constant. The amplitude of the sine wave from the modulators is a, which is equal to b; and since the effective value is .707b, the power in the sine wave is $K(.707b)^2$ or $.5Kb^2$. The sideband power supplied by the modulators is thus one-half the carrier power. It should be borne in mind, however, that these figures hold only for a sine wave; and from this comes the statement that for 100 per cent modulation, the output of the modulators must be one-half the class C input.

A more general statement which would eliminate the wave form of the modulators would take into account peak modulator power, rather than average power. In Figure I, since a equals b, the carrier power Kb^2 is equal to the peak modulator power Ka^2.

In Figure 2 is shown a carrier 100 per cent modulated by a complex wave.

The distance a is still equal to the distance b; and it may be seen that the average power represented in the sidebands is much less than the power in a sine wave of equivalent amplitude a, since the

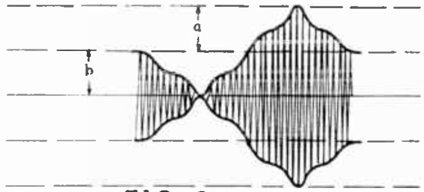


FIG. 2

area under the complex wave is less. The average power in the sidebands, then, is less than one-half the carrier power. Speech wave form is similar to the wave form in Figure 2 in that the average sideband power is similarly less than half the carrier power. In other words, to modulate 100 per cent an input of 100 watts, the peak power supplied by the modulators is 100 watts; although for a sine wave this 100 watts of peak power represents but 50 watts of average power, and for voice frequencies this 100 watts of peak power may represent only 30 watts of average power. This does not mean that a 30 watt amplifier will modulate an input of 100 watts on voice frequencies; but it does mean, in order to modulate 100 per cent on input of 100 watts, that the peak modulator power must be 100 watts regardless of wave form.

Figure 3 shows a partially modulated carrier.

Here, a is less than b; and the percentage of modulation is equal to $\left(\frac{a}{b} \times 100\right)$. The modulator power for any percentage

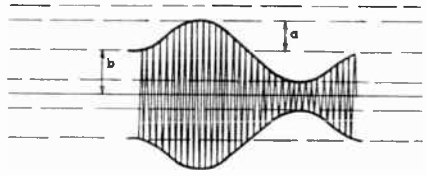


FIG. 3

of modulation may be easily calculated. Suppose that it is necessary to know the modulator power for 50 per cent modulation. This sideband power is equal to $K(.707a)^2$ or $.5Ka^2$. However, since a equals .5b, for 50 per cent modulation, the sideband power is $.5K(.5b)^2$ or $.125Kb^2$. The modulator power for 50 per cent modulation is equal to .125 times the class C input It would be possible to modulate 50 per cent an input of 100 watts with a modulator power of 12.5 watts.

CLASS B AUDIO OUTPUT CALCULATIONS

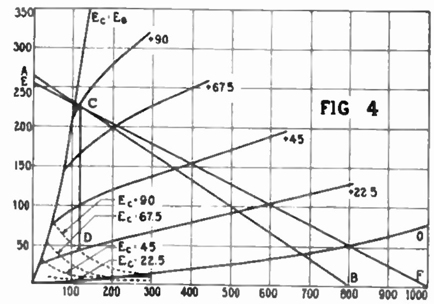
Because of the relatively low power output of class A amplifiers and the fact that the plate dissipation is maximum for no-signal conditions, the overall efficiency of such an amplifier is very low. Where considerable audio power is desired the size of the tubes and the cost of plate power supply, per watt output, increases so rapidly that such amplifiers are seldom used.

The grid swing in the class A amplifiers is usually limited to the negative region for the entire input cycle because, in general, grid swings into the positive region result in plate circuit distortion.

According to the definition of a class B amplifier, the bias is such that the operating plate current is small, so that for the no signal conditions the plate dissipation is low. The class B amplifier is the most efficient type of amplifier for audio frequencies, and may attain a plate efficiency of 65 to 70 per cent at full output power for some of the larger tubes.

Although a class B audio amplifier operates with two tubes in a push-pull circuit, only one tube supplies power to the load at any one instant.

Since only one tube operates at a time, the plate curve of only one tube is used in making class B calculations. In Figure 4 is shown the plate curve of a type T-20



tube. The normal plate to plate load for a pair of these tubes is 12,000 ohms for an output of 70 watts at a plate voltage of 800 volts. The plate load on one class B tube is one quarter the plate to plate load; and in this case, the plate load is $\frac{12000}{4}$ or 3000 ohms. The load line corresponding to this load is shown at AB. Since the tubes operate at 800 volts, the load line intersects the abscissa at 800 volts; and the point of intersection on the ordinate is $\frac{800}{3000}$ or 266 M.A.

In reality, this load line AB is the relation between the useful drop across the load and the tube drop. In order that the tube drop be low and consequently the efficiency high, it is necessary to operate in the positive grid region. For instance, at the intersection of the load line and the curve + 45, it may be seen that the tube drop is approximately 350 volts; and the useful drop across the load line is only 450 volts. The peak plate current at this intersection is 150 M.A. At this point the drop across the load may be checked, and it should be equal to (.150 x 3000) or 450 volts. Assuming that the voltage on the grids of class B stage is a sine wave, this voltage drop across the load is in reality the peak value of a sine wave voltage across the load. This voltage, then, must be multiplied by .707 in order to obtain an effective value from which power is calculated. The effective value of the voltage across the load is then equal to (.150 x 300 x .707). Since the power is equal to EI, if the voltage (.150 x 3000 x .707) is multiplied by the effective current, we will have the power output of the class B stage. The effective value of the current is (.707 x .150). The class B power output, then is (.150 x 3000 x .707)

(.150 x .707) or $(.150)^2$ x 3000 x $(.707)^2$. If .150 is designated by I and 3000 by R, the class B output is I^2R x $(.707)^2$ or $\frac{I^2R}{2}$ which is the well-known expression for class B output. I is called the dynamic plate current, and the average value for a sine wave as read on a D.C. meter is .636 I. For any dynamic peak plate current I, the power output is $\frac{I^2R}{2}$; and the power input is .636IE. The class B efficiency is thus

$$\frac{I^2R}{2 \times .636\ IE^2} = \frac{IR}{1.272\ E}$$

The plate dissipation per tube is

$$\frac{.636\ IE - \frac{I^2R}{2}}{2}$$

In the above numerical example, the class B output is 33.8 watts, the efficiency is 44 per cent, and the plate dissipation per tube is 18 watts.

If the grid swing is increased to +90 volts, the dynamic peak plate current is 230 M.A., the power output is 80 watts, the efficiency is 68 per cent, and the plate dissipation per tube is 18.5 watts. It may be seen from the curve that the drop across the tube is now only 125 volts, and the drop across the load is 675 volts. We see that the higher the voltage across the load, the higher the efficiency. If now we may assume that the entire voltage is effectively across the load, we may figure the maximum theoretical efficiency of a class B stage. Using the same notations of I, R, and E, the dynamic plate current is $\frac{E}{R}$; and the power output is $\frac{E^2}{R^2} \times \frac{R}{2}$. The power input is .636 IE, or .636 $\frac{E^2}{R}$. The efficiency is

$$\frac{\frac{E^2}{2R}}{\frac{.636E^2}{R}} = \frac{1 \times 100\%}{1.272} = 78.5\%$$

which is the maximum theoretical efficiency of a class B amplifier.

CLASS B DRIVING POWER AND DRIVE TRANSFORMER RATIO

In the previous discussion on class B output, it was stated that a certain amount of power is required to drive a class B amplifier. The grid circuit of the class B amplifier is a non-linear impedance. At some positive value of the grid signal voltage E, the grid current may be 5 ma.; if the signal voltage is increased to 2E, the grid current may be 15 or 20 ma., depending upon the actual value of E and upon the plate circuit conditions. The grid circuit may be compared to a variable impedance which decreases in value as the grid voltage increases. The driver, then, must supply power to a varying load; and if the class B grids are to be driven properly, this driving power must be supplied in such a way that the grid voltage does not drop appreciably as the power taken by the grid circuit increases. In other words, the source of power must have good regulation.

In Figure 5 is shown the equivalent circuit of a single class B grid. The driver stage may be considered a source of

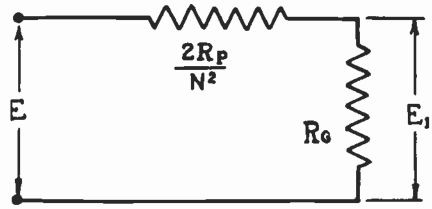


FIG. 5

voltage E of perfect regulation which supplies power through $\frac{2R_p}{N^2}$, the equivalent resistance of the driver tubes. Rg is the instantaneous impedance of the grid circuit, which varies from an infinite (in the case of class B tubes operating with fixed bias) to a very definite value. In order to maintain the voltage E_1 constant regardless of the value of Rg, the resistance $\frac{2R_p}{N^2}$ must be small compared to Rg. The actual value of $\frac{2R_p}{N^2}$ is the driver tube plate impedance referred to one-half the secondary; and in the case of a push-pull driver, it is equal to the plate resistance of both tubes divided by the turns ratio squared of the driver transformer. This ratio is figured from the total primary to one-half the secondary. It may be seen that in order to reduce the resistance of the source, the driver tubes must have low plate resistance, the driver transformer should have as high a step-down ratio as possible, and the ohmic resistance of both the primary and the secondary of the driver transformer should be small. It is the function of the driver transformer to reflect into the plate circuit of the driver tubes a load of such value that the required driving power is just developed with full excitation to the driver grids. If this is done, the driver transformer will have as high a step-down ratio as is consistent with delivering the necessary voltage to the class B grids.

In Figure 4, if the grid voltage is +90 (point C) with the 12,000 ohm plate to plate load, the grid current as read on the dotted curve (point D) is 45 ma. The average driving power, then, is

EI or .707 (90+ class B bias) x (.707x45)=
.707 (90+40) x (.707x45) or
EI = 2.92 watts.

Suppose that a pair of 2A3 tubes operating at 250 volts are to be used as drivers. Although the 2A3 tubes are capable of about 10 watts output, in this case only 2.92 watts are necessary; and the 2A3 tubes should operate with a plate to plate load of a value such that the 2.92 watts are just developed with full excitation to the driver grids. The power output of the 2A3 push-pull stage is approximately: (see class A output calculations, page 36).

$$\left\{\frac{\mu Eg}{Rp+R_L}\right\}^2 \times R_L \text{ or } \left\{\frac{4.2 \times 43.5}{800+R_L}\right\}^2 \times R_L.$$

Where R_L is one-half the plate to plate load, equating $\left\{\frac{183}{800+R_L}\right\}^2$ x R_L equal to 2.92, then the value of R_L is 9800 ohms.

The peak voltage developed across the driver primary is equal to $\frac{(183 \times 9800)}{(9800 + 800)}$ x 2 or 358 volts.

The class B grid swing is 90+40 or 130 volts. The driver transformer step down ratio is $\frac{358}{130}$ or 2.75 to 1. Actually, this ratio should be lowered about 15 per cent to allow the driving power to be developed slightly below the grid current point of the drivers. The correct ratio, then is 2.2 to 1.

OVERLOADING OF MODULATOR TUBES

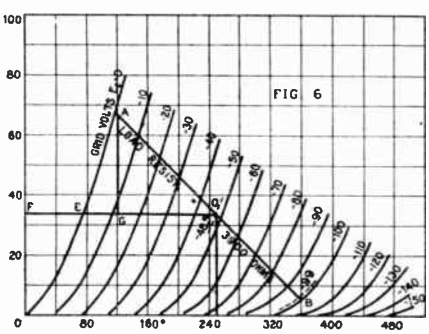
As we have already seen, the peak modulator power to modulate 100 per cent a given input is equal to the class C input. This statement holds true regardless of modulator wave form. Since ordinary speech wave form is peaked, the average power in speech is considerably less than the average power in a sine wave of equivalent amplitude. In other words, for speech, an average modulator power of between 250 and 300 watts is required to modulate 100 per cent a class C input of one kilowatt.

This does not mean, however, that 250 to 300 watts of audio based on sine wave output will modulate an input of one kilowatt with voice input. This is the source of a great deal of confusion, as it is frequently claimed that a modulator set-up with an output of say 200 watts will modulate up to 800 watts with voice frequencies. This is a fallacy, for if the operating constants of the amplifier have been correctly set for the 200 watt average condition, the peak power output is 400 watts, and the maximum amount of power capable of being modulated is 400 watts, regardless of modulator wave form. However, it is possible to obtain higher values of peak power from certain types of class B tubes without greatly exceeding the rated plate dissipation. If the tube insulation is good, the plate voltage and the plate to plate load may be increased without increasing the dynamic peak plate current.

Using the T20 tube as an example, Figure 4, the load line $\frac{12000}{4}$ is shown at AB. The normal power output is given as 70 watts; from the equation $\frac{I^2R}{2}$, this power requires a dynamic peak plate current of 215 M.A. Since this tube may be modulated at 750 volts, it seems reasonable to assume that at least 1000 volts may be used safely in a class B audio amplifier. The tube drop with the normal rating is 155 volts, so the voltage available across the load with 1000 plate volts is 1000—155 or 845 volts. Since the dynamic peak current is still 215 M.A., the new plate to plate load is now $\frac{845}{.215} \times 4$ or 15,700 ohms, which is shown at EF. The peak power output is 845 x .215 or 182 watts. In other words, a pair of T20's operating at 1000 volts with a plate to plate load of 15 700 ohms would modulate an input of 182 watts at voice frequencies.

This modulator set-up is also capable of delivering 91 watts output based on a sine wave signal, although the plate dissipation is exceeded. The average plate input to the two tubes is .215 x 1000 x .636 or 137 watts; and the plate dissipation per tube is thus $\frac{137\text{-}91}{2}$ or 23 watts. This overload is not serious even with a sine wave signal, and the plate voltage may be further increased to 1100 volts with a corresponding increase in the plate to plate load and power output.

The required class B driving power is practically unchanged; however, since the class B bias must be increased slightly to take care of the increase in plate voltage, the driving voltage must be increased by the amount of increase in the bias voltage.



CLASS A OUTPUT CALCULATIONS

The class A amplifier is an amplifier in which the grid bias voltage permits a steady plate current flow of such a value that the plate current varies directly as the grid voltage for the complete cycle of 360 electrical degrees. The resulting output voltage for the ideal class A amplifier is an exact reproduction of the grid voltage.

It is particularly important, especially in driver calculations, to calculate class A power output from the value of tube plate resistance alone. In Figure 6 are shown the plate curves of the type 45 tube Each one of the curves marked Ec=O, −10, −20, etc., is the slope of the tube plate resistance.

Let us assume that the operating conditions of a single 45 tubo are as follows: plate voltage, 250 volts; bias, −48.5 volts; and plate load, 3900 ohms. The operating point "O" may be located at the intersection of a line drawn vertically from 250 volts and the curve marked Ec = −48.5. A load line, AB, corresponding to 3900 ohms is drawn through the point "O"; this load line is merely the relation between load voltage and plate current. To determine the slope of the 3900 ohm load, divide 250 by 3900: this gives 64 M.A., which, when added to the static current of 32 M.A., gives the point on the ordinate through which the 3900 ohm load passes.

A line OE is drawn through the operating point "O'. This line OE corresponds to an infinitely high plate load and theoretically is the maximum voltage which may be developed across the plate load.

The voltage FE is the tube drop due to the static plate current and is equal approximately to the tube resistance multiplied by the static plate current. The voltage OE is now the voltage actually available for use across the load and for the additional tube drop due to the increase in plate current. If a line AG is drawn at right angles to OE, then OG is the actual voltage across the load; and GF is the total tube drop. Since OG is the voltage across the 3900 ohm load, it is possible to calculate the power output of the tube. The peak signal current is equal to $\frac{OG}{3900}$ This peak current is also equal to the voltage Eg divided by Rp, the plate resistance of the tube. Thus the peak signal current is equal to $\frac{OE}{Rp+3900}$ or $\frac{OE}{Rp+R}$ if 3900 ohms be replaced by R.

Since this current is a peak value and since power is figured on the basis of a sine wave, I must be multiplied by .707 to give an effective value. Therefore $I=\frac{.707\,OE}{Rp+R}$. Since power equals I^2R, the power output of the tube is

$$\left\{\frac{707\,OE}{Rp+R}\right\}^2 \times R = \left\{\frac{OE}{Rp+R}\right\}^2 \frac{\times R}{2}.$$

All that remains to be done is to find the value of OE in terms of the tube constants.

By definition, the amplification factor of a tube is the ratio of a plate voltage change to a grid voltage change which produces a like change in the plate current. If Ec is the grid voltage change and if Ep is the plate voltage change, then the amplification factor, μ, is equal to $\frac{Ep}{Ec}$ or $Ep = \mu Ec$. Since in the above case the grid voltage change is 48.5 volts, the maximum plate voltage change is 48.5μ, which is equal to OE. The power output of the class A stage is thus

$$\left\{\frac{48.5\mu}{Rp+R}\right\}^2 \times \frac{R}{2}.$$

For a more general equation, if 48.5 is replaced by Ec (which may be any grid voltage swing up to 48.5 volts), the power output is

$$\left\{\frac{\mu Ec}{Rp+R}\right\}^2 \times \frac{R}{2}.$$

This is a simplified formula for determining the power output of a class A stage. If two tubes are used in push-pull, the above output is doubled and R is one-half the total plate-to-plate load on the push-pull tubes.

PLATE CIRCUIT REGULATION

Correct driver transformer design is not the only consideration in driver regulation. All of the circuit between the driver grids and the class B grids is involved.

The voltage regulation of any generating device is its ability to furnish different amounts of current (hence power) to the load with little change in voltage. A device has poor regulation if the voltage falls rapidly with increased power drain. There is, then, a loss of voltage in the output, or load circuit, when regulation is poor, and since this voltage does not appear across the load, it must be lost in the generating source where it is, of course, not effective.

If the voltage regulation is poor at the class B grids, there must be voltage losses either in the driver transformer or the driver tubes. If the design of the driver transformer is correct, the regulation is negligible compared with that tolerable at the class B grids. The driver tubes, then, must be the source of poor regulation, and since a voltage drop can occur only across an impedance of some sort, resistive or otherwise (the only impedance in the driver tube is the plate resistance) this must be the source of trouble.

A tube may be considered a source of voltage E, having perfect regulation, which supplies power to a load R through resistance Rp. (Figure 7).

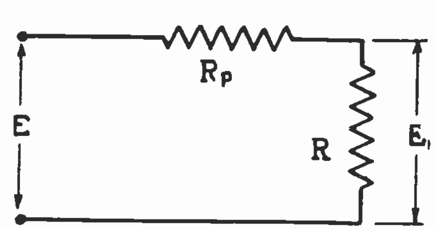


FIG. 7

This resistance Rp is called the plate resistance of the tube. It is possible to determine the value of Rp by means of two measurements. If R be removed so that there is no load across E_1, then E_1 is equal to E. If R is now replaced, the voltage E_1 will be less than E due to the voltage drop across Rp. The total current is $\frac{E}{Rp + R}$; and the voltage drop across Rp is $\frac{E \times Rp}{Rp + R}$ which is equal to $E - E_1$. Therefore,

$$E - E_1 = \frac{E \cdot Rp}{Rp + R}$$

where every value is known except Rp, and this can be determined from the formula.

In the same way, it is possible to determine the plate resistance directly from the plate characteristics of the tube. In Figure 8 are shown the plate characteristics of the 2A3 tube. The operating conditions are as follows: 250 volts on the plate and 43.5 volts of bias. Assuming that the peak grid swing is 43.5 volts, then operation is between the operating point O and the Curve Ec = O. For an infinite load (load line parallel to the abscissa), the peak voltage developed across the load is OA, or 250-70 volts or 180 volts. If a 2500 ohm load is now placed in the plate circuit, the voltage across the load is then only OB, or 250-110 volts or 140 volts. The difference between 180 and 140 volts or 40 volts is caused by the plate resistance of the tube. Therefore, if in the equation

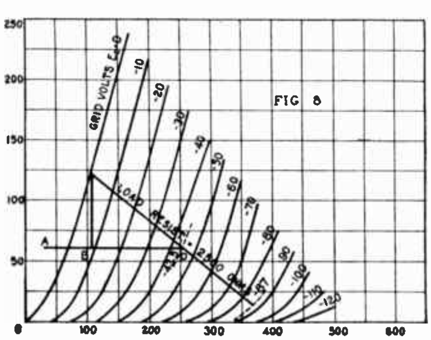
$$E - E_1 = \frac{E \cdot Rp}{Rp + R}$$

we substitute our known values, the value of the plate resistance may be found.

$$180 - 140 = \frac{180 \cdot Rp}{Rp + 2500}$$

and Rp = 715 ohms.

Referring to Figure 7—the value of E_1 may be determined for different values of Rp by removing R. It will be seen that with lower values of Rp the difference between E_1 and E decreases.



An inspection of the characteristics of tube types available for driver purposes will show that only power triodes, such as 2A3's, 45's etc., have relatively low plate resistance values. Pentode and beam power tubes, because of their high plate resistance values, are not suitable as drivers. The type 6L6 tubes can be used with highly satisfactory results if inverse feed-back is employed to reduce the effective plate resistance to a low value.

TURNS RATIO OF LINE TO CLASS B GRID TRANSFORMERS

There seems to be some confusion on the subject of transformers which couple a line to the grids of class B tubes. Either the principles of operation are not completely understood, or they are entirely overlooked. This misunderstanding usually arises when a given amplifier with a 500 ohm output winding is used to drive a class B audio stage. It is common practice, especially if the amplifier is located some distance from the class B stage, to connect a line from the 500 ohm winding of the amplifier directly to a line to grid transformer rather than to replace the output transformer on the amplifier with a driver transformer. This practice is perfectly correct when the line to grid transformer is designed to operate with the specific output transformer on the amplifier.

Actually, the operating conditions of a tube when used as a power amplifier are entirely different from the conditions under which it operates as a driver. As a power amplifier, the plate load is of such a value that the power output is a maximum with a reasonable amount of distortion, and the plate load is constant throughout the cycle. However, as a driver, power output is not the prime consideration. The plate load, which varies throughout the cycle with the class B grid swing, should be as high as is consistent with developing the required driving power. Good regulation is thus the most important feature of the driver, and this is obtained by making the plate load high in comparison with the tube plate resistance.

In ordinary power amplifier design, the plate to plate load is fairly low. For push-pull 2A3's it may be 3000 or 5000 ohms; however, when used as drivers, the 2A3's should have a plate-to-plate load two or three times these values. Since the line to grid transformer is connected to the output of the amplifier, its function is to reflect a load of such a value that the required driving power is just developed with full excitation to the driver grids.

Suppose that an amplifier using 2A3's with a plate-to-plate load of 3000 ohms were coupled to a line to grid transformer through a 500 ohm line and suppose that the 2A3's were to be coupled directly to the class B grids through a driver transformer, the correct turns ratio of the driver transformer would be 3.2 to 1. Then, when the amplifier is connected to the class B grids through the line, the turns ratio from the total primary of the output transformer on the amplifier to one-half the secondary on the line to grid transformer should also be 3.2 to 1.

Assuming that the plate-to-plate load on the 2A3's is 3000 ohms, the turns ratio of the output transformer from the primary to the 500 ohm secondary is 2.45 to 1. The correct ratio of the line to grid transformer to give an effective overall ratio of 3.2 to 1 is 1 to .765. If the plate-to-plate load on the 2A3's had been 5000 ohms instead of 3000 ohms, the turns ratio of the line to grid transformer would have been 1 to .98 in order to preserve the overall ratio of 3.2 to 1. It may be seen from this that the correct turns ratio of the line to class B grid transformer is entirely dependent upon the turns ratio of the output transformer with which it is used, and that the so-called 500 ohm line is merely a connecting link between the two transformers.

Frequently some engineers make the mistake of designing a line to class B grid transformer on the sole basis of the so-called 500 ohm line. To give a concrete example, let us assume that it is necessary to design a line to grid transformer to couple from the above amplifier when the only known condition is the fact that the output of the amplifier is 500 ohms. Suppose that the class B stage consists of a pair of 830-Bs. The average driving power required by the 830-B's is 6 watts, and the peak grid swing is 135 volts. The minimum grid impedance is thus 1500 ohms. The turns ratio of the line to grid transformer on the basis that the impedance of the line is 500 ohms would be 1 to 1.73. This would give an effective overall ratio of 1.41 to 1 instead of the correct value of 3 to 1. This change in effective ratio would result in very poor driver regulation. Actually, the impedance of the "500 ohm line" with the correct ratio is 2250 ohms at the peak of the wave, and the average value over the entire cycle is much higher. The plate-to-plate load on the drivers in the case of the 3 to 1 ratio is 13,500 ohms, whereas with the incorrect ratio the plate-to-plate load is the original value of 3000 ohms.

Less driver excitation is required for the 3000 ohm plate-to-plate load, and for this reason it may seem that the lower effective ratio is more satisfactory. However, the driver distortion is much higher with the lower plate-to-plate load.

In actual practice, the turns ratio of the line to grid transformer is increased from the theoretical value to allow for the losses in the transformer. These losses are not great, and if the theoretical value is increased 10 to 15 per cent, sufficient class B grid swing will be developed with excitation slightly below the grid current point of the drivers.

Unless the output transformer on the amplifier has adequate primary inductance, the overall frequency response of the amplifier will suffer due to the changes in the value of the plate-to-plate load on the output transformer. However, this change in frequency response is usually not great enough to be considered.

Thus, it may be readily seen that to design a line to class B grid transformer properly, the method using the so-called 500 ohm line should be disregarded in favor of the method which takes into account the actual turns ratio of the output transformer.

BIAS SUPPLY CIRCUITS

A radio frequency amplifier may be biased by means of a resistor in the grid circuit, by cathode bias, by some external bias supply, or by a combination of any of the above methods. The first method, using the resistor in the grid circuit, is one very commonly used. The bias voltage is developed (see Figure 9) by virtue of the rectified grid current flowing through the grid resistor R.

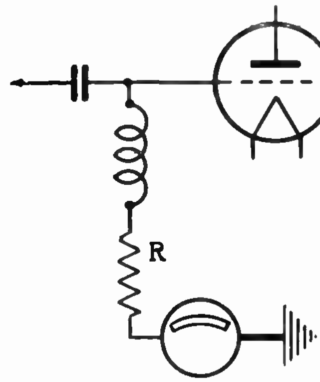


FIG. 9

If the value of R is 10,000 ohms and if the rectified grid current as read by the meter is 20 M.A., the bias is 200 volts. If the excitation is removed, the bias automatically drops to zero; and the tube may be damaged due to excessive plate current. This method should be used only with zero bias tubes or with tubes with a high amplification factor because, with these types, the plate current is low even without bias. In calculating driving power, the power dissipated in the bias resistor must be taken into account along with the actual grid driving power required by the tube.

The second method, that of using cathode bias, is shown in Figure 10. The bias is developed across R by virtue of the plate current.

The bias is equal to the value of R multiplied by the meter readings. It may

(Continued on next page)

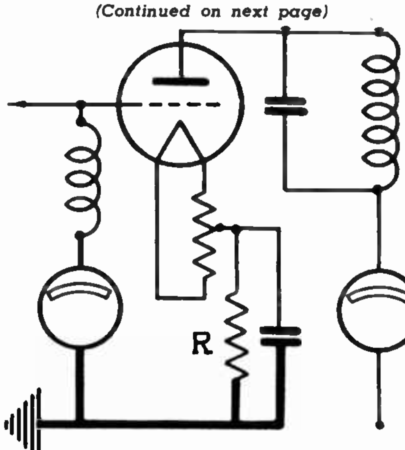


FIG. 10

be seen that the effective voltage on the plate is lessened by the amount of the bias voltage. The bias resistor should be adequately by-passed. This method is often used in conjunction with the first method. Enough cathode bias is provided to limit the plate current to a safe value when excitation is removed.

The third and simplest method of obtaining bias is by means of an external bias supply. In Figure 11 the bias is adjustable from zero to the maximum voltage of the supply. The bias should always be adjusted with the RF amplifier turned on, so that the rated grid current flows through the bias supply. The bias voltage is developed across R by both the current delivered by the rectifier and by the rectified grid current from the RF stage.

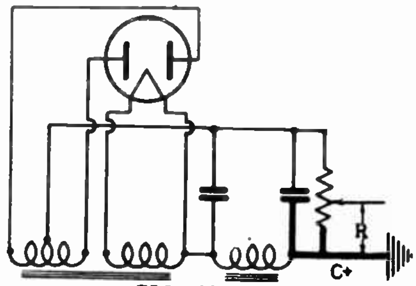


FIG. 11

Bias to a number of RF stages may be supplied by a single bias supply. In Figure 12 three stages are supplied. These

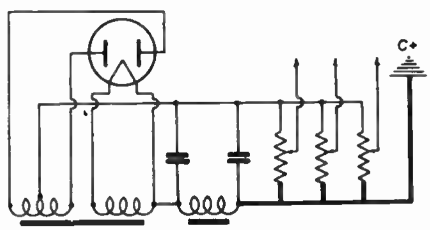


FIG. 12

stages may be adjusted separately; and the adjustment of one will not affect the others, provided that the bleeder current from the bias supply is large compared to the grid current.

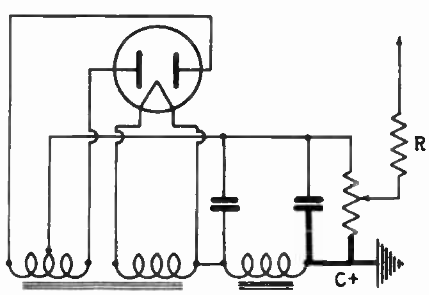


FIG. 13

It may be necessary to provide more bias than the bias supply will deliver. In that case the circuit of Figure 13 is used. The bias over and above the voltage of the supply is developed across R by grid current alone. The bias supply should be turned on along with the filaments in order to eliminate the possibility of turning on the plate supply without bias. In Figure 14 is shown a bias circuit using transformers designed for this type of service. The secondaries are tapped to cover ranges of 90 to 150 volts, 150 to 275 volts and 275 to 500 volts.

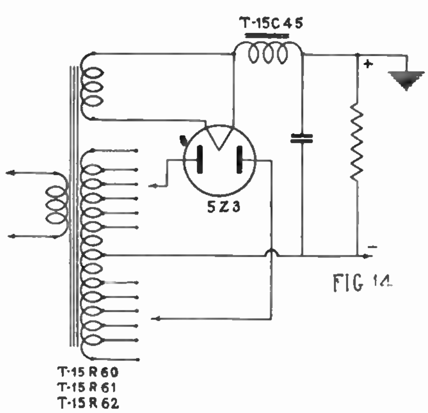


FIG 14

MATCHING CLASS C LOADS

The matching of class C loads has for its basis regular transformer theory. The transformer consists essentially of two or more windings on an iron core. The windings are coupled to one another so that, if an AC voltage is applied across one winding, a voltage in proportion to the turns ratio is induced in the other winding. A transformer may be thought of, therefore, as an impedance changing device as well as a voltage changer.

In Figure 15 is shown a transformer with a step up ratio of 1 to N. Let us place E volts across the primary, then the

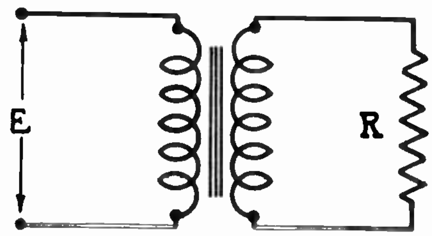


FIG. 15

secondary voltage due to the step up ratio, will be NE volts. Now let us place a resistance R across the secondary and determine what equivalent primary resistance is reflected from R ohms across the secondary. Since the secondary voltage is NE, the secondary current is $\frac{NE}{R}$; and the power in the resistor is $\frac{NE}{R} \times NE$ or $\frac{N^2E^2}{R}$. The power in the secondary circuit must come from the primary; and neglecting transformer losses, the primary power is also $\frac{N^2E^2}{R}$.

However, this primary power is delivered at a voltage E. The primary current is thus equal to

$$\frac{\frac{N^2E^2}{R}}{E} = \frac{N^2E}{R}$$

The primary impedance Z is thus equal to $\frac{E}{I}$, or

$$\frac{E}{\frac{N^2E}{R}} = \frac{R}{N^2}$$

The reflected primary impedance is equal to the turns ratio of the transformer squared (from secondary to primary) multiplied by the impedance across the secondary. In the case of a class B output transformer, for instance, the transformer itself is an impedance changing device which will reflect a class B plate to plate load which is entirely dependent upon the class C load. As an example, suppose that we have a class B transformer which normally operates from a 10,000 ohm plate to plate load to an 8,000 ohm class C load. The impedance ratio is thus 1.25 to 1; it is possible to operate this transformer with almost any plate to plate load, depending upon the class C load on the secondary.

Since the class C voltage is usually fixed, the usual procedure is to determine the correct transformer ratio for a given modulator power and class C voltage. Let us assume that our available class C voltage is 2000 volts and that we have enough audio power to modulate 500 watts input. The class C load in this case is $\frac{2000^2}{500}$ or 8,000 ohms. If our modulators have a plate to plate load of 12,000 ohms, the output transformer has an impedance ratio of 12,000 to 8,000 or a turns ratio of $\sqrt{\frac{12,000}{8,000}}$ or 1.22 to 1.

Let us assume that the above transformer is on hand and that we wish to modulate 200 watts input with a pair of tubes which require a plate to plate load of 15,000 ohms. We must determine the class C operating conditions in order that the above transformer may be used. Since the impedance ratio of the transformer is 1.5 to 1, the correct secondary load, in order to reflect a 15,000 ohm plate to plate load, is 10,000 ohms. From the relation $\frac{E^2}{R} = 200$ where R is 10,000 ohms, we find that the value of class C voltage E is equal to 1000 volts. Knowing the class C voltage, the correct class C current is thus 200 divided by 1000 or 200 ma.

Following the same line of reasoning, it is possible to match almost any plate to plate load with a given transformer by determining the correct class C operating conditions.

THE USE OF 6L6 TUBES AS DRIVERS

With the introduction of beam power tubes and their high power output the question of their adaptability as drivers naturally arises. The beam power tube has a high plate resistance characteristic which is undesirable in a good driver tube, and for this reason, the 6L6 as a tetrode is not a good driver. However, with a suitable amount of inverse feedback, it is possible to decrease the effective plate resistance to a suitable value.

Basically, inverse feedback consists in feeding back into the grid circuit a portion of the voltage developed in the plate circuit. This feedback is out of phase with the voltage in the grid circuit, so that the effective gain of the 6L6's is lowered and the plate resistance decreased. With inverse feedback a beam power tube may be made to assume the characteristics of a low mu triode, the plate resistance of which is a function of the amount of inverse feedback. In Figure 16 the amount of feedback is $\frac{20,000}{100,000 + 20,000}$ or 16.6 per cent.

If an amount of inverse feedback N is used, the plate resistance may be considered shunted with a resistance equal to $\frac{1}{N \times \text{Mutual Conductance}}$. With 16.6 per cent feedback, the effective plate resistance consists of 22,500 and 1000 ohms in

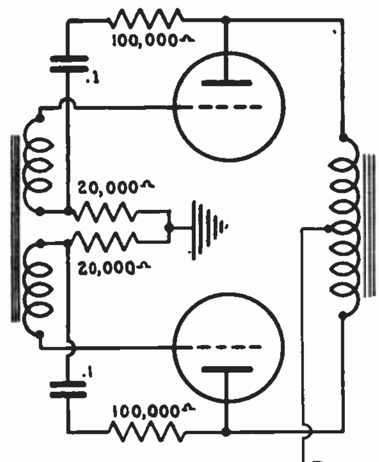


FIG. 16

parallel for a value of 960 ohms. The pair of 6L6's in Figure 16 then, have the same characteristics as a pair of triodes with a plate resistance of 960 ohms.

A much simpler method of obtaining the correct amount of feedback voltage is shown in Figure 17. In this circuit the driver transformer has a special tertiary winding T_3 to supply the correct feedback voltage.

The power output of a pair of 6L6's with inverse feedback is calculated by the method outlined under "Class A Output Calculations." The plate resistance is already known and the value of μ with feedback is equal to $\frac{\mu_0}{N\mu+1}$ where μ_0 is the original amplification factor of the tube without feedback or 135 in the case of the

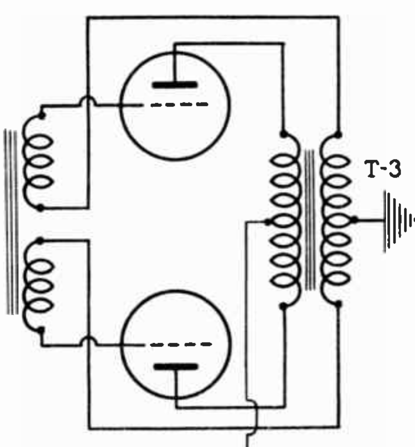


FIG. 17

6L6. The only remaining unknown factor in the equation for class A power output is Eg, which is slightly different from the permissible grid swing with conventional triodes. In the case of the 6L6 with inverse feed-back the plate characteristics are somewhat crowded at low values of plate voltage and, if the grid swing is too great, serious distortion will result although the grid swing may still be in the negative region. Operation is further complicated by the fact that for driver purposes the 6L6's are operated with a plate to plate load several times greater than the optimum value for maximum power output. The plate characteristics with feedback are fairly uniform down to the point at which the tube drop is equal to the product of the plate resistance and the static plate current. The minimum plate voltage is thus I_sR_p where I_s is the static plate current and R_p the plate resistance with feedback. The voltage difference between I_sR_p and the plate supply voltage is the peak signal voltage which is equal to μEg. All values are now known and the peak voltage at any power output may be determined.

With biased class B tubes the 6L6 driver stage is operated into an open load during part of the cycle and oscillation may occur due to the phase shift between the signal voltage applied to the driver grids and the voltage developed in the plate circuit. This shift is further increased by the capacity and inductance associated with the input transformer. Oscillation will exist only for that part of the signal during which the driver stage is unloaded and it is therefore noticeable only on an oscilloscope. If the oscillation does appear it may be eliminated by placing a 50,000 ohm, 1 watt resistor across each half of the input transformer and also by placing a 25,000 ohm, 5 watt resistor across the primary of the driver transformer. It is recommended that these resistors be installed whether oscillations are suspected or not.

The improvement resulting from inverse feedback may be seen from the curves of Figure 18, in which voltage output is plotted against different values of plate to plate load. This plate to plate load corresponds to the varying grid impedance. Curve B was obtained with and curve A without feedback. It may be seen that the regulation has been considerably improved by the addition of feedback and that this is the only method of obtaining satisfactory driving performance from 6L6's.

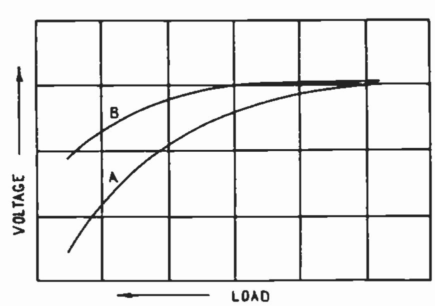


FIG. 18

DETERMINATION OF CORRECT DRIVER TRANSFORMER RATIO

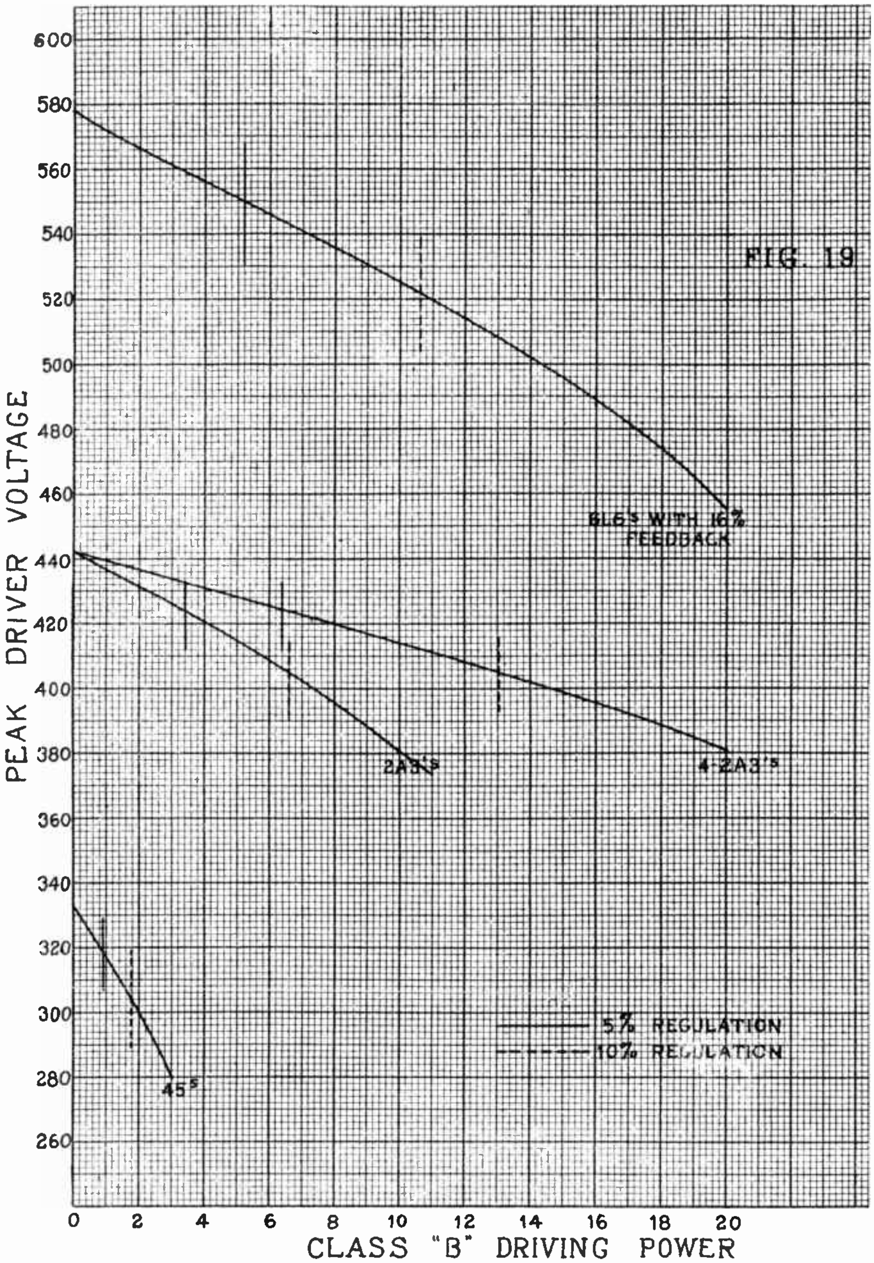
The determination of the correct driver transformer ratio is of extreme importance if the most is to be realized from a class B audio stage. In Figure 19 are shown curves from which the correct ratio may be quickly determined. The only data about the class B tube which must be known are the average driving power and the peak A.F. grid voltage.

As an example, from the data furnished by the tube manufacturer, the average class B driving power for type 805 tubes is 6 watts, and the peak A.F. grid voltage is 117.5 volts.

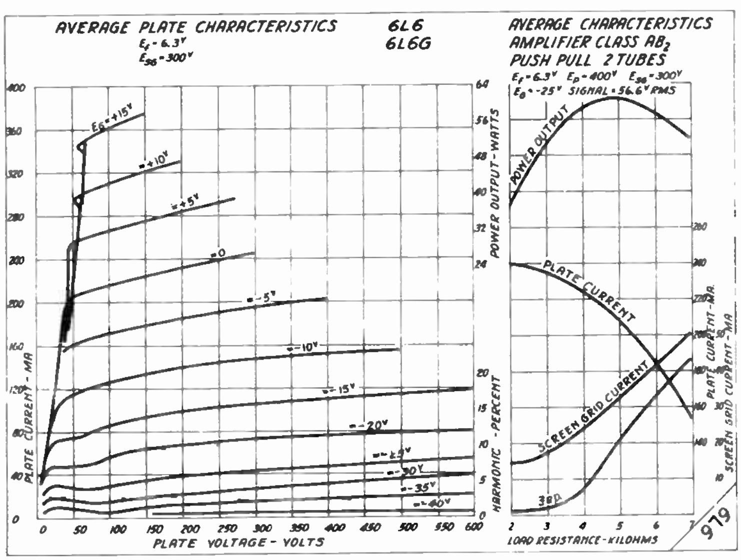
Curves on the 2A3 show that at 6 watts output a peak voltage of 408 volts is developed across the primary of the driver transformer. The ratio of the driver transformer is then $\frac{408}{117.5}$ or 3.48 to 1, total primary to one-half the secondary.

Although a tube may be capable of high power output when used as a power amplifier, it should not be used as a driver if the required class B driving power is comparable to its maximum power output. In other words, the output of a pair of 2A3's is 15 watts; however, these tubes operating as drivers should not be called upon to deliver more than 8 watts of driving power. A pair of 2A3's will deliver 3.4 watts with a regulation of 5 per cent, which is the limit for broadcast work, or 6.6 watts with 10 per cent regulation. Regulation much higher than this will result in excessive distortion.

It is frequently necessary to know the results of varying the driver transformer turns ratio from the optimum value. If the step-down ratio is too great, the required class B grid voltage will not be developed; and as a result the class B output is necessarily limited. If, on the other hand, the ratio is too low, the required class B grid voltage will be developed but the regulation will be poor and the signal distorted. The turns ratio should be so proportioned that the required class B driving voltage is developed at a point slightly below the grid current point of the drivers. Under this condition the driving power is developed across as high a plate to plate load as possible, providing the maximum step down ratio. If the ratio is too low, there is danger of over-driving the class B stage. The operating conditions of the class B stage are such that the minimum plate voltage at peak output is comparable in value to the positive grid swing. Beyond this point the grid impedance changes abruptly and the dynamic characteristic of the tube curves sharply. There is thus the possibility of over-driving the class B stage and introducing excessive distortion in the class B plate circuit, to say nothing of the driver distortion. With the low step-down ratio the signal to the driver grids is somewhat less than it is with the correct ratio; for this reason it may seem that the lower ratio is more effective. However, it must be borne in mind that the purpose of the driver transformer is not to provide gain but a source of good regulation.



The tubes are operated self-biased as follows: 2A3's, 300 volts; 6L6's, 400 volts plate, 300 volts screen; 45's, 275 volts.



REVIEW QUESTIONS

1. Name two types of oscillator circuits.

2. At a considerable distance from the transmitter does electro-magnetic or electro-static radiation play a more impotant part?

3. The second harmonic of a 40 meter oscillator lies in what band?

4. Why are meters used in tansmitters?

5. Usually a code transmitter can be changed to phone service by adding what equipment?

6. What is another name for an oscillator?

7. A R.F. amplifier that amplifies a harmonic is called by a special name. What is this name?

8. Is the final amplifier always coupled to the antenna?

9. Why are plug-in type coils used in some transmitters?

10. What is the process of neutralization? Is this required when pentode tubes are used?

11. Why are Class B tubes used in large modulators?

12. Why must a Class B driver transformer be very carefully designed? This requirement is not important in driving Class A amplifiers.

13. Does inverse feed-back reduce harmonic content? What other advantages does this circuit have?

14. How can a meter be used to indicate that an oscillator is functioning? How does one use a pilot bulb for the same purpose?

15. Why are crystals used? What main fault does a self-excited oscillator have?

16. What is a split-stator condenser? (Examine the circuit where this condenser is used).

17. What power output modulator is needed to 100% modulate a 150 watt (input) transmitter?

18. Name three methods of obtaining bias for R.F. amplifiers.

19. Briefly explain the theory of matching a modulator to a Class C amplifier.

LESSON 19

FREQUENCY CONTROL with QUARTZ CRYSTALS

THEORETICAL CONSIDERATIONS

Certain crystalline substances such as quartz, Rochelle Salts and tourmaline, exhibit a most interesting property. In brief, if any one of these substances is distorted mechanically an electric charge will be developed; and, conversely, mechanical distortion will result if the substance is placed in an electric field. This property, the Piezo-Electric Effect, makes possible precision frequency-control of radio transmitting equipment.

There are a surprisingly large number of crystalline substances which exhibit piezo-electric properties but, out of the entire group, quartz is the only material which is truly satisfactory for frequency control purposes. Rochelle Salts exhibits the most intense piezo-electric properties but is not a suitable material as it is too unstable both physically and electrically. Tourmaline, a gem material, has been employed but due to its relatively high cost and the superior qualities of quartz, it is no longer in general use.

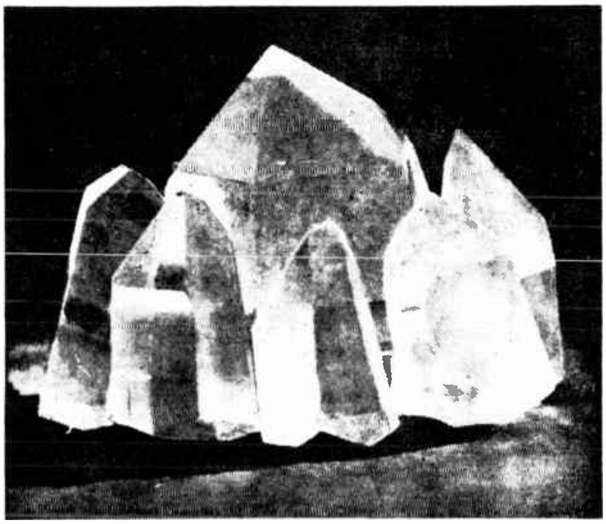


Figure 1—Group of Natural Quartz Crystals

Quartz is silica (silicon dioxide). It is found throughout the world in many different forms and appears most commonly in the sands and sandstones of the earth. Quartz is an exceptionally hard material and is very stable both mechanically and chemically; it is not affected by common acids and cannot be fused by ordinary means. For piezo-electric purposes comparatively large natural crystals of high purity are required and, at the present time, Brazil is the only reliable source of supply.

To take advantage of the piezo-electric effect of quartz, it is necessary to cut small "plates" from the raw natural crystals. These plates must be cut in certain definite directions with respect to the axes of the raw crystals, they must be free from mechanical and electrical flaws, and each must be carefully ground such that its major faces will be essentially plane and parallel. If one of these plates is placed in an oscillating electric field, it will vibrate mechanically and produce a counter-voltage at the frequency of the applied field. The magnitude of this action will be quite small, but, should the frequency of the applied field be adjusted to correspond with a natural period of vibration of the plate, the vibrations will become vigorous and have an appreciable amplitude. In fact, if the strength of the applied field is sufficiently great, the vibrations will become so strong that the plate will be physically ruptured.

A quartz plate, when used for frequency control purposes, is termed a "crystal". The electrical action of an oscillating quartz crystal may be most readily analyzed by reference to its equivalent electrical network as shown in figure 2. The inductance, L, represents the mass of the crystal, the capacity, C, represents the resilience, and the resistance, R, represents the frictional losses. C_1, is the capacity due to the crystal electrodes with the crystal as the dielectric while C_2 represents the series capacity between the crystal and its electrodes.

Neglecting C_2, it should be noticed that the equivalent electrical network made up of L, C, C_1, and R has the properties of either a series or a parallel resonant circuit. At some definite frequency, for a given crystal, the reactances of L and C will be numerically equal. This is the requirement for a series resonant circuit and the frequency at which this resonance occurs is the series resonant or natural frequency of the crystal. At a slightly higher frequency, the effective reactance of L and C combined will be inductive and numerically equal to the reactance of C_1. At this frequency anti-resonance occurs and the crystal acts as a parallel or anti-resonant electrical circuit. C_2 is only effective when the crystal electrodes are not in intimate contact with the crystal faces. As the value of C_2 is decreased, the resonant frequency will increase.

The inductance, L, of quartz crystals is very large. It varies, from 0.1 henry to 100 henries with individual crystals, and depends on the manner in which the crystal is cut from the raw quartz, its physical proportions, and the frequency. The reactance of L is many times greater than R which means that quartz crystals have a very high Q ($Q=2\pi FL \div R$).

In an oscillator circuit operating at radio frequencies, the frequency stability is largely determined by the Q of the frequency determining 'tank'. The Q of quartz crystals is many times greater than can be obtained with conventional inductance-capacity tanks, and it follows, therefore, that crystal frequency-control offers the highest degree of frequency stability. In explanation, it may be pointed out that the oscillating frequency of a conventional oscillator circuit is that frequency at which the total circuit reactance reduces to zero. Any circuit changes caused by varying voltages, aging of the tube or circuit

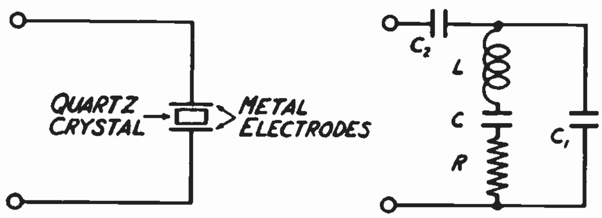


Figure 2—Equivalent Electrical Circuit of the Quartz Oscillating Crystal

components, or other causes, necessitates a change in frequency to again bring the net circuit reactance to zero. As quartz crystals have a very steep resonance curve, a large change in reactance can be brought about with only a small shift in circuit frequency

CRYSTALS AT ANTI-RESONANCE

In the standard crystal oscillator circuits, which are employed in the majority of radio transmitter installations, the crystal operates in the same manner as a parallel, or anti-resonant, electrical circuit. For this reason, quartz crystals employed for frequency control of vacuum tube oscillators are usually calibrated at their anti-resonant frequencies.

The true value of the capacity, C_1, changes when a crystal is placed in a vacuum tube oscillator circuit. In the theoretical analysis, C_1 represents the capacity between the crystal electrodes with the crystal acting as the dielectric. When, however, the crystal is connected in an actual circuit, the value of C_1 will vary with different crystal holders and will, in addition, be increased by the input capacity of the oscillator tube and the capacity added by connecting wires between the crystal and the tube. Also, the impedance in the plate circuit of the tube will affect the electrical characteristics of the grid circuit to an extent dependent on individual operating conditions. It is evident that the total capacity added to C_1 by the oscillator will vary between different circuits and layouts, thereby causing the crystal frequency to assume different values in each particular oscillator set-up. Because of the possible variations in frequency, Bliley Crystals are guaranteed to operate within a certain variation from the calibrated frequency (generally .025%-.03%) when operated in the purchaser's equipment despite the fact that each crystal is accurately calibrated in the manufacturing laboratory. The crystals are, for the same reason, supplied complete with holders only.

When a quartz crystal is required for a specific service or application where frequency accuracy is most important, the possible change in frequency between the manufacturer's calibrating oscillator and the final equipment must be considered. This is an especially important consideration in commercial equipment where the allowable frequency tolerance is very small. It is equally important to radio amateurs who wish to operate close to the edge of any amateur band.

By taking full advantage of the fact that the parallel capacity will influence the frequency of a crystal, it is possible to include a variable frequency feature. This is invaluable to radio broadcast services in the standard broadcast band where the carrier must be held within 50 cycles of the assigned value. It is an equally valuable feature in many other services where the frequency must be held within close limits and in amateur service where a simple method of shifting the station frequency often permits contacts under ordinarily impossible conditions of interference.

There are two methods of effecting a change in the oscillating frequency of a crystal. The obvious arrangement is to connect a variable air-condenser in parallel with the crystal to effect a change in C_1, (figure 1). As the capacity of the condenser is increased, the frequency of the crystal will be lowered until the capacity becomes sufficiently large to effectively short out the crystal. The added capacity of the condenser will 'load up' the crystal thereby decreasing its oscillating ability. For small ranges of frequency adjustment the effect of the condenser will not be harmful and the decrease in the oscillating properties of the crystal is readily offset by the variable frequency feature. This method of shifting the frequency is generally applied with crystals higher than 3000kc. but can be used at lower frequencies if desirable. At the very high frequencies it is not satisfactory because the amount of capacity sufficient to stop oscillation is quite small. This, of course, greatly limits the amount by which the frequency can be varied.

A variable air-gap holder offers the most convenient method of shifting frequency with crystals in the range from 150kc. to 5000kc. In a typical holder of this type, one of the crystal electrodes is mounted on a micrometer-screw such that the electrode may be raised or lowered over the crystal. This brings about a simultaneous change in the values of C_1 and C_2 (figure 1). As the air-gap between the movable electrode and the crystal is increased, the crystal frequency will be raised with an accompanying decrease in oscillating properties. For small ranges of frequency adjustment, the detrimental effect of the air-gap is not serious and the only essential consideration is that the crystal be used in a circuit where the crystal voltage will not reach high values. Unless this precaution is taken, an arc will be developed across the air-gap causing erratic oscillation and, sometimes, damaging the crystal because of the concentrated heat of the arc.

CRYSTALS AT RESONANCE

The impedance of a quartz crystal at frequencies near its natural frequency, is lowest at the resonant frequency and highest at the anti-resonant frequency. At frequencies remote from these values the crystal acts merely as a fixed condenser. This is illustrated by the representative reactance curve

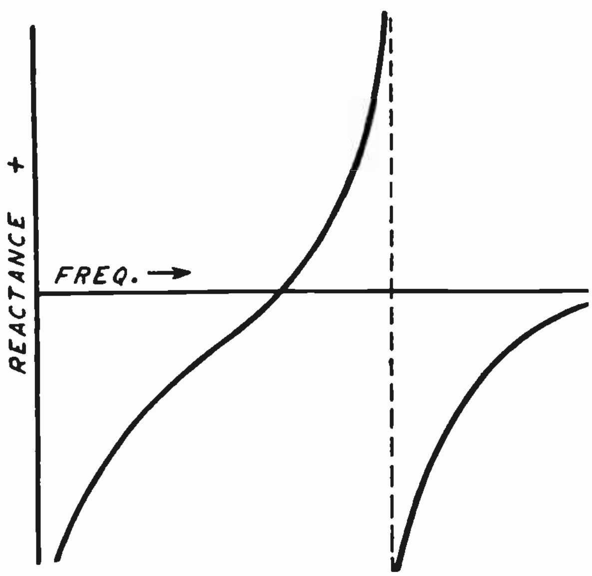


Figure 3—Reactance Curve of a Quartz Crystal

shown in figure 3. The property of a crystal to act as a resonant circuit, with a very rapid increase in impedance on either side of resonance, is most useful in radio frequency filters and for frequency control of certain types of oscillator arrangements

Relaxation oscillators, which rely on the time constant of resistance-capacity networks, have characteristics which are desirable in some applications. Such oscillators are mechanically simple and have a high harmonic output but are not very stable. They can, however, be readily stabilized by substituting a quartz crystal for one of the grid coupling condensers. The crystal, acting as a resonant circuit, permits oscillation only at its resonant frequency. Such circuits are limited to frequencies below about 150 kc. because of practical limitations in obtaining resistance-capacity combinations with a very short time constant.

Another arrangement, more widely used, employs an inductance-capacity tank with the crystal connected directly into the tank circuit. This is the modified Colpitt's Oscillator shown in figure 14 and discussed in the section LOW FREQUENCY OSCILLATORS. The crystal acts as a filter and controls the frequency of oscillation by virtue of the fact that its impedance is lowest at the resonant frequency and rises rapidly for all other frequencies. Circuits of this type are outstanding for high frequency stability and, for that reason, are used in precision frequency standards.

The frequency of a crystal oscillating at resonance cannot be varied by means of a parallel condenser. It can, however, be varied by effecting a change in C_2 (figure 1). This can be accomplished with a variable air-gap holder or by connecting either a variable air-condenser or an inductance in series with the crystal. Increasing the value of a series inductance will lower the frequency while an increase in frequency will result if the capacity of a series condenser is decreased. A series condenser, with its greater stability and ease of adjustment, gives more satisfactory control than a variable inductance. Whether a condenser or an inductance is used, it must be stable in itself or the frequency stability brought about by the use of a quartz crystal will be considerably lessened The frequency adjustment is limited by the fact that the impedance of the series element reduces the voltage across the crystal (excitation). Naturally, if the excitation is reduced excessively, the crystal will refuse to oscillate.

The resonant properties of quartz crystals are advantageously employed in modern communication receivers to give a very high degree of selectivity. Since crystals ground for filter purposes have an extremely high Q (9,000 to 16,000) the frequency discrimination, or selectivity, will be many times better than could be obtained with ordinary tuned circuits. The selection is so great that it is not difficult to limit the pass-band to 50 cycles.

Figure 4 shows the conventional arrangement of a quartz-crystal-filter stage in a modern superheterodyne communications receiver. It will be noticed that the tapped transformer, the crystal, and the variable condenser, C_1, form a bridge circuit. At frequencies remote from the resonant frequency of the crystal, the bridge circuit is balanced and no voltage appears on the grid of the following amplifier tube. When, however, the transformer voltage is at the resonant frequency, the crystal impedance drops to a low value thereby upsetting the balance and permitting a signal voltage to appear on the grid of the amplifier tube.

The fundamental purpose of the variable condenser, C_1, is to provide an adjustable element such that the bridge circuit can be balanced for

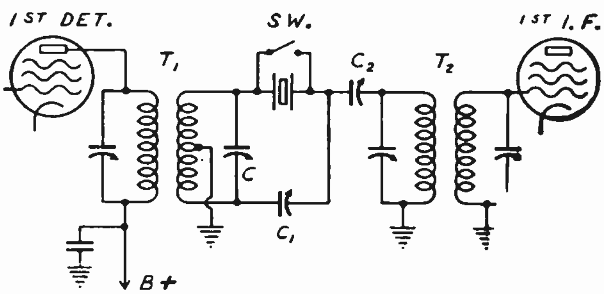


Figure 4—Quartz Crystal Filter Circuit

C_1—Phasing control; 20 mmf.— 30 mmf.
C_2—Coupling control for impedance matching; 50 mmf.

each particular receiver. When the bridge is balanced and the first intermediate-frequency transformer adjusted to give a slightly reactive characteristic at the crystal frequency, greatest selectivity is obtained. The secondary of the intermediate-frequency transformer must not be adjusted to exact resonance with the crystal as it then acts as a pure resistance and reduces the effective Q of the crystal. In that condition, the circuit selectivity will be lowest. Some commercial receivers take advantage of this characteristic by providing a panel control for the transformer condenser. This gives a variable degree of selectivity and is advantageous for radiophone reception where excessive selectivity can be detrimental.

The condenser, C_1, called the phasing control, also influences the selectivity. Most receivers of today use a fixed tuned intermediate frequency transformer and depend on the phasing control for varying the selectivity.

An important feature of the phasing control is that it can be used to change the anti-resonant frequency of the crystal over a narrow range above and below the resonant frequency. Since maximum rejection will occur at anti-resonance, a strong interfering signal may often be eliminated, or greatly reduced, by varying the phasing control until the anti-resonant frequency of the crystal is at the frequency of the interfering signal.

EFFECTS OF TEMPERATURE

The frequency of a crystal is influenced to an appreciable extent by the temperature at which it is operated. The magnitude of this effect is determined by the type of cut, the shape and size of the crystal, the precision of grinding, and the characteristics of the quartz itself. It is expressed as the number of cycles change per million cycles of crystal frequency per degree Centigrade change in temperature and is termed the temperature coefficient of frequency or the frequency-temperature coefficient.

The frequency-temperature coefficient of a quartz crystal varies, with individual cuts, from minus 25 to plus 100 cycles per megacycle per degree Centigrade. With X, C, or E-cut crystals, the frequency at any temperature can be determined from a knowledge of the frequency-temperature coefficient and the crystal frequency at any other temperature. Such calculations are not accurately possible with low frequency-temperature coefficient crystals since the curve of frequency versus temperature is not a straight line; in fact, the coefficient may be positive over one part of the total temperature range and negative over other portions. It is commercial practice, with these crystals, to state the average frequency-temperature coefficient over a given range of temperature (generally 20°C. to 55°C.).

The operating temperature of a crystal is dependent on the ambient temperature, the amount of heat developed by the crystal in oscillating and the rate of heat dissipation by the crystal holder. It can be seen, therefore, that for highest frequency stability, unless automatic temperature control is employed, a crystal holder having high heat dissipating abilities should be employed. In addition, the intensity of vibration should be maintained at the lowest possible value to keep the developed heat at a minimum. Where a very high degree of frequency stability is required, the crystal temperature should be controlled by a constant-temperature oven.

FROM
ENGINEERING BULLETIN
E-6

LESSON 20

Photoelectric cells
Sound motion pictures

THE term photoelectric phenomena has been applied to any electrical effect produced by the action of light. Technically, the photoelectric cell is a light sensitive tube in which the sensitive surface emits electrons under the influence of light or other electromagnetic radiation as distinguished from the actino-electric (selenium cell) or the photo-voltaic (liquid cell) types. Visitron type A and AV cells are of the true photoelectric type in which the sensitized metal plate is sealed into an evacuated envelope, or one containing a low pressure of inert gas.

The action of the cell is illustrated in Fig. 1. The concave surface on which the sensitive material is deposited is the negative electrode of the cell. The anode, or positive electrode, is the centrally located wire which attracts and collects the electrons emitted from the plate (cathode) when light falls on the concave surface. This flow of electrons through the cell and the external circuit is the photoelectric current.

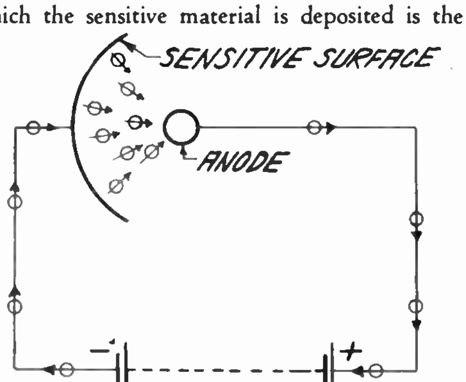


Fig. 1

Schematic drawing illustrating the action of VISITRON Photoelectric Cells. The electrons emitted from the sensitive surface by the action of light are attracted to the positive anode. This flow of electrons through the cell and the external circuit is the photoelectric current.

VISITRON type A cells are filled with an inert gas at a low pressure. In this type of cell the photoelectrons ionize the gas in their passage from the sensitive surface to the anode. The resulting ionization current is added to the electron current, giving a larger total photoelectric current than in the vacuum type cells which are designated as Type AV.

In figures 2 through 9 are shown the principal electrical characteristics for Types A and AV cells of average sensitivity.* In Fig. 2 the linear relationship between cell current and light flux is shown with low load resistance. Type AV cells can be used with higher values of light flux than can the gas-filled Type A cells. At high values of light flux and high voltages, the output of the type A cell is more than would be expected in a cell having a linear characteristic over the entire range. By proper design of the load circuit, it is possible to make this characteristic linear over a predetermined range.

In Fig. 3 are the sensitivity-voltage relations for both Type A and Type AV cells. The sensitivity of the gas-filled cell rises rapidly as the voltage is increased. If the voltage is increased to values greatly exceeding 90 volts, the curve rises almost vertically and the ionization within the cell becomes self-sustaining. In this state the cell passes current without light and a visible glow will be observed. This form of ionization is highly detrimental to the sensitive surface and should be avoided at all times. In general, the voltage used with a gas-filled cell should be as low as will produce the necessary output for satisfactory results. Such use insures long cell life and the maximum stability in operation.

The curve shown was taken with 0.06 lumen of light flux. For higher light intensities the curve has even greater slope at 90 volts. Where the light flux to be used with the cell exceeds 0.2 lumen an operating voltage of less than 90 volts should be used.

In the case of the Type AV cell which contains no gas, the sensitivity does not increase with voltage above the saturation point. With 0.06 lumen at which the curve shown was taken, saturation is practically complete at 30 volts. Above this voltage the cell sensitivity is essentially constant. For high values of light flux, the saturation voltage will necessarily be higher but in all cases an operating voltage can be selected above which voltage fluctuations do not change the output. The sensitivity of the gas-filled cell (Type A) at its maximum safe voltage is from four to five times that of the vacuum cell (Type AV). However, for quantitative purposes, or wherever the constancy of the cell is of greatest importance, the Type AV cell should be used.

In Figures 4 and 5 are shown the current illumination characteristics for both Types A and AV cells of various sizes. The curves are taken with the concave side of the cathodes fully exposed to light. The curves for the various sizes differ in relation to the light collecting areas of the plates. These curves are taken at 90 volts with somewhat higher load resistance than those of Fig. 2.

In Fig. 6 is shown the color response curve of the human eye and that of Type A and Type AV cells. These curves do not show the relative sensitivity of the eye and the cell, but the proportionate response of each to various colors of light. Fig. 7 shows the distribution of energy from a tungsten filament lamp indicating the proportions of each color of light that can be obtained from this type of source. The response of Visitron cells to this source is also shown.

In Fig. 8 and 9 are plotted the voltage developed across various resistors in series with the cell under different conditions of light flux. In using the cell in conjunction with direct coupled amplifiers for such purposes as operating relays, this information makes possible the calculation of amplifier characteristics in relation to light flux.

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* The less common units used in these characteristic curves are:

The Lumen, which is the unit of light (luminous) flux and is equal to the flux emitted in a unit solid angle by a point source of one candle power.

The foot-candle, which is the unit of illumination and is equal to one lumen per square foot.

At about fourteen and one-half inches from the center of a 60 watt 110 volt frosted lamp, the illumination is approximately thirty foot candles. Through an aperture of one square inch in a surface of thirty foot candles illumination, approximately two-tenths of a lumen of light flux passes.

With the optical system in modern sound-on-film equipment, the light flux reaching the cell without film in the gate is about 0.2 to 0.3 lumen. With the film inserted, the light flux varies from approximately 0.01 to 0.04 lumen.

The Angstrom unit is a unit of wave length of light and is equal to one ten-millionth of a millimeter, or about one two-hundred-fifty-millionth of an inch. The visible spectrum extends from about 4000 to 8000 Angstrom Units. Blue light has a wave length in the region of 4700 angstroms; yellow, 5800; and red, 6500.

Electrical Characteristics—Visitron Cells

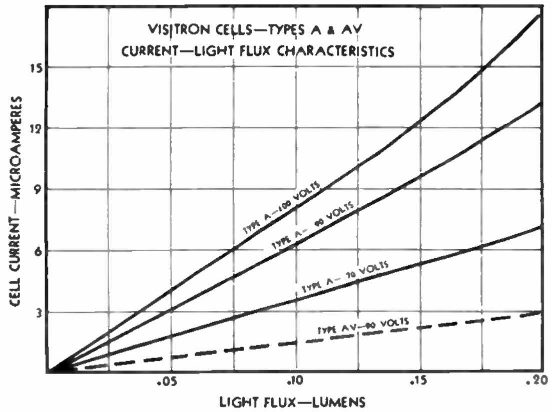


Fig. 2

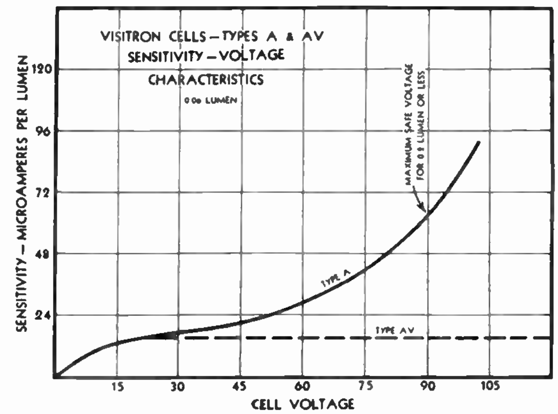


Fig. 3

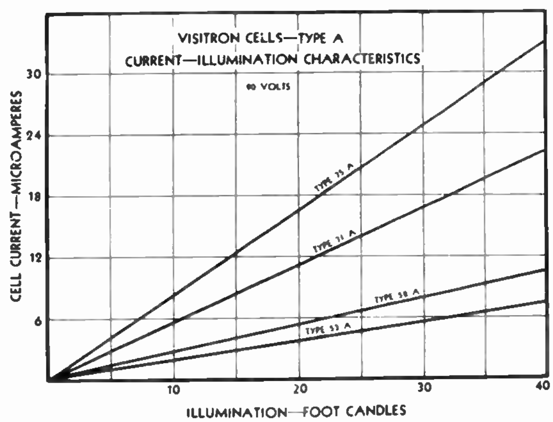


Fig. 4

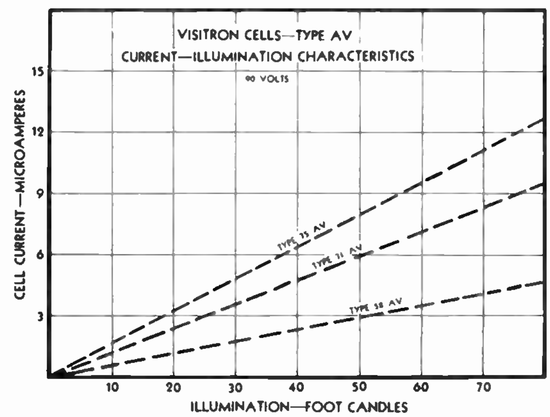


Fig. 5

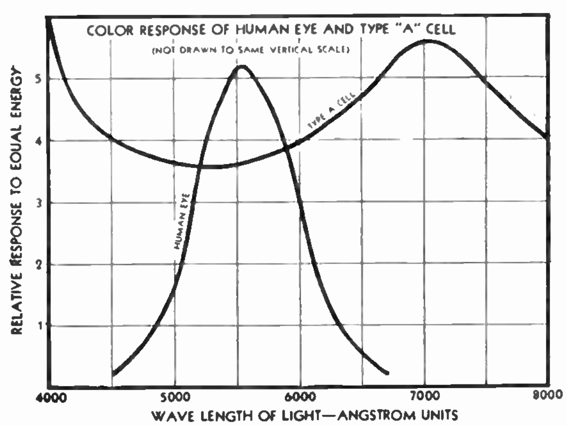


Fig. 6

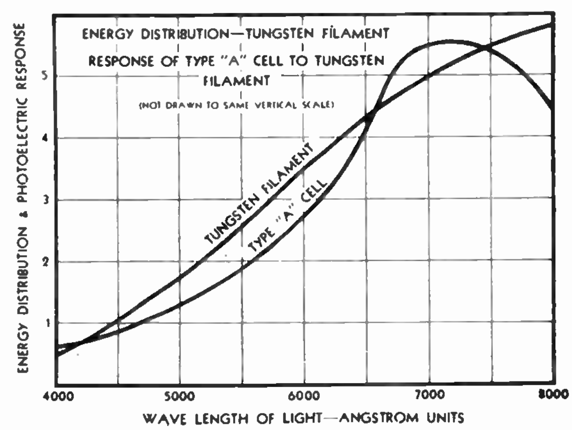


Fig. 7

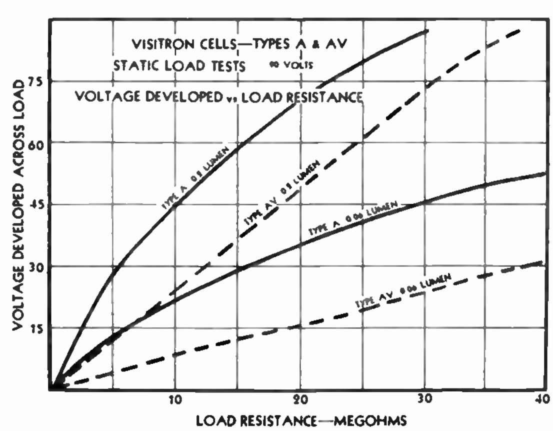


Fig. 8

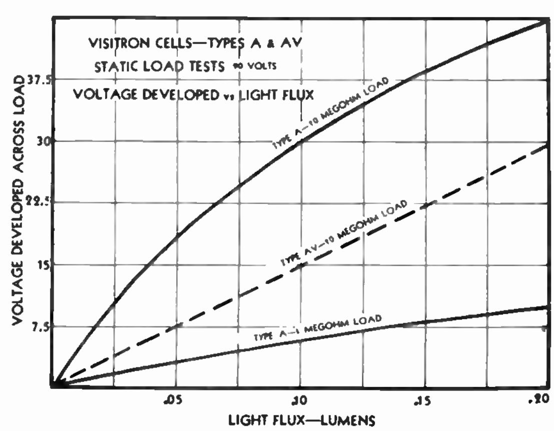
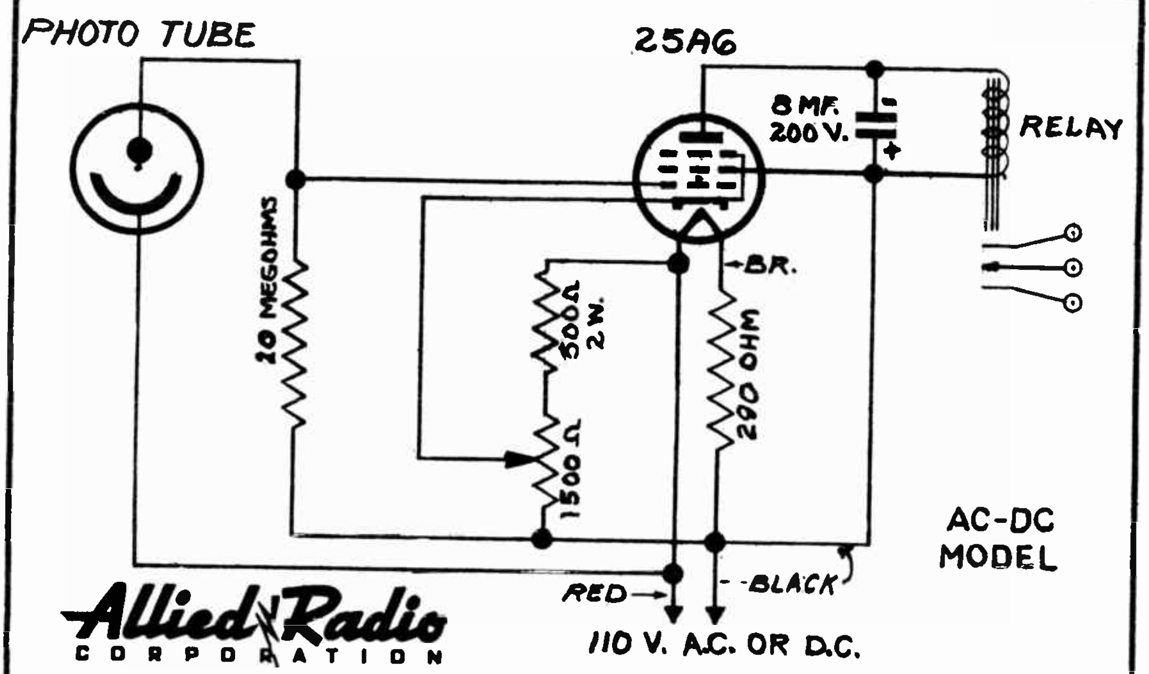


Fig. 9

Information courtesy G-M Laboratories, Inc.

Photo-Electric Cell Kit



SCHEMATIC DIAGRAM

APPLICATION OF THE PHOTO-CELL

One specific application of the photo-cell to industry may serve to illustrate just what some of the possibilities are. In the textile industry a common source of difficulty occurred in checking the colors of materials which had been dyed. In spite of rigid controls, materials which came from different dye vats did not always match exactly in color, and it was a rather laborious process to inspect the color of dyed cloth. In many factories a photo-cell installation now takes care of this job. Light is focused on cloth which passes by on a conveyor belt and is reflected back to the photo-cell. Since variations in color produce variations in intensity of the reflected light, the photo-cell automatically stops the conveyor belt whenever any cloth of the wrong shade passes by.

The experimenter will doubtless think of dozens of possibilities for the photo-cell kit. This particular unit may be used for any number of simple applications and will be most sensitive where stray light is shielded away and the control light is directed on the photo-cell. Generally, photo-cells are more sensitive in localities where comparative darkness exists. In such cases only a small amount of additional light is needed to operate the unit. On the other hand, in well-lighted places considerable differences in light intensity may be required in order to activate the equipment.

Every day new applications are found for photo-cell equipment. We are all familiar with the mysterious swinging doors, automatic drinking fountains, and animated window displays. In industry, too, photo-cell equipment has found hundreds of uses and is now considered an indispensable tool. The photo-cell unit described here offers an excellent opportunity for you to become familiar with the design and operation of these units and, of course, may be used for any number of practical purposes.

This unit can be built for about $6, including the photo-tube, is self-powered, and may be operated from 110 volts A.C. or D.C., or in areas where wired current is not available, the battery model may be constructed. An absolute minimum of inexpensive parts is used. The simple chassis base required is available completely formed and punched so that assembling and wiring the unit is greatly simplified.

OPERATION OF THE CIRCUIT

Consider the circuit at the point where a positive potential exists on the side of the line connected to the relay and screen grid of the 25A6 tube. If the control grid of this tube is not biased to a cut-off point, a certain amount of energy will pass through the plate circuit and activate the relay. The actual bias of the grid will depend on the internal resistance of the photo-tube and also on the setting of the potentiometer.

With the photo-cell receiving a definite amount of light, the potentiometer may be adjusted so that the plate current is just below the point where the relay will have sufficient energy to pull down the armature. Now, if the source of light is reduced, the internal resistance of the photo-tube will rise and cause a higher positive potential to be applied to the grid and counteract the negative potential obtained through the drop in the potentiometer circuit. The net rise of the control grid voltage will cause the additional plate current to pass and the armature to move down to the magnet pole. Since the armature has a contact on each side, it will make another circuit and break the one previously made. In this manner, equipment associated with the photo-cell unit may be started or stopped with the increase or decrease of light.

MOTION PICTURE EQUIPMENT

Sound reproducing apparatus of motion picture equipment is essentially radio equipment used for another purpose. It is therefore of interest to the servicemen to know about this type of equipment and be in position to reap extra profits from this source. And the movie houses are ready to pay fancy prices.

The older method of recording sound on discs is not used anymore and now the sound is recorded directly on the film along one of the edges. In this manner the action and the associated sound are always reproduced in step. There are two methods of sound-on-film recording in general use. In one system, Movietone, the variations in sound are recorded by varying the density of a constant track. This means the track is made up of lines varying in shade from pure black to light grey. In the R.C.A. Photophone system the track is uniformly dark but has varying area.

As the film passes the sound gate, a beam of light from the exciter lamp concentrated by a number of lenses cuts the sound-on-film recording in a pencil of light and strikes the photoelectric cell. Naturally the intensity of the light striking the photo cell is dependent on the sound recorded on the track. The photoelectric cells commonly used at the present time are of the gas-filled caesium type.

The output of the photo cell is equivalent to the recorded sound in electrical form and is used as a source of input of a high gain audio amplifier. The output from this amplifier is handled by a number of speakers stationed in back of the screen.

Please remember that any ordinary high gain good quality amplifier of suitable power output may be used for movie work. However, provisions must be had for photo cell polarizing voltage and exciter lamp current. To follow out the "show must go on" idea many of the movie sound reproducing amplifiers are made in the form of dual units with a handy switch, so that a quick change from one to the other is possible in case of difficulties.

In servicing the equipment proceed in the same manner that you would tackle the repair of a radio. Usually the service manual supplied with the equipment will be available and the instructions and diagrams there will prove of great help.

REVIEW QUESTIONS

1. Compare the advantages of the vacuum and gas filled photo-cells?

2. If a photo-cell is considered as a variable resistor with its resistance changing as the light is altered, what would you estimate the resistance to be under strong light? In total darkness? (In solving, consider the voltage present and current passing. Use Ohm's Law.)

3. In the photo-electric circuit what purpose does the 8 mfd. condenser serve?

LESSON 21

PRINCIPLES of TELEVISION

The transmission of a visual scene by electrical means requires two fundamental processes of changing the light rays to corresponding electrical energy and subdividing the image into many small elements.

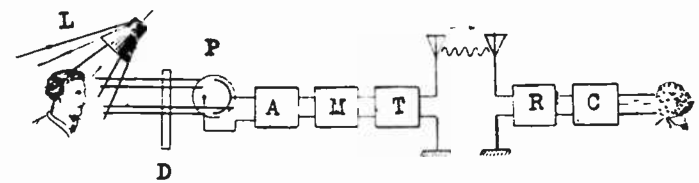
The conversion of light energy to electrical current is performed by photo active materials -- the intensity of light varying the current produced. If the light from an entire scene is televised by a single photo cell, the current produced will vary with the average light present. Light from all parts of the image will fall on the photo cell and will exercise its influence.

A photo cell is a device for changing light intensity of color variations to corresponding electrical energy. The ordinary radio type vacuum tube emits electrons because the cathode element is heated. Photo active substances, on the other hand, depend on electron emission caused by the piculiar reaction of certain metals when in the presence of light rays. These metals include caesium, lithium, potassium, and sodium. Usually the hydrides and oxides of these metals are used. The sensitivity to different colors and the general reaction characteristic of any substance depends on the emitting material used as the cathode and whether the cell is of the vacuum type or contains a small amount of some special gas.

Under ordinary conditions when a piece of photoelectric active metal is exposed to light, the emission of the electrons is retarded by the large atoms of the gases forming the atmosphere. But if the metal is placed in a vacuum and a beam of light is allowed to strike the metal, the electrons will be thrown into the surrounding space. The number of electrons emitted will be proportional to the intensity of the light. Stronger light will cause a greater number of electrons to be emitted.

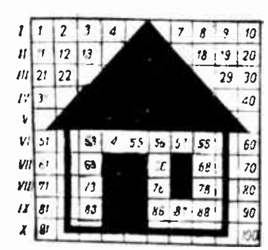
For intelligent television transmission it is essential to separate the image into many elements and transmit these in a regular order. Since various parts of an object being televised reflect different amounts of light, if each one's light is permitted to act separately, a series of current variations will be produced in accord with the light intensity of the elements scanned. A definite order of scanning these elements must be carried out, so that the image can be reconstructed later at the receiver.

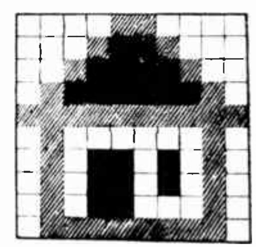
The process of television (no longer used) is shown below. A man's head is located in a strongly illuminated field served by projector lamp L. The revolving Nipkow disc D, permits one element of the image at a time to reflect its light to the photo cell P. The current in the photo cell will vary in accord with the rays. If dark elements, corresponding to sections of the hair, are scanned, low current will be created. If the light elements are scanned much light will be reflected and the photo cell current will increase. These small variations can be amplified in a pre-amplifier A and modulator M, and then placed on the radio carrier produced in transmitter T.



These radio waves modulated with the electrical variations corresponding to the scanned picture may be received by a special radio (television) receiver and used to recreate the picture in a special cathode ray tube having synchronized scanning to remain in step with the transmitter. The light intensity of any element produced will correspond to the signal strength at that moment.

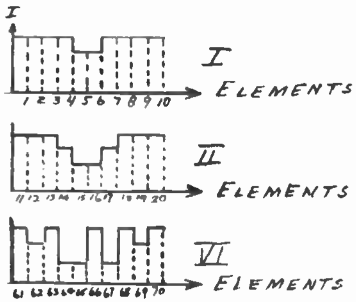
If a block diagram of a house is to be televised by means of 100 elements, we can assume that the illustration is superimposed upon ten horizontal lines each having ten elements.

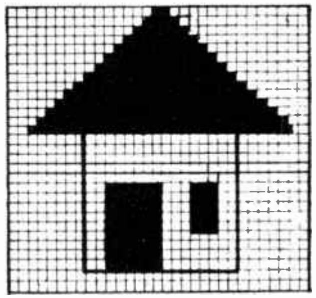




PRINCIPLES of TELEVISION

The scanning may be performed horizontally from line to line, or vertically from row to row. Horizontal method is preferred. If the scanning process is started at the upper left hand corner, the first four elements (1, 2, 3, and 4) will produce maximum current. These elements are white and will reflect a maximum of light. Elements 5 and 6 will reflect less light, being partially covered with the dark roof of the picture. While these elements are scanned less current will be generated by the photo cell. Again elements 7 to 10 of the first line will produce a strong current. These changes are illustrated graphically below. Follow the changes occurring as the other elements are scanned and check your results for the 2nd and 6th lines which are shown below.





These changes in the photo cell current may be amplified and used to amplitude modulate the transmitter carrier. At the receiver these amplitude changes will produce visual effects along similar 100 elements. Many details will be lost because of the small number of elements employed. Notice that when a change of shade occurs in a single elemental area, this change does not appear at the receiver but simply influences the tone of the entire element. Using 900 elements better definition is obtained as shown in the last illustration above.

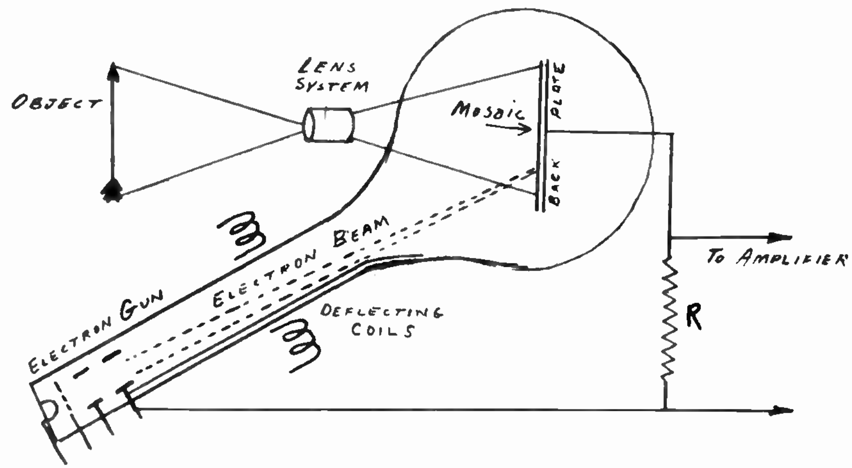
In modern television a cathode ray tube is used for pick up and the scanning is performed automatically. A mosaic is a mica plate having many thousands of photo active globules insulated from each other and from the back conducting plate. Each globule forms a tiny condenser with this back plate; the mica serving as the dielectric. The scene to be televised is projected upon the mosaic. Light sections of the image cause high electron emission from the photo active globules. The globules in the dark parts of the image emit very few electrons.

Light receiving element of the Iconoscope is called the mosaic. It consists of a very large number of photo-sensitive particles mounted on a thin sheet of mica or a coating of vitreous enamel, and these particles are insulated from each other. In case mica is used, the back is coated with conducting metallic film. If vitreous enamel is used, it is painted on a metal plate. In one type of mosaic the silver globules are formed by reducing particles of silver oxide dusted over the mica. Under proper treatment,

the silver particles will form individual droplets. These droplets are photo sensitized with cesium vapor. Photo-electric response similar to that of a high vacuum cesium photo cell is obtained.

The mosaic is mounted in the tube with the photo sensitive side facing the electron beam and light rays from the object.

The mosaic is mounted in the tube as shown. The scene is focused on the mosaic by means of a lens system in the same manner used in photography. An electron gun emitting a stream of electrons is made to scan the mosaic in a regular order. The electron spot falling on the mosaic covers a large number of globules and in some Iconoscopes measures 1/50 of an inch in diameter. The beam may be made to cover the surface of the mosaic in any predetermined order, but under the Radio Manufacturers' Association standards, 441 line scans are used, double interlaced so that the odd lines are scanned first and then the even, the complete image being scanned 30 times per second.

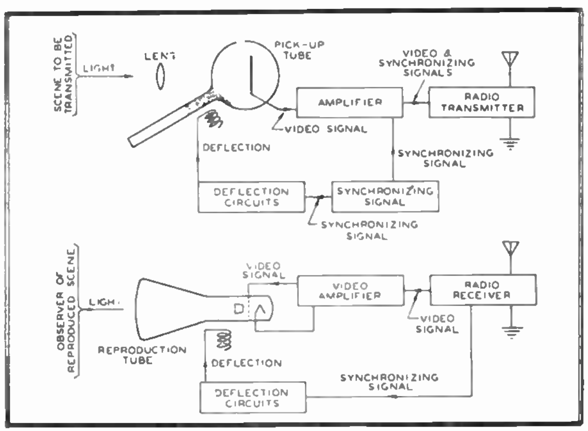


PRINCIPLES of TELEVISION

Now you will recall that light causes the photo active globules to emit electrons which form a space charge around the corresponding globules. Since each globule is actually one plate of a small condenser (the metal deposit on the back of the mica serving as the other plate), the small condenser so formed will become charged.

The electron stream sweeps over these charged "condensers" covering a number at a time and discharges the accumulated electrons through resistance R. The voltage across this resistance, therefore, will depend on the charge of the globules covered by the beam during the corresponding instant. Since the charge, in turn, depends on the light intensity of the image, the signal voltage produced will be in exact accord with the light of the elements covered.

Since any one elemental mosaic area is receiving light while the remaining sections are being scanned, the charge is cumulative and excessive amplification is not needed.



You will see from the diagramatical illustration given (reprinted from the Proceedings of the Institute of Radio Engineers) how the synchronizing signals are applied to the pick up tube and are also transmitted to serve at the receiver. These synchronizing signals of all present American stations follow the R.M.A. standards

In order to have successful television reception, the receiver must be interlocked (be in phase) with the transmitter. This synchronization must be standardized, for a radical change in transmission practice may make all existing television receivers obsolete. Therefore, a set of standards have been worked out by the Radio Manufacturers' Association. These standards are sufficiently broad to permit improvements in the future, and yet assure the purchasers of television receivers of many years of service and the possibility to receive all television programs within range.

It was decided to use but a single side-band transmission and allow a 6 MC. channel for each station. This channel was to include also the small band needed for corresponding sound transmission. Seven of these channels are included between 44 to 108 megacycles. Between these frequencies there are also other ultra high frequency channels for communication purposes. There are also additional channels for television relay stations, remote pick-up rebroadcasts, and link stations.

The video (television) carrier and audio (sound) carrier are separated by 4.5 MC. At the upper end there is also a blank .25 MC. band used to assure proper separation between adjacent channels.

Negative modulation is used. (See the meaning of this term). The 441 line scanning aids to good definition of the picture. To eliminate flicker, 30 frames per second has been decided on. The vertical scanning frequency, field frequency, is 60 per sec., since double interlaced scanning is employed. The selection of 60 fields minimizes 60 cycle "hum" distortion.

Since negative modulation is used, black level corresponds to maximum video modulating signal. Very bright light reduces the carrier to zero amplitude. The line and frame synchronizing impulses must be transmitted as carrier values higher than the black level. These impulses are to be between 20 and 25% of the maximum carrier amplitude. The function of these, of course, is to synchronize the receiver and the transmitter.

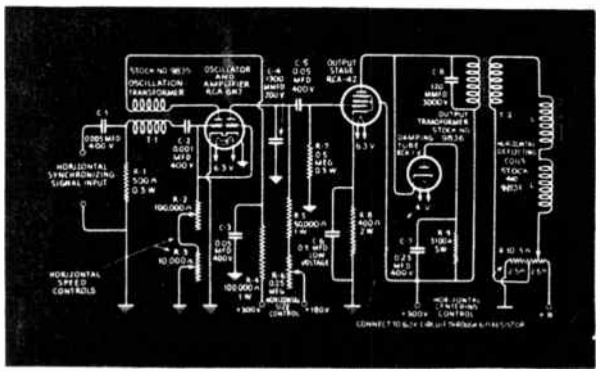
PRINCIPLES of TELEVISION

At the end of each line we have a horizontal synchronizing impulse to retrace the electron beam and to blank out the view of this retrace. Since one line occupies a time element called H, this impulse will occur during a small fraction of H. R.M.A. Standards provide 15% of the time, i.e. .15 H for this purpose. The actual synchronizing impulse occupies about one-half the blanking time.

The vertical scanning impulse lasts during three lines, 3H, but is made up of six small pulses to maintain horizontal scanning at all times. These six impulses are needed to keep horizontal line synchronization active in the double scanning system used. Also six equalizing impulses precede and six follow the vertical impulse period. Since the circuit cannot be changed suddenly from one frequency of operation to another, these impulses serve to prepare the circuit for the vertical (subdivided) impulse after horizontal impulses, and vice versa.

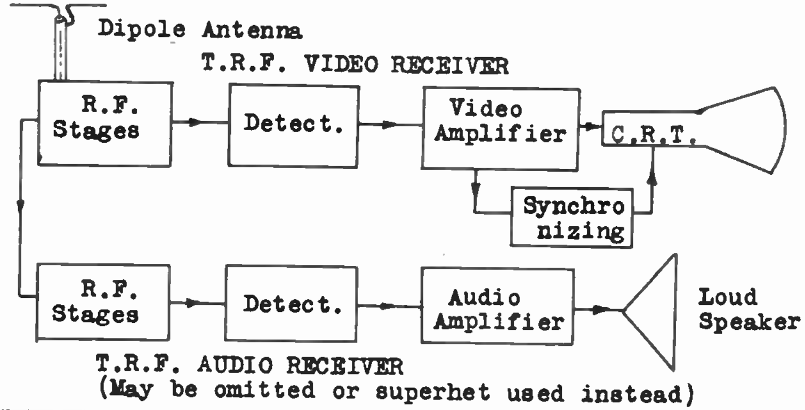
The actual deflection at the cathode ray tubes is accomplished by means of magnetic deflecting coils (electrostatic plates may also be used). Two pairs of coils are employed mounted at right angles to each other. The beam will be deflected as a varying current is applied to the magnetic yokes, and, since electrons have infinitesimal mass, the deflections will be instantaneous.

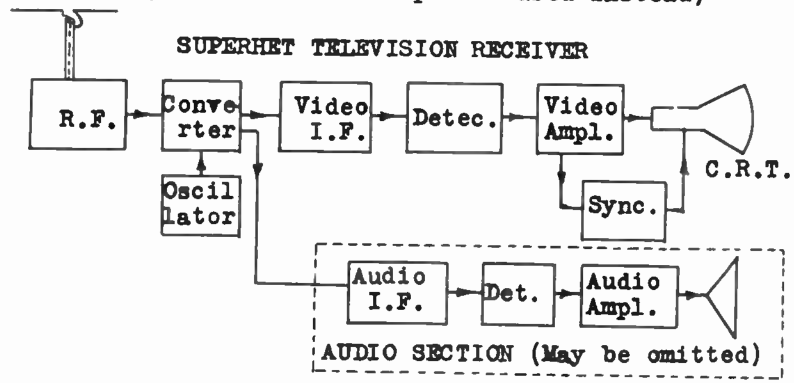
The method used to obtain 441 line horizontal scanning with fast fly back at the receiver, depends on the synchronizing impulses to control the oscillator of the deflecting circuit. See the R.C.A. circuit below.



RCA 1801 Horizontal Deflecting Circuit

Ultra high frequencies are used for transmission of television signals. This is essential because of the extremely high frequency of the side bands. The first television channel is from 44 to 50 MC., and the others are at still higher frequencies.



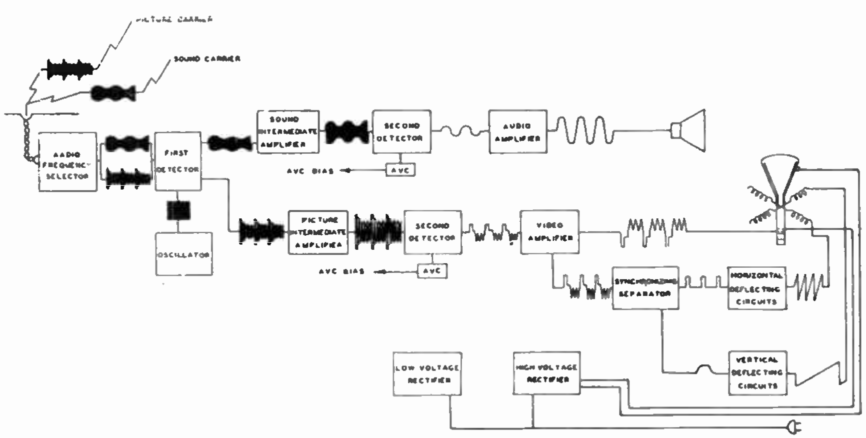


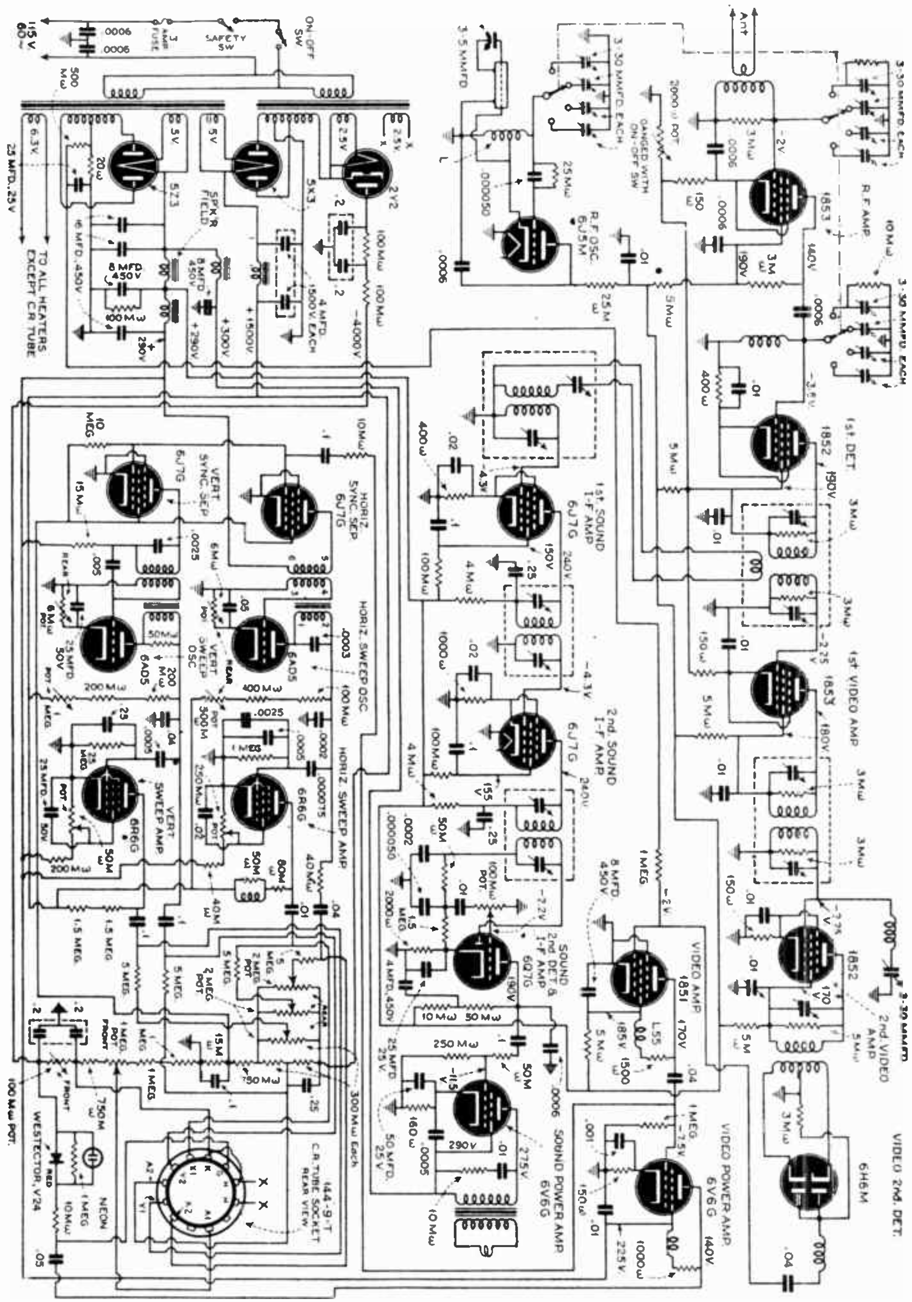
To the practical man the actual function and repair of a television receiver is of prime importance. By dividing the receiver into sections the problem of servicing is greatly simplified. The television receiver may be of the T.R.F. or superhet type, may or may not have the audio channel receiver included. In the T.R.F. type unit an entirely separate receiver is used for audio although the controls may be combined. In the superhet type the R.F. pre-selector and converter-oscillator are common to video and audio channels. If audio is not included simplification of these first stages results and the audio channel I.F., detector, and audio frequency amplifiers are omitted.

PRINCIPLES of TELEVISION

Starting at the antenna input you will notice that the secondary is loaded with a 3,000 ohm resistor to flatten out the response curve. The process of loading inductances is used in television equipment to permit the passage of extremely wide side band. Tuning is accomplished by means of pre-set trimmers connected to a push-button switch. The local oscillations produced by the 6J5 tube beat with both the video and audio carriers producing two different useful I.F. frequencies. One is used for the video I.F., while the other corresponds to the audio I.F. frequency. There are two stages of I.F. in each channel. Ordinary receiving type tubes are employed in the audio section, but special low inter-electrode capacity tubes must be employed in the video I.F. channel. The balance of the audio signal receiving equipment is similar to the type used in regular radio sets.

In the video section also, a second detector is used followed by a video amplifier. After the first video stage part of the signal is tapped off and serves the horizontal and vertical sweep circuits. The synchronizing signal received simply controls the local vertical and horizontal oscillators and locks them in step.





PRINCIPLES of TELEVISION

By noticing the apparent action of the image, the location of the fault may be detected. J. H. Reyner in his book on "Testing Television Sets" gives a complete list of faults that may be found. His listing will serve as our outline.

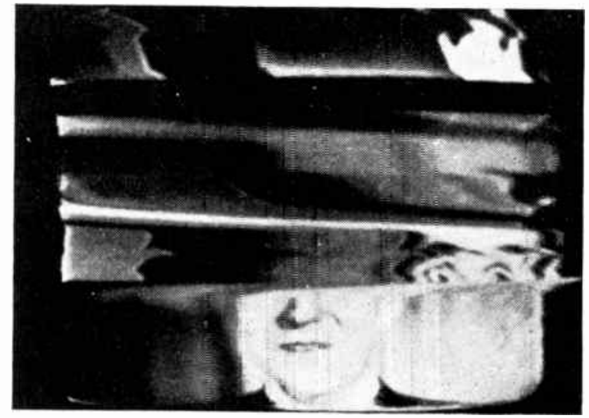
If absolutely no fluorescent light is noticed it is probably that the difficulty lies in the cathode ray tube. The anode voltage may be shorted or missing. Emission may be lacking because of heater supply failure. If the scan is deflected completely off the screen this condition may exist. If tests indicate that these faults are not present, the tube itself should be changed.

If a point of light does exist, but no image is present be sure to reduce the brilliancy while making tests. If the electron spot remains in one position and has sufficient brilliancy, it may burn through the fluorescent material. The trouble in this case, of course, is due to some fault in the scanning circuits. It may go further in the front section of the receiver. If the intensity of the spot does change in a manner that suggests that it is following the modulation the trouble must lie in the scanning circuits.

Sometimes the scanning is present, but there is no modulation so that the entire image is of one shade. First suspect the final video stage, because this is the only stage that does not carry the synchronizing pulses which are operating correctly. Next proceed testing back to converter tube. If the audio section is operating correctly the trouble definitely is not in this stage or the antenna. But if the sound channel too is at fault suspect the R.F. stage, converter, oscillator, or the antenna.

Reversed modulation can only occur if the voltage to the control grid of the cathode ray tube is applied 180° out of phase. This can happen is one video stage is not operating, but the voltage does get to the following stage. Usually due to wrong connection.

A confused jumble appearing or the screen is very difficult to diagnose -- there are so many things that could go wrong and cause this symptom. Usually, however, the vertical or horizontal sweep circuit will be found at fault. Certain type of interference may also cause a jumble of light on the screen.



Picture due to operation of receiver with pronounced unstable line synchronism.

Poor focus may be due to poor adjustment. You should try to make the necessary adjustments. Suspect also defective scanning circuits and poor inter-locking with the incoming synchronizing signals.

Uneven brilliance may be due to poor power filtering. This is not common when 60 cycle A.C. power is used with transmission using 60 fields. Inter-action between the scanning voltages and modulation will have this effect. Spots only lacking brilliance are probably due to burnt screen.

With poor overall frequency response considerable loss of definition will result as is apparent from this photograph.

PRINCIPLES of TELEVISION

Picture will be unsteady if the synchronizing is poor. Leakage in the video circuit may cause the same effect.

Picture flickers are very common to loose aerial. Check this first. Variations in the power supply voltage may also cause this effect. Certain difficulties in the synchronizing circuit may make the picture flicker.

You will find that a double or a partial image is always due to errors in the scanning circuits. Ghost images may be due to the scanning circuit or to the reflection of the incoming wave. If the later is the case shifting the antenna will solve the problem.

Once the defective portion of the television receiver is located the methods used for radio servicing may be applied. The point to point voltage test is about the best. Since very high voltages are present in some circuits your voltmeter should either be able to read to 6,000 volts or else an external series resistor will have to be connected.

If the cathode ray tube is suspected voltage tests should be made. As another alternative, the tubes may be replaced for test. Servicemen experienced in using a cathode ray oscilloscopes should consider the Picture Tube as a special unit of this type. Here sweep frequency is applied both vertically and horizontally at a related rate and interlocked phase. Also the intensity of the beam is influenced by the incoming signal.

The faults in the scanning circuits are ordinarily due to some part failing. This part can be found by one of the regular ways. A cathode ray oscilloscope is a great aid in servicing this section of the television receiver.

Although the individual scanning circuits may not be at fault, there may be interference due to interaction between the vertical and horizontal scans. If the vertical scan influences the horizontal scan, distortion of the trapezoid type will appear. This difficulty is usually due to coupling in the high voltage supply. This is similar to motor boating in an audio receiver and may be eliminated in the same manner.

If the line synchronizing circuit effects the vertical scan the edge of the image seems to lift and bend over. Here too the fault may be due to coupling in the high voltage supply, but is more commonly present because of direct coupling of the two circuits. Shielded leads will help.

An image with ragged edges is produced by very poor line (horizontal) synchronization. The picture may be broken up by horizontal streaks at points where there are high lights in the image. If this defect is slight, the image will hold steady, but will be distorted since the lines will not arrange themselves correctly.

Effect due to non-linear vertical scan.

Effect due to line sweep operating at twice the correct frequency.

LESSON 22

The Radio Servicing Business

While there are opportunities for servicemen in factory and large stores as paid employes, majority of servicemen operate their own businesses. It is just as important to know how to obtain business, as to know how to service radio sets. This chapter has some really worth while tips.

Servicemen forget that they live in a highly-competitive society. They expect Mr. Radio Owner to come to them when he has radio difficulties, to beat a path to their door, and to search high and low for their addresses if necessary. Of course, this does not happen and the fellow down the street gets the job. If you want more business, if you want the business of people who never heard of you, you must let them know of your existance, your good points, your special abilities to serve them. You must approach them many times in many different ways. Advertising does this and advertising pays!

Money invested in advertising is far from being foolishly spent. Not only do you expect to receive back every dollar spent on advertising, but on every dollar you expect a certain definite return in the form of increased business and greater profits. You will get these successful results if you plan your advertising wisely and correctly.

Among the various forms of advertising suitable for the radio service business, advertising in publications such as local newspapers and telephone books is most common. When advertising is sent directly to the prospect, either by mail or messenger, this method is called direct mail. By keeping the names and addresses of your past customers you can remind them of your service from time to time.

Posters, window displays, and signs are very effective ways of obtaining additional business. The are also certain unique methods of advertising salesmanship that get business.

Advertising in any form must get attention. Unless an advertisement or a sign attracts attention it is not present as far as the prospective reader is concerned. Attention is obtained in various ways. Sheer size, black type, white space, color, novelty, illustration, and catch-phrases serve to get attention.

Once the attention is arrested , the interest of the reader must be held. The story, the picture, the idea must "get the reader", compel him to read on. In other words, it is not merely enough to notice an advertisement, but the advertisement must actually prove interesting. With the reader expressing a not personally realized interest in your advertisement, the next step is to create a desire. A desire for a better set, a new set of tubes, or better reception.

After the desire is aroused, the reader must be impressed with conviction that your tubes, your service, or your appliances are what he wants. Your items and service must appear to him as the logical solution of his desires.

At this stage, the reader is convinced that your service or products are what he wants and needs, but you must make him act. Action will make him pick up the 'phone and call you up or stop in to have his tubes tested. Do not merely tell your story in your advertisements. Finish up with action that will make the reader exclaim: "I'll phone that serviceman right now," and not "Well, my radio hasn't been playing right, I'll get it fixed one of these days".

In larger cities, a small advertisement in the want-ad section of the daily newspaper brings excellent results. Some outstanding points about your service must be featured. You may stress that no set is too complicated or that the work is guaranteed. Price is always a leader.

Telephone book advertisements offer excellent possibilities. A large number of people turn to the 'phone book when they are in need of some special commodity or service. Publicity via the telephone is also adaptable for selling service. If Mr. Brown had his radio repaired ten months ago, a telephone call some evening should be made. Here is a typical conversation:

"Good evening, Mr. Brown, I repaired your radio set some time ago. How does it work now?"

"Fine. We haven't had a bit of trouble with it since."

"I'm glad to hear that. I was wondering if you'd be interested in improving your reception by using a high-efficiency antenna system. You have probably heard about these new aerials, they bring in short-wave stations louder and also reduce noise on all stations." etc.

Antennas are not the only topic. Nor is the report of fine reception the only answer. If the set is working satisfactory it is of small value to discuss tube testing or set checking, but you might inquire whether the customer plays phonograph records and, if electrical reproduction is not used, explain the better tone possible through the use of a phonograph adapter. Various accessories are best plugged hard as soon as they come out, and telephone calls based on new products of that type are very helpful in extending your prestige and convincing your customers that you are a live wire.

Window display advertising can be very effective. It is of prime importance, where you have a street front, to have the window dressed not only neetly but also interesting. This is an art in itself and large outfits either have professional window dressers on their payroll or hire them as need arises. You will have to this work yourself. The usual displays as received from manufacturers may serve well on counters and in windows, but the most effective method is one invoking originality. Then one's window becomes distinctive. Services that incur movement are impelling. Anything that evokes an interesting contrast is valuable for its attention quality.

A good display was produced by one fellow who obtained a number of dead transmitting tubes from a station and placed these tubes next to a few regular receiving types. He cited the fact that the station checked tubes hourly. Why should not the listener have his tubes checked twice a year, also for the same reason -- best quality performance? The transmitting tubes cost hundreds of dollars each, a set of receiving tubes less than five.

Another dealer attracted large crowds of real radio prospects by offering $10 prize to the owner of the oldest radio. Certainly the person who thinks he has the oldest radio in a community is a good prospect for a new set.

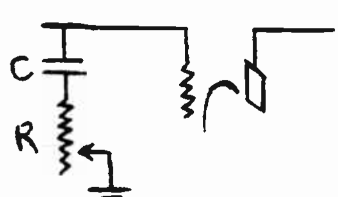
Money in MODERNIZATION A real service can be performed and an extra profit earned when servicing old style radio sets. The adaptation of newer type tubes, the addition of tone controls, the change to more modern dials, the installation of doublet antennas and tuning eyes on A.V.C. sets are just some of the possibilities.

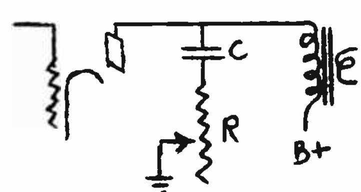
In Edison R_1, R_2, and other such sets using a 27 detector and 26 first audio, the volume can be improved and the hum reduced by replacing these tubes with 56's using the 2.5 volt filament source from the original detector supply. (Type 27 requires 1.75 ampere; 56 only 1 ampere). Remove the grid leak and grid condenser from the detector circuit, and bias the 56 with 50,000 ohm, 1 watt resistor. If the original circuit used a self biased power detector, no such change will be necessary. Bias the first audio 56 tube with a 2,700 ohm, 1 watt cathode resistor. In general in all audio circuits a type 27 tube can be replaced with a 56 resulting in higher gain.

In sets using 24-A tubes, one such tube can be replaced with a 35 without any other changes. This will result in better tone and slightly less noise.

INSTALLATION OF TONE CONTROLS Judging by the almost 100% use of tone controls in modern sets, we may draw the conclusion that it is an excellent addition to any radio set. Individual taste and the type of program vary the demands for either the suppression of high or bass notes. Also some sets, because of their poor design, will stress frequencies in some particular range, and a tone control may be useful to overcome this difficulty. Your customers realize that a tone control is a very desirable feature ordinarily found only on more expensive and modern sets, and because of this will be willing to pay a real price for such an installation.

While it is possible to install a tone control consisting of a number of resistors and condensers with a switch arrangement, the price of these parts makes a continues variable unit more in line of economy and the one used. A fixed paper condenser and a variable high resistance are connected in series and shunted across the power tube(s) input grid circuit or output plate circuit. Theoratically such control will make possible only the suppression of the highs, but in practice it works out very well. For the grid input side a 0.01 mfd. condenser and a 1 megohm resistor may be used; for the plate side a 0.02 mfd. condenser and 150,000 ohm variable resistor may be employed. These values are not critical.





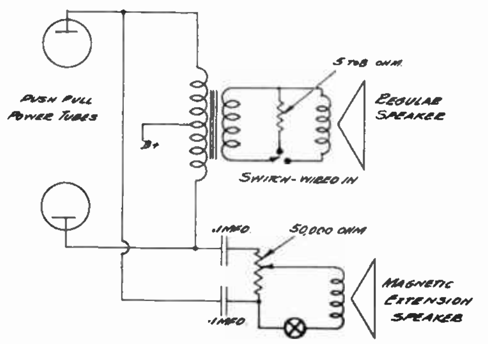
EXTRA SPEAKERS

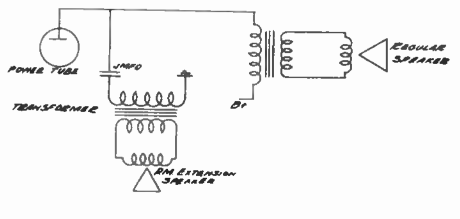
Means Extra Profits to the Radio Service Man

The new profitable field of installing additional extra speakers is open to all servicemen. This type of convenience is wanted by practically all radio owners and should be suggested on every radio repair call. Most homes have only one radio, in a single room of the house. To hear radio programs in other sections this radio must be played at volume levels that prove nerve-wracking to all close to the radio and annoys the neighbors due to the loudness.

Another extensive application of extra speakers is found in schools where it may be desired to serve more than one room with radio programs from a single radio set. Most of the modern radios are sufficiently powerful to satisfactorily operate up to a dozen additional extension speakers with excellent volume.

During the summer season many persons find it desirable to place an extension speaker on their porch or in the garden. This simple application alone offers unlimited opportunities. Extension speakers may also be used for advertising purposes. Store owners quickly realize that an outside speaker mounted above the door will attract the attention of the passerbys and bring in extra trade. Additional speakers for various applications may be connected to practically any radio set simply and inexpensively, netting a nice profit to the servicemen. Any good quality magnetic speaker is suitable and is coupled to the set in the manner described below.





In sets using a single power tube, a lead is brought out from the plate prong of the power tube through a 0.1 mfd. paper condenser.

The return lead of the loudspeaker is connected directly to the radio chassis. Where two tubes are used in push-pull in the output stage, the extra reproducer is connected through 0.1 mfd. condensers to the two plates of the power tubes.

These simple methods of connecting additional speakers, while satisfactory for many ordinary requirements, do not provide for shutting off either the main or the extension speaker, or for varying the volume of the extension speaker. By incorporating a single pole switch in the extension speaker lead, and one switch in the voice coil circuit of the main speaker, either or both speakers may be operated at will. The volume level of the extra speaker may be controlled by means of a 50,000 ohm potentiometer in a voltage divider circuit.

SERVICEMEN CAN TURN ELECTRICIAN-SALESMEN .....

...... EARN EXTRA ON EVERY RADIO JOB

Once you have placed the set in first class operating condition you have won the confidence of the owner. Now is the time to look around. There are some real money making opportunities present. How well we know that almost every cabinet has some ugly scratches. Extra money can be made in almost every home by soliciting touch-up work on the cabinet and other furniture. A kit for doing this work rapidly and well can be obtained for a few dollars and will pay for itself many times over.

And how about the lamp next to the radio. Even if it is in working shape, probably the electrical wires are worn out, you will profit and be thanked for the replacement. In fact there are all sorts of repair jobs in the home that the servicemen can do; being in the house and having just finished one job successfully gives you a real lead.

There is always the possibility of an extra radio sale. Many homes now realize the need for two or even more radio sets. Carry a midget radio with you and demonstrate it after every job. You will be surprised at the number of sales. And if the owner has a car - but no auto radio - talk that up.

Now if you are wondering if there is any money in this new business or if it is best to stick purely to servicing -- here are some practical figures. Every radio job varies, but the average job brings in about $3.00 gross, net about 50¢ an hour for the time spent -- remember also the hours you spent studying for that job, shopping for parts, riding to and from job, etc. If no midget sale can be made, you will know in five minutes, if yes 15 minutes will close the deal. Five dollars is your least profit, net! Is it worth while? And even if you get only a dollar for an hour required to repair the lamp, there is little overhead so it is almost all clear profit. Servicemen don't be afraid to do a little selling and electrical work, your bank account will like it.

NERVE Tackle every job with assurance. Ordinarilly only one thing goes wrong at any one time. Sometimes it may be a little harder to find it, but it can be done. Wiring diagrams given in Rider's and other manuals are helpful in service work.

STUDY Return every so often to this course. After every reading you will find important facts you have missed. Keep up with the times by reading new practical text books and radio technical magazines.

TESTING EQUIPMENT You should be always planning to have the best and latest test equipment. Add equipment as you progress in the business. The larger manufacturers offer time payments and this will be of great help. Good servicing equipment will enable you to do work better and faster, and also impress your customers with your efficiency.

Another

SUPREME PUBLICATIONS

Radio Book