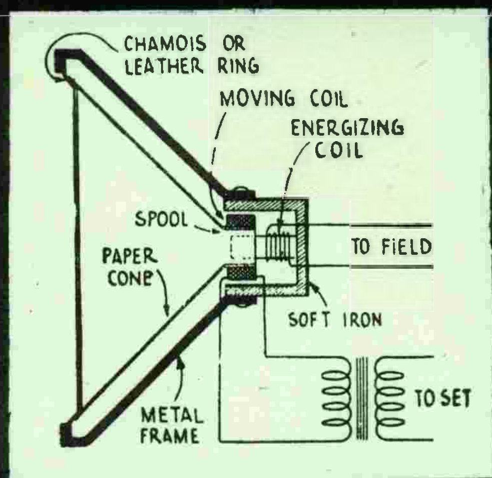

LESSON
58 R

SOUND AND LOUD SPEAKERS

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SOUND AND LOUD SPEAKERS

Whenever any sound is heard and it is traced to its source, it will be found that some object has been set into a stage of rapid quivering motion known as a vibration. For example, if the strings of a piano are examined when a note is struck, it will be found that one or several of them are in vibration; and as soon as these strings are touched with the finger, the sound ceases. These vibrating objects then set the surrounding air into vibration, and these disturbances in the air as they travel outward in all directions are known as sound waves. Sound waves can travel not only through air, but also through solids and liquids. But sound cannot be transmitted through a vacuum, for there is no medium to carry the disturbances.

If a series of sound waves could be seen as they travel through space, they would appear as a succession of disturbances in the air, each disturbance consisting of a portion of condensed air followed by a portion of rarefied air. In technical words, sound waves consist of a series of condensations and rarifications, in much the same nature as a disturbance is sent along a coiled or helical spring. Sound waves travel through the air at a speed of about 1100 feet per second.

When sound waves in passing through space strike an object or a wall, they bound back and are reflected. If these reflected waves then reach the ear of the listener, the sound is heard a second time, the reflected sound being known as the echo. In studio rooms and other places where no echo is wanted as it would cause interfering disturbance, the walls are padded with thick felt or covered with curtains and draperies. These materials then absorb the vibrations and in this manner deaden the echoes.

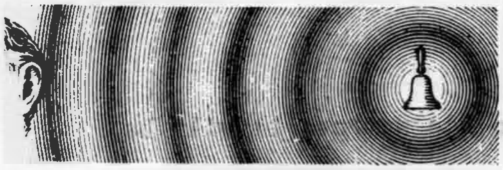
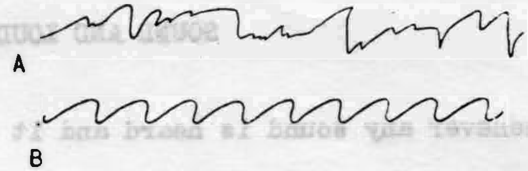


Illustration of sound waves



Curves to represent (*A*) noise and (*B*) music.

PROPERTIES OF SOUNDS

All sounds can be divided into two general classes, musical sounds and noises. Musical sounds are the result of uniform periodic vibrations, while noises are the result of irregular non-periodic vibrations. For example, if an object falls and strikes the floor, the impact produces a number of irregular sound waves that cause the noise. But if a bell is struck, or a banjo string is picked, a series of very uniform and periodic vibrations are sent out that produce the musical sound. Non-periodic irregular vibrations always produce an unpleasant effect to the ear, while on the other hand uniform and periodic vibrations are always pleasing.

Musical tones in turn may differ from one another in three ways, or can be said to have three distinguishing characteristics, pitch, intensity and quality or timbre. The pitch of a tone or note refers to its highness or lowness, that is its position on the musical scale. It depends upon the frequency of vibration, that is the number of vibrations per second. The higher the vibrating frequency the higher will be the pitch of the note. If the strings of a piano are examined, it will be found that those at one end are very thin and light and vibrate very rapidly. These give off the higher notes. The strings at the other end are longer and very heavy. They vibrate very slowly and give off the lower notes. Also, much more force is needed to set the heavier strings into vibration than the lighter ones. Therefore, the lower pitched notes always represent the expenditure of more energy, and consequently large capacity power tubes had to be developed in order to enable these low pitched notes to be reproduced properly through a loud speaker. Middle A on the piano which is generally used as a tuning standard, has a frequency of 435 vibrations per second.

The intensity of a sound is its degree of loudness and depends upon the amplitude, that is the strength of the vibrations. The harder the note on a piano is struck the greater will be the air disturbances around it and the louder will be the sounds produced. Therefore, louder sound also represent the expenditure of more energy, and to reproduce these through a loud speaker requires more energy than can be put out by the average radio tube, therefore the development of the greater capacity power tubes.

The third characteristic of a musical note is its quality known in musical terms as timbre. It is the tone quality that enables one to distinguish between two notes of the same pitch and intensity as produced by different instruments or sung by different persons. For example, the note A may be struck on the piano and on the violin; and although both may be of the same pitch and intensity, one can at once distinguish the piano from the violin by the quality of the note. If a sound is reproduced with a change in quality so that it differs from the original production, it is said to be distorted. It is the faithful reproduction of musical notes in their true nature that distinguishes a good loud speaker from a poorer one. As will be seen a little later, some speakers inherently cause some distortion, while others are more capable of true reproduction.

HARMONICS OR OVERTONES

The manner in which an object vibrates determines the nature of the tone it gives off, and for this reason the same object can be caused to give off entirely different tones by being caused to vibrate in a different manner. For example, if a string on a piano is struck so that it vibrates in one segment or as a whole, it will give off its main fundamental tone. The same string can also be caused to vibrate in two segments, and when doing so it gives off its first harmonic or overtone. The frequency of the first harmonic is twice that of the fundamental. Similarly the string can be caused to vibrate in three segments and give off its second harmonic, or in four segments and give off its third harmonic, etc. The frequency of any harmonic is always a definite number of times that of the fundamental.

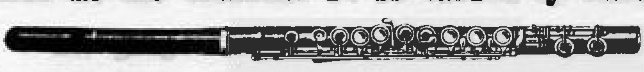
Now an object can vibrate in a very complex manner, that is it can vibrate both as a whole and in various segments simultaneously. In other words, it will give off its fundamental tone with two or more harmonics included with it. It is the number and nature of these harmonics that go to make up a tone, that determines the quality or timbre, and that enable one to distinguish its source. Some combinations of harmonics are much more pleasing to the ear than others. That is why some instruments are said to give off sweeter tones than others. A high priced violin differs from a cheaper one in the richness of the tone it can deliver, and this tone richness in turn depends upon the harmonics that comprise the various notes.

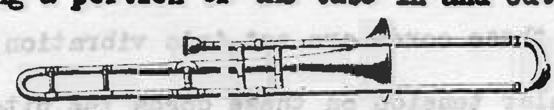
In the broadcasting and reception of musical tones and voices it is of the utmost importance that all of the apparatus be designed so that it will not affect the nature of the tones that are being transmitted or received. In other words, in order that the tone quality will not be changed, none of the harmonics comprising a tone may be omitted and others may not be added to it. The elimination or introduction of any harmonics changes the tone quality and produces what is known as distortion. If one considers the number of stages and transformations through which the tones must pass before they are finally reproduced in the loudspeaker, it readily becomes evident what amount of effort and research work were necessary in order to bring radio broadcasting to its present stage of development.

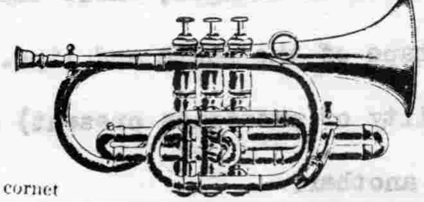
MUSICAL INSTRUMENTS

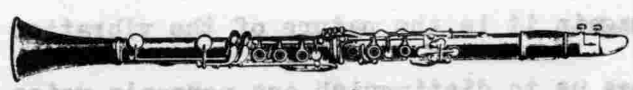
Musical instruments are merely specially designed devices for producing various kinds of pleasing tones or tone combinations. From the point of view of the vibrating object that produces the sounds in each case, instruments can be divided into three general classes -- first, those that employ vibrating columns of air, as the cornet, the flute or the pipe organ; second, those that employ vibrating wires or strings, as the piano, violin and banjo; third, those that employ a vibrating plate or membrane, such as the drum, cymbals or tambourine.

In the so called wind instruments the vibrating object (the source of the sound) is a column of air. Some arrangement is always provided by means of which the length of the air column can be varied so that tones of every desired pitch can be produced. Of the wind instruments the simplest is the organ. Here a series of pipes of various lengths are used, the column of air in each being set into vibration by blowing a small stream of air against a sharp edge or lip. The shorter pipes produce the higher notes, and vice versa. In the cornet the air is set in vibration by holding the lips in a certain position. Different pitches are produced by differences in blowing and by means of valves which change the length of the column of air. In the clarinet vibration is produced with a fine reed in the mouthpiece, and the length of the air column is changed by opening holes in the sides of the tube. In the flute the air column is also varied by opening or closing holes in the sides of the tube, while in the trombone it is varied by sliding a portion of the tube in and out.


FLUTE.


TROMBONE.


The cornet


CLARINET

Of the string instruments the most familiar is the piano. Here we have 88 keys, each striking a string or group of strings. These strings are of different weights and lengths and under different tension. The thinner and shorter strings are stretched more tightly and produce the higher notes, while the heavier strings produce the lower notes. The strings are set into vibration by means of a series of keys that operate small hammers, and these in turn strike the wires. The pitch of any one string will depend upon the length, the tension, and the weight of the string. In tuning a piano the pitch of the strings is raised or lowered by varying the tension. On the violin the strings are set into vibration by drawing a bow across them, and for the different pitches the lengths are varied by pressing down the strings at the proper places on the finger board. In the banjo and mandolin the strings are varied in length in the same way, but they are set into vibration by being picked. The guitar is played in a similar manner. Since these strings can set only a small volume of air into vibration and produce only relatively little volume, the instruments are provided with a sounding board of some kind. This sounding board vibrates in unison with the strings, and on account of its larger area it can set a greater volume of air into vibration.

In the vibrating membrane type of instrument such as the drum, etc., the membrane is struck with a stick or mallet and in this manner set into vibration. In the kettle drum the pitch can be varied within certain limits by regulating the tension of the membrane. The human voice also comes under this classification. In one's throat there is a pair of fine membranes known as the vocal cords; and when these cords are set into vibration, sounds are produced. By changing the muscular tension on these cords the pitch of the voice is changed, while the nature or quality of the voice depends upon the shape of the mouth and lips. Here again it is the nature of the vibration (quality of overtones present) that enables us to distinguish one person's voice from another.

FACTS ABOUT LOUD SPEAKERS

The design and construction of a loud speaker is by no means a simple matter in view of the conditions under which it must operate and the requirements that it is expected to measure up to. For example, an 80-piece brass band playing a fortissimo movement in a large auditorium must be reproduced just as naturally in a small room at home as a woman standing before a microphone and talking in a natural tone, even though the volume in the former case is a small fractional part of that which originally entered the microphone. Then on the other hand, it is often desirable to have a speaker introduce certain distortional effects in order to compensate for deficiencies some where else in the system. Although the tones that enter the microphone range in frequency from 15 or 16 to 12000 cycles per second, a loud speaker will deliver quite satisfactory results if its range is limited from 30 to 8000 cycles per second. In fact, many audio frequency transformers are designed to cut off sharply at from 5000 to 6000 cycles per second so as to eliminate unpleasant background noises and hisses. No preference must be shown for any frequency or group of frequencies, otherwise notes with a pitch falling within this group would be emphasized too highly.

The actual operating efficiency of most loud speakers of today is very low, ranging from one-half of one per cent to only four per cent. The average speaker designed for home use has an efficiency of about two per cent. In other words, for every unit of sound energy put out by the speaker, fifty units or more of electric energy must be supplied by the power tube in the output audio stage. If it were not for these low efficiencies, there would be no demand for the large capacity power tubes. With a speaker efficiency of only 50 per cent the 199 type tube could furnish all the energy that would be necessary for most reception purposes. Better speaker efficiency would, therefore, greatly reduce the cost of radio receivers in that less audio equipment would be needed.

CLASSIFICATION OF LOUD SPEAKERS

Although various attempts have been made to design and construct loud speakers on a number of basically different principles, most speakers in use today depend for their operation upon the variable magnetic action of a fixed magnet on a movable iron diaphragm, armature or coil. It is in the arrangement of these magnetic circuits that the various types of speakers differ from each other.

Speakers in which the fixed magnet is a permanent magnet generally of the horseshoe type, are commonly known as magnetic speakers; while those in which a fixed electromagnet is used consisting of a current carrying coil wound on a soft iron core, are referred to as electromagnetic. Speakers are further classified according to the nature of the actuated device as iron diaphragm, balanced armature, and moving coil types. The dynamic speaker in such common use today, consists of a powerful electromagnet and a movable coil. In all of these speakers the fixed magnet sets up a constant magnetic field upon which is superimposed a second magnetic field which fluctuates in accordance with the variable current supplied by the audio frequency amplifier. The action of these two magnetic fields causes a variable pull on the armature or movable coil, and these in turn set into vibration the column of air or paper cone which sends out the sound waves.

The iron diaphragm unit is the simplest and earliest of all, and is similar in construction to the familiar watch-case telephone receiver. In these a laminated permanent magnet semicircular in shape is used, and around the pole pieces are wound coils of fine wire. These coils are connected in series to the output of the audio amplifier. Supported at a very short distance above the pole pieces is the iron diaphragm which is pulled downward against its own spring tension. As the audio frequency currents flow through the coils, the magnetic pull varies accordingly and the diaphragm is consequently set into vibration.

In the balanced armature type of unit a powerful permanent magnet also is employed, and between the two pole faces is a soft iron bar or armature which acts as the core of the coil carrying the audio frequency current. This armature bar is pivoted at the center, and can swing in a small arc, but is held in check by a light spring. The ends of the bar rest between the split pole pieces of the permanent magnet, and to one end is attached a small rod or lever that connects with an aluminum or mica diaphragm. As the audio frequency current flows through the armature coil, the magnetism within the bar changes, and this causes a variable magnetic pull upon it by the permanent magnet. The motion of the armature bar is then transferred to the diaphragm, and the vibration of the latter sends out the sound waves.

Loud speakers can further be classified as horn and cone speakers. The function of the horn is to provide a column of air for loading the diaphragm and for radiating the energy which the diaphragm is ready to deliver. The shape and size of the horn have a great deal to do with the successful performance of a speaker. At certain pitches the frequency of the emitted sound waves is the same as the natural vibrating frequency of the diaphragm, and when such a condition occurs the speaker unit rattles. But with a longer column of air this effect is greatly lessened. Best performance is obtained if the initial throat area of the horn is as small as possible without introducing appreciable air friction, and then have the cross-sectional area of the horn increase slowly and uniformly. The greater the opening or bell of the horn is, the less will be the tendency of the horn itself to vibrate in resonance with the air column. In general then, a good horn speaker has a small initial throat area, a slow rate of taper, and a large bell opening. Any of the units described above can be used with a horn type speaker, but the better commercial speakers employ a unit of the balanced armature type with an aluminum or mica diaphragm and a gradually tapering horn with a large opening.

THE CONE SPEAKER

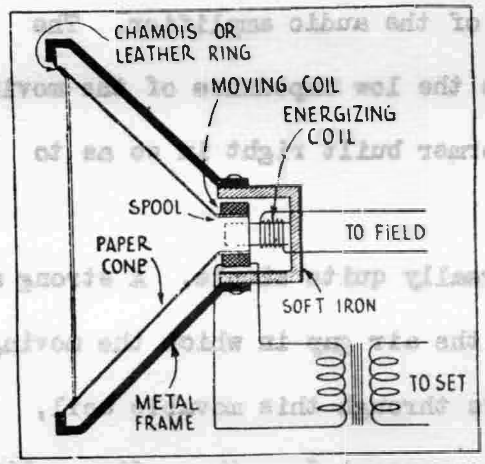
The cone speaker derives its name from the fact that the sound producing element is in the form of a stiff paper cone. The driving unit generally is of the balanced armature type employing a very strong permanent magnet. One end of the armature is connected by means of a rod or lever directly to the apex of the paper cone. As the armature is set into motion by the varying magnetic pull upon it, its movements are transferred directly to the paper cone, and the vibrations of the latter set the surrounding air into vibration, that it radiates the sound waves.

The cone is made of a specially prepared stiff paper treated so that it will retain its shape and stiffness under different conditions of heat and moisture. Cones of various sizes are in use, ranging from 10 to 36 inches in diameter. In the free edge type of cone the paper is secured only at the apex, the outer edge not being supported in any way, while in the fixed edge type of cone the outer edge is securely fastened in some manner. Both types of cones if properly designed give a very good response over the customary frequency range.

One advantage of the cone speaker is that it has practically no directive action. In other words, the sound is distributed uniformly in all directions. The reproduction also is of a very high grade with very little distortion of any kind. However, cone speakers generally require more energy for their best performance, and they should always be supplied from an output power tube. A small set screw is generally provided at the apex of cone speakers for maintaining a firm connection between the paper cone and the armature rod. It is advisable to loosen this set screw occasionally and then tighten it again so as to compensate for any expansion or contraction due to changes in temperatures. Cone speakers must always be handled very carefully as they cannot be built very rigid and are readily thrown out of adjustment.

THE DYNAMIC SPEAKER

The dynamic speaker is a form of movable coil speaker in which the constant magnetic field is established by means of a powerful electromagnet. A good idea of the general constuction of a dynamic speaker can be gained from the diagram shown in the accompanying illustration. The electromagnet consists of a cylindrical shell with the energizing coil wound around the center post. Floating in the air gap between the pole faces is a very light spool that carries the moving coil. This spool is held in place by means of two or three fine springs that at the same time serve as electrical connections to the coil. The paper cone also is attached at its apex to the spool carrying the movable coil, and at its outer edge the cone is secured by means of a chamois or thin leather ring to the metal framework. This construction renders the cone with its coil practically full floating; and since this is all built of the lightest material, it has very little inertia. This makes the operating efficiency considerably higher than that of the speakers discussed previously.



Several types of windings are in use for the energizing coil of the field magnet, depending upon the kind of electric power that is available. In the battery type speaker the winding is designed to be connected across a 6-volt storage battery, and when so used it consumes a current of $\frac{1}{2}$ ampere. The power consumption (volts x amperes) is thus 3 watts. In the 110-volt alternating current type speakers a step-down transformer is used which reduces the pressure to 6 volts. With a rectifier the alternating current is then changed to direct current and in this form issupplied to the field winding. The same winding can therefore, be used for both types. In the 100-volt D.C. type the winding is connected directly across the line and is designed to consume approximately 40 milliamperes (.04 ampere). A very common scheme is to use the field winding of the 100-volt D.C. type speaker as one of the choke coils in the filter system of the B-power supply. This is a satisfactory and at the same time very economical method. In another type of dynamic speaker an 80 rectifying tube is used for converting the alternating to direct current, while some of the newer 110-volt A.C. speakers employ a dry rectifier directly across the A.C. line and in this way eliminate the use of a step-down transformer. At the same time the possibility of a hum is also reduced.

The impedance of the movable coil is rather low (in most types of speakers about 150 turns are used), and consequently some form of transformer must be used to couple the speaker to the output tube of the audio amplifier. The secondary of this coupling transformer matches the low impedance of the moving coil. Most speakers have the coupling transformer built right in so as to form an integral part of the entire unit.

The operation of the dynamic speaker is really quite simple. A strong magnetic field is set up by the electromagnet in the air gap in which the moving coil is suspended. As long as no current flows through this movable coil, nothing happens; but as soon as the fluctuating current from the audio amplifier is sent through it, it sets up a correspondingly variable magnetic field that reacts with the field of the electromagnet. This magnetic reaction causes the cone to vibrate back and forth in unison with the audio current fluctuations. Since the cone is very light, it responds very quickly, and as a result excellent reproduction is obtained. Great volume is obtainable with good dynamic speakers, depending of course upon the capacity of the power amplifier that is used.

The hum neutralizing coil is a special arrangement used in some dynamic speakers designed for use with rectified alternating current. It consists of a coil wound around the center core or pole of the field magnet and is connected in series with the moving coil. It is wound opposite in direction to the moving coil, and is so constructed that it will pickup in opposite phase the same amount of hum as is caused by the field in the movable coil. As a result the induced hum picked up by the moving coil and the hum in the neutralizing coil balance out, and very little hum is heard from the speaker itself.

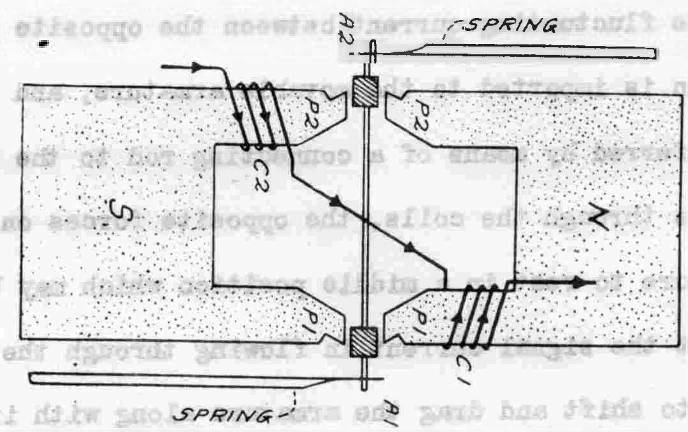
The condition equalizer is another arrangement on some dynamic speakers for controlling the tone quality of the output. It consists of a rotary switch by means of which several different shunt capacities up to about 0.05 mfd. can be connected across the primary of the input or coupling transformer. These shunt capacities control the response of the speaker to the higher frequencies and the more prominent the lower frequencies become. In this way the speaker can be caused to respond in such a manner as to compensate for any frequency preferences that may be shown by a radio receiver or amplifier. The speaker can be caused to emphasize the upper or lower frequencies just as is desired by the listener. The equalizer also reduces the needle scratch when an electric phonograph pick-up is used.

In order to obtain best results from a dynamic speaker, it should be mounted in a cabinet or on a baffle board. The baffle board itself should be at least 3/4 inch thick or better, for thinner boards will vibrate in unison with the sound waves at the middle and lower frequencies. Since the cone of the speaker moves in a back and forth motion, the sound waves created at the front and rear of the cone would interfere and partly eliminate each other. But with a baffle board they would have to travel completely around the board before they could meet, and the interference would be reduced or eliminated. For best results the shortest distance around the baffle from the front to the rear of the cone should be at least one-fourth the wave length of the lowest note to be reproduced. If this low frequency is around 100 cycles per second, the wave length would be 1100 divided by 100 or 11 feet, and one-fourth of this would be 2-3/4 feet or 33 inches. In other words the baffle should be about 33 inches in diameter. Where such a large baffle board would be inconvenient a cabinet baffle can be used, that is the speaker can be mounted in a suitable cabinet, but too deep a cabinet also is likely to cause trouble in that the air column within would produce resonant or deep barrel effects at certain frequencies. If a cabinet is used as a baffle, the rear of the cabinet should be left open. Enclosing the speaker in a box will not work at all. The ideal arrangement is to mount the speaker in the center of a large wall if this is possible, for then the baffle is large enough to enable the speaker to produce the lowest notes effectively. In general it can be said that the dynamic speaker is capable of excellent reproduction if properly designed. The ribbed paper cone construction used in some speakers is to reduce the horn effect that the plain paper cone produces at the higher frequencies. Another scheme used to correct this horn effect is to incorporate a suitable equalizer-filter in the speaker. Due to the horn effect the speakers tend to greatly emphasize the higher pitched notes. An excellent material to use as a baffle is 1-inch thick celotex board, for this substance is not subject to vibration.

In the A.C. dynamic speakers an unpleasant hum is at times experienced; and if no provision is made by the manufacturers for balancing out this hum, the following scheme will always be found very effective. The object is to absorb these pulsations, and for this purpose special A-filter type condensers are now available. These condensers have a low voltage rating but a large capacity, units being available in 1000, 2000 and 4000 mfd. capacities. These condensers are then connected directly across the field coil of the speaker and will produce very satisfactory results. Examine the speaker and the wires, then carefully trace the wires until the two leads are found that run from the rectifier to the field coil. It is across these two wires that the A condsnser is then connected. If the 2000-mfd. capacity is not large enough, the 4000-mfd. will be found more effective.

THE INDUCTOR DYNAMIC SPEAKER

The inductor dynamic speaker is the latest development in the field of loud speakers, and is intended to combine in a new unit the simplicity, light weight and low cost of the magnetic speaker with the tone quality and frequency range of the dynamic speaker. It was developed primarily for the commercial set manufacturer for whom the dynamic speaker was too complicated and too costly in order to produce a satisfactory low priced competitive radio receiver. The inductor dynamic speaker is a reproducer that will deliver excellent volume and good tone quality and at the same time is simple in construction and low in cost.



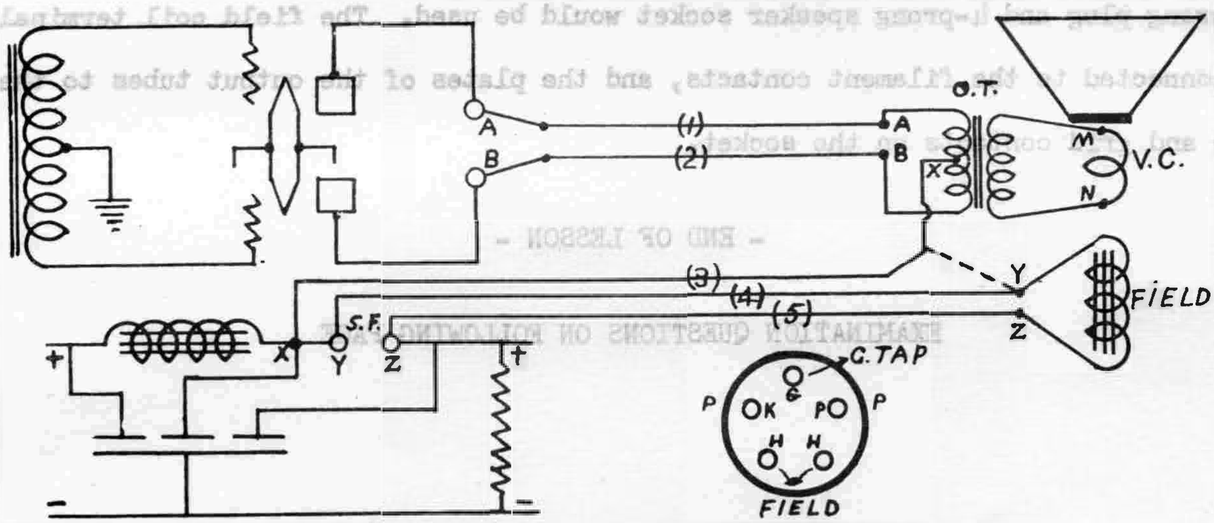
Although in appearance the inductor dynamic resembles the familiar magnetic speaker, still close examination will reveal that it is larger, more powerful and more refined. It has a permanent magnetic field in the form of a pair of strong horseshoe magnets, but its driving mechanism is quite free to move as compared to the rigidity of the magnetic unit. The construction is clearly illustrated in the accompanying schematic diagram. Between the two pole pieces

P-1 and P-2 is suspended freely a pair of armature bars A-1 and A-2 that are connected by tie rods and held in place by means of light strip springs. The gaps between the armature bars and pole faces remain constant due to the action of the springs, but the area by which the armature bars and pole faces overlap is varied as the armature is set in motion by the magnetic action. Around diagonally opposite pole pieces are found the coils C-1 and C-2. These coils are connected in series and to the output of the audio amplifier. As the current flows through these windings in the direction indicated, it increases the magnetic flux through the pole legs P-1 and decreases it through P-2. As a result a greater force is exerted on the armature bar A-1 than A-2, and the bars move in the direction indicated. During the next half cycle the current through coils C-1 and C-2 reverses, pole legs P-2 become the stronger, and the armature bars move in the opposite direction. As a result of the magnetic reactions caused by the fluctuating current between the opposite pole faces, a back and forth motion is imparted to the movable armature, and this vibratory motion is then transferred by means of a connecting rod to the cone itself. When no current flows through the coils, the opposite forces on the two armature bars cause the armature to rest in a middle position which may be called the magnetic center. But the signal current in flowing through the coils causes the magnetic center to shift and drag the armature along with it. Since the distance between the armature and pole faces does not vary, the speaker does not cause a rattle due to what is commonly known as pole slap. The armature moves parallel with the pole faces. However, if great sensitivity and power are desired, the air gap can be made quite small and no stiff restraining spring is required. It is this restraining spring in the magnetic speakers that causes the suppression of the lower notes.

The elimination of the electromagnetic field as is used in the dynamic speaker makes it rather simple to apply the inductor dynamic. In fact, it is connected in the same manner as the magnetic type by means of two connecting cords. Of course, an output transformer or filter is required in order to keep the heavy direct current out of the speaker windings. Another advantage of the inductor dynamic is that if it is to be used in connection with a push-pull amplifier, a tap can be brought out between the two coils C-1 and C-2, so that they will then take the place of the usual output transformer or choke in the amplifier. On a large production scale, this means quite a material saving. In any case the inductor dynamic speaker must be carefully matched to the impedance of the amplifier, and for this reason it is available in four different inductance values, which include virtually all applications.

5-WIRE AND 4-WIRE SPEAKER CONNECTIONS

Practically all A.C. receivers now employ dynamic speakers. A dynamic speaker has two voice coils, a voice coil and a field coil, and there are four terminal connections, M & N for the voice coil (see Fig. 5) and Y and Z for the field coil. The field coil is generally caused to do double duty by also being connected into the filter as a choke coil. This would require two leads running from the set chassis to the speaker, lines (4) and (5) in Fig. 5.



Methods of connecting a dynamic speaker to a radio receiver.

Fig. 5

The voice coil of the speaker must be coupled to the output power tubes through a suitable output transformer, labeled O.T. in the diagram. It is common practice to mount this output transformer directly on the speaker frame so that it forms an integral part of the speaker. To connect the primary of this output transformer to the plates of the power tubes also requires two leads running to the speaker lines (1) and (2) in the diagram. The secondary of the output transformer is connected directly to the voice coil by means of two short wires within the speaker. To supply the high voltage energy to the plates of the output tubes, the center tap X on the transformer primary must be connected to some point on the voltage divider. Generally this connection is made between the first and second filter chokes, or between the first choke and the speaker field, point X in the diagram. However, another line, No. (3), must be run from the chassis to the speaker. There are thus five wires connecting the speaker to the chassis.

It is possible to reduce the number of connecting wires from five to four in the following manner. Instead of connecting point X on the filter to the tap X on the transformer by means of a long wire such as No. (3), simply connect point X on the transformer to terminal Y of the field coil right within the speaker. The electrical circuit will be the same, and the number of wires has been reduced. In this case, a 4-prong plug and 4-prong speaker socket would be used. The field coil terminals are connected to the filament contacts, and the plates of the output tubes to the plate and grid contacts on the socket.

- END OF LESSON -

EXAMINATION QUESTIONS ON FOLLOWING PAGE