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Complete Course in PRACTICAL RADIO

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Lesson Text No. 14

RADIO SOUND REPRODUCERS

Originators of Radio Home Study Courses
··· Established 1914 ···
Washington, D. C.

"Heaven is not reached at a single bound, but we build the ladder by which we rise from the lowly earth to the vaulted skies and we mount to its summit round by round."—Josiah Gilbert Holland.

SOME GOOD STUDY HABITS

A Personal Message from J. E. Smith

Despatch. There is no habit more detrimental to good mental work than procrastination. Procrastination is not a "disease," as someone has said, but it is a habit. Putting it off until tomorrow merely encourages putting it off another day. "Some people," says Swift, "again, are always making resolutions—always promising themselves to begin work vigorously, tomorrow, always waiting for a great and perhaps conspicuous opportunity to do social service, always preparing to break a bad habit; and then, as the habit postponement becomes fixed, moments of anguish come, followed by periods of elation, as emotional virtue again soothes the mind. These people are rich in purposes, resolutions, and plans, but they never cross the Rubicon and burn the bridges."

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RADIO SOUND REPRODUCERS

Radio's success has largely depended upon the quality and faithfulness of reproduction from the sound producing device, whether it came from the first headsets, or our latest dynamic loud speakers of today. Radio reception today is quality reception and this faithfulness of reproduction is the result of intensive and exhaustive studies and development on Acoustical (sound producing) Devices.

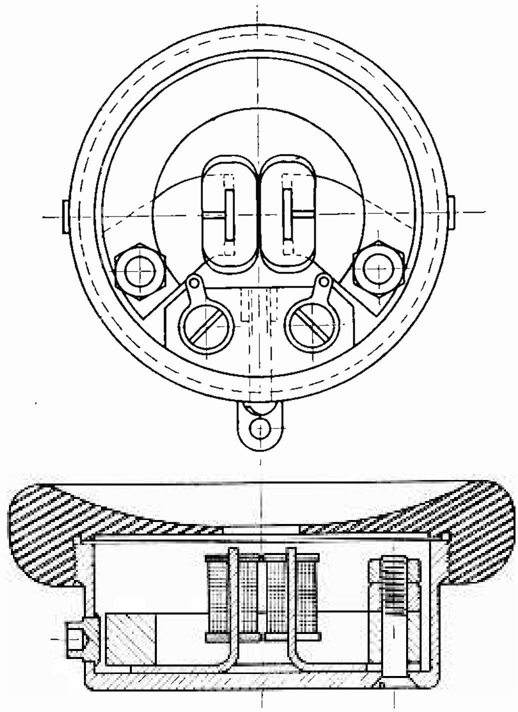

Fig. 1—Illustration showing details of the bi-polar type headphone unit.

The types of Acoustical Devices illustrated and described in this text are those used for listening to the speech and music of a radio broadcast receiver. The first acoustical device used in radio was the headset, and for years the principle employed in headset units was used in loud speaker devices. Even today, the principle used in one of the old standard headsets is still used.

Acoustical devices for radio broadcast reception should be distinctly classified into two groups: Telephone Headsets and Loud speakers or Reproducers. The loud speaker of today is the result of careful study and development of the ordinary headset, and, for this reason, due and careful consideration must be given to the types, theory and performance of the telephone headset.

TELEPHONE HEADSET

The telephone headset is known to us as headphones, earphones, or headsets, or those devices used over the ears for

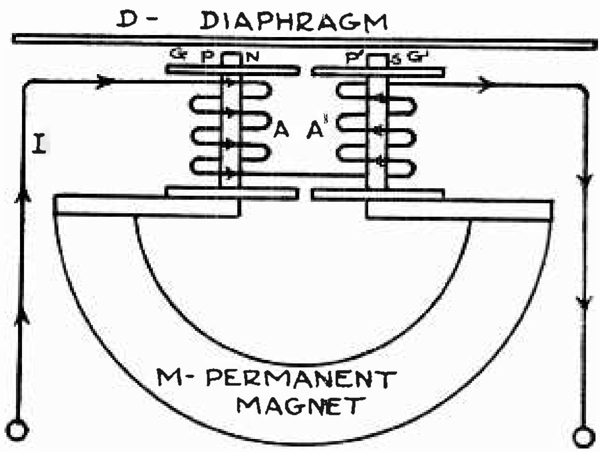

Fig. 2—Bi-polar type headphone unit.

listening in during the old days of first broadcasting of music. Before the era of broadcasting, these devices were used by radio operators on ships and land stations. Few realize today that these same units formed the foundation of the first important loud speaker devices.

There are two important types of telephone headsets, **bi-polar** and **balanced armature.** The bi-polar type is illustrated in Figs. 1 and 2, and the balanced armature in Figs. 3 and 4.

Referring to Fig. 2: A and A^1 represent the pole pieces which consist of bobbins with many thousands of turns of wire and the iron pole pieces P and P^1; D the diaphragm; G and G^1 the air gaps between pole pieces and diaphragm; and M the permanent magnet. Permanent magnets are used because they produce a greater response for a given current than obtained with soft iron magnets. As current I passes through the winding as indicated, the pole pieces P and P^1 become north and south respectively, setting up a magnetic field around the pole pieces. This magnetic field passes through the diaphragm. The diaphragm attracted to the pole pieces depends upon **two factors**, the **strength of the magnetic field** and the **strength of the magnets.** The current which passes through the bobbins, being a pulsating current, that is always in the same direction, but varying in strength from a minimum to a maximum, the diaphragm is attracted to the pole pieces when the current is maximum and returns to its neutral position when the current is zero.

The strength of the magnetic field around the pole pieces is directly proportional to the amount of current passing through the bobbins, the number of turns in the bobbins, and the quality

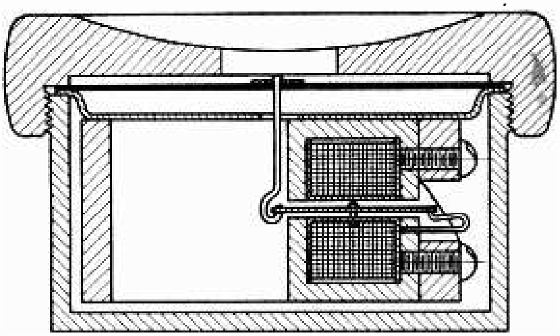

Fig. 3—Constructional details of balanced armature type headphone unit.

of steel in the pole pieces. The product of the number of turns and the current in the bobbin is known as the ampere turns of the bobbin, that is current times number of turns, and this should be a maximum. In telephone headsets, three to five thousand turns of very small enamel wire, generally No. 40 to No. 42 B. & S. gauge, are used in bobbins. Since the quality of iron in the pole pieces plays a very important part, only the best grades of iron are used, such as high grade Swedish iron, very carefully treated pure soft iron free from impurities, or the good grades of silicon steels having 3 to 5% silicon content.

The magnetic field above the pole pieces passes through the diaphragm D, and the quality of this diaphragm metal is of the best, such as soft iron or silicon steel. In headsets, where the ear piece comes in contact with the air and ear, the diaphragm is lacquered or japanned to prevent rusting.

The length of the air gaps G and G^1 is dependent only upon the amount of maximum vibration of the diaphragm, the gaps being so adjusted that the diaphragm will not touch the pole pieces.

The permanent magnet M is of sufficient size and strength to initially magnetize the pole pieces P and P^1. This magnet is so designed that it will not lose its magnetism in time. Chrome and Tungsten magnets are generally employed. In the high grade units Tungsten magnets are used because they hold their magnetism for a much longer time than Chrome magnets.

The theory of a telephone headset unit is best understood perhaps by analyzing the changes occurring in the magnetic circuit which, of course, is the important factor to take into consideration when transforming electric current into sound waves.

The attraction or pull of the diaphragm to the pole pieces is approximately proportional to the square of the magnetic field passing from pole to pole through the metal of the diaphragm.

From the above paragraph, it can be seen that the greater the permanent magnetic field, or flux, as it is sometimes called, the greater will be the efficiency of a good telephone headset unit. The magnetic field is increased by strengthening the magnet or by using thicker diaphragms, also by reducing the air gaps between the diaphragm and the pole pieces, but the magnetic saturation of the diaphragm sets the limit to useful increase of strength of the magnet as readily becomes evident. If, with a certain thickness of diaphragm, we unnecessarily increase the strength of the magnet in the unit, the superfluous magnetic field will cause a magnetic leakage which will be wasted as it cannot be crowded through the diaphragm.

With diaphragms of a given diameter, a thicker one carries more magnetic lines, is stiffer and can, therefore, be brought nearer to the pole pieces, but a limit to the thickness of the diaphragm is soon imposed by the increase of thickness and inertia, and also by the decrease in the natural period of vibration of the diaphragm, which should also be in the neighborhood of the periodicity of the current sent through the unit. As the diaphragm is a stretched elastic body it tends to vibrate most easily and perfectly at a frequency depending upon its construction and elastic properties, which is known as its natural frequency, hence it is found that if the input current to the unit is kept constant in amplitude, but if its frequency is varied, then the greatest response or motion of the diaphragm occurs when the impressed frequency is identical to the natural frequency of the diaphragm.

Figures 3 and 4 represent the balanced armature type of headset unit:

In the balanced armature type of unit, a soft iron armature is placed in the center of a coil, mechanically supported at the middle, and the diaphragm is connected to one end of the armature by a connecting link. Tips of two sets of pole pieces are located at both ends of the armature, and these pole pieces are magnetized by the permanent magnet M. As the current passes through the single winding as indicated (Fig. 4), the respective ends of the armature become north and south and the armature is

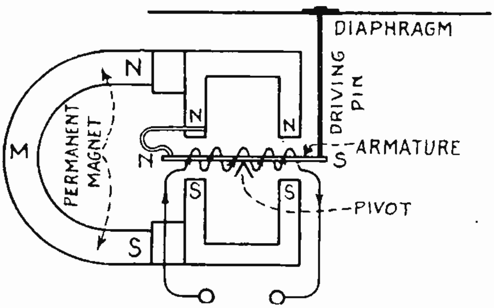

Fig. 4—Balanced armature type headphone unit.

thus caused to pivot at the fulcrum. The attraction or repulsion of the armature to the pole pieces is governed by the same laws as in the bi-polar unit, the pivoted movement of the armature depending upon the amount of current passing through the coil, the number of turns in the coil, the quality of the iron of the armature and pole pieces and the strength of the magnetic field at the pole pieces.

With the proper design of pole pieces, diaphragm, magnets, etc., very efficient telephone headsets were developed and manufactured in great quantities, especially during the first years of radio broadcasting. During the years of 1922, 1923 and 1924 manufacturers were producing great quantities of these headsets and one manufacturer produced as high as seven to eight thousand headsets a day.

Soon after broadcasting seriously gripped the country many headsets were used in a single home, several persons sitting around a single radio receiver, each with a headphone clamped on his or her head, listening intensively to the broadcasting received. It was not long before everyone realized the necessity of an acoustical device such that everyone could hear the reception of music or speech from the radio receiver without the inconvenience and uncomfortableness of a telephone headset on one's head. This was seriously appreciated as early as 1923 and all important engineering departments began on this most important development—the **"Loud Speaker"** or **"Reproducer."**

HORN TYPE LOUD SPEAKER OR REPRODUCER

The first loud speaker was nothing more than a horn placed on a telephone receiver unit, as shown in Fig. 5.

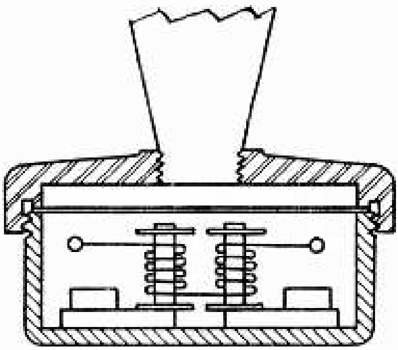

Fig. 5—Illustration showing how a horn can be attached to a headphone unit.

These first loud speakers served the purpose for a time, because they eliminated the use of headsets, but the quality of reproduction from these loud speakers was not as good as from the headset unit. During those days, it was often remarked, "Yes, I like your loud speaker, but for good quality reception, I still use my headset." The public demanded loud speakers and the quickest developed loud speaker was a simple horn on a simple unit. Engineers soon found that pole pieces and component parts designed for telephone headset units were not correct for a loud speaker device.

Referring again to Fig. 2, it was brought out that there were two kinds of magnetic fields in the magnetic circuit, the permanent magnetic field produced by the permanent magnet and the varying or fluctuating magnetic field produced by the pulsating current passing through the bobbin coils. In following both of these fields through the magnetic circuit, they both have the same path, that is, from one pole piece through air gap G, through diaphragm D, across air gap G^1 to the other pole piece and through the permanent magnet back to the first pole piece. Due to the high reluctance or magnetic resistivity of the permanent magnet to this varying magnetic flux, if some other path could be provided besides going through the permanent magnet the varying magnetic flux would be stronger at the pole piece tips P and P^1. Such a path was made available in the improved horn speakers.

Figure 6 shows the redesign of pole pieces of a telephone unit for a horn type loud speaker. R is a very small reluctance (magnetic equivalent of electrical resistance) gap between five to ten

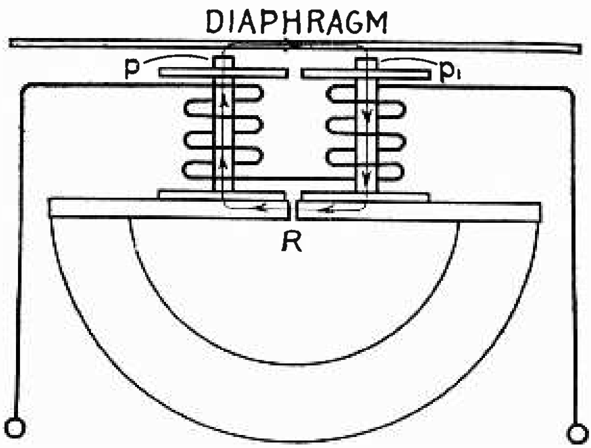

Fig. 6—The segregation of the current in a horn type loud speaker.

thousandths of an inch, to prevent magnetic short circuit of the permanent flux from the permanent magnet, but which allows a very good path for the varying magnetic flux as shown by arrows. This not only increased the magnetic force upon the diaphragm, but increased the efficiency of the loud speaker unit at the lower frequencies.

In ordinary telephone headsets the energy passing through the unit was so small that laminating the pole pieces did not appreciably help its efficiency, but in loud speaker units, the energy coming from first and second stage audio amplifiers, it was found that laminating the pole pieces increased its efficiency tremendously. As is appreciated, laminating iron decreases the iron losses, such as eddy currents (stray currents set up in the core of electro-magnets) and hysteresis (slowness or lagging behind when a change of condition is taking place), and, in laminating the pole pieces in loud speaker units, the principal iron losses are the eddy currents induced in the solid pole pieces.

Larger and thicker diaphragms of silicon steel, bigger and better magnets, redesign and introduction of a reluctance gap in the pole pieces, replaced those of the ordinary telephone improved horn type loud speaker.

HORNS AND THEIR DESIGNS

Two types of horns were first used on loud speaker devices, **conical** and **exponential.** In the conical horn, the area varies directly per unit length as shown in Fig. 7 while in the exponential horn the area varies exponentially per unit length as shown in Fig. 8.

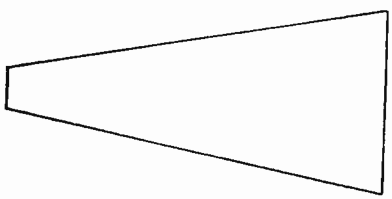

Fig. 7—The conical horn.

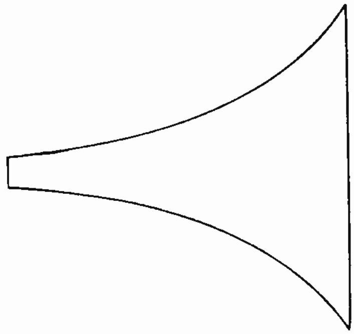

Fig. 8—The exponential horn.

The correct type of horn for a loud speaker is one which places a sufficient air pressure upon the diaphragm, and this air pressure to be gradually released through the horn. The taper of the horn controls the air pressure in the horn, and it is important that this air pressure is not suddenly released until towards the free end of the horn. It is for this reason that the exponential horn is far superior to the conical horn, as, by examining the illustrations, Figs. 7 and 8, the rate of change of areas at the beginning in the respective horns is very much greater in the conical horn than in the exponential. The exponential horn is used now almost entirely.

The length of the horn determines the range of response from the loud speaker. The longer the air column in the horn, the better will be the response of the lower frequencies. As in the case of organ pipes, the longer the air column in an organ tube, the lower will be the note produced. It is, therefore, to be expected that a horn-type speaker with a short horn will sound thin and high pitched, lacking in low notes, whereas a speaker with a very long horn will be rich and full in its response, due to the reproduction of the low notes. Horns vary in length from 18 inches to 120 inches, depending upon how they are used. It is not important what material the horn is made of, providing its walls are strong and thick enough to prevent vibrations setting up a natural period of their own.

UNITS FOR HORN-TYPE SPEAKERS

Besides the bi-polar type of unit for horn-type speakers, the balanced armature and moving coil type of units can be em-

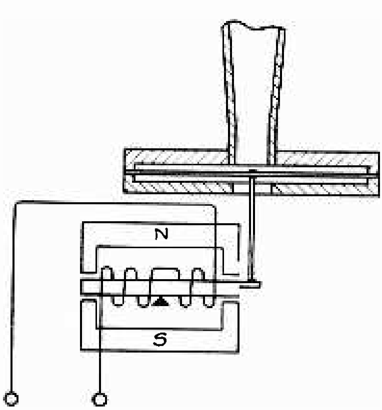

Fig. 9.

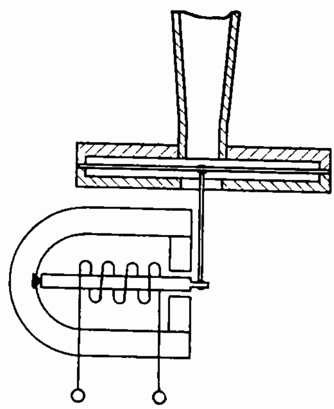

Fig. 10.

Illustrations showing the balanced armature type coil units.

ployed. Two important types of balanced armature horn-type units are shown in Figs. 9 and 10 and the moving coil type is shown in Fig. 11.

The importance of **steels, windings, air gaps** and **magnets** in balanced armature type of units hold the same as bi-polar type of units, and the same efficiency and performance can be obtained from both. The bi-polar type of unit has its advantages in its simplicity of design for mass production whereas the balanced armature has the advantages of slightly better performance by its adaptability to employing special diaphragms which will be taken up later.

The moving-coil type of unit for horn-type speakers was introduced early in 1924. It was first invented by Sir Oliver

Lodge in 1898, in which he employed large thin pieces of wood for diaphragms.

The theory and operation of this very important moving coil system is as follows:

Figure 12 shows the principle of the moving coil unit. Around the center core of the shell type casting A is a large magnetizing coil B. When this type of unit came out for a horn-type speaker, this winding, which is called the "energizing field," was designed for 6 volts, drawing one to three amperes in order that it could be used with a standard 6-volt battery. This winding magnetizes the shell iron casting A, so that the center core B is

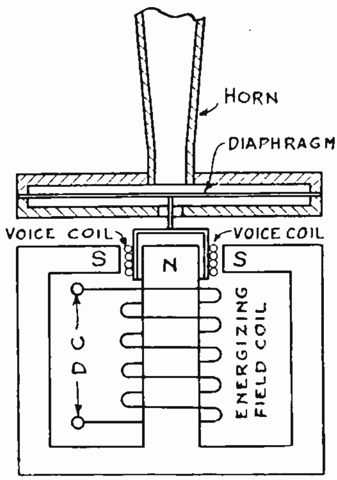

Fig. 11—The original moving coil type loud speaker unit.

"North" and the outer ring "South" as indicated. Centrally located in the gap between the center core and outer ring is a small coil "V.C.," known as the "Voice Coil." This voice coil is in a gap of a very strong magnetic field, set up by the energizing field "B." The current which is passed through this voice coil is an **alternating current** from the last tube of an audio amplifier. The coil is shown cross-sectionally. Now let us assume that the current in the **left winding** is coming towards us, as represented by the "arrow," and the current in the **right winding** is going away from us, as represented by the other "arrow." It is the law of a motor that when a current is passed through a coil of wire in a magnetic field the wire will be forced to move, and by the left-hand rule for a motor, the movement of the voice coil is "down." When the current in the voice coil is reversed, the movement of the coil is "up." By the movement of the voice coil the diaphragm is caused to vibrate.

This type of unit for a horn-type loud speaker was not very popular, because the field coil was too much of a drain upon the six-volt storage battery, running down the battery too quickly which meant that the battery had to be recharged often. The response of this type of speaker was very little better than the other existing bi-polar and balanced armature types, and yet this moving coil principle was soon to become the outstanding development of the "Cone Dynamic Speakers."

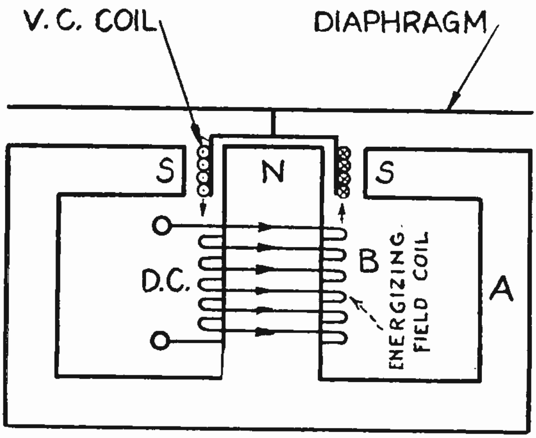

Fig. 12—Illustration showing the principle of the moving coil speaker with shell type casting. This unit was the forerunner of the dynamic speaker of today.

DIAPHRAGMS FOR HORN-TYPE SPEAKERS

Diaphragms in horn-type speakers vary in diameter from 1½ inches to 4 and 5 inches, and in thickness from .006″ to .032″. Larger diaphragms are used in loud speakers than headsets in order to obtain greater frequency response.

Diaphragms employed in bi-polar type of units are perfectly flat and made of a good grade of magnetic material, generally silicon steel.

In the balanced armature type of unit, great varieties of diaphragms are used, several of which are illustrated in Figs. 13 and 14.

Figure 13 shows at the left a flat corrugated type of diaphragm commonly used, the material of which is generally light pressed aluminum, the corrugations running concentrically. The corrugations not only add stiffness and rigidity to the diaphragm, but break up the tendency of a diaphragm to have local vibrations of its own. This figure also shows two types of conical diaphragms, one being plain and the other corrugated. Light pressed aluminum is very often used in these types of diaphragms. By making the diaphragm in the form of a cone, greater rigidity is obtained, and slightly better performance results. Figure 14 illustrates one type of diaphragm made of a

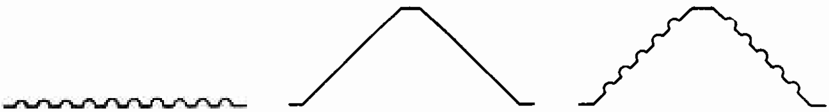

Fig. 13—Different types of diaphragms.

non-magnetic material, a moulded composition, its thickness at the center being greater than at its edges. A magnetic metal button is fastened at the center.

Most of the diaphragms are clamped at the edges, but not clamped rigidly, two methods of which are shown in Figs. 15 and 16.

Figure 15 shows where two rubber tubings are used on each side of the diaphragm, the pressure of the clamping depending upon the compression of the rubber tubing against the diaphragm. Fig. 16 shows a similar method whereas rubber gaskets are used in place of the rubber tubing. By clamping the diaphragm between rubber tubings or gaskets, the diaphragm is not

Fig. 14—A type of diaphragm made of a non-magnetic material, the thickness at the center being greater than at its edges.

rigidly held at its edges and it has a greater freedom of vibration, particularly helpful for the response of the lower frequencies.

LIMITATIONS OF A HORN-TYPE SPEAKER

It has been brought out in this text that the first horn-type speaker was nothing more than a horn on an ordinary headset unit, but great improvements were made by proper detail consideration of unit design, larger and thicker diaphragms and longer and better horns. However, after all of these improvements were made it was still noticed that speech and music was not distinct and clear, lacking in good articulation, and reproduction of music at times unnatural with an overexaggeration of the low notes.

The lower frequencies of a horn-type speaker can be controlled by the following factors:

(1) Low reluctance magnetic circuits.

(2) Large diaphragms.

(3) Long air column horns.

(4) Strong magnetic fields.

The higher frequencies can be controlled by—

(1) Laminated magnetic pole pieces, to reduce the magnetic losses.

(2) Small or thick diaphragms.

(3) Short horns.

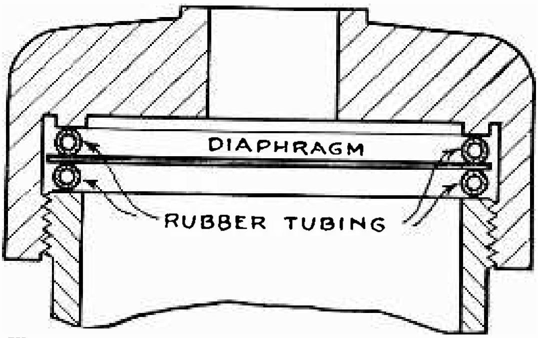

Fig. 15—Illustration showing how two rubber tubings are placed on each side of the diaphragm.

For good reproduction of speech and music a loud speaker should reproduce frequencies from 100 cycles to 5000 cycles per second, that is, the diaphragm should be able to respond faithfully from 100 vibrations to 5000 vibrations per second.

Because a diaphragm is clamped at its edges, it is very difficult for it to vibrate at a very high frequency, the best horn-type speaker being only capable of vibration as high as 2500 to 3000 cycles per second. Also to obtain the fundamental notes at 100 to 200 cycles, the diaphragms would necessarily have to be very large, and if too large to get the lower frequencies, the higher frequencies would suffer. The use of very long horns to obtain these low notes is an economical difficulty both in development and manufacture. At its best, the choice of parts in the design of a horn-type speaker is a compromise. Satisfactory high frequencies could not be obtained and lower frequencies were obtained with difficulty. This was the problem in horn-type speakers when the cone type was introduced.

HISTORY OF THE CONE-TYPE SPEAKER

The first cone type of speaker known to be used as a real sound producing device was in 1908 when two English scientists, Starling and Cole, used a cone to reproduce music from a phonograph record, as shown in Fig. 17.

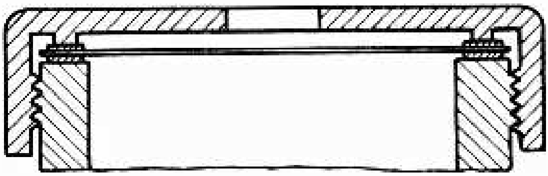

Fig. 16—Illustration showing how rubber gaskets are used in place of the rubber tubing, as shown in Figure 15.

A is an ordinary 2″ mailing tube, with a cone 6″ in diameter made of manila paper, glued at its apex to one end of the mailing tube. As the mailing tube rides over the tubular reproducing record, the mechanical vibrations from the record are transferred to the mailing tube, and thus to the cone, giving a feeble response of sound. This device was only used where loud response

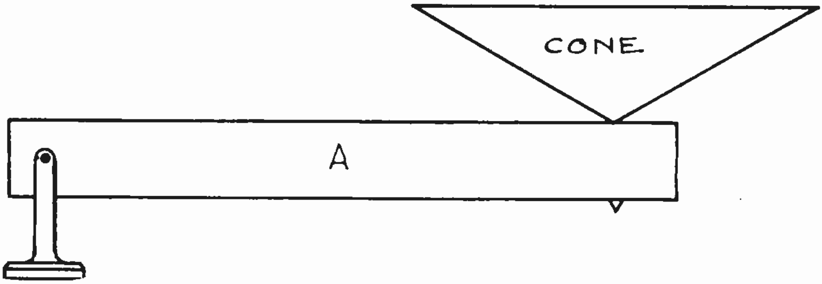

Fig. 17—Diagram showing how the first cone type of loud speaker was used. It consisted of a mailing tube with a cone attached at one end.

was not required, for if this cone vibrated too much, its edges would whip and vibrate in a local vibration causing rattles.

Of course cone-type diaphragms were used in horn-type speakers but their diameters rarely exceeded 4″ and were not used as a direct acting radiator of sound.

In 1918 the first important patent on a cone-type invention was allowed to Marcus L. Hopkins in his letters patent No. 1271529, granted July 2, 1918, but it was some time after 1918 before this was used commercially. The patent relates to a cone diaphragm of the direct acting type, to reproduce sound from a phonograph record. Details of this cone is shown in Fig. 18.

Hopkins calls the portion within the huge bulky rings AA, a tympanum, the other part of the unit consists of a conical central portion C and a plane peripheral portion DD. The edge of the conical portion C is not held rigidly at its edges, and thus the conical portion is free to move in accordance with the vibrations given to it at its apex B. This diaphragm was intended to be used for the reproduction of sound from a phonograph record, but complicated and elaborate mechanical devices were necessary to transfer the mechanical vibrations from the record to the apex of the cone, and, on account of the mechanical parts involved, serious difficulties were encountered and the cone-type

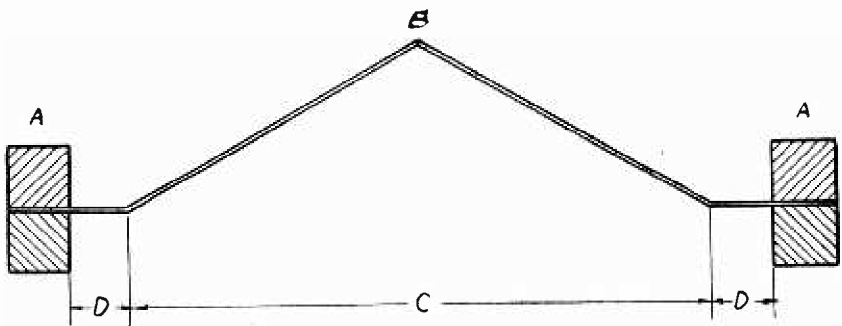

Fig. 18—Details of the original Hopkins cone.

speaker was not very successful in the reproduction of sound from a phonograph record. However, in the cone-type speakers, the construction of the majority of the cones came within the claims of the Hopkins patent, so today a number of manufacturers of cone-type speakers are paying tribute to the Hopkins patent of 1918.

CONE-TYPE SPEAKERS

The introduction of a cone on a unit is a great improvement over the flat and other diaphragms of horn-type speakers. It had been realized for some time that large diaphragms were desirable, but in most cases flat diaphragms made of a variety of materials were used, which proved unsatisfactory because the flat surfaces would break up into local vibrations of their own, introducing harmonics into the original vibrations given to the diaphragm, resulting in distortion. By shaping the diaphragm in the form of a cone the diaphragm became stiff and rigid and vibrates in accordance with the vibrations given to it at its apex.

Constructional details of several types of Cone Speakers are shown in Figs. 19, 20, 20(a) and 24.

Figure 19 shows the constructional details of one early form of interesting cone speaker employing the bi-polar principle, two of these units were used in "Push-Pull." As the current of the windings of one of the units sets up a magnetic field about the pole pieces to attract the armature, the current in the windings of the other unit is in such a direction as to give a magnetic field to repel the armature. The cone is connected to the armature at

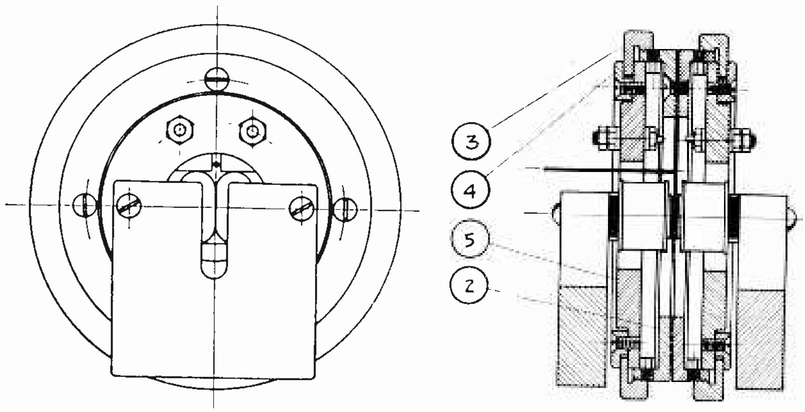

Fig. 19—Drawing showing details of construction of one of the early forms of cone speakers employing the bi-polar principle.

the center by a connecting link. Although this unit was popular for some time, the limitation of a heavy thick armature clamped at its edges prevented satisfactory response of the high frequencies.

In Figures 20 and 20(a) we see again two forms of the balanced armature type units. The balanced armature principle has always been desirable because the mechanical system of the unit itself, consisting of a small armature free to pivot inside an exciting coil, was flexible to satisfactory slow vibrations and capable of extremely high vibrations. These high vibrations were limited to the diaphragms in the horn-type speakers, not to the mechanical system of the unit, and so when cones were employed for diaphragms improvement in results was immediately noticed.

CONES, THEIR STRUCTURE AND THEORY—THE BAFFLE BOARD

The cone when used as a diaphragm is so designed that it is free to vibrate without distortion, in accordance with the mechanical vibration actuated at its apex. By the vibration of the cone, it sets up an air displacement about it and reproduction of sound results.

By referring to Fig. 18, the conical portion C is generally made out of a good grade of paper, ranging in thickness from .005″ to .025″ and from 6″ to 36″ in diameter. A "Waterfalls Ledger" (trade name), Alhambra low frequency and high grade manila are some of the best papers used. The plane peripheral

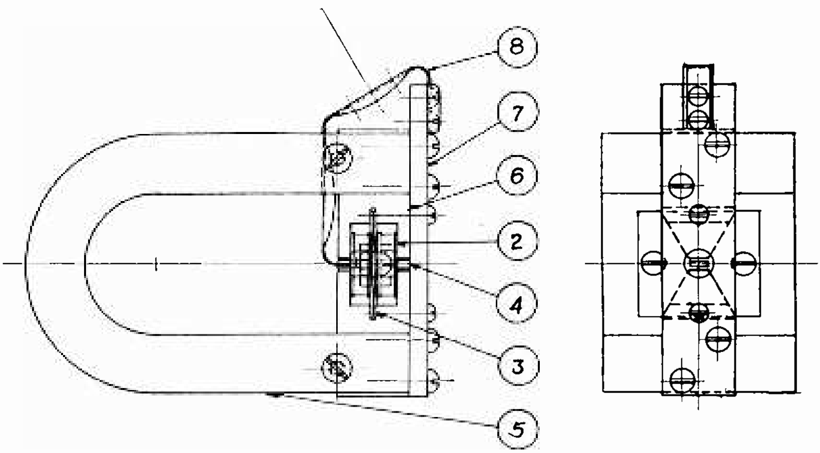

Fig. 20—Constructional details of a balanced armature type of loud speaker unit.

portion D may be paper, rubber, leather or even strings, supported at the ponderous rings AA.

As the apex B is actuated from a mechanical source the cone is set into vibration, as shown in Fig. 21.

In Figure 21 an actual wave vibration is set up from the apex to the edge of the cone, and nodes "N" appearing, depending upon the frequency and the length of the cone from the apex to the edge; the longer this length the greater will be the response from the lower frequencies, as the cone will have a lower natural period.

Cones are generally circular but some cones are made eliptical or egg-shape. There is very little advantage gained in using cones of peculiar design as the cost and difficulty of manufacture do not warrant the little, if any, acoustic gain obtained.

As the cone is made to vibrate, a rarefication of air occurs in front of the cone and a condensation of air in back of the cone setting up sound waves in front and back of the cone opposite in phase relation. If the sound waves emitted from the back of the cone are allowed to come around to the front of the cone, these waves, being in opposite phase to the sound waves emitted from the front of the cone, will neutralize the sound wave from the front. This is particularly noticeable on the lower frequencies or longer waves, since the length of the sound wave at these

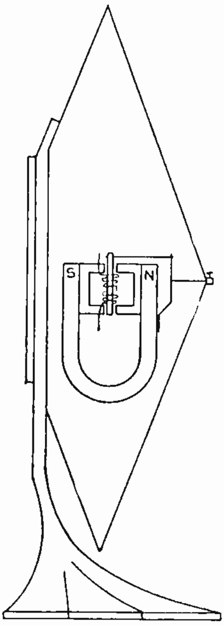

Fig. 20(a)—A transparent view of an early type of cone speaker showing how the loud speaker unit is attached to the large cone.

lower frequencies is sufficient to extend around to the front of the cone.

It is for this reason that the "Baffle Board" plays such an important part in the reproduction of the lower frequencies of a cone speaker.

Figure 22 shows how a baffle board is used with a cone. It can be seen that the baffle board is of such proportions to prevent the sound waves from the back of the cone to interfere with the waves emitted from the front of the cone.

A good baffle board should be made of wood or wall board not less than 3/8" to 1½" of an inch thick. This baffle board should be of non-resonant material so that it will not vibrate or rattle and radiate sound when the unit is being operated. The opening in the baffle board must be of the proper diameter determined by the size of the cone being used. The unit should be mounted behind the baffle board with a felt ring on the front of the cone housing pressed evenly and tightly against the board. The unit should be held in this position by screwing down the base to a shelf provided for that purpose. It is not necessary or desirable to screw the cone housing itself to the baffle board. When a speaker is mounted in a console cabinet care must be taken to insure that it is properly baffled. When the grill opening is larger than the cone a baffle board the size of the cone should be placed behind the grill and the speaker unit mounted tightly against it.

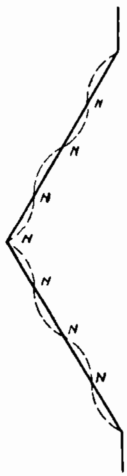

Fig. 21—Illustration showing how the actual wave vibration is set up from the apex to the edge of the cone.

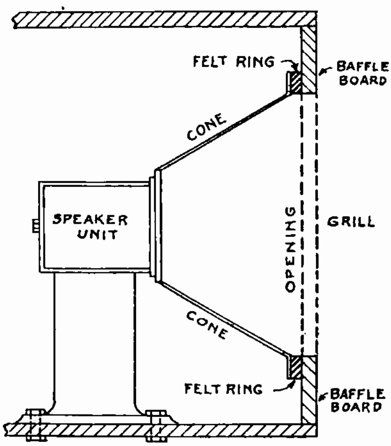

Fig. 22—Illustration showing how a suitable baffle board is used with a cone.

You probably have noticed that when a cone speaker is placed in a cabinet a difference in response is noticed, particularly in the lower frequencies. This is due to the "baffle effect" of the cabinet, the partitions around and behind the cone serving as a good baffle. Very small cones with large baffles can produce practically the same results as large cones with small or no baffles. A cone of large diameter not only reproduces lower frequencies on account of its lower natural frequency, but on account of its large size it acts in itself as a baffle.

Several types of cones are used as illustrated in Fig. 23.

In Figure 23, "A" is the simple type of cone commonly used;

"B" is a popular cone structure, having a back membrane forming a partially enclosed air chamber behind the cone proper; and "C" shows a double cone structure operating from a single unit.

THE DYNAMIC SPEAKER—POWER CONE

The types of cone speakers described so far excell by far the horn-type speakers because they are able to reproduce the higher frequencies much better, going readily as high as 4000 cycles per second, and the reproduction of the lower frequencies is more pleasing and natural.

For a loud speaker to reproduce lower frequencies satisfactorily, the cone and armature must vibrate at large amplitudes. Also for a speaker to give out large volumes, the amplitudes become so great as to cause rattles by the armature hitting

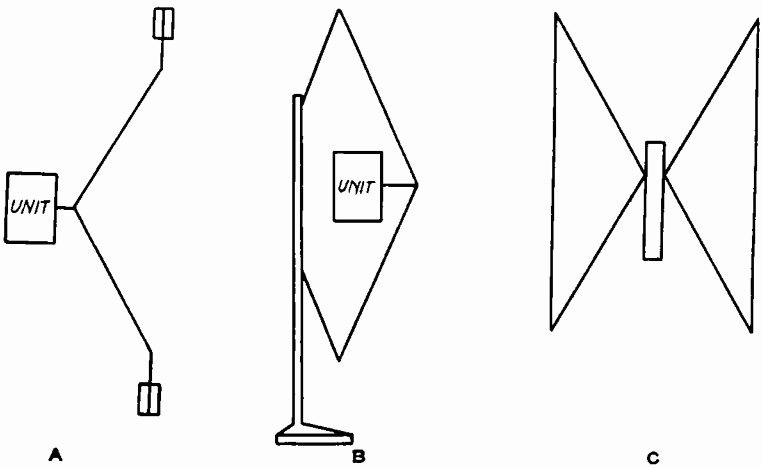

Fig. 23—Several types of cone loud speakers.

against the pole pieces, and distortion by the whipping and movement of the paper cone.

Power from audio amplifying tube circuits is necessary for the proper reproduction of the low notes and volume. Ordinary speakers cannot use this power to full advantage. To obtain better quality of reproduction with large volumes, the "dynamic" or "moving coil" principle of cone speaker was developed.

The reason that they are called "dynamic" speakers is because the moving or voice coil principle is the principle of the motor or dynamo and the reason that they are called "Power Cones" is because this moving coil takes its power from a power tube such as the UX-171A, UX-210, UX-245 and UX-250 to operate it satisfactorily.

The theory of the moving coil principle as explained in reference to Fig. 12 and Figs. 24, 24(a), 25 and 26 show types of important dynamic speakers of today.

The first important commercial dynamic or power cone speaker was developed by C. W. Rice and E. W. Kellogg, two General Electric research engineers of Schenectady, New York. This power cone speaker was put on the market the latter part of 1925. The principle of this speaker is shown in Figs. 24 and 24(a). The field winding is different than that shown in Fig. 12 for a horn-type speaker, inasmuch as it is designed for 100 volts,

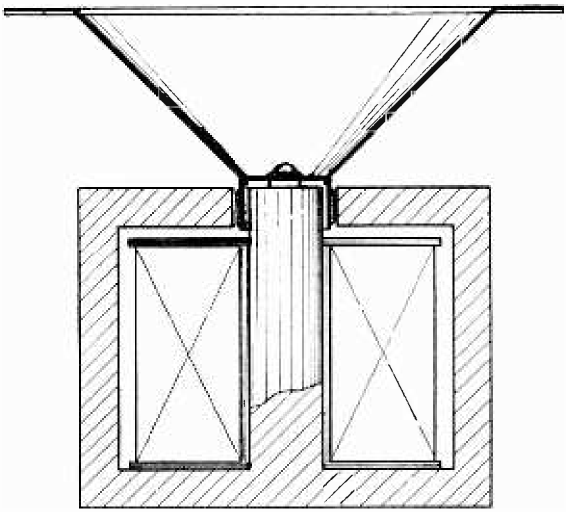

Fig. 24—The first commercial type of dynamic cone speaker.

50 milliamperes, instead of 6 volts, 2 amperes. The voice current coil is wound on a circular tubing and connected to a frustrum of a cone. Glued at the frustrum of the cone is a spider membrane, held to the center core by a screw, to centralize and hold the voice current coil in the magnetic gap, the spider, however, being so designed as not to impede the motion of the cone. The diameter of this cone is six inches, made of manila paper, and placed behind a suitable baffle board. The current in the voice coil is obtained from an output transformer, the primary of which is connected to the plate circuit of a power tube.

Figure 25 shows another type of successful power cone. In this case the voice coil is wound on a circular moulded bobbin which is glued near the apex of the cone and centralized in the magnetic gap by a small leather diaphragm which is stretched between two rings. The small stretched leather diaphragm also aids in the performance of the cone. The cone is a full cone having a diameter of 10″ or 12″ with an apex angle of 120°. The center core of the magnetic circuit is cupped to allow room for the apex of the cone. In this type of dynamic speaker a 350-volt, 50-milliampere field winding is employed, consisting of 50,000 turns of No. 33 B. & S. enamel wire.

Dynamic speakers differ principally in the method of centralizing the voice coil in the magnetic gap. A great many of

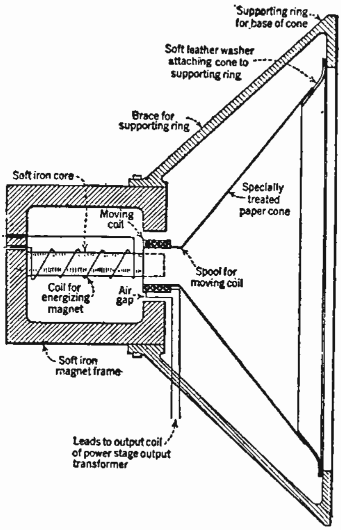

Fig. 24(a)—Construction of the moving coil type of Dynamic Speaker.

these speakers use the three-point suspension for positioning the voice coil, as shown in Fig. 27. Some of the suspensions are non-metallic such as bakelite; others are made of aluminum or phosphorus bronze.

FIELD EXCITATION FOR POWER CONES

When dynamic speakers are used as power cones, to work from the output of power tubes the field excitation consists of a rectified voltage obtained from one of the sections of an electrical filter circuit.

Figure 28 shows a standard electrical rectified filter circuit with the field coil of a dynamic speaker shown as the second reactance or choke coil in the second section of the filter. The field coil, besides being efficiently used for field excitation, serves as a fine choke coil for the filter circuit. By the proper design of the rectifying and filter circuit, any field coil voltages and currents can be readily obtained.

Dynamic speakers which are to be operated from a small power tube, such as the UX-171A, with rectified circuits, do not adapt themselves to such high voltages and currents for field excitation. In these cases separate field excitation must be employed. Two methods are used for this purpose, a vacuum tube rectifier or a dry rectifier. In the vacuum tube rectifier some rectifying tube such as the UX-280 or Raytheon must be used,

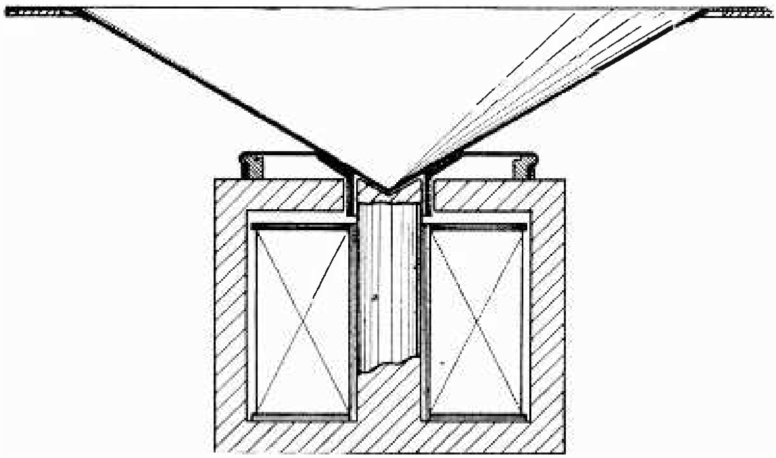

Fig. 25—Another type of power cone.

and the field coil is connected directly across the rectified output. A condenser of 2 or 4 microfarads can be used across the field coil to filter the ripple. Absolute rectification is not necessary in a field coil winding, as quite a large A. C. ripple can be tolerated before it is noticed as a hum in the voice coil. Satisfactory dry metallic plate rectifiers such as the Westinghouse, Kuprox or Elkon dry rectifiers are designed for 6 to 7½ volts one ampere output for dynamic speaker field excitation. Some of these dry rectifiers are designed for much higher voltages, such as 60-100 volts, with 50 to 100 milliamperes output.

ELECTRICAL DATA AND ACOUSTIC MEASUREMENTS

In designing loud speakers it is important that the characteristics of the speaker will fit the condition of the vacuum tubes with which it is to be worked.

The resistance or impedance between the filament and plate elements of vacuum tube power tubes vary from 1800 to 4000 ohms. In order to obtain the maximum power in a loud speaker device, the speaker must be designed to have an impedance to match that of the power tube.

The reason for this is due entirely to a standard electrical rule, such as used when dealing with direct current circuits to get maximum power (watts) output.

The current which will flow in the circuit can be obtained by dividing the voltage of the battery or generator by the resistance of the whole circuit (internal and external added together).

The power in the external circuit will be given by multiplying the voltage drop (the fall of potential caused by the resistance through which the current is flowing) across the external resistance by the current that flows.

The voltage drop across the external resistance is given by multiplying its resistance by the current that flows through it. For example: If we have a 12-volt battery with a **constant internal resistance** of 1 ohm, and a variable resistance, forming an outside circuit, suppose this resistance in the outside circuit is .5 ohm

$$I = \frac{E}{R} = \frac{12}{1 + .5} = \frac{12}{1.5} = 8 \text{ Amperes}$$

Voltage drop $= 8 \times .5 = 4$
Power Output $= 4 \times 8 = 32$ watts

If the external resistance is changed to 1 ohm then we have:

$$I = \frac{E}{R} = \frac{12}{1 + 1} = \frac{12}{2} = 6 \text{ Amperes}$$

Voltage drop $= 6 \times 1 = 6$
Power Output $= 6 \times 6 = 36$ watts

Again if the external resistance is changed to 2 ohms, then we have:

$$I = \frac{E}{R} = \frac{12}{1 + 2} = \frac{12}{3} = 4 \text{ Amperes}$$

Voltage drop $= 4 \times 2 = 8$
Power Output $= 8 \times 4 = 32$ watts

From this it can be seen that a battery gives the most output in watts when the load resistance has the same value as the internal resistance because when the load resistance is lower the current rises and the voltage drops off, and when the external resistance is higher than the internal resistance the current drops

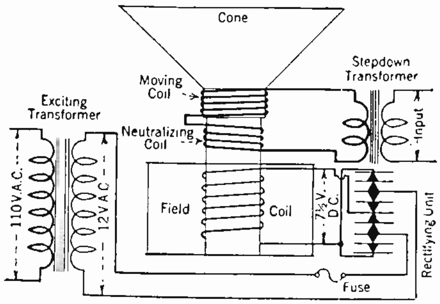

Fig. 26—Circuit diagram of Dynamic Speaker showing connections to moving coil and output transformer, also to field coil from rectifier unit.

off and the voltage rises, therefore the power output is maximum when internal and external resistances are equal or matched.

This same rule applies to a vacuum tube circuit. The difference in impedance between tubes and loud speakers can be taken care of by means of a coupling device (output trans-

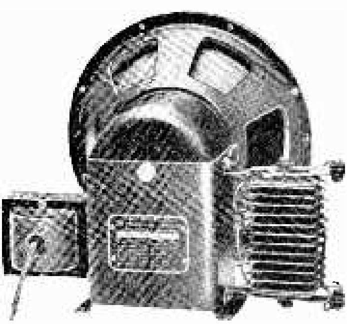

Fig. 26(a)—Rear view of dynamic speaker showing output transformer. and rectifier unit.

former). When this plan is resorted to, it is necessary for the impedance of the transformer primary to approximately match that of the tube. The secondary of this output transformer should have an impedance similar to that of the loud speaker. In this way, it becomes possible to use a low impedance speaker with a high impedance tube, although it is not particularly advisable since the high impedance tubes are not capable of handling any great amount of power and will very likely overload, if they are used to supply certain loud speakers.

Since the plate resistances of various tubes differ especially under different conditions of operation, it is important that the plate resistance characteristics of the tube under the conditions with which it is operated be known, before it is possible to recommend a loud speaker or coupling system that will give best results with a given output tube.

The A. C. plate resistance of the various popular power output tubes under different conditions of operation, are given in Table No. 1.

The figures in the plate resistance column show that the

TABLE NO. 1

Tube Type	Plate Voltage	Grid Bias Voltage	A. C. Plate Resistance
—01A	90	4.5	11,000
	135	9.0	10,000
—12A	135	9.0	5,000
	157.5	10.5	4,700
—71A	90	16.5	2,500
	135	27.0	2,200
	180	40.5	2,000
—10	250	18.0	6,000
	350	27.0	5,150
	425	35.0	5,000
—45	180	33.0	1,950
	250	50.0	1,900
—50	250	46.0	2,100
	350	63.0	1,900
	450	84.0	1,800

characteristics of the —71A tube, when operated at 180 volts plate voltage and 40.5 volts grid bias are very similar to those of the —45 and the —50 tubes. Practically the same loud speaker and coupling means can therefore be used for all three of these tubes, provided that the loud speaker and coupling means are capable of handling the power output and the plate current of the tube with which they are used. The —12A and the —10 tubes, however, would require a loud speaker and coupling combination of different characteristics while the speaker and coupling required by the —01A tube would be still different.

The usual type of magnetic speaker has a coil winding having a D. C. resistance of from 1,000 to 2,000 ohms with an impedance which varies from that value at zero frequency (D. C. current flowing through the winding) up to 30,000 to 40,000 ohms at the higher frequencies up to 5,000 cycles per second. These

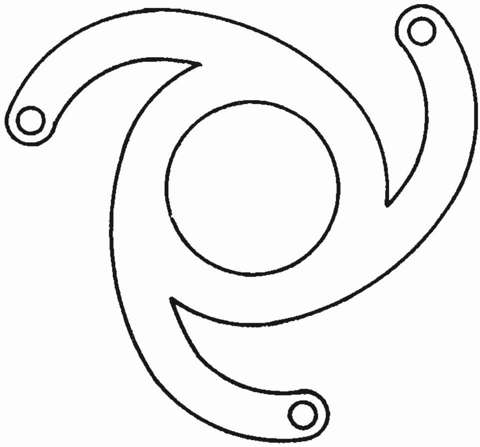

Fig. 27—A 3-point suspension for positioning the voice coil on a power cone unit.

high values of impedance for this type of loud speaker unit are due to the comparatively high inductance of the winding which is made up of a large number of turns.

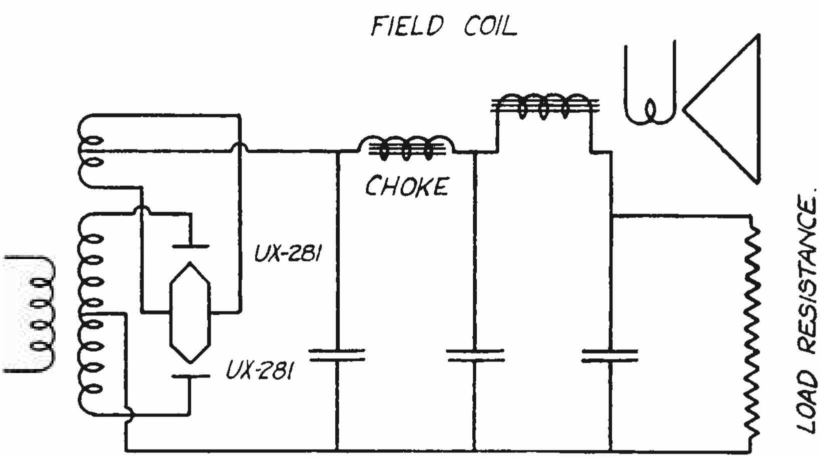

Fig. 28—A standard electrical rectifying filter circuit with the field coil of a dynamic speaker shown as the second reactance coil in the second section of the filter.

In the dynamic speaker, however, the voice coil is wound with as few turns as possible to keep the weight of the moving coil very low and to prevent excessive inertia of the moving system. The small number of turns results in a practically constant load impedance over a wide range of frequencies.

In the usual types of dynamic speakers, the impedance of the moving coil may vary from approximately 6 ohms at 100 cycles to not higher than 30 ohms at 5,000 cycles.

In some dynamic speakers, the impedance of the voice coil is much less.

These facts should be kept in mind since they have an important bearing when matching the characteristics of loud speakers to the characteristics of the output tubes.

When a loud speaker is properly designed and its characteristics match the tube it is going to be used with, it is not difficult to measure its performance. The procedure is to hang a

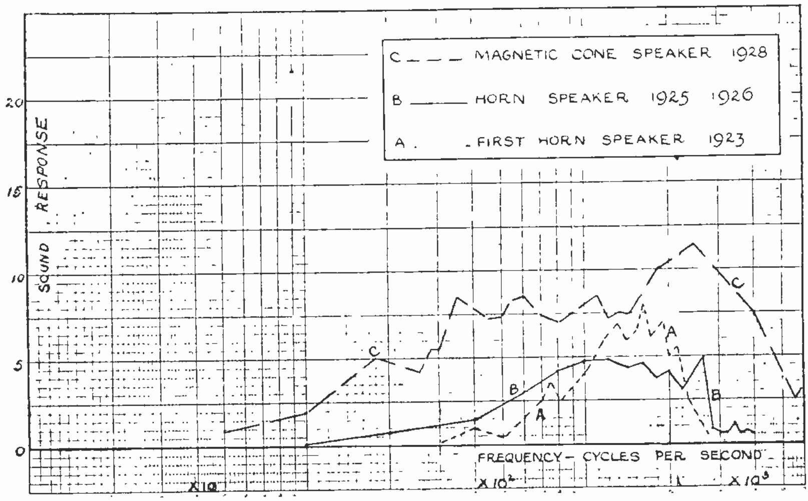

Fig. 29—Graph showing some actual sound curves taken using different types of loud speaker units.

calibrated microphone in front of the speaker which is actuated by various tones of known amplitudes from an oscillator. The output of the microphone is amplified and measured, and thus curves of output versus frequency may be obtained.

Fig. 29 shows some actual sound curves taken. A is the range of one of the first horn-type units; B is one of the latest horn-type speakers and C a cone-type speaker. Note how the range of speaker B is improved over speaker A and how speaker C is greatly superior to speaker B, indicating particularly the increase at the higher frequencies, due to the limitation of the diaphragm in B.

Loud speaker sound curves show the sound output of speakers over a complete frequency range and they always have bad peaks and valleys due to electrical and mechanical resonances, acoustic reflections and other irregularities. By sound measurements, these irregularities can be readily studied, improved and the range of the speaker extended.

TEST QUESTIONS

Number your Answer Sheet No. 14-3 and add your **Student Number**

Never hold up one set of lesson answers until you have another set ready to send in. Send each lesson in by itself before you start on the next lesson.

In that way we will be able to work together much more closely, you'll get more out of your course, and better lesson service.

1. What two types of telephone units were employed in radio telephone headsets?

2. What two factors governed the movement of the armature or diaphragm in a telephone headset?

3. How was the first horn-type loud speaker constructed?

4. Name three important types of units used with horn-type speakers.

5. How were cone diaphragms first employed?

6. What is the importance of the Baffle Board?

7. What type of speaker is generally used today to obtain quality with large volume?

8. How many ways can the voltage for the field excitation of a dynamic speaker be obtained?

9. Draw a diagram showing connections to the moving coil, also field coil of a dynamic speaker.

10. What are "sound curves"?

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