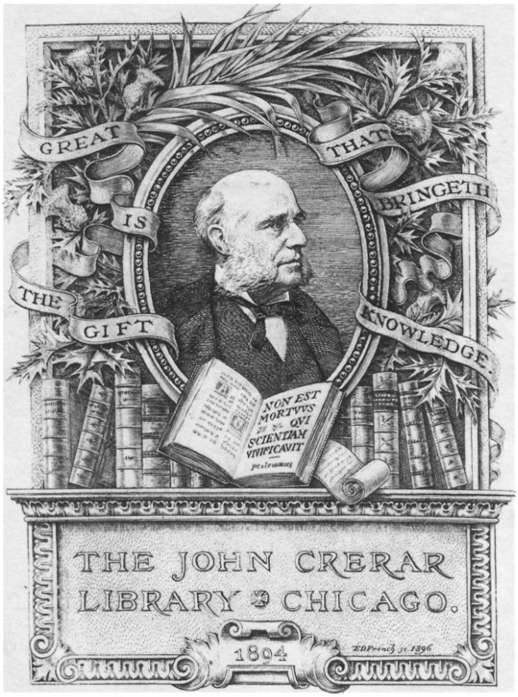
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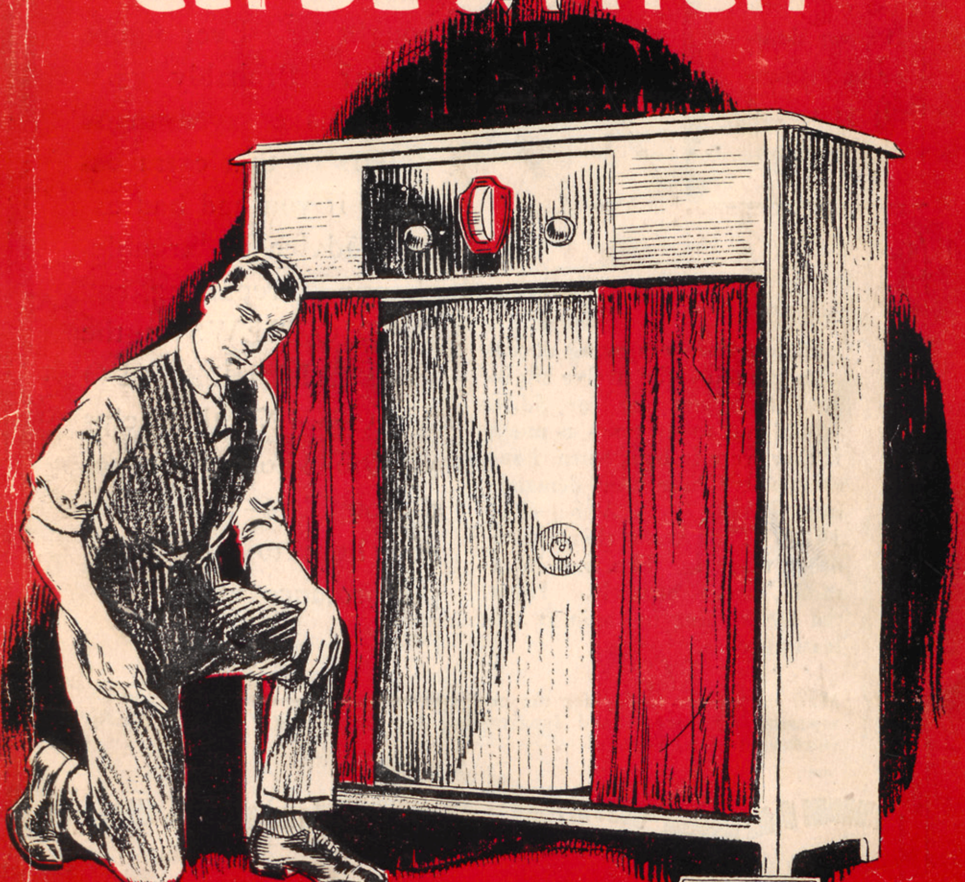
# HOW TO BUILD MODERN LOUD SPEAKERS



by
CLYDE J. FITCH



PRICE 25¢

E.I.CO.
NEW YORK CITY

# How to Build Modern Loud Speakers

Full information for building and operating the latest types of loud speakers---written by the most eminent acoustical authorities

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COMPILED BY CLYDE J. FITCH

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# Introduction

It seems needless to say that perhaps the most interesting field of research open to the radio experimenter is in the sound reproducing end of the set. It is easy to build a good loud speaker; but the best ones known to-day fall far short of being perfect. What is wanted is radio reproduction so nearly like the original that even the best musicians will be fooled. Volume and quality are usually considered the main requisites of a good loud speaker, quality being the more important because volume can easily be obtained with the amplifier. The man who judges a loud speaker solely on volume probably has what is called in radio parlance a "tin ear." Quality being the aim, we find that modern loud speakers assume many different forms. Generally speaking, they are larger than the early types. These large speakers lend themselves admirably to home construction, and the many different types described in this booklet show the radio experimenter and set builder the wide range of experimentation possible.

Of the modern loud speakers, we find the large exponential horns and large cones the most popular. The reason for this is obvious. Musical instruments that give bass tones are comparatively large, and a speaker that is required to reproduce bass tones should likewise be large, in spite of the fact that some very small cone speakers with the proper baffle board mounting give very wonderful bass note reproduction. It is the bass that is lacking in most radio receivers. Without it the music sounds high pitched, metallic, and tinny, and is very irritable. To obtain it, requires proper loud speaker design, and it is hoped that this little booklet will guide many experimenters and radio listeners in selecting the proper speaker to buy or build.

From the experimenters standpoint, the exponential horn type of reproducer seems quite satisfactory. But it is doubtful if this speaker will ever be adapted to general use among the radio listeners. When we realize that the horn opening should be in the neighborhood of 1/5 the wave length of the bass notes that we would like reproduced, or about five feet, making its length tremendous if it follows the exponential curve, we see how impractical it is for home use unless built into the wall of the house. As a suggestion to experimentrs, one method of accomplishing nearly as good a result it to employe a small horn for the upper range of musical tones, and a long pipe, such as an organ pipe with a unit attached to one end, for the bass. The pipe may be doubled back on itself to save space. It should be 20 to 30 feet long.

For home use the large cone is probably the best for good quality reproduction, many of which are clearly described in the following pages. There are other variations which give good results. The Balsa wood diaphragm, consisting of a large flat surface of thin balsa wood actuated by a cone unit is very good. Balsa wood is used on account of its very light weight. Linen, waterproofed and stretched on a wooden frame with the center drawn in forming a point, proved quite effective when attached to a cone unit. Many other loud speaker designs written by authorities on the subject, are given in this booklet. It will not only give the experimenter a complete survey of the modern loud speaker art, but also may prove a valuable source of ideas which may eventually turn out to be quite lucrative to one of an imaginative turn of mind.

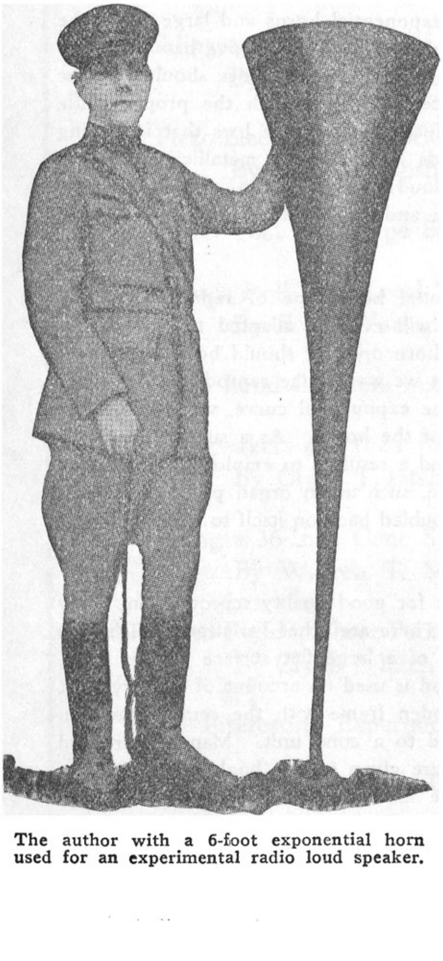
# THE PASSING OF "CANNED MUSIC"

By MAJOR J. S. HATCHER

***Ever since the advent of radio, the reproduction of music has been the subject of a great deal of research. Major Hatcher, for many months, has been devoting his time to research work in audio frequency transformers and loud speaker horns, and tells of his findings in a most interesting manner.***

DURING the past year there was presented to the public what amounts to a veritable revolution in the field of both the phonograph and the radio. At this writing it is possible to obtain either a radio set or a phonograph which will reproduce music with a fidelity and mellowness of tone destined to render obsolete the term of "canned music"—which has been applied with a considerable amount of justice to the radio and phonograph music of the past.

The change is principally due to the fact that the low, or bass, notes which have hitherto been absent from music of this nature, are reproduced fully by these new instruments. Doubtless the reader will recollect instances of having listened to pipe organ music, in which some of the notes were merely a deep rumble. In fact sometimes these notes are so low that they are practically felt more than they are heard.



**The author with a 6-foot exponential horn used for an experimental radio loud speaker.**

Who can remember having heard such a note from a radio receiver or phonograph, and who can remember having heard the deepest bass of a piano on either one of these sound reproducers? It is now possible to hear the deepest organ notes, and the lowest bass of the piano perfectly reproduced.

The difference between one of these new instruments and the old type is simply indescribable, and must be heard to be appreciated. The best way to realize the difference is to switch the music from one of the new instruments to an old one. Tune in an orchestra program on one of the new radio instruments, and the hearer is enchanted with a tremendous volume of soft and mellow sound, containing all the full rounded tones of the bass as a background for the higher notes. Switch to one of the old instruments and the music changes suddenly to a strident volume of shrill metallic noise. The listener then realizes for the first time what has always been the matter with the phonograph music and radio music of the past. It is "canned music." Some metallic mockery of each note remains, but all the living, mellow tones have been filtered out.

### Development of Reproduction

Radio is somewhat similar to the phonograph in its general development. It was first announced to the public as a scientific curiosity, capable of sending signals without wires for a short distance. As it developed to a practical agent of communication, it was used for telegraphic code and the developments were all directed towards clarity in detecting dots and dashes. After the vacuum tube amplifier was invented, it was found necessary to have some device to couple each stage of amplification with the next one, and transformers were used for this purpose.

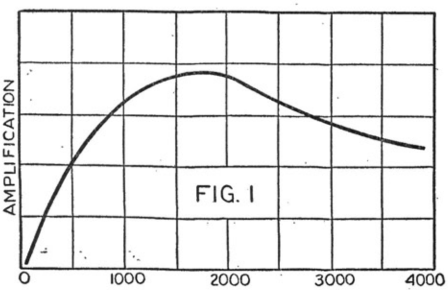
A transformer is essentially an inductance device, and therefore it depends on the frequency of the electrical impulses for its efficiency. In addition to its inductance, every transformer has capacity between the adjacent coils of its winding. This capacity, taken in conjunction with its inductance, will form a tuned circuit which will respond more strongly to some particular frequency to which it is tuned.

It was found by experience that the greatest audibility of code message was obtained when the transformers were made to respond most strongly at about one thousand cycles per second, and accordingly when broadcast speech and music first made its appearance, the transformers on the market were of the type giving a strong response, or peak of audibility, at this point. (See Fig. 1).

When radio first became a popular form of entertainment, reproduced speech had a high-pitched nasal sound, and the music was more metallic than ever. Some makers of loud speakers attacked this defect by making mica diaphragms, or metallic diaphragms which were corrugated in order to break up the vibrations.

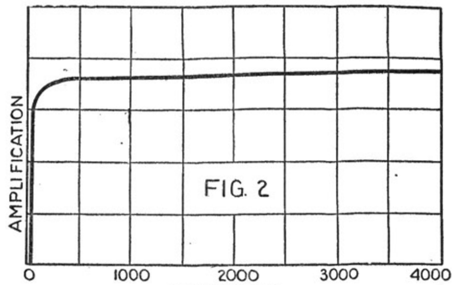
Some advertised a wooden horn to introduce a mellow tone. One maker advocated a copper horn, and covered the inside with a rough finish similar to the alcohol-proof finish used on microscopes and optical instruments the theory being that this roughness would prevent undesirable reflections which would distort the tones.

However, at the beginning of the radio craze, tone quality was really a very secondary consideration, as most of the radio experimenters of several years ago were striving for distance as the most desirable qualification of the radio receiver.




FREQUENCY. TRANS. COUPLED AMPLIFIER WITH POORLY DESIGNED TRANS..

**The above curve shows why some transformers produce distorted music in the loud speaker.**




FREQUENCY
RESISTANCE COUPLED AMPLIFIER

**With a resistance-coupled amplifier the amplification curve is flat over a wider range of frequencies than that of a transformer-coupled amplifier.**

## Improvements in Transformers

Lately new audio frequency transformers have been placed on the market which have been specially designed to reproduce the lowest audible frequencies. Several of these give very satisfactory reproductions of tones below one hundred cycles a second. (See Fig. 2).

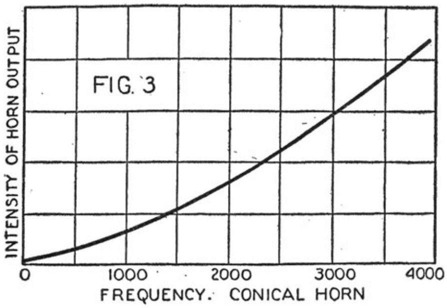
Some radio makers have sought to attain tone quality by using these improved transformers. Others have discarded transformers entirely, and are using resistance-coupled amplification, which has the advantage of giving a uniform response over almost the entire range of audible frequencies, but which has the disadvantage of giving less amplification per tube.

In spite of the fact that these improved types of amplifiers were given a great deal of publicity in the radio magazines, and were tried by thousands of amateur builders, the improvement in tone quality was not as marked as had been hoped, and many people were disappointed by the improved amplifiers. The reason for this was that these were in most instances used with loud speakers which were not capable of reproducing the low notes, after they had been amplified by the radio set.

## Eliminating the Horn

However, the existence of amplifiers which made it possible to receive the lower audible frequencies, was an incentive to the development of improved types of loud speakers. Before these new amplifiers were produced there was really no point in getting a loud speaker which would produce the deepest bass notes, because these notes were not present in the radio set.

One of the earliest improved loud speakers is the now well known paper disc type. A




**Compare this curve with Fig. 4 to see the difference in efficiency between the two types of horns.**

sheet of brass has a given frequency at which it will vibrate if struck (that is, it has a given note of its own) but a sheet of paper has no such note or frequency to which it responds.. The cone loud speakers consist of a sheet of paper or parchment to which a metallic pin is attached in the center and this to the armature of an electro magnet which is actuated by the electrical impulses from the radio receiver. The metallic pin moves in unison with the impulses which correspond to the sounds that it is desired to receive and as the paper is fastened to the pin, it also moves at the same frequency and its large, flat surface being in contact with the air, sets up corresponding air waves which the ear receives as sound.

### Studying the Horn

The problem was also attacked in another direction, that of investigating the horn to see if it could be made to transmit the deeper notes. Assuming that sound travels at approximately 1,120 feet per second, the lowest audible notes, which are around 30 cycles per second, have a wave-length of approximately 38 feet; whereas notes towards the higher end of the audibility range, say around 5,000 cycles per second, would have a wave-length of only about 3 inches. It will be readily understood that a wave 3 inches long will have time to undergo numerous reflections and re-enforcements in a horn of ordinary length, whereas a wave 38 feet long will not.

It was found that with our ordinary cone-shaped horn, the higher the frequency of the sound, the more strongly will it be transmitted. The low notes are transmitted so weakly that they are practically not heard at all; and this in itself is sufficient to account for the peculiar metallic quality of the radio and phonograph music of the past.

### Complexities of Sound

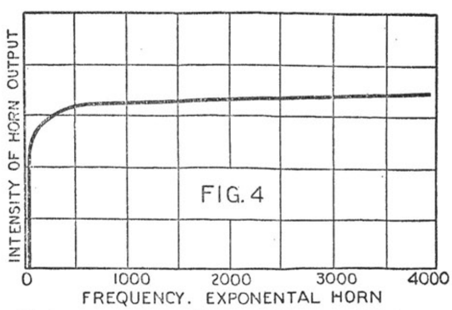
Practically no musical instrument gives pure tones in the physical sense, that is, none of the notes are composed entirely of vibrations of one frequency. Take for example, middle "C." This is supposed to represnt a frequency of 256 vibrations per second. If this were strictly a pure tone. it would sound the same whether given off by a piano, violin, flute or harp; but as a matter of fact its sound varies greatly, depending upon what instrument produces it.

The reason is that instead of being a pure tone, it is accompanied by many harmonics and over-tones, the number, pitch and intensity of which are determined by the character of the instrument producing the original sound. The harmonics and over-tones determine the character of the various instruments, and if they are slighted or left out, the music sounds unnatural.

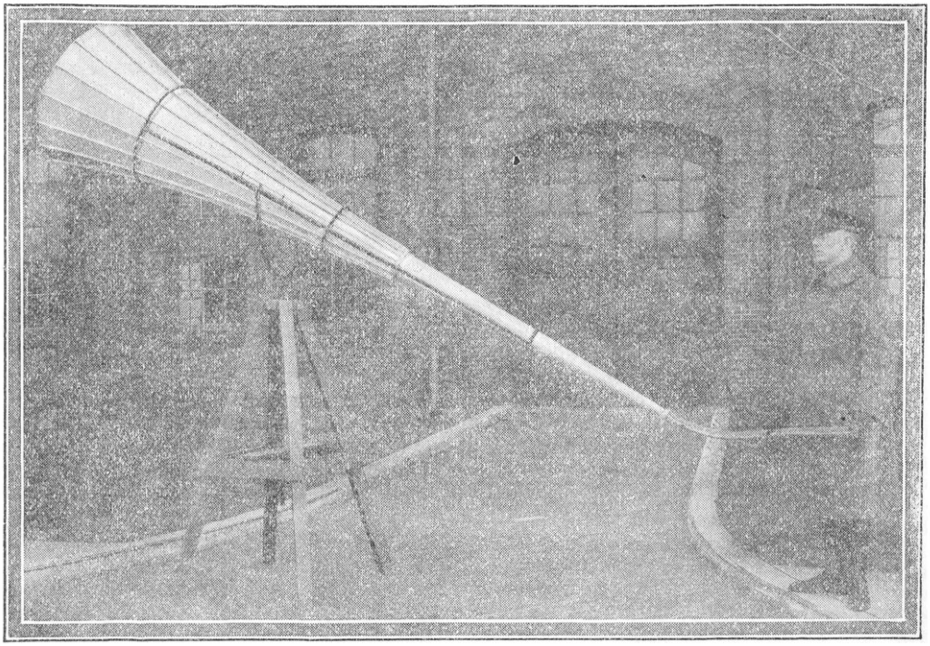
Psychological studies have indicated that it is very tiring to listen to music in which the lower tones are omitted. Instead of being reposeful, music of this character is actually a nervous irritant; though as is often the case with eye-strain and other such sources of irritation, the victim may not be conscious of it at the time.

The average radio loud speaker will not reproduce notes below about 300 cycles per second. The different investigators in this field have tried various-shaped horns, with a view to overcoming this difficulty. Among the curves tried are the parabola, hyperbola, etc.

However, the most successful horn from the theoretical standpoint, is built on what is called the exponential curve. In the cone, as we leave the small end, the horn gradually expands. If, for example, the cone has an opening at the small end 1 inch wide and expands to double its width for the first




**This curve shows that an Exponential horn gives maximum intensity over the greatest frequency range.**



**Capt. Hiram B. Ely, head of the Government Sound Laboratory at the Frankford Arsenal, Philadelphia, with experimental 12-foot Exponential horn, designed by him for use in sound investigation.**

foot of length, the width at that point will then be 2 inches. At the end of the second foot the width will be 3 inches; at the third it will be 4 inches, and so on, getting an inch wider for every foot of added length.

On the other hand, an exponential horn having an original opening of 1 inch, and an expansion double this amount, or 2 inches at the end of the first foot, would again double, or have 4 inches at the end of the second foot, 8 inches at the end of the third foot, and so on; for each unit of length adding a given percentage, not of the original opening, but of the opening at the last measurement.

In any phonograph or radio horn the sound waves generated at high pressure in the small end, are gradually expanded as they travel along the horn until, when they reach the large end, they are released into the room at atmospheric pressures.

By extensive calculations it has been demonstrated that, in order to amplify the different tones equally, there must be the same proportion of expansion for each unit of extension in length. The exponential horn fulfills these conditions, and gives a practically uniform amplification of all frequencies within the range for which it is designed.

### Limit of Range

It is found, however, that there is a certain point called the "cut-off," and the exponential horn will not reproduce frequencies below this point. The "cut-off" point, or lowest frequency at which the horn will reproduce, is dependent on the rate of expansion. The wider the conical angle, or the greater the rate of expansion, the higher will be the "cut-off" point. The horn illustrated will bring in notes as low as 29 cycles, and the result is that the music which it gives off creates the impression that a real orchestra, or a real singer, is present in the room. In every instance where a visitor has heard this outfit, the result has been an instant desire to obtain something similar.

During the early days of radio it was common to hear phonograph attachments recommended instead of the conventional loud speakers; with the new phonograph employing exponential horns the results are almost unbelievable.

# A SIX-FOOT EXPONENTIAL HORN

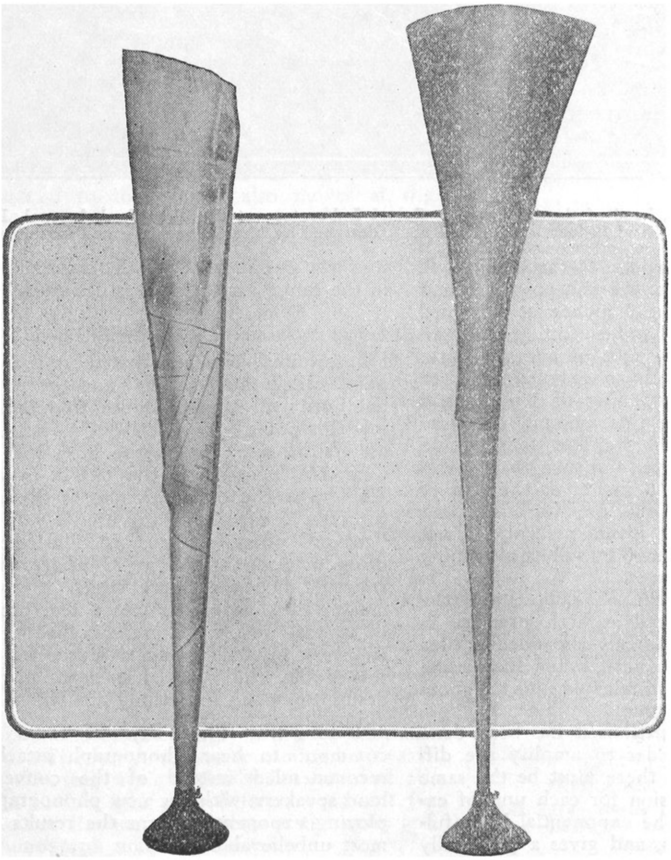
*Instructions for Building an Efficient Speaker of Heavy Paper*

By R. E. BAUMGARNER

AN exponential horn of correct design will, in conjunction with a nearly-perfect amplifying system, reproduce notes as low as 35 cycles and higher than 4,000 cycles. It can be seen that all voice frequencies and nearly all ordinarily audible frequencies are included in its range.

The exponential horn differs from the ordinary conical horn in two distinct respects: first, it is radically different in design. The conical horn increases its diameter by adding a **constant figure** to the preceding diameter at the end of each unit of length. For example, at the end of the first foot we add an inch to the preceding diameter, the first being the diameter at the bottom. At the end of the second foot we add another inch, and so on to the end of the horn, adding a constant figure to the preceding diameter, until the end is reached. The exponential horn increases its diameter with a **constant multiple** for each unit of length; each unit must expand in an equal ratio. The two principles are shown graphically in Fig. 1.

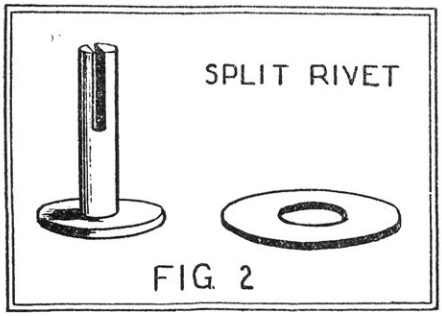
The second difference is in their respective lengths. Heretofore the longest loud speaker in common use measured about two and a half feet. As a result, its average range was limited from about 200 to 1,500 cycles. This greatly-limited range cut off most of the harmonics and delicate overtones which are necessary to good music.



**Simple Materials Required**

Two methods of making and exponential horn are here cited, and each serves its purpose faithfully. Before constructing a new horn for the parlor or living-room, the average constructor wishes to experiment and practice a little. In order to do this, material found in almost any home is utilized.

**The horn at the left is an experimental one of the conial type; it is made of newspaper. The one on the right is of the exponential design, and was made according to the directions in the accompanying article.**




**A split rivet and washer of the kind used for fastening the two sections of the horn.**

Ordinary wrapping paper is used in the first attempt. When we have mastered the peculiarities of the construction of an exponential horn we may use stiff paper of the kind used for cone speakers.

First, we shall need several sheets of heavy brown paper, such as used in wrapping laundry, a small box of rivets of the split-shank variety, preferably of brass, and a number of thin fibre or heavy paper washers, having holes to fit the rivet shank (Fig. 2). The remaining factor is a quarter of a pound of glue, commonly known as "horse glue." This may be obtained at any hardware store, at about 40 cents the pound. The flake variety is the best, but that which comes in flattened bar form will suffice.

The paper must consist of four thicknesses, cemented together by cooked starch paste. All the wrinkles must be smoothened out. This sort of paste is so strong that, when the paper cemented with it is dry, the paper will tear before the two sheets will separate.

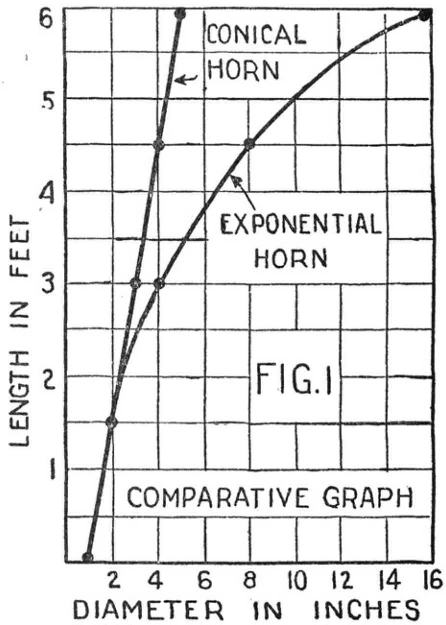
We shall need five pieces 18x38 inches, each consisting of four layers of paper.

## Method of Construction

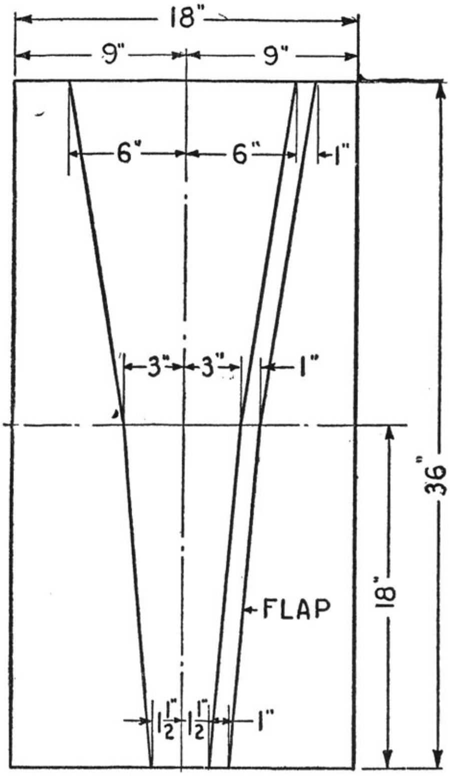
For convenience in marking and handling, the horn is divided into two sections; the lower having one segment, and the upper having four segments. The lower segment is identical with the four upper ones, except that it is two inches shorter.

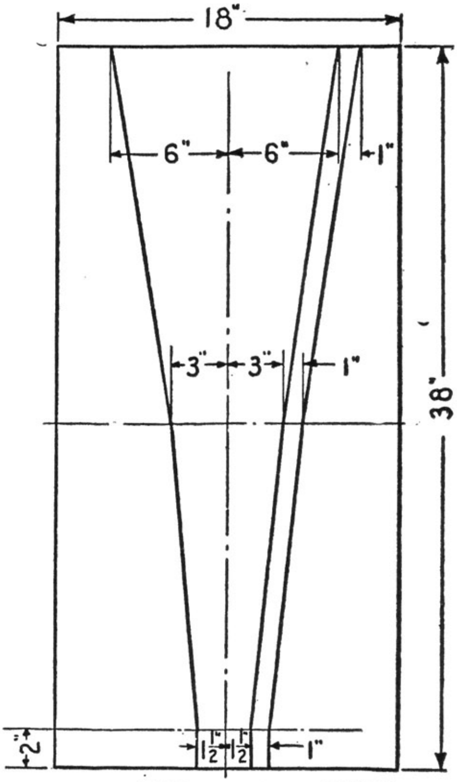
When the five sections have been made up of their respective four sheets each and are thoroughly dry, we may begin to mark off the lines to guide in cutting. To aid in doing this, a yardstick and soft lead pencil are necessary. Each of the five sheets is marked with a line running through its center, from end to end. Now we sart marking the first sheet, for the lower section. A two-inch strip is cut from its length, so that it now measures 18x36 inches. At the bottom of the paper, measure one and a half inches on each side of the center line and place dots accordingly; and place another dot an inch to right of the dot already on that side. This extra inch is to allow a lap for gluing. Eighteen inches from the bottom these dots are again placed, but this time three inches on each side of the center line. Be sure to place the extra dot an inch to the right as before. At the top of the paper we measure six inches on each side of the center line, and again add the inch for lap. This inch lap is marked on every piece. Its importance cannot be emphasized too much. With the yardstick connect the dot at the bottom with the dot on the same side near the center with a straight line. The end of this line which terminates near the center is connected with the dot at the top on the same side. The remaining dots are connected in the same manner. The finished piece will resemble the sketch in Fig. 3-A.

All the other pieces are done in a similar manner, but for one exception: the two inches which we cut off the first sheet is merely indicated by a ruled line on the other




**This curve shows the difference, in the rate of expansion, between an exponential and a conical horn.**




**The sizes of the parts required to build up the two sections of the experimental-horn loud speaker are given in the sketches above. The method of laying out and assembling them is fully described in the text.**

four sheets. Instead of starting at the bottom of these when marking, we start on this line two inches from the bottom (See Fig. 3-B). When the lines are drawn to connect the dots on these four sheets, the first line is extended down across the two-inch piece which was marked off from the segments to begin with.

It will be seen that the three dots are not in a straight line. The exponential principle explains this eccentricity.

Now that all the segments are marked off, we may begin to cut them out. Starting at the bottom on the line at the left, cut close along it until a point about four inches from the bend of the line, or rather the intersection of the two lines, is reached. Here we begin to leave the line and gradually round out just enough to keep the turn from being angular. This is clearly shown in Fig. 4. The heavy line is the one we first marked, and the light one is the one showing the direction in which we cut. On the right side of the segment we cut the **outside** line, marking the edge of the lap. If the inside one is cut, our whole segment will be ruined. An ounce of prevention is worth a pound of cure, you know. This outside edge is rounded out as was the first. All the segments undergo the same treatment.

### Assembling the Segments

The next operation is perhaps the most difficult. It is on this that the efficiency of the whole horn rests. If a good job of gluing is done, decided efficiency results.

The lower section is rolled on a long, round wooden rod about an inch in diameter.

A broomstick will serve the purpose very nicely. The upper segments are rolled likewise over a larger rod, about four or five inches in diameter. This little kink helps the horn to form more naturally when glued. The resultant curl is also a great advantage when glueing.

The rivets and their washers play an important role. Holes for the rivets are punched at intervals of four inches along the laps by means of a small nail or punch. Care should be taken to see that the holes are just a half inch from each edge of the paper. This situates them in the center of the lap. Now we are ready to glue the parts of the horn.

The "horse glue" has first been soaked in a small amount of water overnight, and cooked in a double boiler afterward. Before application it should be quite warm and of the consistency of syrup.

The lower half is glued first. The warm "horse glue" is spread thinly, but thoroughly over the inch lap. The marked side should be on the outside. The rivets and washers are inserted and the two edges are pulled together by them. The rivets are then split to hold them in place. If some of the inside of the lap is left unglued, the horn will rattle and clatter when it is used.

The upper four segments are likewise glued and riveted together, making sure that the small end of the finished job fits snugly over the large end of the lower half. After the two parts fit satisfactorily, rivet holes are punched. Only a few will be needed, due to the small diameter of the horn at this part. The small section is then removed and glue is applied outside around its top, extending down about two inches, not more. This small section is replaced in the larger one, the rivets set, and it is left to dry.

The remainder of the work is only finishing. When all the rivets are removed, the holes are covered with brown paper. To improve its appearance and tone quality, the horn should be given several coats of a good grade of black paint.

### Use of Special Paper

A neater and more efficient horn can be constructed of the new cone paper, which has no fundamental frequency of its own. This paper can be obtained in sheets 38x38 inches. Three such sheets are required, but only five halves are used. The sheets must be cut in halves, cutting with the "grain" of the paper. This is absolutely necessary, because if they are cut the other way, considerable wrinkling will be the result. A special cement is needed. This may be procured from the manufacturers of the cone paper.

All the foregoing specifications are adhered to, as this horn is identical in construction with the first.

Owing to the parchment-like texture of the cone paper, it is easily decorated. It may be hand painted in design, or shellac may be applied to its surface.

### Amplifier and Speaker Unit

It is grossly unfair to expect startling results if a reproducing unit or amplifier of poor quality or workmanship is employed. With a good transformer-, impedance-, or resistance-coupled amplifier, and a power or semi-power tube in the last stage, this horn produces excellent results. And by all means, **don't** try to use this horn without an output unit between the last tube and the speaker unit. It simply can't be done satisfactorily.

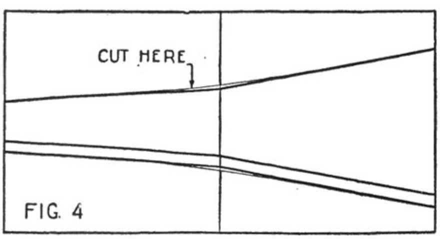



FIG. 4

How the cutting of the paper is rounded out from that in Fig. 3.

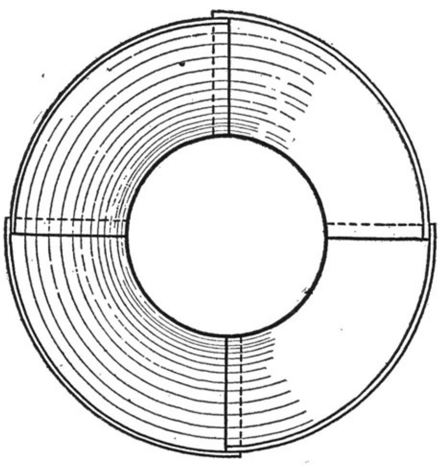


FIG. 5

The appearance of the "bell" of the exponential horn after assembling.

# AN EXPONENTIAL HORN OF SQUARE CROSS-SECTION

## *How to Construct a Substantial Six-Foot Horn Which Will Give Remarkable Low-Note Reproduction*

By T. H. MILLAR, Jr.

A VERY interesting field for experiment was opened to the writer, and several of his friends, by Major J. S. Hatcher's article, "The Passing of Canned Music," in Radio News for April, 1926. Data very kindly furnished by Major Hatcher have recently been utilized in the construction of a number of exponential horns, and the results have been found most satisfactory. This article will explain the constructional methods adopted.

The horn described is six feet long, and straight. While several of us have been trying to shape it into more compact form, yet preserving its characteristics, such a construction is exceedingly difficult with ordinary facilities. On the other hand, the horn shown here can be made with ordinary mechanical ability and easily-procured materials, and it has such superior tonal qualities that an agreeable surprise is waiting for anyone with the inclination to build one. It will reproduce broadcast programs with a fidelity attained by the best of speakers.

Major Hatcher's article described and illustrated round horns; but with ordinary tools it has been found much easier to construct a square one and the shape of the cross-section does not appear to be a critical factor, as the square horns have given excellent results. The particular one here described was, with other speakers, tested on a bench regularly equipped with the usual switches for testing speakers alone or in combination. This home-made horn was found to be perceptibly better in tone quality than several standard speakers of good quality.

### Composition Board Used

The six-foot length was chosen, on Major Hatcher's recommendation; and the inside dimensions, from the ⅝-inch throat to the 20-inch mouth of the bell, are shown in Fig. 1. Dimensions are given for every six inches up to four feet from the throat; and for every three inches thereafter, because of the more rapid increase of the curve. After the points have been laid off, they may be joined by freely-drawn lines, if no suitable curve is at hand. If you have not a straight-edge sufficiently long, a chalk-line may be used for the center.

A single sheet of beaver or wall board contains enough material to make one horn; it is eight feet long, four feet wide, and 3/16-inch thick. It is divided into four pieces, as shown in Fig. 2, as a preliminary step. The pattern, laid out as shown in Fig. 1, is then applied to each piece in succession; a strip equal to the thickness of the material being added to one side, on each strip. All four pieces may then be cut out; they are exactly alike.

### Mounting the Sides

The next move is to shellac each piece on the face which will be inside. They are then put together, as shown in Fig. 3, overlapping on successive sides. All are fastened partly by small brads. (It is well to drill the wall board for the brads, as otherwise they are apt to split it.) In this operation, two pairs of hands, though not absolutely necessary, are better than one.

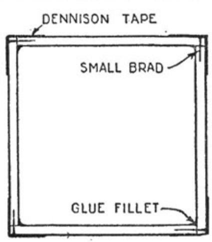



FIG. 3

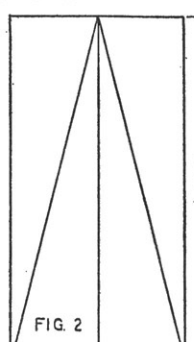



**Fig. 2 shows how the wall board is cut, the four pieces necessary being taken from the same sheet. Fig. 3 illustrates the method of making the corners of the square horn air-tight.**

The wall board is sufficiently flexible to accommodate itself to the curve desired, under pressure; and the outside edges are fastened with gummed mending tape, 1¼ inches wide. This tape should be creased down the center before it is applied. A ten-yard box, costing fifty cents or less is ample for one horn.

When everything is in place and dry, a very neat fillet can be made in the inside corners, by carefully running a good glue down each in turn, catching the excess at the bottom. One corner, of course, must dry before work is undertaken on the next. This will prevent pin-hole leaks at the corners.

Before finishing the horn on the outside, try it with your set at full volume. If the bell develops a vibration, due to the thinness of the material, reinforce it with paneling of the same material. After that, the horn may be decorated to suit your fancy.

Although this horn is large, it is easy to handle if it is mounted on a suitable base. The results are so satisfying as to encourage experiments to find a more compact form, which can be mounted in a cabinet, with no sacrifice of efficiency. It is well worth trying, and the writer is still working on this problem with his colleagues.

**Above are shown the widths of the six-foot exponential loud-speaker horn at suitable short intervals along its length. The material necessary for making one of these horns can be obtained from a single sheet of wall board. The pattern, which is shown in Fig. 1, is prepared and laid upon the wall board; and the latter is cut along the lines indicated, allowing on one side an extra lap equal to the thickness.**

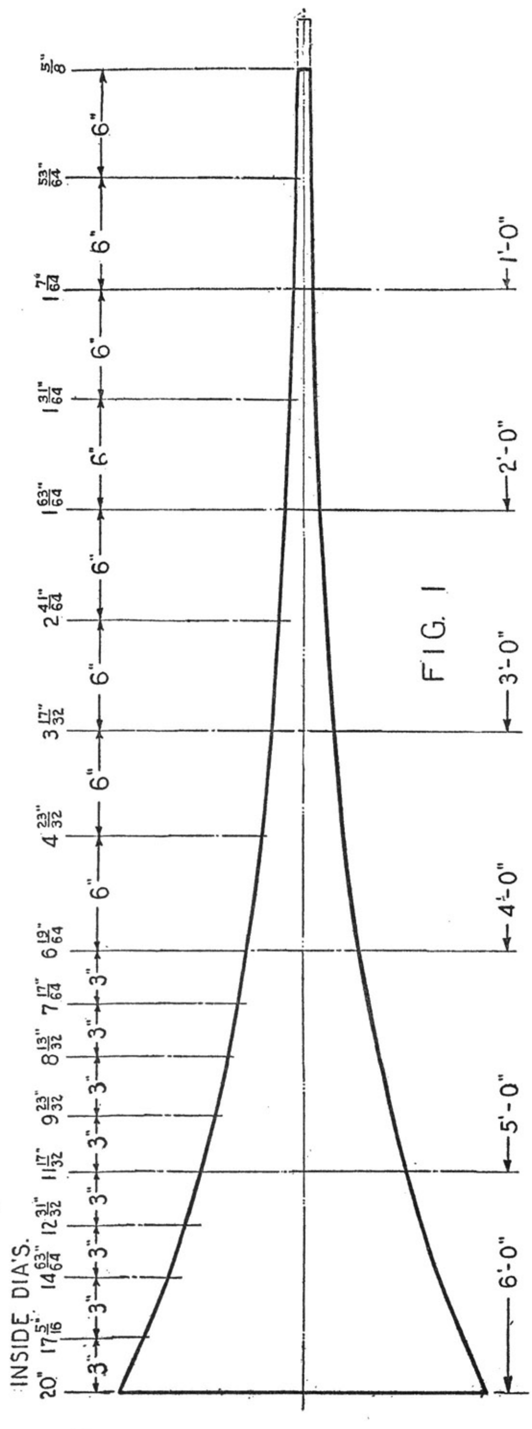



FIG. I

# A LOUD SPEAKER WITH A THREE-QUARTER MILE RANGE

*An Explanation of the Theory and Operation of a Large Exponential Horn*

By CLINTON R. HANNA

**The author in his laboratory. The unit in the foreground is the one used in the exponential horn shown on opposite page.**

THE exponential horn is a sound-radiating device whose usefulness is appreciated more and more as time goes on. Over three years ago methods of designing such horns for loud speakers or other reproducing instruments were published by the writer and Dr. Slepian. At that time the principal advantage of a reproducer using the properly-designed exponential horn, over those using the conventional short horn of random shape, was that the bass notes were given more nearly their correct prominence, and that the resonances of the diaphragm were minimized to prevent undue prominence of notes in the middle- and upper-frequency ranges.

Today the correctly-designed horn is useful also in making it possible for relatively simple and small vibrating mechanisms to radiate the very great amounts of sound required for large auditoriums, ballrooms, out-of-door concerts, etc. With apparatus recently developed, it is possible to reproduce Sousa's Band at full volume, or 2,500 voices singing to full-organ accompaniment, without the slightest rattle or overloading.

Applications for such reproducers are at once apparent. Within a short space of time it will be unnecessary to travel to the big cities to hear a famed symphony orchestra, or an acclaimed musician playing the organ scores of a picture. Such music can be reproduced in local auditoriums or theatres.

### Function of Horn

In view of the importance of the horn in the new development, it is advisable to review some of the characteristics of horns and methods of designing them. Contrary to the popular conception, a horn on either a talking machine or loud speaker is **not** an amplifier. Nor is it necessary that it shall resonate in order to perform its function; in fact the best horns for reproducers do not resonate strongly at any frequency.

The real function of a horn is to be a sound radiator; much the same as that of an antenna is to be an electromagnetic wave radiator. The horn enables the relatively small diaphragm to get a "grip" on the air, so to speak; just as the antenna enables the radio transmitter to get a "grip" on the medium through which radio impulses travel. Of course, it is possible to radiate sound directly from the vibrating member to the air, but much larger surfaces are required when this is done. The horn enables a small diaphragm to radiate large amounts of sound to the atmosphere.

How does the horn accomplish this? The student of physics knows that, in a mechanical system, power is measured by the product of force and velocity. Thus, if two vibrating diaphragms of greatly different size are radiating equal amounts of sound-power when moving with the same velocity, the total force must be the same for each; and the pressure per square inch on the smaller diaphragm must be much greater than it is on the larger. The horn is the device which brings this about. It causes the **pressure per square inch** over the surface of the diaphragm, for a given velocity, to be many times greater than if the diaphragm were to vibrate in free space. The horn, therefore, **makes the diaphragm work better;** and this is the reason more sound is radiated from a given diaphragm with a horn than without.

A horn does not amplify. It increases the amount of sound radiation by causing a greater load to be placed on the diaphragm.

### "Exponential" Defined

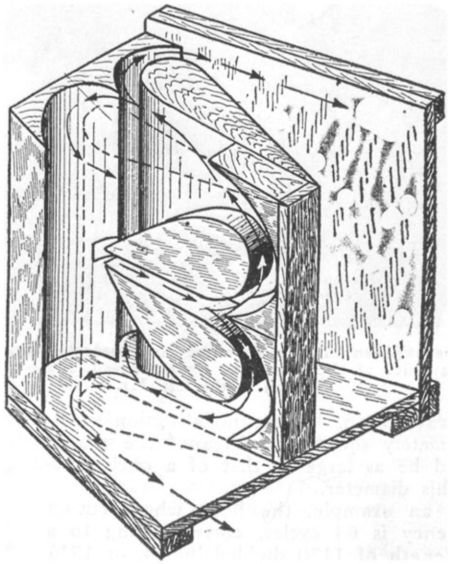
The best horn is one which radiates most uniformly over the required range of pitches. It can be shown that, of all horns having a given size **(i.e.,** same length and terminal areas), the **exponentially-shaped horn is the most uniform sound radiator.** The mathematical equation of such a horn could be given; but it is much more easily understood if described as a horn whose cross-section doubles at equal intervals along its length.

For example, if a horn has an orifice with an area of half a square inch, and at one, two and three feet, etc., from the orifice the sections are one square inch, two square inches and four square inches respectively, we have an exponential horn in which the area doubles every foot. A horn whose area doubles at smaller intervals would be said to expand more rapidly, and one whose area doubles at longer intervals would expand at a lower rate.

This rate of expansion is an important factor in horn design, for it determines the lowest frequency down to which the horn is a uniform radiator. This limiting frequency is called the "cut-off" frequency; for below it the radiation is very small. A horn whose area doubles every foot cuts off at 64 cycles. One expanding half as rapidly would cut off at 32 cycles, and one expanding twice as rapidly at 128 cycles. Thus the contour of the horn is determined, if we know at how low a frequency we wish to reproduce.

### Mouth of Horn

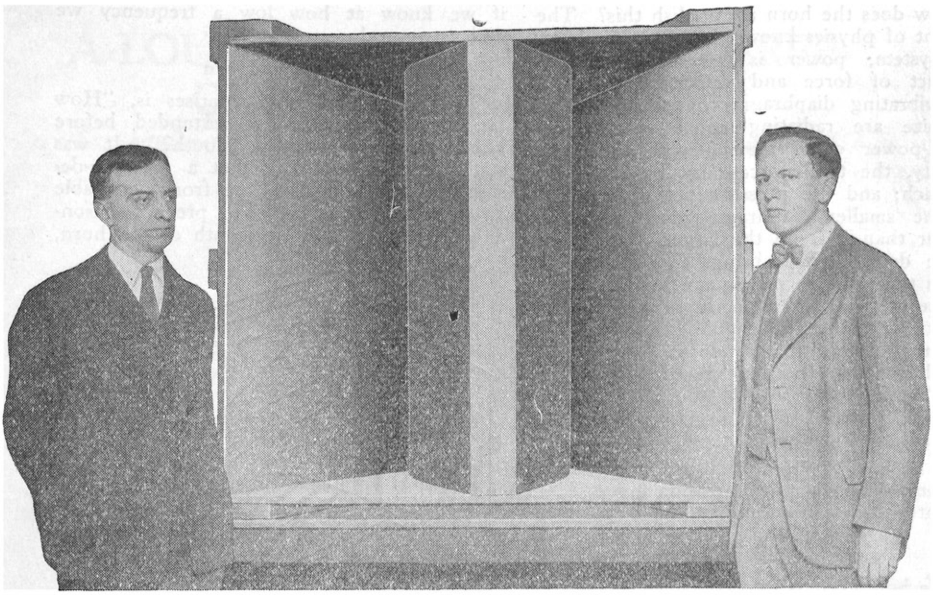
The next question that arises is, "How far should the horn be extended before being terminated at the mouth?" It was stated at the beginning that a properly-designed horn should be free from noticeable air-column resonance. To prevent resonance, the large end, or mouth of the horn,



The peculiar method of folding the Westinghouse exponential horn (shown above) was developed by engineers of the Bell Telephone Laboratories. This design makes possible a long horn within a reasonable space. The folding in no wise affects the performance of the horn.

should be large enough to transmit the pressure emanating from the horn to the atmosphere without any reflection. Of course this is impossible, because of the sudden relief of pressure as the wave passes outside the confining walls of the horn. But, if the mouth is made comparable to one-quarter of the wavelength corresponding to the cut-off frequency of the horn, (as determined by its rate of expansion) the resonance of the horn will be very small.

The wavelength in feet is determined by dividing 1120 (the velocity of sound in air in feet per second) by the frequency. So the horn should be extended until the mouth has a diameter about one-quarter



**The exponential horn mounted on a pedestal, preparatory to the demonstration during which the voice of the horn was clearly heard, three-quarters of a mile away. The inventors—Dr. Slepian at the left, Mr. Hanna at the right, are shown beside it.**

this wavelength. If the horn section is approximately square, the area of the mouth should be as large as that of a circle having this diameter.

As an example, the horn whose cut-off frequency is 64 cycles, corresponding to a wavelength of 1120 divided by 64, or 17½ feet, should have a mouth about 4½ feet in diameter, if circular, or four feet square.

### Throat of Horn

Now we come to the small end of the horn. What cross section should we choose for this end? Just as the large end was determined to secure the proper coupling to the atmosphere, so the small end must be chosen to give the best coupling to the vibrating mechanism. This area is fixed by three things: (1) the mass of the diaphragm, (2) the area of the diaphragm, and (3) the highest frequency to which the reproducer is to respond with uniformity.

To understand this part of the problem we must get a clear picture of how the horn loads the diaphragm. Imagine a diaphragm vibrating back and forth as a piston (i.e., every part moving together through the same amplitude), pumping air in and out of the throat of a horn. If the air cavity just above the diaphragm is small, nearly all of the air displaced by the diaphragm will move into the horn, and only a small part of the motion will be lost in compressing the air in the cavity.

Suppose the diaphragm in vibrating back and forth moves 100 cubic inches of air per second into the horn. If the horn has a throat area of half a square inch, the velocity of air in the throat will be 100 divided by 0.5 or 200 inches, per second. If the area of the throat were only one-quarter of a square inch, the velocity would be twice as great or 400 inches per second.

Now the characteristic of the horn is such that, when air is moving back and forth at its throat with a frequency greater than the cut-off frequency, a pressure, known as radiation pressure, is created. This pressure is directly proportional to the velocity of the air particles at the throat, and makes itself felt back into the air cavity and all over the surface of the diaphragm. Since the air velocity in the horn is greater for the horn having the smaller throat, the pressure will be greater; and the total force exerted on the diaphragm, which is the pressure multiplied by the diaphragm area, will be greater.

Part of the force used in moving the diaphragm will be spent in overcoming this radiation pressure, and part will be spent in overcoming the inertia and stiffness of the diaphragm. Now it is desirable that the greater part of the driving force shall be spent in overcoming the radiation pressure, at least over a good part of the range of pitches required. To bring this about, the radiation pressure must be high, and thus the throat of the horn must be relatively small.

We have then the requirements of a good horn. First, it must be approximately exponential in shape and of slowly increasing section, in order to transmit the lower pitches. Second, it must be large at its mouth in order to prevent noticeable horn resonance. And third, it must be small at its throat in order to cause sufficient radiation pressure to be exerted on the diaphragm as it moves. It will be noted that all three of these requirements make for a long horn. Length, however, is merely incidental and not fundamental in determining the performance of a horn. It should be stated that while good horns are long, the exponential horn is shorter than any other covering the same range of tones.

### Application to Power Loud Speakers

It has been hinted that horns are advantageous because small vibrating systems may be used instead of large ones. This advantage is greater for loud speakers which are to radiate very great amounts of sound.

To illustrate this, consider a horn having a throat area of half a square inch and a mouth area of 2,304 square inches (corresponding to 4 feet square). Let the rate of expansion be low enough to include 64 cycles. If a diaphragm pumps air in and out of this size throat at the rate of 50 cubic inches per second, approximately one watt of sound will be radiated, provided the frequency is above the cut-off of the horn.

Now let us see what is taking place at the large end or mouth. The rate of flow of air in cubic inches per second is not the same along the horn but is greater for the larger sections in proportion to the square root of the area. Thus, at the mouth of the horn the area is 4,608 times as great as at the small end, and the air current, instead of being 50 cubic inches per second, will be 50 times the square root of 4,608, or 3,400 cubic inches per second. This increase does not singnify **amplification** but rather **multiplication;** for what is gained in air flow is lost in pressure, so that the power remains the same. But the significant thing is that a smal diaphragm, perhaps two or three inches in diameter, displacing only 50 cubic inches per second when attached to a horn, is capable of moving, in this case, 3,400 cubic inches of air per second at the mouth of the horn.

The horn and small diaphragm can of course be replaced by a large diaphragm, of size equivalent to the mounth of the horn, moving in free air so as to displace 3,400 cubic inches of air per second. The mechanical difficulties of arranging such a large diaphragm are at once apparent, however. Also the force required to move such a diaphragm is very much greater, due to its greater ineria; and this makes for much lower efficiency. When large amounts of sound are needed, relatively large amounts of driving power from amplifiers are required. Naturally the device having lower efficiency will require the largest amplifier to drive it.

Summing up the advantages of the horn in its new high-power development, we may say that; (1) it allows the use of relatively small and easily-constructed vibrating systems; and (2) it makes for high efficiency.

**THIS is an important development in the science of acoustic—a huge exponential horn for reproducing notes of all pitches with great volume—was demonstrated in Pittsburgh recently before an audience of newspapermen, music critics, and electrical engineers. The horn was operated from the research laboratory of the Westinghouse Electric and Manufacturing Company, and with the auditors assembled on a hill three-quarters of a mile away from the horn, its riadiating capacity was put to the acid test.**

**Phonograph records were used for the demonstration, and afforded a wide range of frequencies. The piccolos and bass horns of Sousa's Band; the treble and contra-bass notes of the pipe organ, and the 2,500 voices of the Associated Glee Clubs of America singing to full-organ accompaniment, bridged the wide gap between auditors and horn without bluring or faltering.**

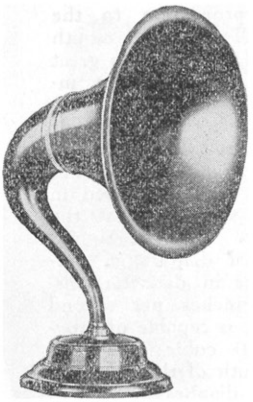
**The inventors are Dr. Joseph Slepian and Clinton R. Hanna, of the Westinghouse research staff, to whom a patent has been recently granted.**

**The basic principles underlying the exponential method of sound radiation are explained by Mr. Hanna in this article. The popular theory, that the function of a horn is to amplify sound, is exploded by the writer, who is recognized as one of the leading authorities on the science of acoustics.**

**—EDITOR.**

# WHAT IS THE BEST LOUD SPEAKER, AND WHY?

By H. WINFIELD SECOR



A good horn-type loud speaker is desirable for use with most cone speakers. The horn-type speaker shown in the accompanying cut is one recommended by the author, because of its large, well-designed-horn, which has a thick non-metallic wall.

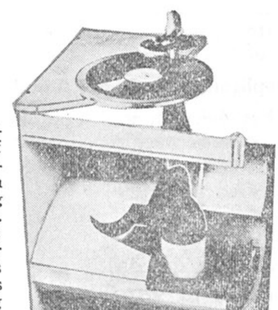
THE task of designing and building a satisfactory loud speaker for use in radio receiving sets, has hidden within it a vast amount of science and laboratory research. This is not realized by the average person; he may, perhaps, buy a loud-speaker unit and fit it to a talking-machine or other horn, and ask proudly, "What's the matter with that?"

It has taken most of us quite a long time to become educated to the fact that the average loud speaker, whether of the cone or the horne type, left much to be desired. We thought that we were hearing good music from even the first loud speakers, in many instances; but since the cone speakers came to the front so strongly, during the past year, we have begun to realize that the real backbone, of a great portion of the musical renditions by orchestras and bands, is represented by the bass and baritone notes, which are the tones in the lower part of the musical scale. All who have a true musical ear, and who are used to listening to quartettes and other vocal and instrumental groups, are aware of the importance of the bass and baritone.

### Double-Speaker Equipment

At least one of the well-known American radio manufactures (the Zenith Company of Chicago) has for several years supplied in every one of its cabinet sets, two loud speakers; one to take care of the higher audio frequencies, and the other to care for the lower and intermediate vocal frequencies. At the present time this idea has been gaining favor with the radio public very rapidly; and during the past few months, several radio set builders have announced that their cabinets are being fitted with the very happy combination of a cone speaker and a horn speaker. The merit of this lies in the fact that the cone gives us a very fine reproduction of the extremely valuable bass and baritone notes, while the horn helps tremendously, on all vocal selections especially, by doing its part to bring out the higher intermediate and treble notes.

Il we refer to the graphic chart (Fig. 1) we find the whole story of this loud-speaker problem pretty well exemplified by the horizontal graph lines which indicate clearly the range of the various human voices, such as soprano, alto, bass and baritone;



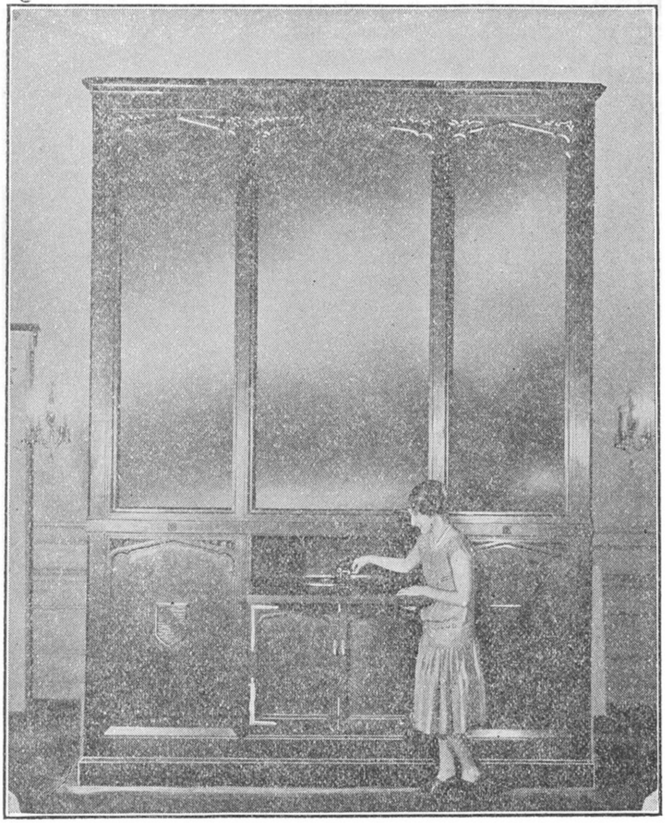
This is a semi-sectional view of the new orthophonic horn used in one of the leading talking machines. This orthophonic horn is curved or folded so that its great length is capable of being contained in a small space. It makes a very fine radio loud speaker.

and also we learn the position of the lowest, medium and highest instrumental notes —those of the bass viol, violin and piccolo. From these graphs, it is clear why the average cone or horn speaker, with the range of frequencies shown, does not cover all of the audio frequencies that are so necessary in faithful musical and vocal reproduction.

### Remarkable New Horn

The new orthophonic horn which is now supplied on a wellknown line of

**The picture at the right shows a taling machine, containing a large 20-foot orthophonic horn, installed in a hotel. This horn gives tremendous volume and very faithful reproduction of bass, baritone, and treble notes from an ordinary phonograph record. Radio music and voice can be reproduced through this horn when desired.**



talking machine, is a remarkable product of the scientist's laboratory. The range of notes to which the orthophonic horn, in the 72-inch size, will respond or resonate, is shown graphically and clearly in Fig. 1. Therefore, it would seem to indicate to us that the solution of the loud - speaker problem may eventually resolve itself into the utilization of a horn of this type fitted with a good loud-speaker unit. In a $1000 model talking machine, fitted with the orthophonic horn and connected to a superheterodyne radio set, for instance, its owner has a most wonderful sound-reproducer; and those who have heard this instrument have stated repeatedly that it gives the finest reproduction of the human voice or musical instruments that they have ever heard.

In this case, it is well to remember that the orthophonic horn does most of the work; it is not necessary to fit it with an elaborate loud-speaker unit, though a good unit should be used. In the case of the talking machine

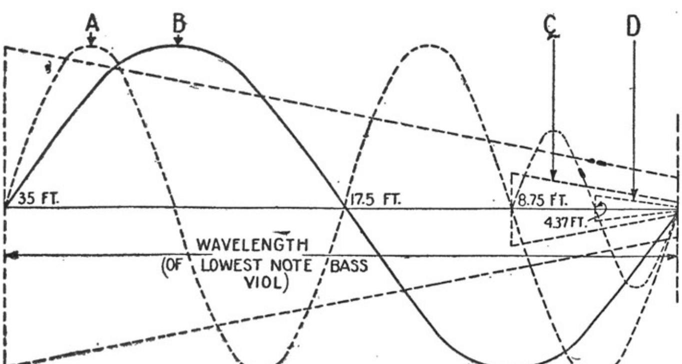
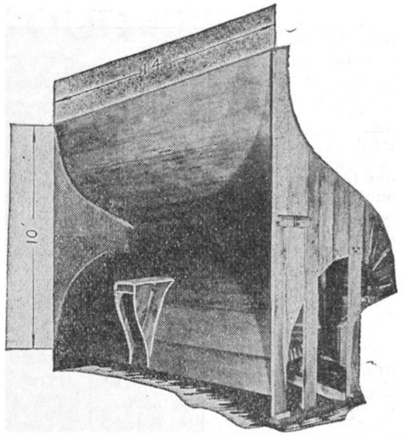



FIG. 6

**A great deal of the science required in the design of a satisfactory loud speaker, whether of the horn or cone type, is made evident by means of the accompanying graphic diagram. If we want to listen to an exact reproduction of a musical selection being rendered by an orchestra, we actually need a horn 35-feet long, as the wavelength of the lowest note given out by the bass viol is 35 feet in air. As the dotted outlines of various sizes of horns indicate, the smaller horns are able to give us an imitation of a bass note only by vibrating at one of its harmonics.**

referred to, the makers have designed what they call an "orthophonic-speaker" unit which has a special duralumin diaphragm, with a special suspension, which gives a very fine quality of reproduction in itself. The point, however, which the writer wishes to emphasize, is that this orthophonic-loud-speaker unit is practically as helpless as any other speaker unit, if fitted to an ordinary horn.

In any event, as Prof. Dayton C. Miller pointed out quite a few years ago to the writer, the long horn, anywhere from 4½ to 7 feet in length, will far surpass anything that a small horn can do. It is interesting to note in passing that Prof. Miller at that time about ten years ago, mentioned that he had obtained very wonderful results with a 7-foot horn made of concrete 4 inches thick, as well as with wooden horns of the same length. The orthophonic horn is 6 feet or 72 inches in length, and larger



**The above picture shows dimensions and appearance of an experimental 40-foot orthophonic horn.**

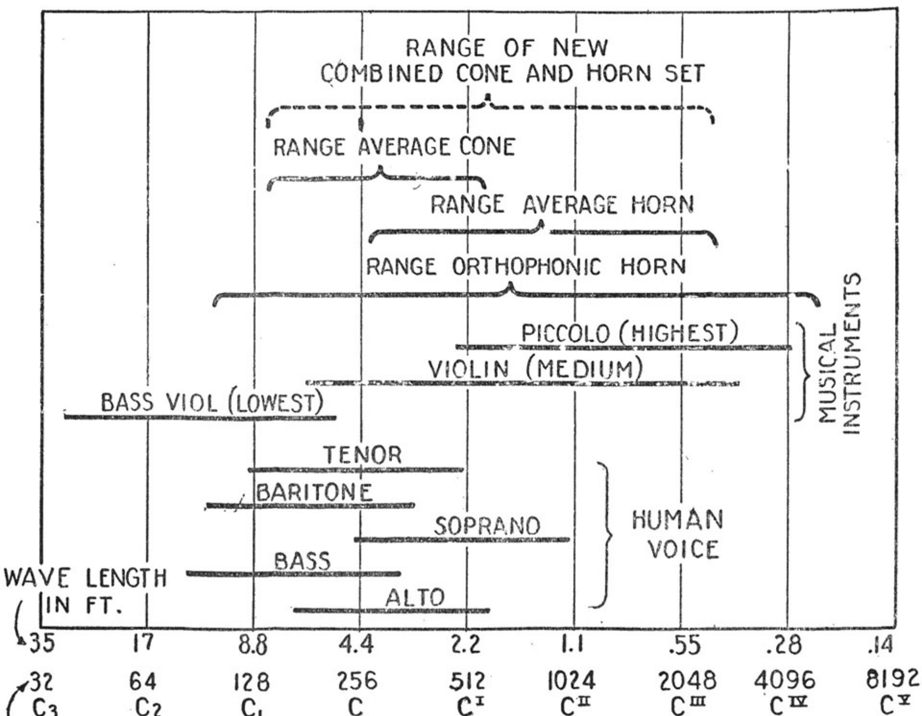



FIG. 1

**This diagram, prepared with the aid of data given in a recent scientific paper by S. T. Williams, chief engineer of the Victor Talking Machine Company, makes it very clear why the average horn or cone speaker is not entirely satisfactory. The orthophonic horn in the 72-inch size, however has a range from 100 to 5,000 vibrations per second, covering practically all musical notes. To approximate this, anyone can improve his radio quality a great deal by using a horn together with a cone speaker, connected in series or parallel, as trial may dictate.**

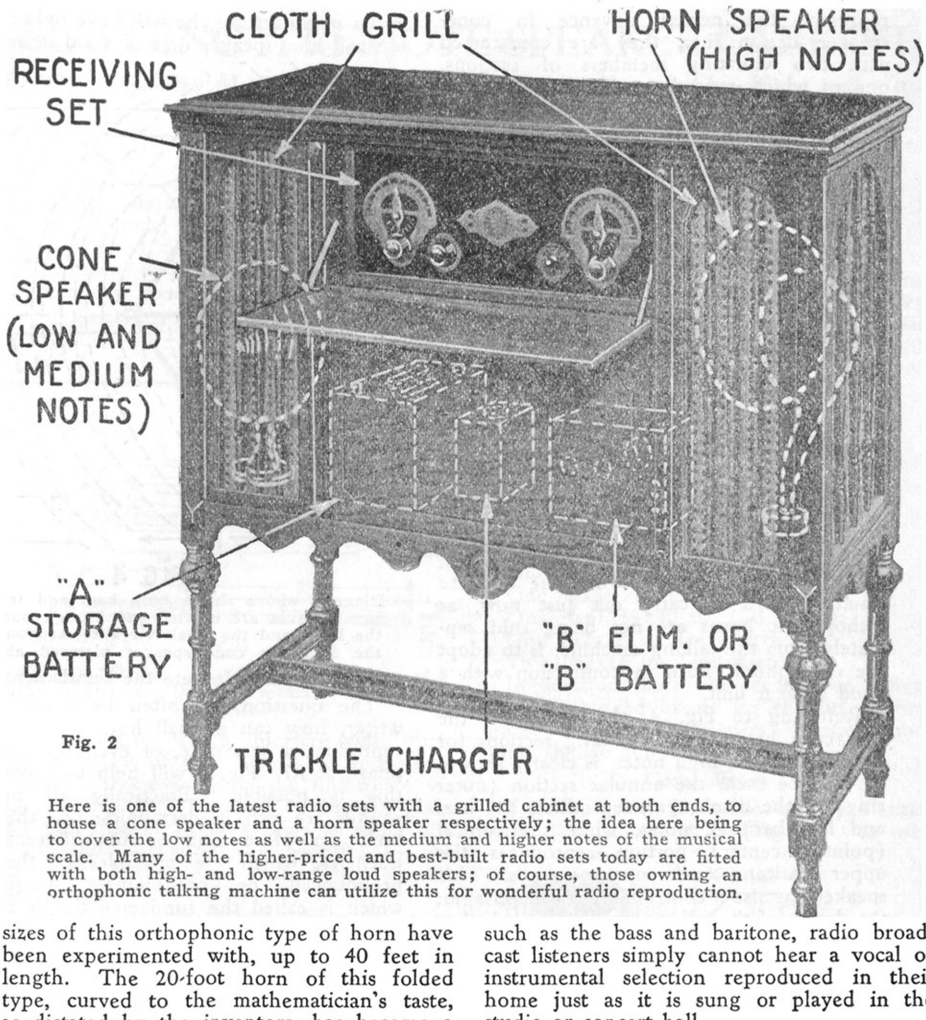



Fig. 2

Here is one of the latest radio sets with a grilled cabinet at both ends, to house a cone speaker and a horn speaker respectively; the idea here being to cover the low notes as well as the medium and higher notes of the musical scale. Many of the higher-priced and best-built radio sets today are fitted with both high- and low-range loud speakers; of course, those owning an orthophonic talking machine can utilize this for wonderful radio reproduction.

sizes of this orthophonic type of horn have been experimented with, up to 40 feet in length. The 20-foot horn of this folded type, curved to the mathematician's taste, as dictated by the inventors, has become a standard unit, for use in large hotel dining rooms and other locations, where an ordinary phonograph record and electrical pick-up arm are used to send forth sonorous tones of tremendous volume and power.

It would seem to a present-day observer, after carefully reviewing all that has been done by the various loud-speaker manufacturers in the past few years, that the old-fashioned horn (having an average axial length of about 1½ feet) can never be made to do any more than it does at present, as shown in the graph (Fig. 1). This means that, unless the small horn is supplemented by a cone, to take care of the lower notes, such as the bass and baritone, radio broadcast listeners simply cannot hear a vocal or instrumental selection reproduced in their home just as it is sung or played in the studio or concert hall.

The next step in the development of our future loud speakers would seem to be toward something on the order of the orthophonic horn; or else direct adoption of this device, fitting the horn with a good loud-speaker unit. Another alternative appears in the development of a new type of cone, the advance models of which have recently been put on the market. Fig. 2 shows a new model receiving set, fitted with both cone and horn speakers.

Figs. 3 and 4 illustrate and explain one of the latest developments in cone speakers, which the writer has been testing for some time. This cone and one or two others represent the newest advance in cone-speaker design: **i.e.,** they are constructed with two vibrating members of sections, one of which reproduces the bass and low intermediate notes, such as baritone, while the high-pitched part of the cone reproduces the high intermediate and treble notes, such as tenor and soprano. The writer feels free to express an opinion to which many of his colleagues agree, that the average single-cone speaker is liable to lower the register of the tenor and soprano voices, as well as that of the high-pitched musical instruments. In fact, this usually occurs unless special care is taken to adjust the unit very carefully and also see to it that the cone is operated with a suitable set and in the proper manner. Cones are best connected to the output of a radio receiver by means of a choke-oil and condenser, in order to eliminate the "B" battery current from the speaker.

The most obvious remedy for the high-note deficiency in the musical reproduction of the average cone is to use two speakers, as previously mentioned: while the ultimate solution, hard to carry out just now, as orthophonic horns are not being sold separately from the talking machine, is to adopt the orthophonic horn in connection with a good speaker unit.

Referring to Fig. 4, the action of the new cone having two vibrating sections for the low and the high notes, is clearly shown. As will be seen, the annular section (outer ring) of the diaphragm, reproduces the bass and low baritone notes, while the conical (pointed center) portion reproduces the upper baritone and soprano notes. This speaker has also a controlled mica diaphragm; the design of the talking unit being such that a push-pull action on the diaprhagm is obtained. This speaker is the best the writer has

Fig. 3

There are dozens of cone speakers on the market, each of which seems to have some little advantage or merit of its own; but the one here shown, and recommended by the author from among several which he has tested, not only possesses the unusual faculty of bringing out and emphasizing the bass and baritone notes, but it is so designed that the smaller section of the cone emphasizes the high notes.

ever tried out for use realized. This means a great deal in the future development of radio loud speakers; for we at once see that, if we ever reach the point where orthophonic horns or their equivalent become available to the radio manufacturer, he will have only to add a small loud-speaker unit of good design.

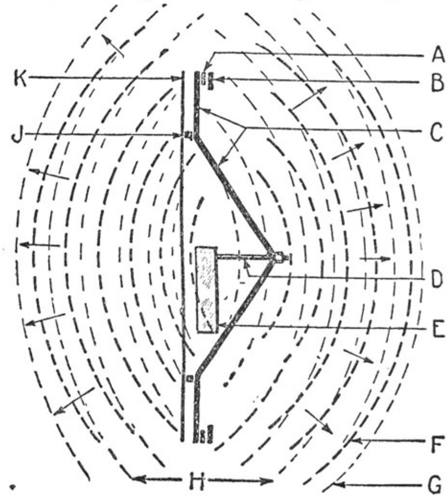



FIG. 4

**Diagram above shows both bass and treble sound waves are created and brough out by the large and the small vibrating sections of the dual-type cone speaker pictured above.**

### The Octaves Imitate the Fundamental

The question has often been asked the writer, how can a small horn ever possibly reproduce a bass note, or even make an attempt at it? Fig. 6 will help to show how this is possible. Practically all musical sounds are rich in harmonics: **i.e.,** they are built up of a number of different frequencies, which are multiples of the one pronounced or predominant frequency, which is called the fundamental. It is this fundamental frequency, or tone, which we hear most strongly, in the case illustrated in Fig. 6; but, as we look at this diagram, we see that the second harmonic is of a different frequency (it is exactly an octave above the fundamental). Suppose the bass viol sends forth a note with a wavelength of 35 feet and that you have only an 8¾-foot horn to reproduce it; this horn will have to resonate this note on the fourth harmonic (second octave) which has a wavelength of 8.75 feet in air, as Fig. 6 shows. Suppose again you have only a short horn with an axial length of 4.37 feet; if the bass viol's lowest note, about 35-foot wavelength, is sounded, this little horn, 4-1/3 feet in length, will attempt to give you a sound something like the fundamental, by resonating at the partial frequency or eighth harmonic (third octave).

# BUILDING A REMOTE-SPEAKER CABINET

## *Excellent Quality May Be Obtained Through the Use of This Horn and Cone Combination*

By HERBERT C. McKAY

IN these days, when quality is the aim of all radio fans, nothing should be overlooked to attain this goal. It is well known that too close an association between set, speaker and batteries will result in pick-up which interfere with quality. In view of this fact, these accessories should be removed from the immediate vicinity of the set. This may be done by placing the speaker upon a table at some distance and relegating the batteries to the basement, but such a method has its disadvantages.

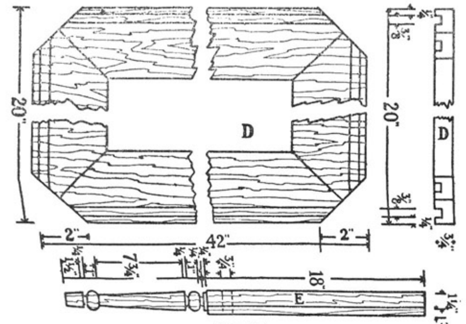



Fig. II

**Fig. 2. Details for the legs and corners of the cabinet and the shelf members are given herewith.**

In the first place, many fans object to the appearance of the exposed horn or cone, and with reason. Again, the basement is not the most convenient location for batteries. To overcome these objections, yet gain the advantage of a remote speaker and battery accommodation, this speaker cabinet was built.

Briefly, the cabinet consists of a low console, of a height whch wll make t convenient for use as a table. Inside this console there is space for two speakers—a horn and a cone. On the front panel is located a selective switch which will enable the operator to secure both speakers in series or in parallel, either speaker alone or both off. (See Figs. 7 and 8.) Below this switch, in the horn circuit, is a high resistance, in the order of 200,000 ohms, which will act as a balancer between the two speakers. There is also ample space for "A" battery, charger and "B" socket-power unit.

### Materials required

As will be seen from Fig. 3, the overall dimensions are 31⅛x44 inches. The extreme depth is 2½ inches. The materials needed are the following pieces of suitable wood:

Four 2x2x30 in. (legs);
Two 1x3x42 in. (shelf members);
Two 1x3x20 in. (shelf members);
Two 1x3x21½ in. (lid members);
Two 1x3x44 in. (lid members);
One 1x3½x16 in. (mid-panel);
Two ⅜x16¼x17¾ in. (front panels);
Two ⅜x16½x16¼ in. (end panels);
One ⅜x16¼x38½ in. (rear panel);
One ⅜x19¼x41¼ in. (shelf);
One ⅜x17½x40 in. (lid panel);
One 1x2x38 in. (rear stretcher);
Two 1x2x16 in. (end stretchers).

In addition there are needed two hinges and two hinged braces for the lid, screws, brads, corrugated fasteners, plastic wood, stain, shellac and wax.

### Construction

The legs may be made in any desired form; that shown at E (Fig. 2) was used by the writer. The corner was ripped from the leg pieces. Then a circle was drawn upon the end for use as a guide in turning, and the lower part of the leg turned as

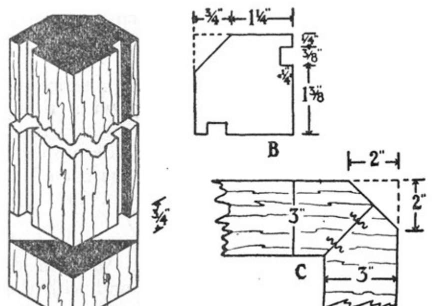
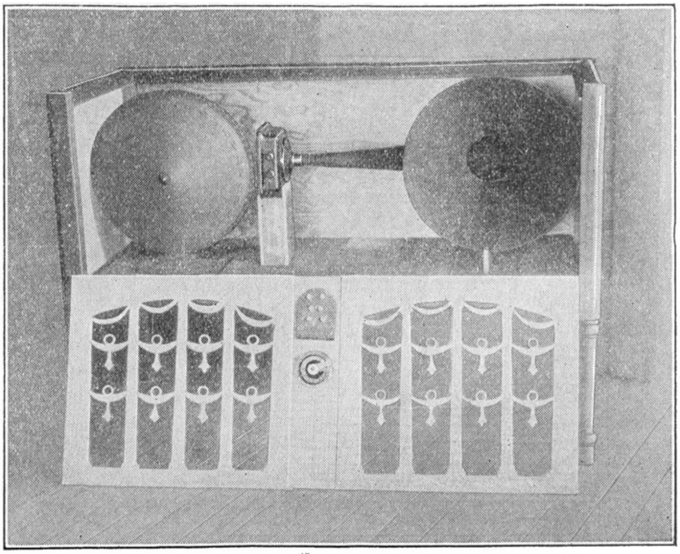



Fig. I

**Details are shown above for the construction of the legs of the cabinet, if a lathe is not available.**

**At the right is shown the finished remote loud-speaker cabinet. As mentioned in the accompanying text, it is found that two loud speakers, one of the horn and one of the cone type, give the best reproduction. The decorative front piece of the cabinet is lowered in order that the position of the two speakers may be clearly shown. The instructions for this mounting are given in the accompanying text.**

**In the center of the front panel will be seen the selector switch and a resistor for controlling the volume of the output. The details for making this switch will be found on page 27.**



shown. In case a lathe is not available, the legs may be left square and tapered as shown in Fig. 3.

After turning or tapering, a notch ¾-inch wide is cut across the leg from corner to corner, diagonally as shown at A (Fig. 1). This notch receives the corner of the shelf. The top of this notch is sixteen inches from the top of the leg, fixing the height of the shelf. When this is done, two dadoes ⅜ inch wire are cut as shown at A (Fig. 1). These dadoes are ¼ inch deep, and receive the ⅜-inch, three-ply panels. This completes the legs.

The shelf is made by mitering the shelf members and fastening with three corrugated fasteners at each corner, two on the lower side and one on the upper. When this is done, the corners are cut off as shown at C (Fig. 1) and D (Fig. 2). (B in Fig. 1 shows the leg section.)

Dadoes are cut in the top of the shelf ¼ inch from the edge, ¼ inch deep and ⅜ inch wide, to correspond with the dadoes in the legs. This may be done either before or after assembling the shelf. Using a small power saw with a dado head, it is easy to do this after the assembly, making a closer job.

The shelf is now fitted to the legs by inserting the corners of the shelf in the notches cut in the legs. Be sure that a good fit is made and that the edges of shelf and legs match exactly. This will entail some chiselling and hand-fitting. When a good fit is secured, remove the legs, paint a liberal quantity of good glue in the notch, replace the shelf and secure by driving two 1½-inch brads into the shelf from the two outside faces of each leg. Now toenail the inside faces of the legs to the shelf.

Notch the shelf panel, and lay it in place. True up the assembly with a square and secure the panel with ¾-inch screws placed about every four inches around all sides.

Try end and rear panels for fit. If they fit snugly, remove them, paint the dadoes with glue, replace the end and rear panels, and secure with a 1-inch brad through each top corner, from the outside.

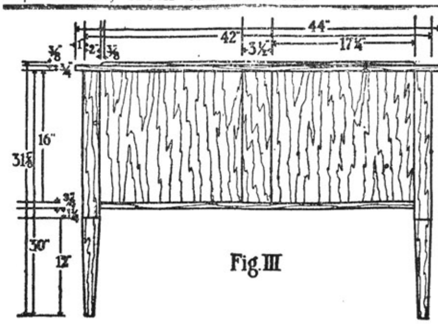
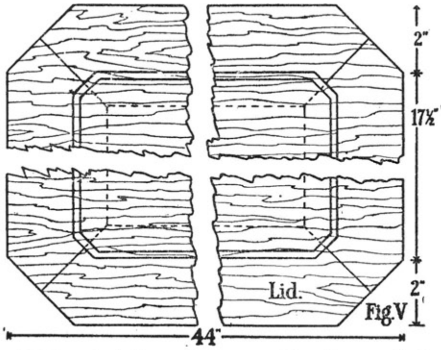



**Fig. 3. Here are given the principal dimensions of the loud-speaker cabinet.**




Place stretchers between the tops of the legs, inside, on ends and at rear. Secure these with a 1-inch brad every six inches, from the outside, ½-inch from the top of the panel. Secure to legs by ½-inch screws placed diagonally.

### Decorative design

The front panels are then cut out with a fret saw as shown in Fig. 4. The opening is outlined first according to dimensions shown. The bases and capitals of the pillars are drawn, each ¼-inch deep. The pillars are 1-inch wide at the bottom and ¾ inch wide at the top. When the pillars are drawn, draw the four lines C-D, E-F, G-H and J-K. Place these according to dimensions shown.

Set your dividers at a 2-inch radius. Then, from points "b" as centers; and from the intersection of lines E-F and J-K with edges of the pillars as centers draw intersecting arcs to determine points B. With these as centers, draw the arcs shown. Then, with a 3½-inch radius, follow the same procedure; using points "a" and the intersection of lines C-D and G-H wih edges of pillars as centers. This locates points A. Using these in turn as centers draw the flatter arcs. The arc which determines the top of the entire opening is drawn with a 24-inch radius.

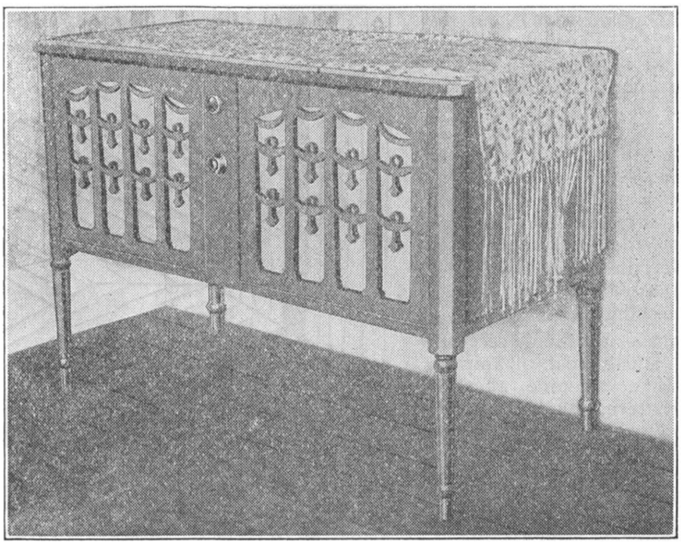
This locates pillars and garlands. Now draw center lines in each of the four spaces. Where lines C-D and G-H intersect these center lines, draw two concentric circles whose radii are ¼ and ⅜ inch, respectively. Finally draw the ornamental drops as shown in the right lower portion of Fig. 4.

Only one circle and drop is shown, to preserve the clarity of the drawing.

The first step is to cut the openings in the small circles, using a ½-inch bit for the purpose. This is done first to prevent tearing the wood, as would result if the outer circle were cut first. Then cut out the rest of the design in the usual way.

Cut dadoes in the edge of the mid-panel. Set in place and mark the notch necessary to be cut in the front edge of the shelf panel to receive this mid-panel. Cut this out with a chisel.

Mount the switch and resistance upon the mid-panel, set it in place and secure with



**At the left is shown the completed loud speaker cabinet. As explained in the accompanying text, if the open-work front panels are lined with thin cloth a very harmonious combination may be made with the existing color scheme of the room in which the cabinet is to be installed. Another very advantageous use to which this cabinet can be put during the summer months, is to place it on the porch where it will furnish radio entertainment to the family and, at the same time, be a useful piece of furniture.**

**At the right is Fig. 4, in which are provided the details for cutting out the front panels with a fret saw. Although these decorations may seem not altogether necessary, yet there must be an opening of some shape in the front panels, so that there will be no impediment to the egress of the sound from the loud speakers. If it is desired to have a plainer opening, one more simple can doubtless be devised by the ingenious constructor. Fig. 5, gives the dimensions of the lid and its general shape.**

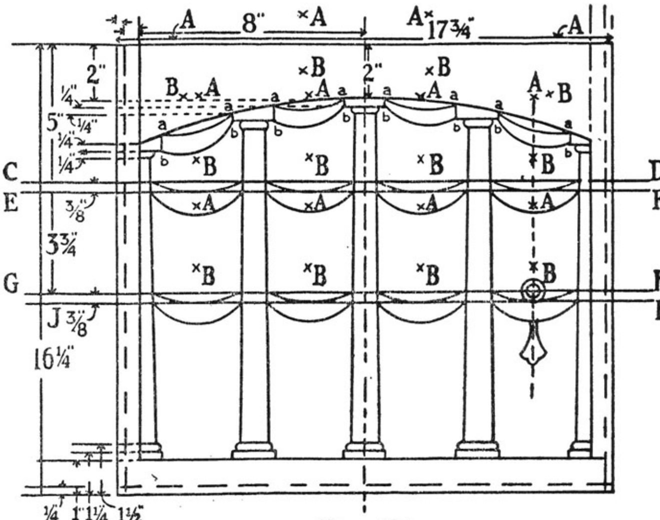



Fig. IV

two 2-inch screws from beneath, passing through the front shelf member. Now glue the dadoes and insert the front panels as has been described.

The lid is made just as the shelf was. If the legs have the corners cut off, the corners of the lid will also be cut off as shown; but if the legs are left square-cornered, the lid will also be left square. The lid panel is cut 2 inches smaller on all sides (4 inches less on each dimension) and the edges bevelled at 45°. The lid panel is placed in position and secured with two 1-inch brads at each corner. The lid is then reversed and the panel secured with a 1-inch screw every four inches around all edges. The 1-inch screw will not quite pass through both pieces.

The lid is hinged to the legs with good steel butts and the brackets are put in place. These brackets allow the lid to be raised and hold it up a little past the center. They prevent strain upon the hinges.

**Finishing**

The entire cabinet is then carefully scraped and sanded and a coat of spirit-or oil-stain applied. If a two-tone effect is desired, draw the pattern, cut the pattern into the wood for about 1/16-inch with a sharp knife. This prevent the stain and filler from spreading. Now rub into the portions which are to be light, a good wood filler. When the stain is applied, the portions thus treated will not take nearly so much of the stain and will give a good two-tone effect.

When this is done, thin silk of any appropriate shade is carefully glued to the front panels, on the rear side, of course.

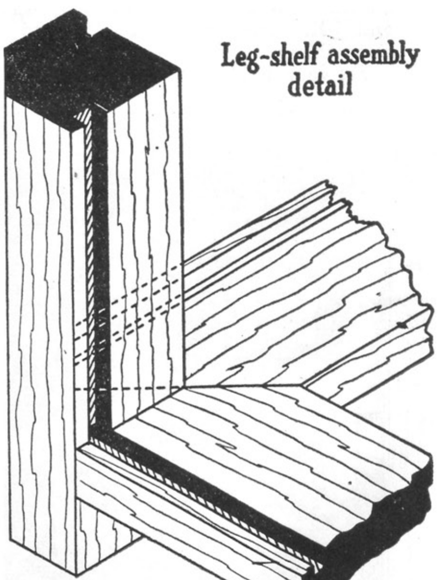



Fig. VI

**Fig. 6. Here is shown the method used in joining the legs to the shelf of the cabinet.**

This silk is stretched tightly and left to dry. When it is dry the cabinet is complete.

### Mounting the speakers

In the case of larger horns, the horn will probably have to be laid upon its side. This requires three cradles for support; one at the base, one at the edge of the bell, and one midway along the gooseneck. The batteries, etc., may be placed in any convenient spaces.

In setting up, a series of ¼-inch holes bored in the back panel will admit the necessary connecting cords.

In use, it may often be convenient to house the set in a table cabinet, provided with handles at the end. The set is placed upon this speaker cabinet when not in use. When in use it may be placed upon any convenient table six feet or more from the speakers. This gives all of the quality of the remote speakers without crowding two consoles into a room which may be small.

### Control for speakers

The two knobs on the central panel of the cabinet provide full control of the speakers. The upper knob is connected to a six-point selector switch and the lower knob is connected to a high resistance, which may be a heavy resistor of the conventional type.

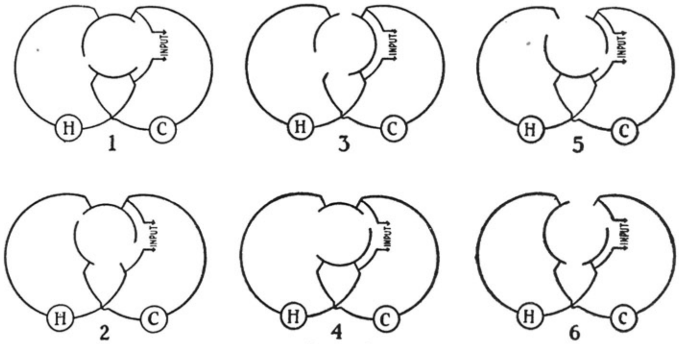



Fig. VIII A Fig. VIII B Fig. VIII C

**In Fig. 7, below are shown the details of the selector switch and in Fig. 8, above are the switch positions, as enumerated at the end of the article.**

Fig. VII A

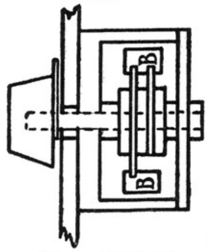



Fig. VII B

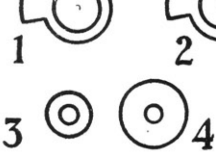



Fig. VII C

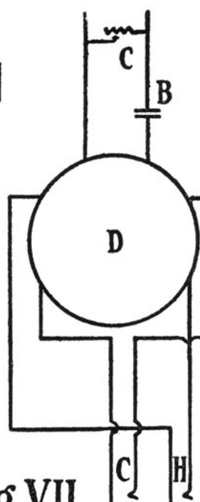
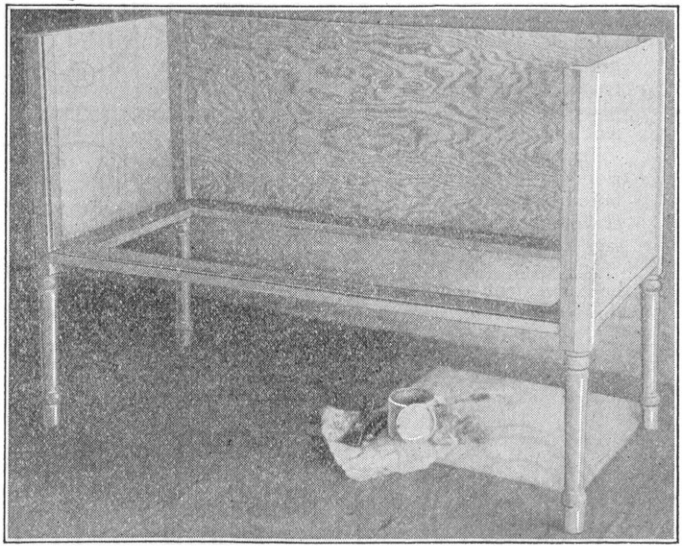



Fig. VII

Reference to Fig. 7 will plainly show how the selector switch is made. The frame is an old receiver shell, and the other parts will be found in any experimenter's "junk" box. Fig. 7A is a plan view of the assembly and 7B is a section. It will be seen that four wiping contacts have been secured to the inside of the receiver shell by means of machine screws, size 6-32. The nuts provide connection on the outside of the shell. It will also be seen that one upper and one lower contact are connected to two extra binding posts. This is the input circuit. If the switch be divided by a horizontal line we have on each side, one input, one horn and one cone connection.

The switch blades are made of 1/16-inch brass. They are sectors of 95° and 135°, respectively, bored large to take an insulating bushing. These are assembled upon a 3/16-inch shaft, pieces of ⅛-inch hard rubber being used for separators. Such rubber can be found in old storage-battery jars. The assembly of sectors and shaft is slipped into the shell. Holes drilled in the rear of the shell provide mounting. A strip of hard rubber, ⅛ x ½ inch, is secured across the open end of the shell; it has a hole drilled to take the free end of the shaft with a nut or collar to hold the shaft in place. The dial anchors the other end of the shaft.

This is the simplest form for this switch. The switch shown in the illustration is identical in action but the sectors are riveted to a flat disc and the contacts are sidewiping, thus forming a two-disc switch. It is more difficult to secure good contact in the disc type of switch than in the type just described. The receiver switch has been substituted for the disc switch in the speaker console described.



**At the right, the interior of the partially-assembled loud-speaker cabinet.**

In case the set is not provided with an output unit, one such may be placed in the speaker cabinet, or a good A.F. choke and by-pass condenser may be mounted on the center panel, just below the resistor. In any case the set leads are connected to the high resistance, so that it is shunted across these leads; and a by-pass of at least 2-mf. is used in series with one lead. This provides ample volume control for the speakers.

The schematic diagrams (Fig. 8) numbered from one to six show clearly how the selector switch will give parallel or series connections of the two speakers, will cut out either, leaving the other, or will cut out both. These diagrams are, in order: (1) Parallel; (2) Horn; (3) Off; (4) Parallel; (5) Cone; (6) Series.

# The Why of Power Tubes

WHY are large audio amplifier tubes of the 112, 171 and 210 types essential for quolity quality reproduction? This question can be answered, briefly, as follows:

Older types of radio receivers reproduced with full intensity only the medium-pitched notes, to which both the loud speaker and the human ear are sensitive. The lower bass notes were not reproduced and the high frequencies were slighted. Under such conditions, tubes of the 201A type were capable of giving satisfactory service.

Present day requirements call for full reproduction of a much wider range of frequencies with uniform intensity. The high frequencies do not carry much energy, and hence impose no additional load on the tube supplying the speaker. The low frequencies, on the other hand, contain most of the energy present in musical selections or speech and, therefore, have a tendency to greatly overload the tubes. At the same time, the reproduction of these notes does not give the impression of loudness, because the ear is less sensitive to them.

It will be evident, therefore, that quality reproduction requires tubes capable of furnishing greater power output than can be obtained from 201A type and similar tubes. Emphasis should be placed on this feature of tone quality in reproduction, and not on the volume obtainable from power tubes.

# A PIEZO-ELECTRIC LOUD SPEAKER

***This article describes another very interesting piece of apparatus for the experimenter's radio set. The actuating mechanism for the loud speaker is simply a Rochelle-salt crystal.***

By R. F. SHROPSHIRE

WOOD many years ago, scientists discovered that in certain crystalline bodies there is a marked relationship between electrical and mechanical effects. This is termed "piezo-electricity," and has been defined as a study of the electrical phenomena produced when crystalline bodies are subjected to mechanical stresses, and of the mechanical deformation occurring as the result of applied electrical potentials.

In other words, if a piezo-electrically active crystal is subjected to an applied potential, there will be manifest a mechanical deformation. Conversely also, when such a crystal is subjected to mechanical forces which tend to deform it, there is a change of potential between its poles. The exact nature of that which occurs within a crystal is still a matter of conjecture, although the theory that the action is of a more or less electrostatic nature seems to be supported by the results of the experiments that have been made in this field.

One cause for this belief is the fact that the hysteresis loops for crystals are similar to those for iron. That and other properties of crystals have led scientists to believe that piezo-electricity and ferro-magnetism are closely linked. Suffice it to say, however, that whatever the cause of the various effects that manifest themselves, they are of such a nature that they readily lend themselves to many uses.

So far as the researches that have been made public have shown, there are only two classes of crystals which are piezo-electrically active. The first of these is the group in which there is an asymmetrical arrangement of the atoms in the organic molecules, which includes the tartrates, sugar, camphor, etc.; and the second is the group in which there is an asymmetrical arrangement of the mineral.

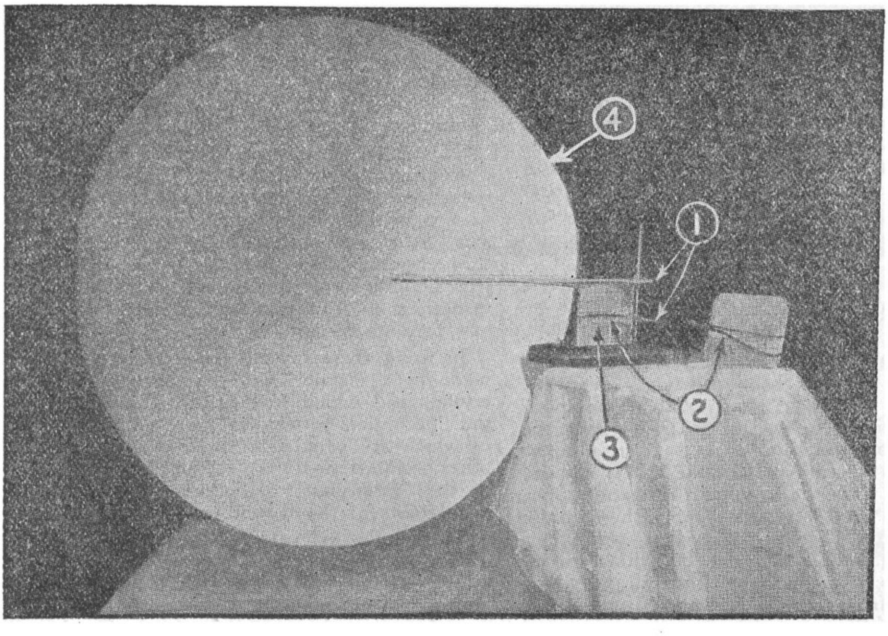
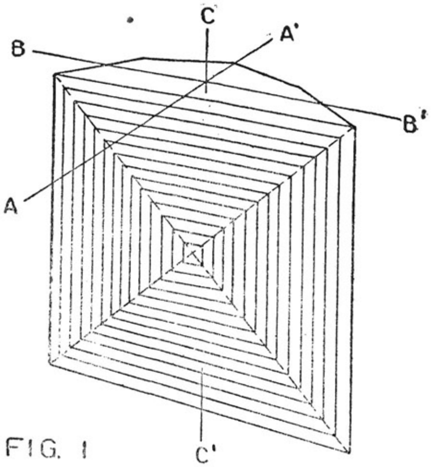



**Fig. 3. This photograph shows a crystal loud speaker assembled. 1 shows the terminal connections; 2, the girdle; 3, the crystal and, 4, the paper cone.**




The sketch shows a diagrammatic view of a Rochelle salt crystal. Note the axes C-C[1] and the "hour-glass" formation.

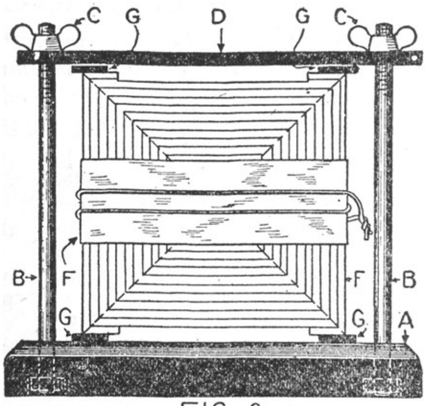



FIG. 2

The mounted crystal is here shown ready to be attached to the paper diaphragm (Fig. 3). See the text for legends of the letters.

**molecules,** such as in quartz, tourmaline and boracite. Quartz, tourmaline and sodium potassium tartrate (better known as "Rochelle salt") have been the principal subjects of study. Of these, Rochelle salt shows the highest activity.

The particular activity in which we are most interested is that mechanical deformation which occurs as the result of applied electrical potentials; and which manifests itself in the form of torsion about the main axis of crystallization. This is comparatively large, and has been calculated to be—

$10^{-5}$ radians (2.06 seconds of arc)
per applied volt

for a crystal approximately seven centimeters in length.

**Preparing a Crystal**

Although a method of growing crystals of Rochelle salt has been previously described in **Radio News** (August, 1925, issue, page 233) it might be well to go briefly over the salient points in this process. First, a super-saturated solution of Rochele salt is allowed to cool, with the resultant formation of a crop of "seed" crystals. From these, those are selected which have grown with their crystallographic axis horizontal, which are approximately one-half inch square, and which are free from flaws and other malformation.

One of the selected seeds is then immersed in a super-saturated growing solution of Rochelle salt, and allowed to "grow," or build up, until it has attained a size of approximately 2½x2¼ inches. It is then desiccated. This desiccation process is for the removal of the waters of crystallization, and is further aided by a subsequent heat treatment. The finally-prepared crystal is then ready for use.

It should be of about the dimensions mentioned above, and should exhibit a marked "hour-glass" formation. The latter is important. Fig. 1 shows a sketch of a crystal, and on it are indicated the axes, and the "hour-glass" formation.

This peculiar effect consists of stratifications perpendicular to the c-c' axis, and the remainder of the crystal structure, the stratification of which is ordinarily parallel to the axis. It is believed that the crystal molecules throughout these pyramidal regions are subjected to forces during growth, that tend to turn them in planes containing the principal axis, through 90 degrees.

In using these crystals, one connection is made to a metallic girdle surrounding the crystal, and which includes that section of the "hour-glass formation," the stratifications of which are parallel to the c-c' axis. The other connection is made to the basal regions of the "hour-glass" formation through the metal parts of the mounting mechanism.

The girdle, referred to above, is usually a strip of tinfoil, which is wrapped about the middle of the crystal. Its width should be approximately one-third the length of the crystal, measured along the c-c' axis. To this girdle is fastned a wire which serves as one connection to the crystal.

### Arranging the Loud Speaker

In mounting the crystal for use as a loud speaker, a heavy base, two tie rods and nuts, and an arm are required. Fig. 2 shows a mounted crystal. A is a heavy metal base; B the tie rods; C the nuts for securing the tone arm D; E is the crystal, surrounded by the tinfoil girdle F, and supported by the lead cushions G.

The base should be as heavy as possible and the tie rods should be as light and as close together as the crystal will permit. The length of the tone arm can only be determined by experiment, and depends on the thickness of the material used. Using 1/8-inch brass, one inch wide, it has been found possible to fasten the diaphragm as far as six inches from the crystal. The lead cushions are used to prevent chipping of the crystal and to provide better adhesion between the crystal and the metal parts of the system.

It will be noted that the middle section of the crystal is partially cut away at the basal regions, between G-G. This is occasionally found necessary, in order to render more salient the "horns," or corners, of the crystal.

### Constructing the Diaphragm

Fig. 3 shows a mounted crystal with diaphragm attached at the outermost point of the tone arm. To make this diaphragm, a circle of paper (preferably 3-ply bristol board), about eighteen inches in diameter, is cut out. A 15-degree sector is next cut from the circle, and the two edges fastened together, thus forming a cone whose shape is about 15 degrees. A short piece of bus-bar is then secured at the apex of the cone, with a paste made from melted Rochelle salt.

It may be of interest to add that by melting Rochelle salt to a paste, and then permitting it to harden, a cement is formed that, in addition to having great strength, is easy to use, sets quickly, and is very useful around the laboratory.

The conical diaphragm is then secured by soldering the bus-bar to the tone arm. Due, as has already been said, to the effect of the thickness of the metal used in the tone arm, it may be necessary to try the diaphragm at various distances from the crystal, but it should operate best at a distance of from four to six inches.

### Natural Reproduction

It will be found that a loud speaker of this type will give more natural reproduction of both voice and music, than one actuated by a magnetic driving element. However, it has the disadvantage, from the standpoint of the average set, that an output transformer is necessary for its operation, because of the high internal impedance of the crystal. This impedance is not a constant, but depends on the size of the crystal and the degree of desiccation. It will be found that it is usually on the order of 100,000 ohms, at 1,000 cycles. The ordinary audio coupling transformer has a secondary impedance of about this value, so that it may be used as a means of coupling the output of a set to the crystal loud speaker.

### A Simpler Construction

For those whose facilities do not permit them to make the more elaborate device, the simpler form may be found to give good results. To make this, two circular discs of aluminum, approximately 3½ inches in diameter, are required. These are drilled in such a manner that tie rods can be used to hold the crystal between the discs. When the crystal is mounted in place, connections have been made to the poles, and a connection from the girdle has been brought out through an insulated bushing fastened in one of the end plates, a diaphragm is secured in place about the edges of the two discs. Then the diaphragm is twisted so that it is stretched in diagonal folds, and it is securely fastened by means of rings. Small adjustable embroidery rings may be used for this purpose. It will be found that varnishing the diaphragm will improve the tone and pitch. Fig. 4 shows a device of this type in its completed form.

The two forms of loud speakers that I have described are not the only two that it is possible to make. One of the remarkable features of these crystals is the great driving force that is obtained.

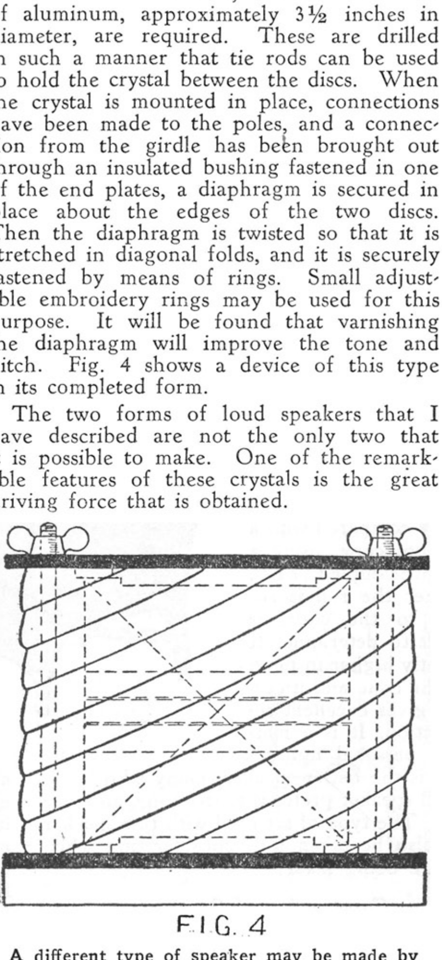


FIG. 4

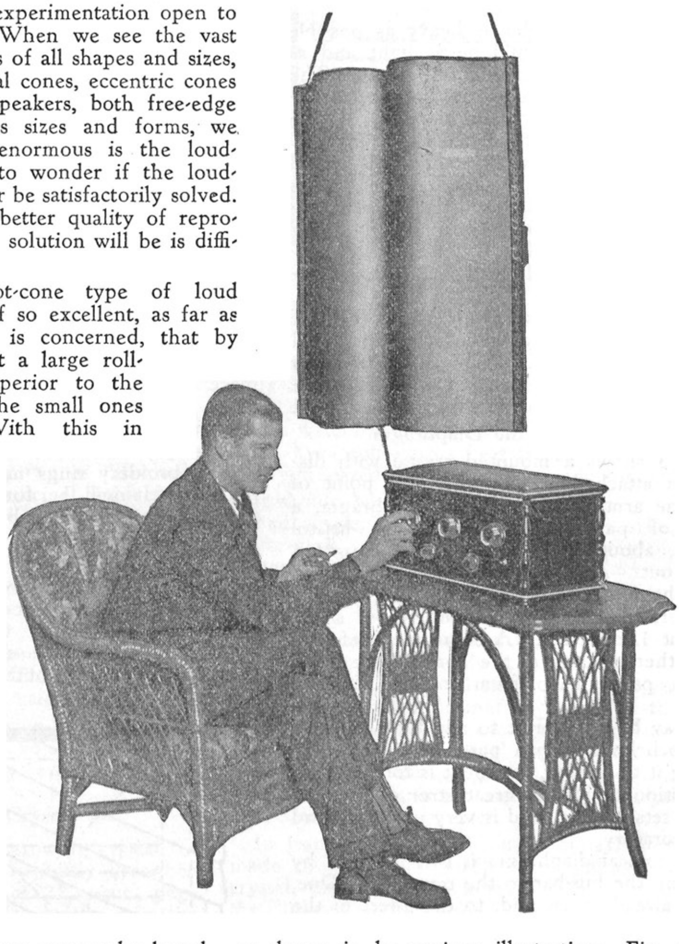
**A different type of speaker may be made by using two aluminum discs; the diaphragm being secured to their edges and twisted diagonally.**

# A THREE-FOOT ROLL-TYPE SPEAKER

*A Reproducer Simple of Construction and With Excellent Tonal Quality*

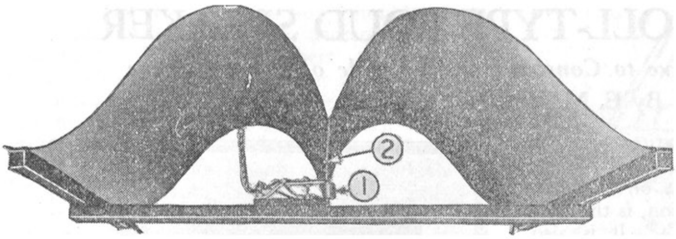
THE loud speaker offers one of the most interesting fields of experimentation open to the radio listener. When we see the vast number of horn speakers of all shapes and sizes, and also plain cones, oval cones, eccentric cones and roll or book-type speakers, both free-edge or otherwise, of various sizes and forms, we begin to realize how enormous is the loud-speaker field, and also to wonder if the loud-speaker problem will ever be satisfactorily solved. Its evolution is toward better quality of reproduction. What the final solution will be is difficult to predict.

The large, three-foot-cone type of loud speaker has proven itself so excellent, as far as quality of reproduction is concerned, that by analogy why should not a large roll-type speaker prove superior to the smaller ones? (And the small ones are very good.) With this in mind, a large roll speaker was built, with the parts designed for a three-foot cone speaker. The roll speaker, shown in the accompanying illustrations, was found surprisingly simple to make. Only a few minutes were required to assemble it; it was then directly compared with a three-foot cone, using a resistance-coupled set. Whether the roll is superior to the cone, is difficult to determine. It is slightly higher in pitch than the cone and it certainly gives excellent reproduction. It is a matter of personal opinion which is the better speaker, many who heard the roll speaker prefer it to the cone, and vice versa. The type of set used with this speaker must also be taken into consideration when tests are being made.



### Construction of Speaker

The construction of the speaker is so utterly simple that it requires little comment here. First a frame of three sticks was built, as shown in he various illustrations, Fig. 4 giving the dimensions. Be sure to use a heavy, hard wood, such as oak; because, the more weight added to the unit, the better will be the results. Remember that, on these large speakers, the vibrating member or diaphragm weighs as much as the unit; and unless weight is added to the unit, the diaphragm will remain stationary and the unit will vibrate.




On the left is the end view of the speaker, showing the manner in which the unit is mounted. No. 1 in both views is this unit and No. 2 is the point where the unit's drive rod is attached to the paper diaphragm.

The roll, or rather double roll, is made from one sheet of 38x38-inch speaker cone material. The sheet is folded once through the center, across the grain, as shown in Fig. 4. (This material is usually supplied in rolls, with the grain running lengthwise with the roll.) Before folding, draw a line through the center with a straight edge. Now using the straight edge and a sharp pointed tool, go over this line, making an indentation in the paper. The sheet may now be folded along this line without fear of crushing.

Next we require a thin piece of brass cut out and drilled as shown in Fig. 4A. This is fastened to the threaded drive rod of the unit, bent up around the outside nut, and clamped upon the center of the folded edge of the sheet with a small nut and screw, as shown at B. Before clamping this piece to the sheet, mount the unit on the center of the wooden frame with wood screws.

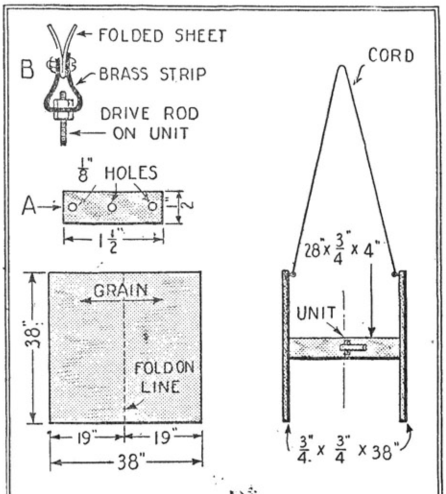
With the unit in place and the folded sheet attached to it, procure a few thumb tacks; bend the sheet over to the sides of the frame and securely attach it with the tacks. If desired, a gold braid may be placed along the sides to improve the appearance. The addition of a cord to hang the instrument to the picture moulding completes the assembly. Although called a three-foot roll, the speaker in fact is 38 inches long and 28 inches wide.

A loud speaker of this type lends itself admirably to decoration in a style harmonious with its surroundings. In contrast to the neutral tint of the diaphragm paper, braid trimmings may be used in brighter colors, agreeing with the other furnishings and the general scheme of the room in which it is hung.

In selecting the parts for this speaker be sure to procure a good cone unit, preferably a direct-drive one; in other words, one that has no mechanical reducing levers for reducing the motion applied to the cone. The one used in the writer's experiments was not a balanced unit, and could therefore be directly connected in the plate circuit of the output power tube of the set, without the use of an output transformer or choke coil and condenser system. A type 112, 171, or 210 power tube may be used in this manner without fear of damaging the unit.

### Theory of operation

The theory of operation of the large roll speaker is somewhat similar to that of the cone speaker. In order to obtain faithful reproduction of the low tones, such as are produced by the bass viol, it is necessary to move a large volume of air. This requires a large, light, and strong diaphragm, the larger the better, up to a certain point where the lowest musical tones are reproduced. A sheet of paper may be large and of light weight; but it has no strength unless formed into a cone or roll, after which it serves as an excellent diaphragm. In the cone the vibrations are applied at the apex and waves radiate outward; in the roll speaker the transition between vibratory and undulatory motion is more gradual, giving it a distinctive tone of its own, not found in other speakers.




Details of construction for the roll-type speaker. At the upper left are data for preparing the metal strip that is attached to the diaphragm.

# A SIMPLE ROLL-TYPE LOUD SPEAKER

*Easy and Inexpensive to Construct and Capable of Great Volume*

By E. M. YARBROUGH

OF all loud speakers the writer has ever heard, the double-cylindrical diaphragm now to be described, built on the principle of Dr. de Forest's Audalion, is the most nearly perfect in reproduction. It is also, in contrast with most other paper-diaphragm devices, highly efficient, and absurdly cheap and simple to construct.

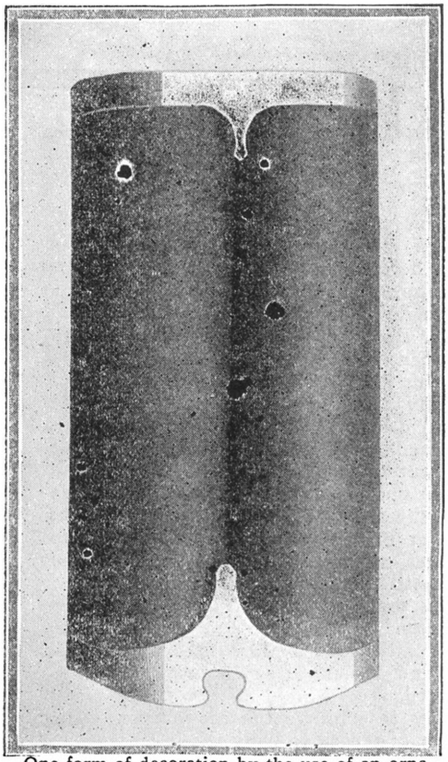
Briefly, this reproducer consists of a sheet of heavy paper folded in the middle, with the two halves rolled into semi-cylindrical shape so that the end view is like an "m"; the outer edges being supported, while the center of the crease floats on the diaphragm of a loud-speaker unit. This construction results in a quality of tone realized only by the best free-edge cones, with a slight increase in actual volume over horn-type reproduction.

The only materials essential to its construction are a high-grade telephone unit, a cork, and a sheet of heavy art paper, about 20 x 30 inches, such as used for the covers of advertising pamphlets and programs. The latter may be obtained in several shades at any stationery store, or at the local printshop, for about fifteen cents.

### Construction is easy

Art paper comes with a colored parchment finish on one side. Fold the sheet in the middle by placing one end true with the other and creasing the fold, being sure that the parchment finish is on the **inside.** Fasten the edges together with wire paper-clips about two inches, up from each end of the crease, in order to stiffen the crease. Mark the center of the crease and insert it into a knife slit in one end of a long, narrow cork. (See Fig. 1). This cork should be long enough to rest on the diaphragm of the phone without allowing the paper to touch the cap. Cork, being of nearly the same density as paper, makes a much better acoustic link than metal.

Make a light, rectangular, wooden frame, about a foot wide and the length of the crease. (See Fig. 2-A). In the center of the frame, fasten crosspiece to which the phone is to be attached. Mount the phone exactly in the center, using the method of fastening best adapted to the unit. Now tack the free ends of the paper to the sidepieces and set the cork link on the center of the diaphragm. (See Fig. 2-B). The instrument may now be used in a horizontal position with good results.



One form of decoration by the use of an ornamental guard rail at each end of the diaphragm, if so desired. A very neat ecect is thus obtained.

If it is desired to use the speaker in a vertical position, by standing it on end or hanging it on the wall, the crease must be supported from the end-pieces by light rubber bands, both to give the cork a proper contact with the diaphragm and to prevent sagging of the crease. The diagram makes this clear. If a drop of glue is used to stick the cork to the diaphragm, the tension on the bands need not be great.

### Finishing the speaker

The ornamentation of the finished product may be as simple or as elaborate as the constructor desires. However, if the result is to be in good taste, it is best to follow the old rule that construction should be ornamental in itself, and ornamentation constructional. Perhaps the best treatment would be to leave the two columns of paper unadorned, thus accenting the beauty of the parchment, and to provide at each end artistic guard rails, as illustrated, matching the style of furniture in the room in which the instrument is to be used. These rails should not touch the membrane. If the paper is used alone, a neat row of inked swastikas mav be used at each end.

In order to get the best possible tone from the speaker (assuming of course that the output of the radio amplifier is distortionless) we must eliminate, as far as possible, the distortion arising from the use of a stretched metal diaphragm in the phone unit. The best low-priced units are those in which

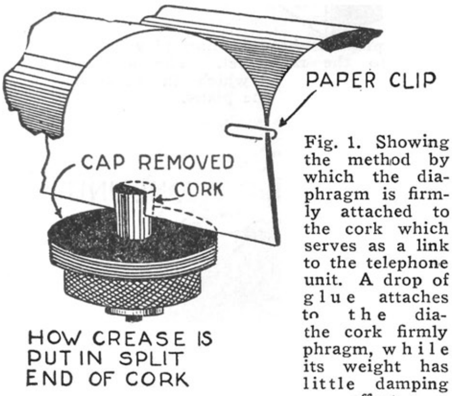



Fig. 1. Showing the method by which the diaphragm is firmly attached to the cork which serves as a link to the telephone unit. A drop of glue attaches to the diathe cork firmly phragm, while its weight has little damping effect.

a large diaphragm is supported between resilient washers, and in which the distance between the magnets and the diaphragm is adjustable. Simply unscrew the cap altogether and adjust the magnets until good tone and volume is had. The cork can now be made very short, resulting in better linkage, and may, if desired, be set on various parts of the diaphragm until the best point is found.

### Powerful and compact

The efficiency of conversion by this speaker, of electrical energy into sound energy, is attested by the fact that the resultant sound is as loud and distinct all over the room as it is an inch from the membrane. As a result, excessively powerful signals are not necessary for good volume. The writer uses only 66 volts on three "bootleg" 199's in a Roberts Reflex, with a choke coil for the last step. But to hear this outfit talk, you would think that five

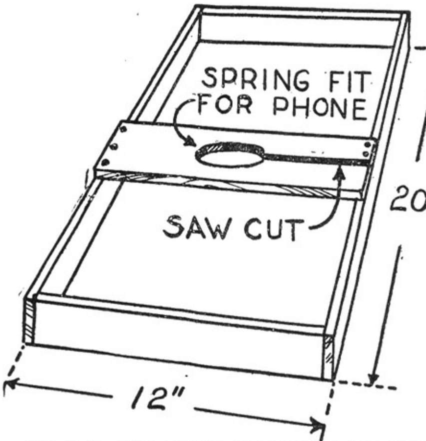



Fig. 2-A. The simple framework upon which the loud speaker is assembled.

hundred miles were five, and that "twenty bits" were "twenty bones."

The rectangular construction of this loudspeaker is admirably adapted for portable receivers, for the paper may be made removable from the sides, and folded flat, so that the whole may be packed in the lid of a suitcase. Another stunt is to use a single horizontal cylinder as a combination speaker and dust cover for an open-built set.

As a final word to those who intend to convert their old phonographs for electrical operation, you will find that the available space within the cabinet is more completely utilized by the cylinder than by a cone.

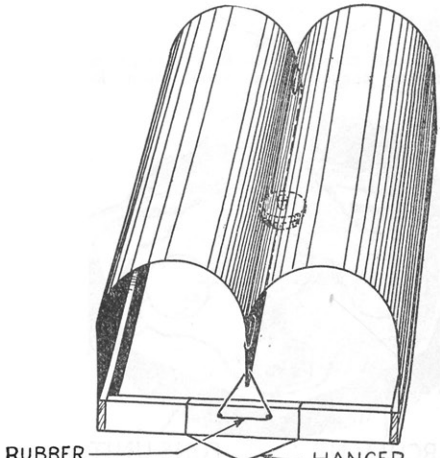
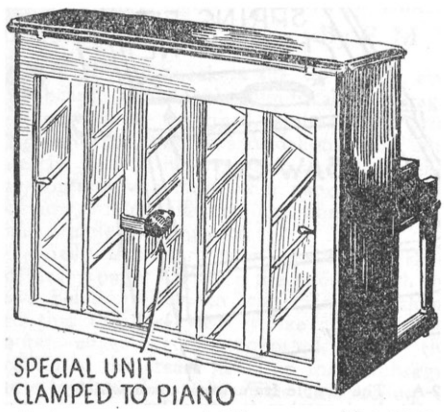
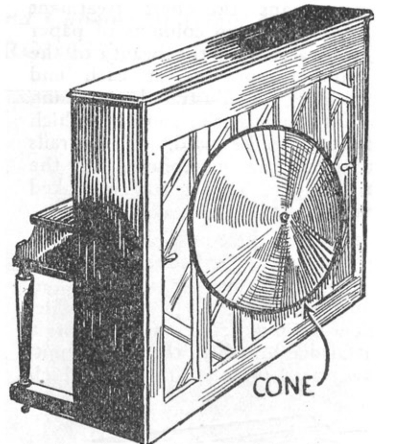



Fig. 2-B. The completed loud speaker, arranged for use on the wall, as viewed from the top. The position of the unit is indicated.

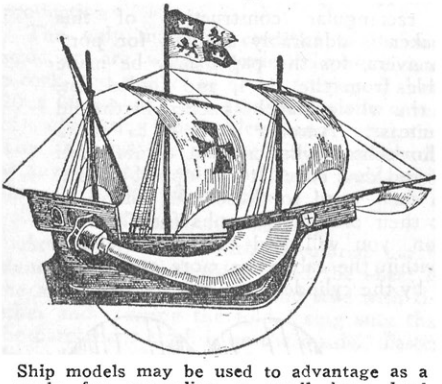
# ARTISTIC LOUD SPEAKERS



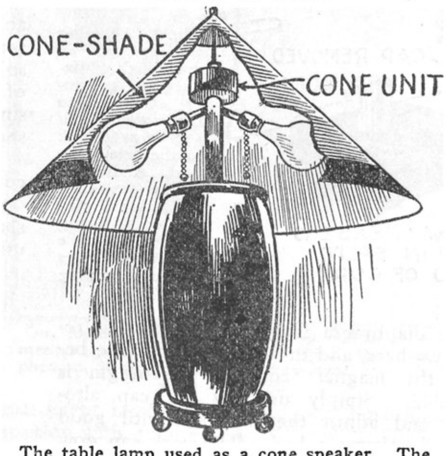

A clever arrangement doing away with a cone entirely. The unit is attached directly to the piano sounding board.



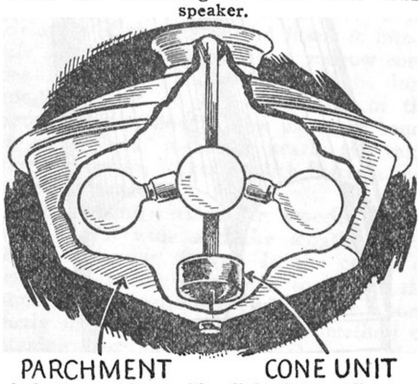

Again the piano is brought into play as an accessory to the radio set. The unit is attached to the cone, which in turn is fastened to the piano.



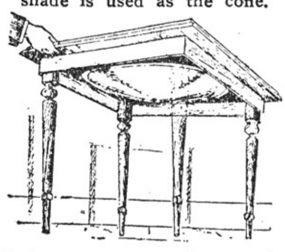
Ship models may be used to advantage as a mode for concealing a small horn loud speaker.



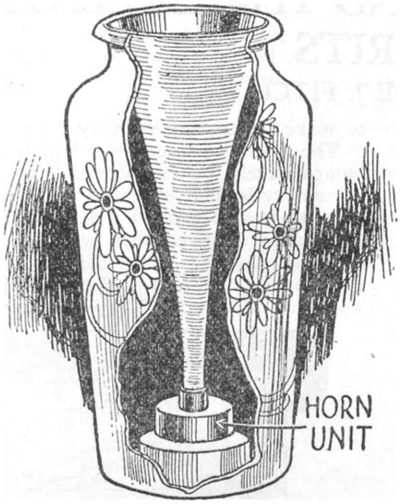

The table lamp used as a cone speaker. The shade is used as the cone.



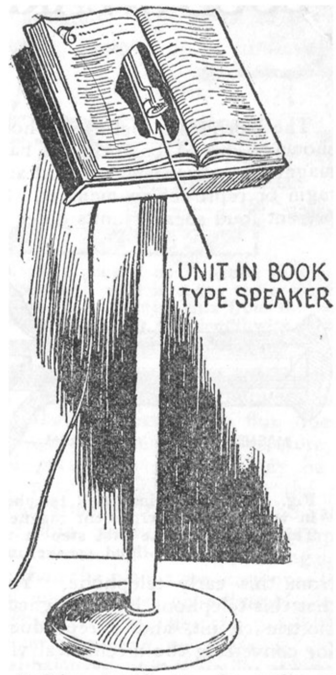

A loud speaking ceiling-light is an effort to get away from the commonplace. The globe itself is made of parchment. The unit is concealed within the globe.



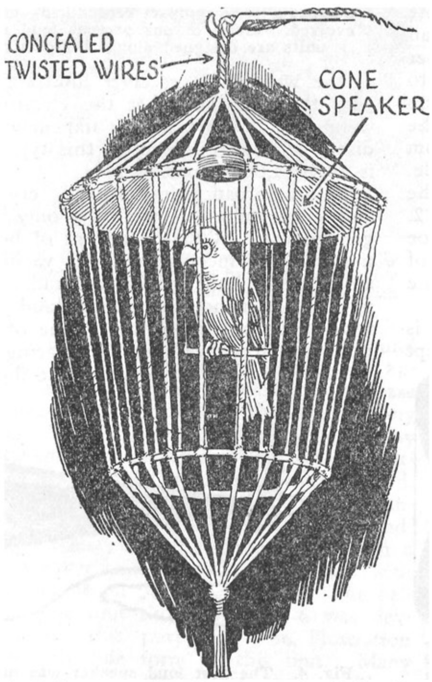
One of the most convenient methods for concealing the cone speaker is to place it beneath the top of a small table. In this manner the speaker may be readily moved from place to place.



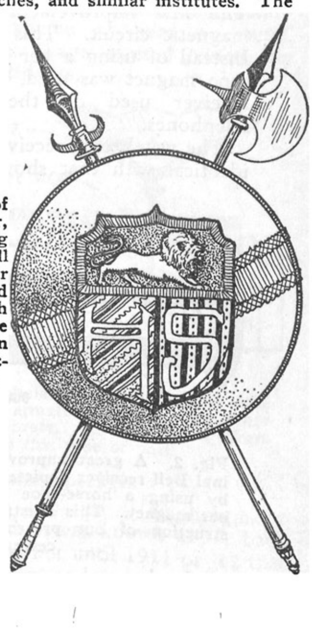

A horn and a unit may be cleverly concealed within a vase. It is well to support the unit upon a piece of sponge rubber.




The "talking book" may be easily carried from place to place and also provides a unique mounting for the loud speaker. This particular type can be used to advantage in schools, churches, and similar institutes. The




A bird cage speaker for those who desire the unusual. The cone and unit are situated in the upper part of the cage. Plush or chenille cord holds the cone in plac.



A new type of wall speaker, the talking shield. One will have to go far in order to find a speaker which can compare with this one in artistic and decorative effect.

# LOUD SPEAKERS AND THEIR RELATIVE MERITS

By CLYDE J. FITCH

The original Bell telephone receiver shown in Fig. 1 comprised a bar permanent magnet, an electromagnet, and an iron diaphragm or reproducing member. Some of the present loud speaker units differ very silghtly

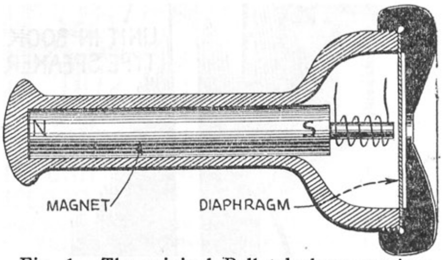



**Fig. 1. The original Bell telephone receiver in which a bar permanent magnet was used. This represents the first step in the development of a loud speaker unit.**

from this early telephone. You will note that this telephone has a magnetic circuit, an electric circuit, and a reproducing member for converting the mechanical vibrations into sound waves. If any one of these features are faulty, the 'phone unit fails to give the proper volume. The volume obtained from this early 'phone was obviously very little. The first improvement was made in the magnetic circuit. This is shown in Fig. 2. Instead of using a bar magnet a horse-shoe type magnet was used. This is the type of receiver used on the present day line telephones.

The watch case receiver shown in Fig. 3 is identical with that shown in Fig. 2 except

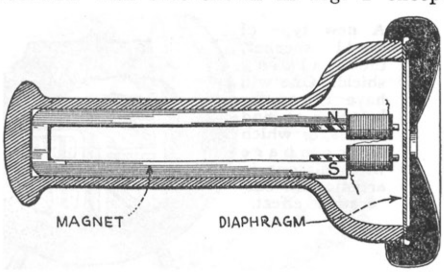



**Fig. 2. A great improvement over the original Bell receiver depicted in Fig. 1 was made by using a horse-shoe magnet instead of a bar magnet. This illustrates the general construction of our present line telephone receivers.**

that the horse-shoe magnet is shaped so as to make the instrument very compact.

The receivers used in telephones are of comparatively low impedance, having a direct current resistance of about 75 ohms. The advent of radio created a demand for a high impedance receiver that would match the impedance of the crystal detector or vacuum tube used. Therefore, the early head sets used in radio were of the same construction

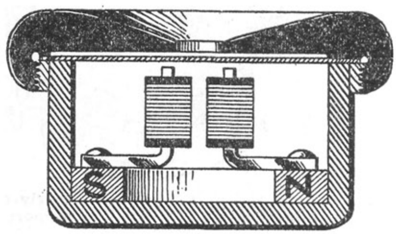



**Fig. 3. By properly shaping the horse-shoe magnet a very compact reproducing unit was evolved. Many of our present loud speaker units are designed along this principle.**

as the watch case receiver illustrated above with the exception that the electromagnets were wound for a higher impedance. The direct current resistance of this type of unit is about 1,000 ohms.

Before broadcasting started, crystal sets and single tube sets were the only types in general use. With the advent of broadcasting and the increased use of vacuum tube amplifiers, a loud speaker for radio use was in great demand. The first loud speakers were made by simply taking one of the ear phones of the head set and placing a horn on it. This type is shown in the illustration Fig. 4.

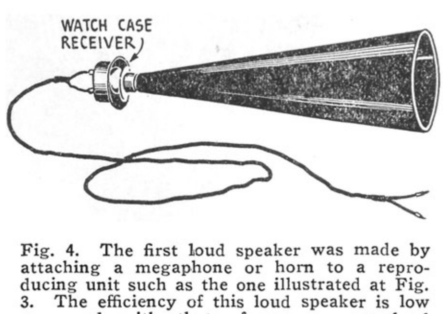



**Fig. 4. The first loud speaker was made by attaching a megaphone or horn to a reproducing unit such as the one illustrated at Fig. 3. The efficiency of this loud speaker is low compared with that of our present loud speakers.**

The horn type loud speaker illustrated in Fig. 5 is of excellent electrical and acoustical design as well as of pleasing appearance. The gracefully curved panelled wooden horn is highly finished. It measures 14½ inches in diameter at the opening. The acoustically correct "dragon shape" of the sound conduit provides—in compact space—exceptionally long tone travel with gradual amplification. Also, the conduit is non-resonating, being rubber insulated at both

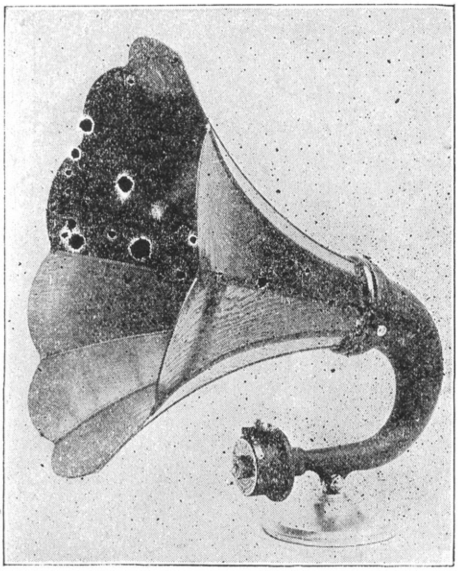


Fig. 5. A horn type loud speaker of unusually good design. The wooden horn and adjustable unit are insulated from the metal conduit with rubber, which absorbs horn vibrations.

ends. Crystalline enamel on both sound conduit and unit add further beauty to appearance. The weighted nickel-plated base is hinged to permit tilting the horn to any angle. The "floating diaphragm" unit may be taken off and with proper adaptor attached to a phonograph whenever desired.

The demand for more volume and the increasing use of loud speakers for public address systems made it necessary to design a loud speaker unit that would operate with great volume on power amplifiers. The balanced type unit shown in Fig. 6 was developed for this purpose. The illustration shows only one form of this unit. Many slight variations have been made without departing from the general principle. For example, Fig. 7 shows a semi-balanced one.

The balanced unit has what is called a floating armature. The armature is pivoted

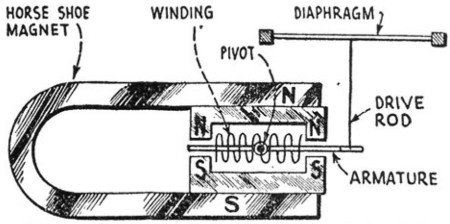



Fig. 6. The general construction of the balanced type unit used in many radio speakers. Note that the permanent flux from the horseshoe magnet does not pass lengthwise through the light floating armature.

midway between the poles of permanent magnet, and the magnetic circuits are so arranged that the permanent flux does not pass through the armature. Therefore, very powerful permanent magnets may be used with no possibility of saturating the armature. The armature carries only the variable magnetic flux produced by the amplified audio currents. This unit, being more sensitive than the plain type, employes longer air gaps, which makes an adjustable feature unnecessary and eliminates the possibility of blasting or chattering on excessive volume. The semi-balanced unit is similar except that one end of the armature is fixed.

When this type of unit is used on a horn speaker a drive rod connects one end of the floating armature to the center of a diaphragm, which may be of mica or metal. When a metal diaphragm is used it is usually corrugated for stiffness.

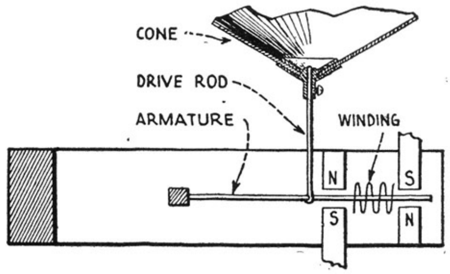



Fig. 7. A semi-balanced unit. In this case one end of the armature is uxed, the other being free to vibrate. Many cone speakers employ this type of unit.

## Cone Speakers

The use of a cone as a diaphragm or reproducing member was known as far back as 1900, but it was not until 1911 or '12 that it was fully developed for use on the phonograph. The cone took the place of the torn. Recently the cone has replaced the horn in

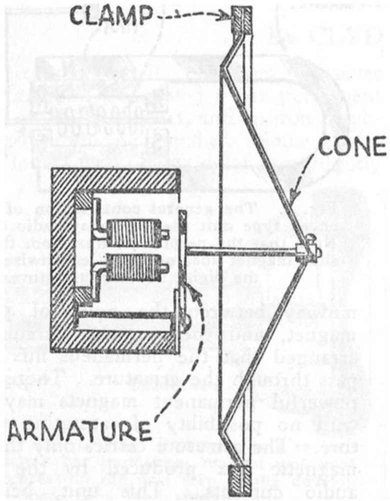



**Fig. 8. This shows the general construction of one of the first radio cone speakers. The ordinary type of unit, with an armature substituted for the diaphragm, was used.**

many radio loud speakers. A simple cone speaker can be constructed by glueing a disc of drawing paper about 12 inches in diameter in a shape of a cone and fastening it with sealing wax to the center of the diaphragm of any of the telephone units shown above. This cone may not give great volume but the quality of sound is pleasing.

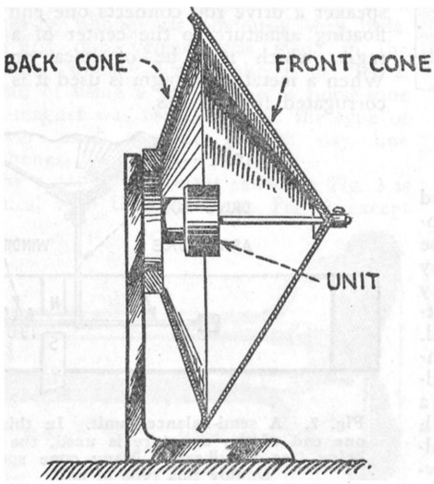



**Fig. 9. This type of construction is quite popular among cone speaker manufacturers. The back cone is used merely as a support for the front cone, it having no acoustical advantages. In fact, the enclosed effect is detrimental.**

In one of the first speakers utilizing this principle the cone was securely clamped around the periphery with metal rings. An armature was used on the unit in place of a diaphragm and a drive rod connected this armature to the apex of the cone. This type

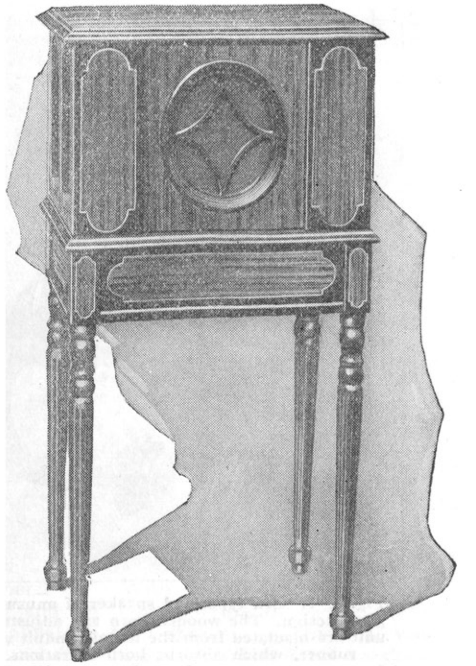


**Fig. 10. A radio reproducer comprising a built-in power amplifier and floating cone speaker. The amplifier is operated from the house lighting line. Quality at any desired volume is possible with this combination.**

of construction is shown in Fig. 8. Note that a reduction in motion of about 2:1 is obtained by the lever action of the armature.

Fig. 9 shows another popular type of cone speaker. The front cone of this speaker is supported by the frustrum of a similar back cone as shown. The unit is of the floating armature type and is mounted inside. While this type of speaker gives greatly improved results over many of the earlier types, it still has the disadvantage of a slight muffling effect of the sound due to the enclosed air space.

If you make a simple paper cone and attach it to a driving unit, you will note that the volume of sound given off by the cone is much greater on the concave side than it is on the convex side. Therefore, the more recent cone speakers employ a single cone with the concave side facing out. The cone is of the free edge type or flexibly supported around the periphery. An example if this type of construction is depicted in Fig. 10. Although this illustration shows little as far as the cone is concerned. It seems necessary to add that the ten inch cone of light paper has the convex side facing out it is mounted directly in back of the oval aperture in the beautiful cabinet. This reproducer not only consists of a loud speaker, but also employs a built-in power amplifier operated directly from the house lighting circuit. Enormous volume with excellent tonal quality is obtained from this reproducer.

If you construct a single cone speaker and mount it on a unit you will find that when placed in a cabinet the volume is increased. The cabinet not only acts as a sound chamber, but it reflects the sound waves out from the convex side of the cone. Another way of obtaining this same effect is to place a baffle plate around the cone. This may be a wooden ring about two or three inches wide, as shown in Fig. 11. Note how the sound waves are forced to continue propagating from the front. A speaker built on this principle is shown in the reproduced photograph, Fig. 12.

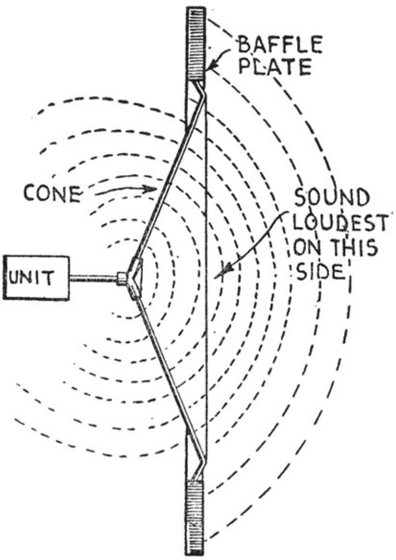


**Fig. 11. A baffle plate around the periphery of a cone increases the volume. Note that the sound is louder at the concave side, which should be the front.**

### Loud Speaker Distortion

To understand the causes of distortion in loud speakers, one must investigate thoroughly the character of musical tones. Each tone has a fundamental frequency of its own, giving it pitch. For example, the lowest pitched note on the piano has a frequency of 27 cycles per second, and the highest pitched one a frequency of 4096 cycles. Middle C has a frequency of 256 cycles. These are the figures of the scientific scale which differ slightly from those of the musical scale. You can see, therefore, that the ideal loud speaker should operate uniformly over a frequency range of 27 cycles to 4096 cycles, which is the range of the piano keyboard.

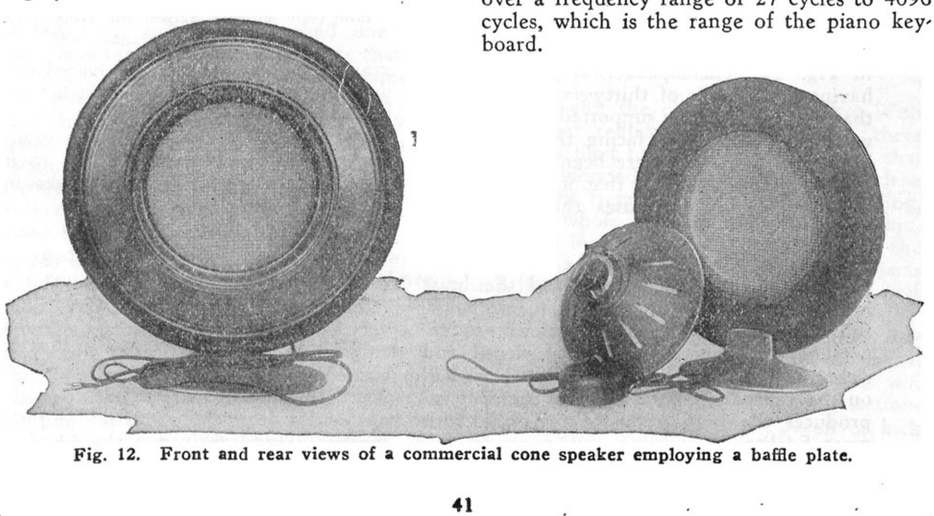


**Fig. 12. Front and rear views of a commercial cone speaker employing a baffle plate.**

To get the true tonal color of the highest notes of the piano the speaker should reproduce the higher harmonics of these notes which include frequencies as high as 8000 cycles per second. Most speakers operate very well up to about 10,000 cycles and little trouble is experienced in operating them on this end of the scale. The difficulty is in designing a speaker to operate on the lower end of the scale. Few speakers reproduce tones below middle C on the piano, faithfully. When these tones are played, you hear the harmonics, and not the fundamental, which makes the reproduced music sound "tinny."

The average horn type speaker reproduces the higher tones very well. You have probably noticed that some of these speakers are high pitched and some pitched. As a rule the larger the horn and the greater the diameter of the diaphragm, the lower the pitch. Cone speakers, that may be considered horn speakers with an extra large diaphragm, are usually lower pitched than the conventional horn speakers.

This leaves us with two methods for obtaining low tones from a speaker. First, the horn must be extra large, or, second, the diaphragm must be of large diameter. The exponential curve is found by test to be the best for proper acoustical effects. It is needless to say that this type of loudspeaker reproduces the low tones with virtually no effect on the quality of reproduction of the high tones. A speaker of this type is described on page 4 of this book. In the second case, the use of a large diaphragm merely lowers the pitch of a horn speaker, so we are forced to use a large cone. This principle has been carried out in the speaker illustrated in Fig. 13. This speaker employs a cone having a diameter of thirty-six inches. Note that a single, flexibly supported cone is used, with the convex side facing the front. The objection to size has here been overcome by designing the frame so that it supports the radio set and also houses the batteries if desired.

The design is such that the low notes of the cello, organ, and piano, and the brass instruments of the lower register are faithfully reproduced. This gives to the reproduction of instrumental music true depth and richness. While particular stress has been laid on the reproduction of the low notes, it reproduces the high notes of the scale with great fidelity.

The artificial parchment used for lamp shades is unsatisfactory for cone speakers. This material is nothing but a heavy paper, oiled to make it translucent. The oil deadens the sound. The paper used by the majority of cone speaker manufacturers is a special cover stock known as Alhambra. This paper is particularly applicable to cone speakers due to the fact that it has practically no grain. It is made up of a foundation skin or

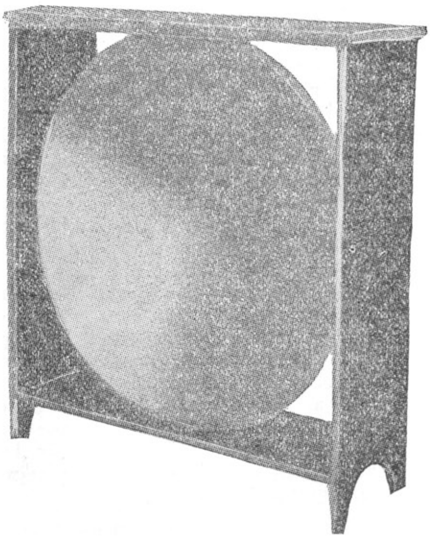


Fig. 13. A three-foot cone speaker designed by the author. Note that a single, flexibly supported cone with concave side facing the ront is used. The stand may also support the radio set and accessories. An ornamental curtain (not shown) across the front improves the appearance.

grained paper, completely covered or loaded with a mass of pulp. This construction causes the cone to reproduce the various frequencies more uniformly than if a heavy grained paper were used. The grain seems to increase the bad effects of resonant peaks inherent in all cone speakers.

### Operation

For ordinary home use any of the speakers described above when used on the average radio set with the type 201-A tubes gives very good results. Speakers employing balanced type units work better when connected according to either the circuits of Fig. 19 or 20. In Fig. 19 an output transformer is connected between the radio set and the loud speaker. This transformer should have a ratio of about 1:1. The use of this transformer prevents the direct current from the B batteries from passing through the windings of the balanced unit and unbalancing it. Fig. 15 will give identically the same results. A chocke coil and condenser are used in place of a transformer. The choke coil in this case serves as a 1:1 ratio auto-transformer.

There is another reason why the circuits of Fig. 14 and 15 are recommended. When using power tubes such as the UX112 or the UX117 in the last stage with two or three

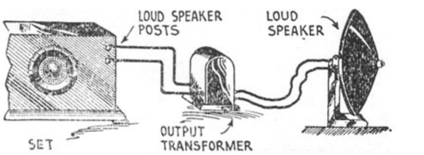



**Fig. 14. An output transformer connected between the set and speaker is the simplest way to insulate the speaker from the high voltage "B" battery circuit.**

hundred volts on the plate for power amplification, there is a possibility of damaging the speaker unit if connected directly to the high voltage circuit. Therefore, by using either the output transformer or the choke coil, the speaker is protected. If anything blows up it will be the transformer or coil. There is a rare possibility of this happening because we are not crowded for space in the transformer or coil design, and comparatively larger wire is used in their windings.

The operation of two or more speakers in series or in parallel has often been done for improving quality. For example, a high pitched horn and a low pitched one give very pleasing results. It is obvious that the use of two such horns widens the frequency band over which the system responds, and more natural reproduction results. Another method which is recommended is the use of a small high pitched horn speaker operating in conjunction with a large low pitched cone speaker. Whether or not the speakers work better in series or in parallel must be determined by test. If both speakers have the same impedance it would make little difference which way they were connected; but with the wide range of impedances found in commercial speakers the best method of operation can only be found by trial.

It has always been thought that the inertia of the vibrating members of a loud speaker or loud speaker unit greatly affect the quality as well as the volume of sound produced. For this reason the diaphragms of many of the early telephone units were made extremely light and of thin material. For the average head set this construction is very good as it gives great sensitivity. For the operation of cone speakers where a large amount of material is vibrated the design of the unit has to be altered. Instead of using a very light diaphragm or armature, the armature of the average cone unit is made of comparatively heavier material and of much more rugged construction. As a rule, the larger the diameter of the diaphragm or cone the less distance it must vibrate to produce the same volume of sound. Therefore, a heavy armature designed to vibrate at a very small amplitude in a proportionately small air gap is employed for cone speaker operation. In addition, a reduction of motion of about 2 to 1 is usually effected between the unit and the cone by a lever arm. By mounting the cone at different points on the lever arm different results are obtained. There seems no limit to the amount of weight that can be vibrated by means of a good cone unit provided the point of contact between the weight and the lever arm is at the proper place. As Archimedes said, "give me a place to stand and I will move the earth."

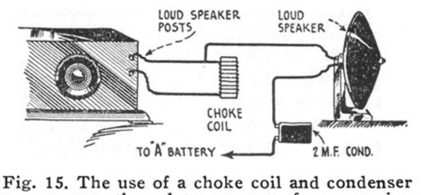



**Fig. 15. The use of a choke coil and condenser to prevent the plate current from passing through the speaker windings. This circuit is recommended for speakers employing balanced units.**

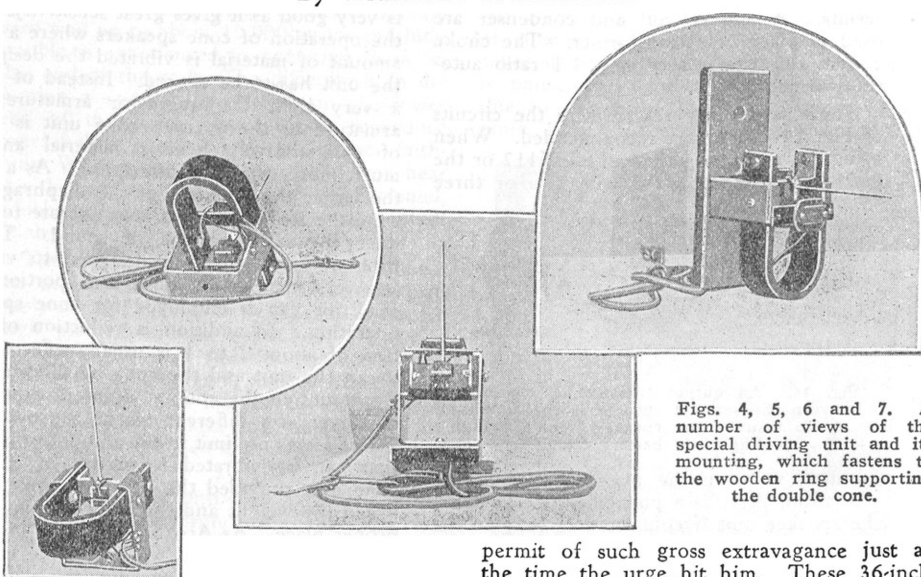
So it is with the cone speaker unit. With the proper reduction ratio of motion there seems no limit to the amount of weight that can be vibrated. I have attached such a unit to the framework of a wooden building, and the whole building vibrated. The music could be heard in the basement with the unit attached to the roof. While this seems unbelievable, one may prove it to himself by experiment.

To successfully vibrate a large heavy surface with a light cone unit requires additional weight on the unit. Otherwise the unit will vibrate and the "diaphragm" remain stationary. The action resembles the recoil or kick of a gun.

# BUILDING A 36-INCH CONE SPEAKER

*A Large Cone Capable of Reproducing Notes of Very Low Frequency*

By WARREN T. MITHOFF



Figs. 4, 5, 6 and 7. A number of views of the special driving unit and its mounting, which fastens to the wooden ring supporting the double cone.

THE broadcast-listener branch of the happy radio family is divided into two major classifications: first, those individuals who go to the store and order their receiving sets installed complete and who are content forever thereafter to pull the switch, turn the dials and listen, whether the resulting music is good, bad, or indifferent; and secondly, the vast group whose inquiring minds delve into all the seeming mysteries of grid leaks, space-wound solenoids, oscillation controls, and the thousand and one other fascinating items that comprise the modern receiving set.

It is safe to say without qualification that every man, woman, and child of this latter group has, at one time or another, stood gazing with fond desire at the smooth brown expanse of a 36-inch cone speaker as it stood in haughty solitude in a store window. Whether or not this fond desire was translated into action, and the cone carried in triumph to the gazer's cosy heartside, depended solely upon the state of his bank balance.

The writer is one whose radio budget, having suffered ravages from a severe case of superheterodyne construction, would not permit of such gross extravagance just at the time the urge hit him. These 36-inch cones do cost real money, but they are worth every nickel of it, if we judge by results. The only alternative, then, was to build the much-coveted cone. Now there are on the market kits of parts for just this purpose; but the great ambition was to build out of such parts as the junk box afforded.

With this in mind work was started. After several months of experimenting an arrangement was found which stood the test; yet the cost was under ten dollars, even with the full market price put upon the junk-box parts.

The only requisites for success along this line are the materials, a little patience and care—virtues possessed by every true experimenter—and a good audio amplifier. The amplifier, of course, is important, as a cone speaker will show up distortion entirely passed over by the usual type of horn.

### Selection of parts

To start with, certain materials and parts are needed, first in importance being the driving unit. A Baldwin "Type C" is first rate; either the phonograph attachment or one of a pair of earphones. One is being used by the writer with great success, and this article is being prepared with the

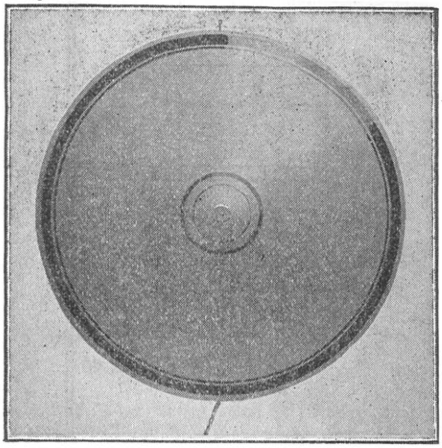


Fig. 1. From the front, the cone presents a very pleasing appearance; and if the constructor is handy with colors it can be made a thing of beauty.

Baldwin unit in mind. Dimensions and instruction are given accordingly; although the same general procedure can be followed with any unit which has the balanced-armature type of construction. Units which have the thin iron diaphragm supported above the coils will not do for this cone, as they are inclined to rattle, and do not have sufficient power.

A large permanent horseshoe magnet is also needed, and can usually be obtained from one of the firms which make a business of scrapping worn-out automobiles and trucks. The magnet required is the kind found on truck magnetos, 3⅜ inches across the legs, 6 inches long, and made of ⅜ x 1⅝-inch steel. These dimensions are used in this article and the accompanying drawings, and if a magnet of different size obtained, allowance must be made accordingly. Most of these magnets are already provided with two drill holes on each leg, to pass ¼-inch machine screws.

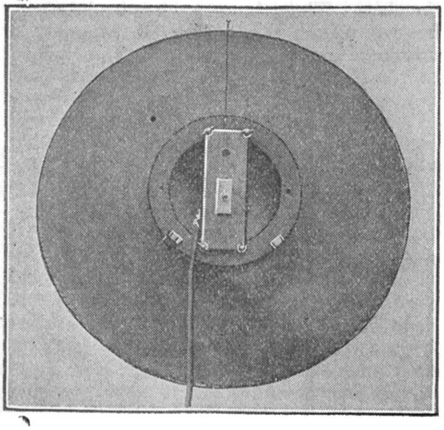


Fig. 3. Showing how the two cones are joined together with sealing wax or glue, and how the cross piece fits across the wooden ring.

The only other major item needed for the speaker is the paper from which to make the cone itself. The very best thing to use here is Alhambra "Low Frequency" paper; as its structure is such that it is not resonant to any particular frequency of its own, but reproduces all frequencies with good uniformity. Other papers can be used with greater or less success, depending on their nature. For example, lampshade parchment, which comes 36 inches wide, is highly satisfactory; and it can be stained a rich brown with walnut-wood stain, and decorated with oil paints to suit the constructor's fancy. Some papers used for covers for catalogs and books can also be used, such as Castilian cover, heavy weight; a good printer can suggest something for the purpose.

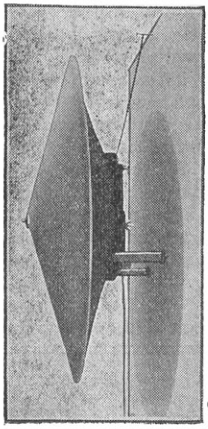


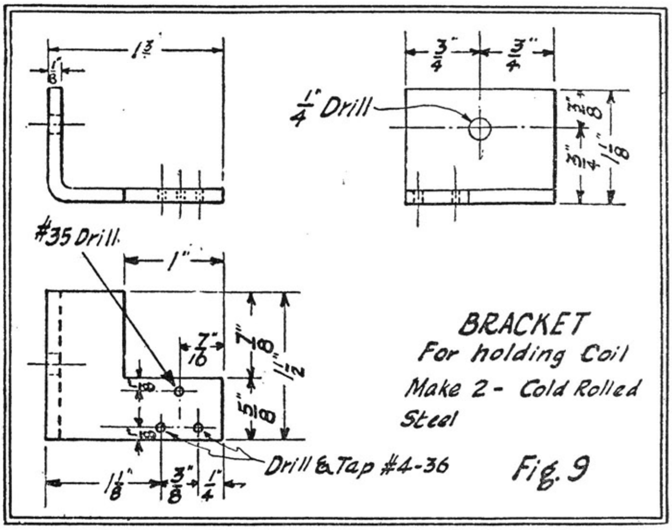
Fig. 2. This shows the manner in which the rear cone is joined to the wooden ring with sealing wax; also the manner of affixing legs, for use in hanging the cone on the wall.

Some odds and ends are needed, of course, such as 6 inches of ⅛x1½-inch cold rolled steel; 12 inches of strip brass the same size; some No. 30 gauge sheet copper or brass, No. 30 gauge phosphor bronze, and ¼-inch, round brass rod. Machine screws in four sizes are used: ¼-inch, No. 6-32, 4-36, and 2-56. Taps should be on hand for the 6-32, 4-36, and 2-56 sizes.

### Adapting the Unit

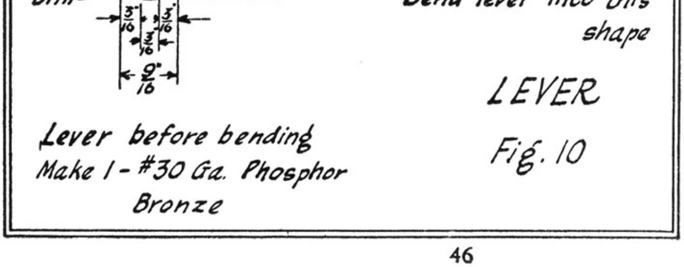
The first step is the dismantling of the Baldwin unit. The top of the hard-rubber case is unscrewed; the entire mechanism may then be removed, and the double speaker

Details of the brackets, two of which are used for supporting the solenoid. These brackets form a part of the magnetic field.

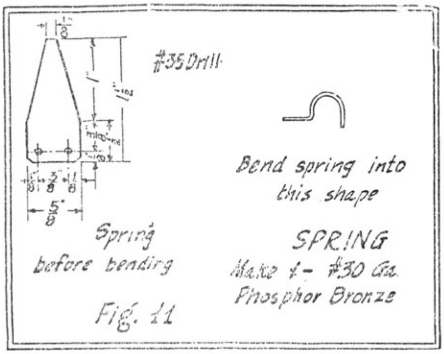



cord disconnected and laid aiside for future use. Before doing any more dismantling, it is well to examine what is found inside the Baldwin case. There is a small coil of very fine wire, oval in shape, with an oblong slot through the center of it. Trough this slot there is a small, flat, iron armature, one side of which is joined to the diaphragm with a fine brass wire and the other held in place with a bent wire spring. Around the coil are "U" shaped pieces of flat steel, and to them is fastened the permanent magnet with machine screws. It is an excellent idea to pay careful attention to the manufacturer's method of assembling this unit, with regard to coil and magnet polarity. In other words, when the unit is re-assembled, this should be done in the same manner as originally, the inner and outer ends of the winding going to the same respective binding posts, and these terminals placed with the same respect to the north and south poles of the magnet.

The diaphragm used in this unit is of mica instead of metal; through the center of it projects the fine brass wire mentioned above, secured with a nut and a drop of solder. The mica should be cut or broken, and the wire clipped and unhooked from the projecting end of the armature. The circular magnet is next removed from the coil by taking out the two small screws which hold it in place. Then the tiny wires leading from the coil to the binding posts are un-




The lever to which is attached the drive rod. One end of the lever is fastened to the frame of the unit, and the other end is attached to the balanced armature.



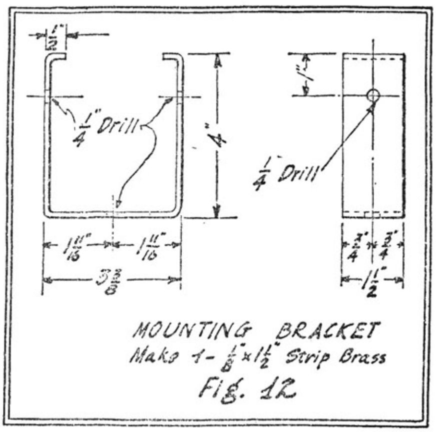

Details of the armature-balancing spring.

soldered, care being used that they are not broken. The binding posts may be removed also. The coil, together with the two "U" shaped pieces of steel, is held with three rivets to a metal disc, on which the mica diaphragm originally rested. These rivets must be cut or filed off to permit the coil to be removed; the disc is then thrown away. The small wire spring holding the armature is removed, and the armature is taken out and laid aside.

The coil is now to be mounted on the large horseshoe magnet; but, in order to do this, it is necessary to make two brackets of cold rolled steel, as shown in Fig. 9. These brackets are drilled and tapped as indicated, smoothed off with a file, and mounted with ¼-inch machine screws on the large magnet, so that there is an even separation between them. The coil, with the two "U" shaped pieces in place, is then put in position, and, if the holes are properly spaced, it can be fastened with two No. 4-36 machine screws, as shown in Fig. 8. It will be noted that the two "U" shaped pieces are already tapped for these screws.

The two brackets should hold the coil level, and the "U" shaped pieces should fit tight against the slot in the center of the coil, both top and bottom. The lever, Fig. 10, and the spring, Fig. 11, are next made. These two, which are of phosphor bronze, are drilled as shown to pass No. 4-36 screws. The lever will be mounted on one side of the coil by means of these screws, fitting the holes tapped in the steel brackets; but, before it is put in place, it should be noted that in the slot in the center of the coil are two small pins projecting from one side. The armature has drill holes provided for these pins and, when put in position through the slot, the pins fit through the drill holes. The lever should be mounted on the side of the coil which has these pins. The spring is then mounted on the opposite side.

The armature is put in place, and adjusted so that it will rock back and forth easily on the pins. A small hole is drilled in the end of the lever (Fig. 10) and a piece of No. 26 copper or brass wire run through this hole. A small hook is formed on the end of this wire, and caught through the hole in the part of the armature projecting from the slot. The spring on the other end of the armature is engaged, and the wire pulled up tight to balance the pressure exerted by the spring. The effect sought is so to balance the armature that it will remain stationary midway of the slot, so that any variations of current flowing through the coil will influence the armature magnetically and

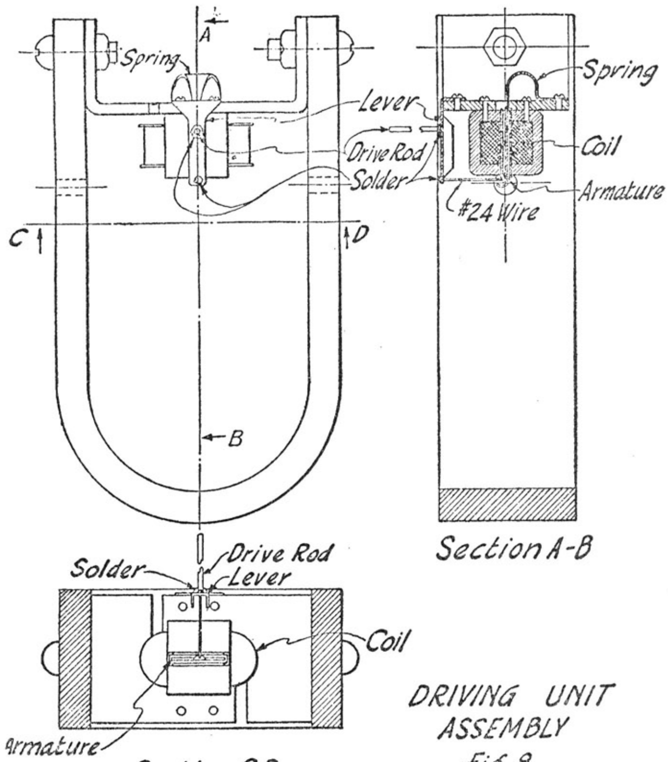



The brass bracket used for mounting the driving unit to the main support.

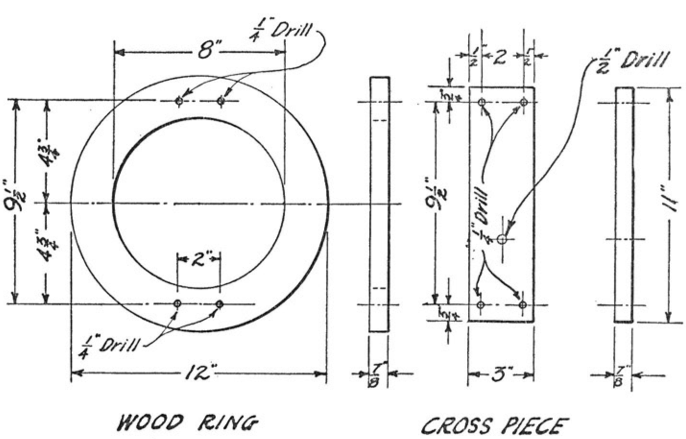
cause it to vibrate. After this has been achieved, the wire is secured to the lever with a drop of solder.

Binding posts should be provided for attaching the speaker cords, and it is best to use the one originally provided in the unit. These may be attached to suit the constructor's convenience, and the terminal wires soldered to them.

If the reader desires to test what he has done so far, he may at this point connect the unit alone to a set, with a good strong local station tuned in. If the unit is working properly, the armature will vibrate strongly with the signal received, giving a faint muffled sound of music or speech.




DRIVING UNIT ASSEMBLY
Fig. 8

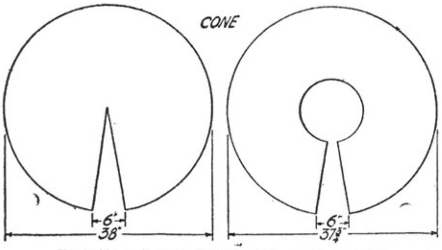



WOOD RING

CROSS PIECE

Fig. 13

This is rather a particular operation, and several attempts may be necessary before a good job is obtained. With reasonable care, however, it can be done successfully. This tip, with its metal cone, is mounted on the apex of the large paper cone, and the other metal cone placed inside. Before putting these in place, it is a good idea to spread a little rubber cement (or the celluloid-base glue may be used) both inside and outside, to join the tip securely to the



Details of the front and rear cones.

paper. Further strength is obtained by passing No. 2-56 machine screws through the holes in the metal cones and through the paper, and tightening up the nuts on the inside. This makes a neat and serviceable job.

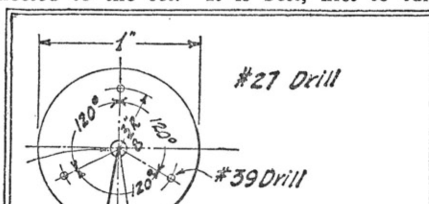
The bracket, Fig. 2, which was made out of strip brass, is used to hold the magnet and unit in place. The bracket is mounted on the magnet with ¼-inch machine screws, and the whole assembly laid in position on the cross piece (the wood strip which is fastened to the back of the wood ring), in such a way that the driving rod is exactly in line with the center point of the cross piece. This is of great importance, and care will be needed to see that there is no appreciable variation from the center. When this has been determined, a ½-inch hole is drilled in the cross piece, to line up with the ¼-inch hole in the back of the bracket. A ¼-inch machine screw is passed through these two holes, and a 1-inch washer slipped over the end of the screw. A suitable square washer can be made from the strip brass used on the bracket. A wing nut is used on the machine screw, as it can be loosened for adjustment without a wrench. It will be noted that the hole drilled in the wood crosspiece is ½-inch in size, while the bolt passing through it is only ¼-inch. This is to permit the entire driving mechanism assembly to be shifted slightly after the cone is put in place, in order to line up the driving rod exactly with the apex of the cone.

The crosspiece, with mechanism attached, is now fastened to the wood ring with ¼-inch machine screws, also using wing nuts to permit easy access. At this stage the writer found it very convenient to construct a rough stand, to hold the cone proper while mounting and adjusting the mechanism. It is very difficult to hold a 36-inch cone with one hand and work with the other, tightening nuts, and fitting the driving rod into the tip of the cone. This stand consisted simply of a board 3 feet long and 10 inches wide, laid flat on the floor, and two 3-foot uprights nailed on the edges at the center. Another strip was used to brace each upright. The cone was fastened to the uprights with wood screws, and was thereby held firmly in position, leaving both hands free for other work. It is strongly recommended that every constructor build such a stand for use during the early experimental stages.

The reader is cautioned at this point not to allow the driving rod to puncture the paper of the cone while trying to fit the unit into the cone; also to make sure that it fits easily into place. If it does not, then some miscalculation has been made in laying out the various parts, and trying to force it into place may injure the mechanism. It is well to proceed slowly.

**Adjustment and Operation**

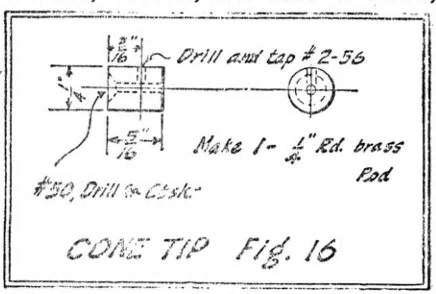
If everything fits properly, and all the nuts are tightened, the speaker may be connected to the set. It is best, first to tune



The small metal cone or apex. Two of these are used, at the point where the drive-rod is attached to the cone.

in a powerful station clear and loud on the present speaker, and then connect the cone. The first sounds may be disappointing; if so, it is because the set screw on the tip of the cone has not been tightened. A No. 2-56 machine screw should be inserted here and tightened, thereby holding the driving rod securely in place. If the mechanism is properly adjusted, and exactly centered, a surprise will follow—a flood of golden melody such as seldom is heard from a receiving set. After making sure that everything is right, the surplus length of driving rod protruding from the tip is cut off, and the cone may be hung on the wall with picture wire; or perhaps the constructor who is ambitious with carpenter's tools will wish to build a permanent stand, of the three-legged variety, so that the speaker may stand on the floor near the set, or as far distant from it as he may choose. Before hanging the cone from the wall, two wooden strips are screwed to the edge of the wood ring near the bottom, and tipped with sponge rubber. The strips hold the cone away from the wall, while the rubber prevents vibrations being transmitted to it.

In case, however, that flood of melody

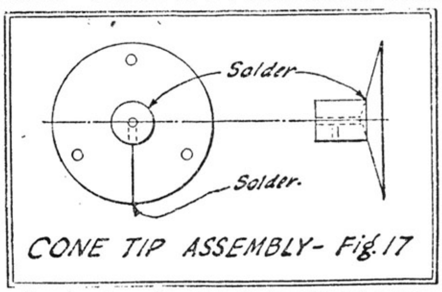



**The cone tip, where adjustments of the drive rod are made, is soldered to one of the apexes, as shown in Fig. 17.**

does not come, there are several minor adjustments to be made that may coax it along. First, it would be well to loosen the set screw on the cone tip, and carefully pull out or push in on the driving rod. If that brings out the volume and richness of tone, then all is well, and the screw may be tightened. If not, the screw is loosened again, and the wing nut in the center of the cross-piece in the rear is unscrewed a little, and the entire mechanism shifted slightly, up, down, or sideways.

If this is unsuccessful, the unit should be removed from the cone, and examined for evidence of damage that may have occurred while fastening it in place. A bent drive rod, or a lever sprung out of place, will cause trouble. The armature should be examined to make sure that it is centered in the slot and able to move freely. A slight adjustment of the spring will usually take care of this.

Another thing that may help is to put a .005-mf. fixed condenser across the speaker terminals. It was found desirable, on the writer's speaker, and was mounted inside the cone. Reversing the speaker cords may induce a change for the better in the tone quality. As a last resort, if results are disappointing (and it is extremely unlikely that they will be, if directions have been followed carefully) the set itself should be looked to. There must be no distortion here, as a cone speaker will reproduce the distortion faithfully where a horn might pass it over. This is not theory but fact. If a milliammeter is available, it should be connected in the "B—" lead to make sure that the proper grid bias is being used on the audio tubes, and that regeneration, if any, is not being pushed too far. This is not the place for a discussion of this subject, which has been covered before in Radio News; suffice it to say that there should be only the most minute variation of the milliammeter needle




**Showing how the cone tip is soldered to one of the apexes.**

with the received signals. Anything more than that indicates distortion, which must be cured before the cone can do its best.

One further word about audio amplifiers. A 36-inch cone deserves the very best amplifier that the pocketbook will permit. Careful tests have been made with several different amplifiers, all of which gave fine results. One test was made with a well-known manufactured receiver, using 201-A tubes throughout, and 90 volts of "B" battery, properly biased. Volume and quality were splendid, on both local and distant stations. Further test included a different set, with transformer-coupled audio, using the 112 type of tube in the last stage, with 135 volts on the plate, and 9 volts negative grid bias. With this arrangement, greater volume was obtained, together with somewhat better quality, especially when full volume was used. A straight resistance-coupled amplifier was also used, with high-mu tubes in the first stages, and a 112 type in the last stage.

# HOW TO BUILD A THREE-FOOT CONE SPEAKER

By CLYDE J. FITCH

***A three-foot cone speaker gives remarkable reproduction. By mounting in a large cabinet sufficient space is provided for the batteries and the set.***

THE average person thinks that a cone speaker three feet or more in diameter is entirely too large for his home, and he hesitates to buy or build one. But by combining the speaker with a radio table, it may be used in a small apartment room without occupying any more space than is ordinarily required for the set alone. Thus, in the speaker illustrated here, the cabinet or table is so designed that the radio set may be placed on top, and the "A" and "B" batteries and other accessories on the lower shelf. This convenient arrangement is clearly shown in the illustrations.

Those who have heard a good three-foot cone operating, with a well-designed audio amplifier, will never be satisfied with any other type of speaker. The quality and depth of tone is so far superior to that of any of the present-day horn or small-cone type speakers that there is no comparison.

Contrary to the general opinion among radio fans, push-pull, resistance coupling, or power amplification is not necessary for the successful operation of a three-foot cone. The writer prefers the standard two-stage audio amplifier. Two of the best make of 2:1-ratio audio transformers are used. No condensers or resistances are connected across the secondaries of the transformers. The by-pass condenser across the primary of the first transformer should not be greater than .0005**mf.**, while a condenser not larger than .002**mf.** may be connected across the speaker. A 90-volt "B" battery and a 4½-volt "C" battery are used. A 1.0**mf.** condenser is recommended across the "B" battery, to by-pass its internal resistance and eliminate amplifier squeal. While a power tube in the last stage, with corresponding changes in "B" and "C" battery voltages, may give a slight improvement, it is not required for average results.

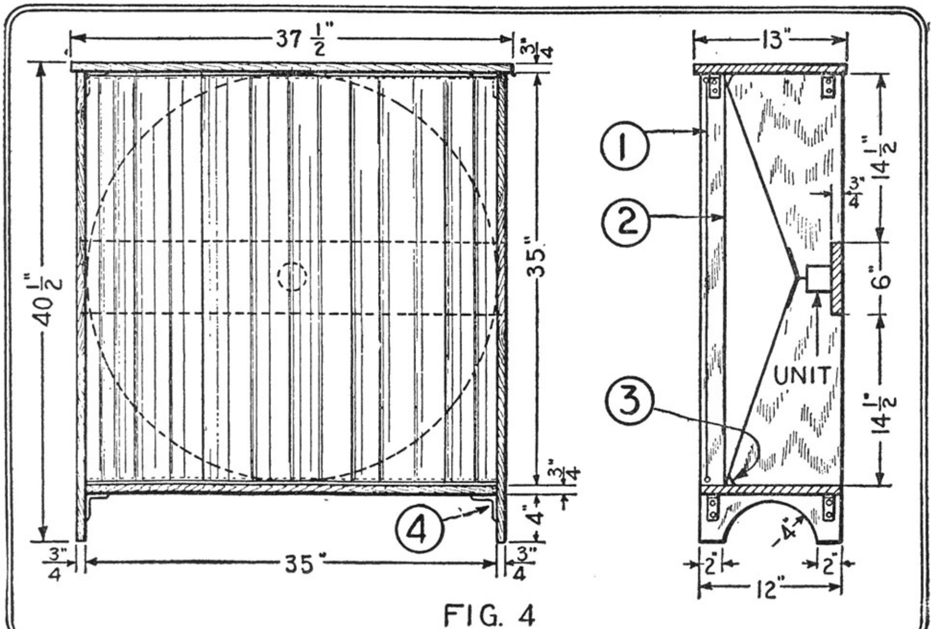



FIG. 4

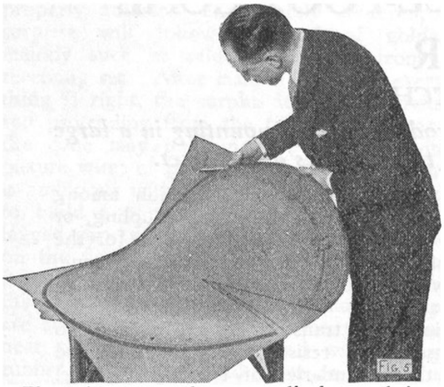


**Fig 3 illustrates the paper diaphragm being cut out, preparatory to glueing and mounting.**

The lumber may be obtained from any carpenter shop, cut to size and finished, for about $5.00, and stained and varnished to harmonize with the furniture in the room. The curtain, curtain rods, iron brackets, etc., may be obtained from any department or 5-and-10-cent store. The unit and paper may be obtained from cone-spaker manufacturers. It seems needless to say that the ordinary horn speaker unit can not be used successfully for driving a large cone. From the list of parts it will not cost more than about $17.00. In performance it is comparable with speakers costing four to five times as much.

The entire structural details of the table may be obtained from the illustrations and further comment is unnecessary. All dimensions are given in Fig. 4.

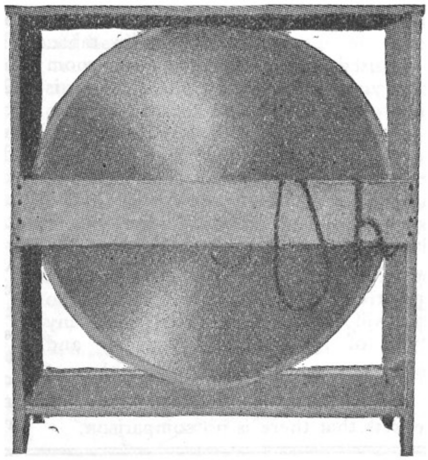
### Making the Cone

Extreme care should be taken in cutting out and glueing up the paper cone. Any folds or creases in the finished cone will decrease the volume of sound given out. The Cone Material is usually furnished with the cutting marks printed, as illustrated in Fig. 3.

A segment is cut out of the paper as shown in Fig. 3. It is very important that the long dimension of the segment be parallel with the grain of the paper, as this prevents wrinkling of the paper where it is glued. If the glue runs along the grain, the paper does not wrinkle; if it runs across the grain, considerable wrinling results. Paper is usually furnished in rolls with the grain running parallel to the axis of the roll. The grain should be marked on the sheet before cutting out the segment.

After cutting, the paper is glued in the shape of a cone and allowed to dry. The rim is then bent back along the scored line as shown, which holds the cone in shape and also provides a means for fastening the cone in the table.

A small conical metal washer, usually furnished with the cone unit, is glued to the apex of the cone; and over this is glued a small paper cone cut out according to the markings on the printed sheet. They are also shown in Fig. 3 on page 56.



**A rear view of the completed cone speaker. The unit is mounted on the wooden cross member.**

The cone may now be attached to the unit and tested on the radio set. Care should be taken in doing this as the cone is heavy and it is apt to bend or break off the connection link of the unit. It is advisable first to position the cone in the table; and then fasten the unit at the proper place on the back strip. The bent-back rim of the cone is then glued, or fastened with thumb tacks, to the top, bottom, and sides of the table. It is there draped by an ornamental curtain, suspended by rings from the rod across the top of the stand, and similarly fastened at the bottom.

In conclusion, this three-foot cone-speaker occupies no more space than is required for the average radio set, is ornamental and inexpensive, and gives remarkable quality of reproduction. The sound, coming from a large surface, is not penetrating. The low tones come out with exceptional volume, sometimes causing the entire floor of the room to vibrate; the high tones are not impaired, and the carrying power or volume of the sound is very great.

# SOME INTERESTING EXPERIMENTS WITH CONE REPRODUCERS

*Using the Three Foot Cone for Reproducing Phonograph Muisc, As a Microphone, and for Many Other Interesting Purposes*

BEFORE describing the various interesting experiments that may be performed with large cone reproducers let us first show how to build and operate one, as much of the success of the super-cone depends upon its proper construction and operation. Thousands are now enjoying well nigh perfect radio reception from large cones of simple construction, yet there are some who have not had such gratifying success simply because some little seemingly unimportant detail in the construction or operation has been neglected.

In all sound recording and reproducing apparatus, the simpler the construction the better the results. Perfectly natural tone quality is only obtained by eliminating superfluous parts. Simplicity is the keynote of success of the speaker about to be described, from the unit illustrated in Fig. 1 to the finished speaker, Fig. 2. The design of the three foot cone has been much improved and simplified since its original appearance on the market.

### Construction of Cone

Keeping in mind simplicity, we select a single virtually free edge cone for the diaphragm. It is cut from a square sheet of cone paper (Alhambra Fonotex) according to the dimensions given in Fig. 3, and glued in shape, using any ordinary glue. The rim of the finished cone is bent towards the front for stiffening purposes, as illustrated. A small three inch paper cone is glued to the apex of the large cone to strengthen it. The finished cone will measure 36 inches in diameter.

The frame on which the cone is mounted is also of simple design. It consists of a block of hard wood with four holes in it, in which are placed the four arms like the spokes of a wheel. The arms are made of ⅝-inch dowel sticks, flattened at the ends where the cone is attached. The dimensions are given in the illustration (Fig. 1 on page 62). The unit is mounted on the block with two wood screws, and the cone attached in

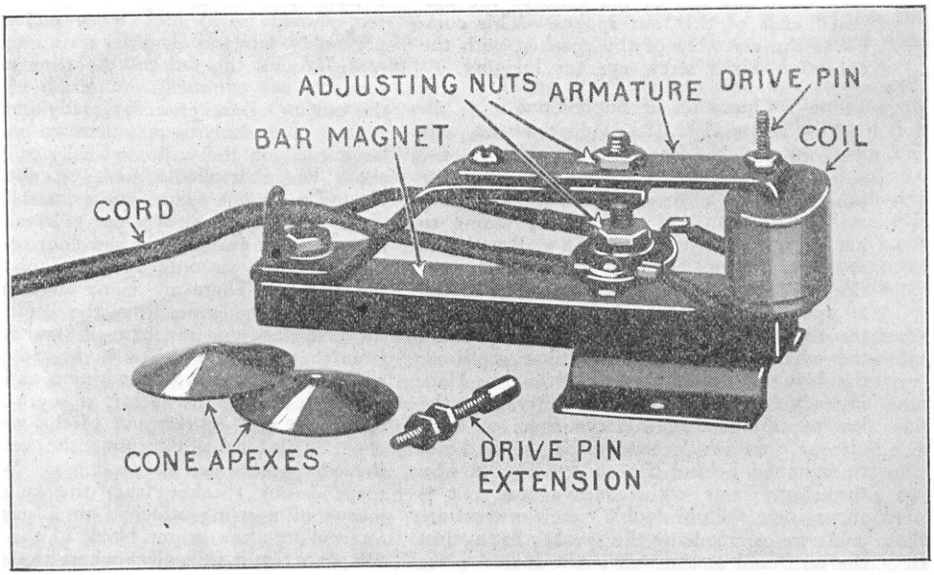



Fig. 1. Cone speaker unit used in experiments described in this article

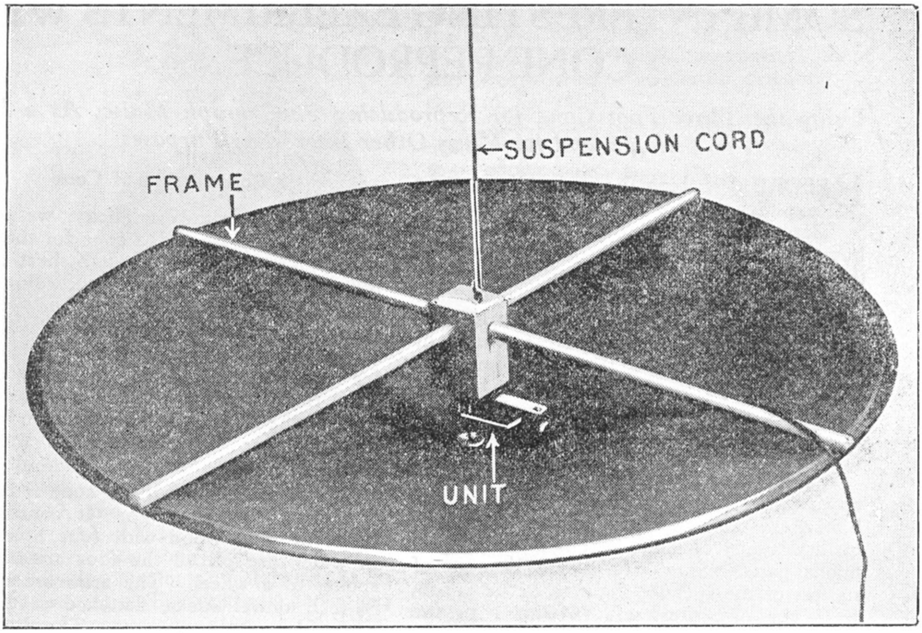



Fig. 2. Method used to suspend cone from ceiling.

place, using the metal cone attachments supplied with the unit. Ordinary thumb tacks hold the rim of the cone to the flattened ends of the four spokes. This completes the assembly of the speaker, with the exception for a screw eye for hanging.

### Operation of Super-Cone

The operation of a cone of this size depends largely upon its location in the room. Knowing that practically all of the sound energy emanates from the **concave** side of the cone, it is obviously wrong to hang the cone flat against the wall with the apex towards the front, as is the usual practice. The sound is then cooped up in the air space between the cone and the wall and the reception is impaired. In this position the average pitch of the speaker is raised; the low tones fail to come through. Having a wave length of some thirty feet, the low tones must have a large room or open air space in which to reverberate, and not be confined behind the cone. This is why the single cone with concave side out is superseding the old double cone construction.

As we cannot hang the speaker flat against the wall, and as the wall is the logical place to hang it in many instances, we must use some means of spacing it from the wall. The simplest way is to place two wooden feet or spacers on the lower ends of the bottom arms as illustration Fig. 5. These feet should be at least three inches long, preferably longer. This leaves an open air space around the rear of the cone and the sound is not confined. When so mounted, the quality of reception is greatly improved.

It is not always convenient to mount a large cone on the wall, especially in a small room where it would look unsightly and occupy too much space, so we must look for some other place. We don't have far to look, because leaving out the floor as a possible location we only have one place left, the ceiling. There are many advantages in suspending the cone from the ceiling. In the first place you can hang it several inches from the ceiling, which is highly advantageous from an acoustical standpoint, and it will not be noticed. In fact it is more or less decorative and entirely out of the way. In dance halls and auditoriums the ceiling is the ideal place for large cones. We can suspend our speaker from the ceiling by means of a string attached to a screw eye screwed into the center block of the frame. Simply screw it in a place where the speaker balances. It is connected to the radio set with an extension cord. See Fig. 6.

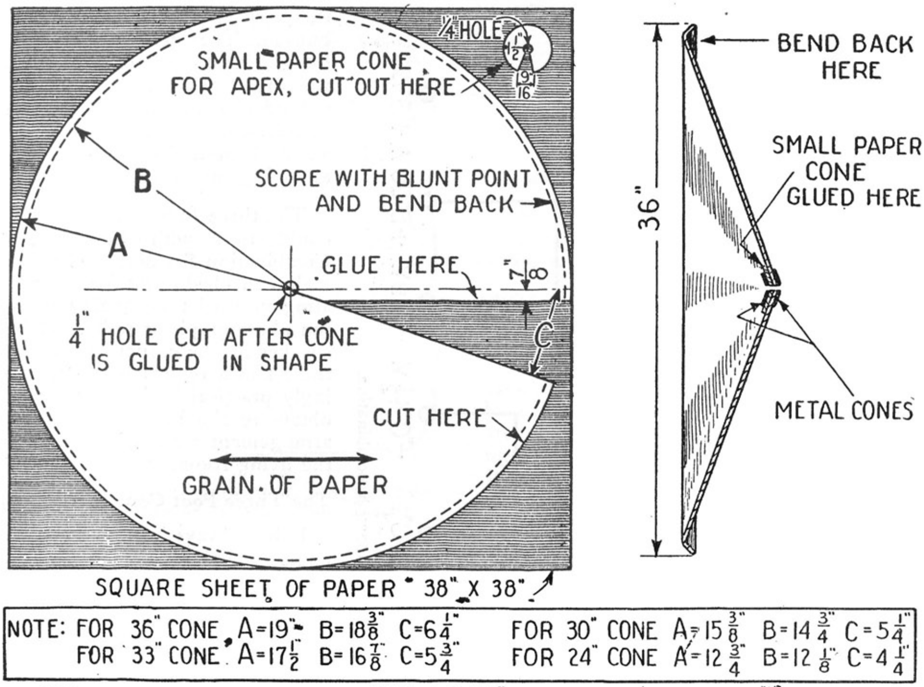



**Fig. 3. Details for the cutting and preparation of the special paper cone.**

The three foot cone must be operated through a fairly good audio amplifier, otherwise its advantages are lost. It makes no difference how cheaply the set is made; simply replace the audio transformers with two good low ratio ones and startling tone quality will result. Best results are obtained with a 135-volt B battery and the proper C battery for a 112 output tube, although 90 volts are sufficient for ordinary requirements.

## Electrifying the Phonograph

During the past year an unusual amount of interest has been shown in various methods of electrifying the phonograph. Many "pick up" devices have been perfected for translating the vibrations from the phonograph record into electrical impulses, which can be passed through the audio amplifier of the radio set and reproduced by the loud speaker. This gives something beyond ordinary phonograph music; but with the average loud speaker, while enormous volume is possible the tone quality is characteristic to that of radio plus the bad effects of the phonograph in spite of the fact that the newer records are electrically recorded with an emphasis on the bass notes.

Using the three foot cone as a reproducer, music really beyond ordinary phonograph music is obtained. All that is required is a good pick up device and a good audio amplifier. Phonograph music with the volume and depth of tone of a symphony orchestra is possible, under perfect control by the volume control on the amplifier. This combination is ideal for staging dances and entertainments, especially where suitable radio reception cannot be had.

The pick up devices usually have attachments for connecting directly to the radio set, so further comment seems unnecessary. The illustrations, Figs. 7 and 8, show how the apparatus is used. The writer once used an electro magnetic pick up device and a three stage resistance coupled amplifier with a power tube in the last stage for his experiments. Exceptionally good results were obtained with this combination. On such extreme volume, it was found advisable to fasten a metal weight of several pounds to

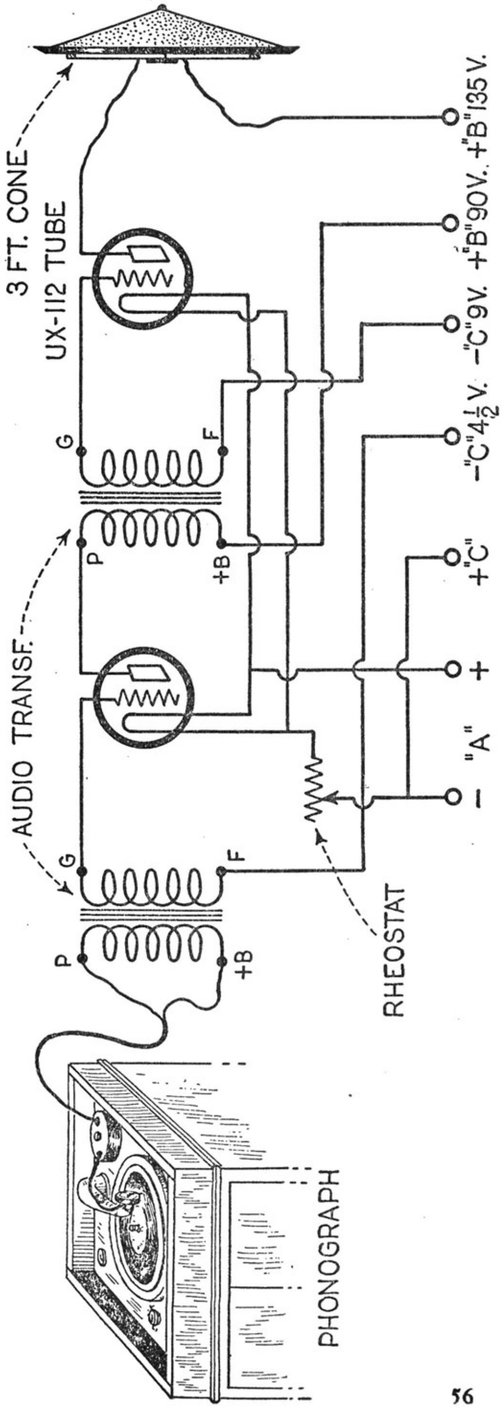



Fig. 8. Schematic diagram of radio-phonograph combination.

the back speaker frame to reduce vibration. The ceiling mounted cone, hung at least one foot from the ceiling, was found best for this purpose. Many radio dealers in small towns where good broadcasting is not possible find this an ideal method of demonstrating and attracting attention.

The three foot cone speaker used in conjunction with the **Phono-Radio Combination Set** described in this issue makes an ideal outfit for those appreciating unusual tone quality from either the phonograph or radio. Having the speaker in one corner of the room and the set in a remote location, is surprisingly practical both from the point of obtaining the best tonal effect and in arrangement with other furnishings in the living room.

**The Three Foot Cone as a Microphone**

It has always been the aim of radio engineers in connection with broadcasting to perfect a microphone that would respond to the entire musical range uniformly and at the same time have no inherent noises. One of the best microphones of this type is the capacity one. This consists of two metal discs spaced a small distance apart. Sound waves strike the discs, causing them to vibrate, which vibration varies the spacing between them and the electrostatic capacity varies likewise. While this microphone produced the desired results, it was very inefficient from a sensity standpoint, and the output from it required considerable amplification before it was strong enough to operate the transmitter. For this reason the carbon button type of microphone of special construction is now widely used for broadcastings. As the carbon type depends upon a loose electrical contact for its operation, it produces disturbing noises which are objectionable to good transmission.

The original pick-up device or transmitter used by Bell in his first telephone operated on the electro-dynamic principle. Sound waves strike the soft iron diaphragm, and in most of the

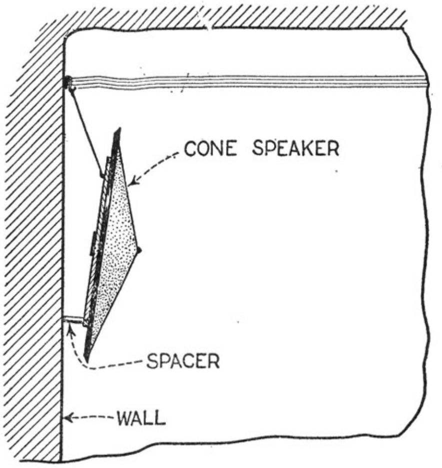



Fig. 5. Correct method of hanging large free edged cones for best tonal results.

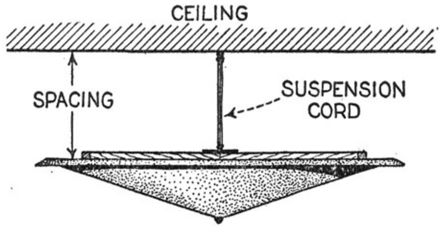



Fig. 6. Ceiling suspension of cone speaker.

ordinary telephone receivers generate an electric current in the winding of the receiver. Of course the efficiency is low, but having no loose electrical contact in the circuit, foreign noises are eliminated .

The three-foot cone speaker serves as an excellent microphone or pick-up device for broadcasting studios. Having such a large area it is very efficient, because it is acted upon by a greater volume of sound energy. It covers a much wider tonal range than the ordinary telephone receiver covers for the same reason. This is also apparent from the fact that it has a wider tonal range when used as a reproducer.

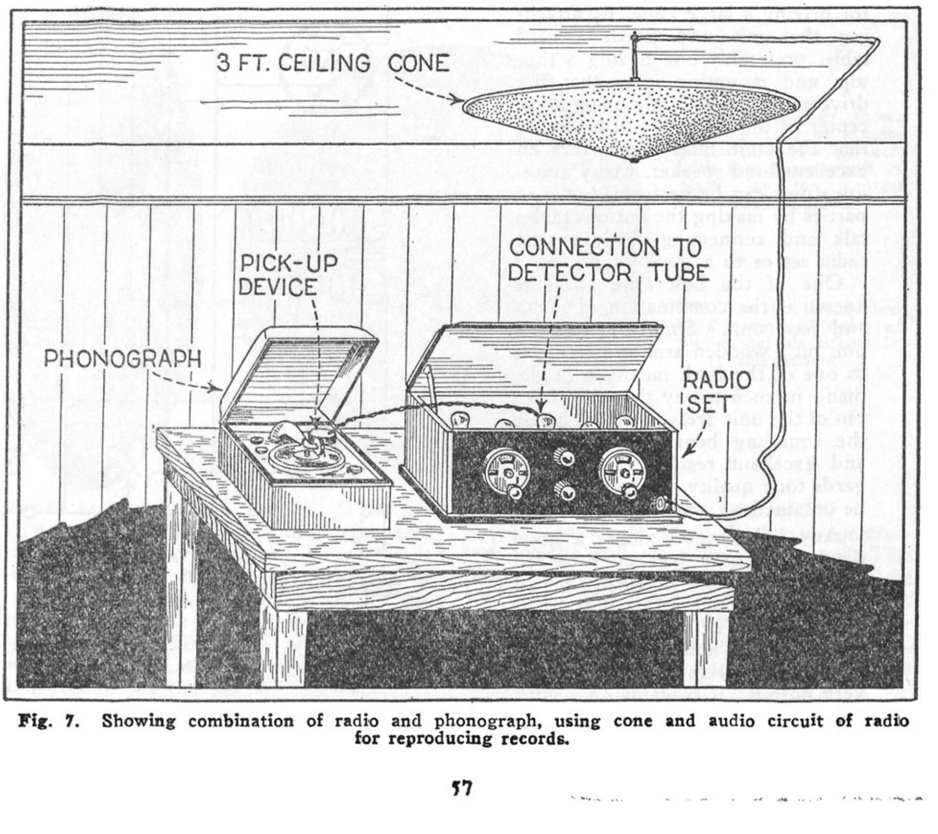



Fig. 7. Showing combination of radio and phonograph, using cone and audio circuit of radio for reproducing records.

The radio experimenter and amateur will find the three foot cone very interesting for use in the armature transmitter as a microphone. For experimental purposes the terminals of the three foot cone speaker may be connected across the grid and filament of the detector tube of the radio set. It will be found that the audio frequency current generated in the speaker winding will be amplified by the audio amplifier of the set and reproduced to the output of the set. It is almost impossible to operate the two speakers in the same room as a continuous howl will result, due to a transfer of sound energy from the output speaker to the input one. This device serves as an excellent detectaphone. The connections are given in the diagram, Fig. 9.

**The Talking Table**

Many starting experiments can be performed with the special unit shown in Fig. 1, designed primarily for driving a large cone. By attaching the unit underneath a card table, preferably one having a thin top, and mounting it so that the drive pin presses firmly against the center of the table, it will be found that the table talks and makes an excellent loud speaker. Many amusing stunts can be performed at card parties by making the various tables talk and connecting them to the radio set or to a microphone.

One of the best loud speakers known is the combination of piano and cone unit. Simply mount the unit on a wooden arm and clamp it to one of the back members of the piano in such a way that the drive pin of the unit presses firmly against the sounding board of the piano and excellent results, both as regards tone quality and volume, will be obtained.

Any light, wood makes a good diaphragm for a speaker, provided it is large enough in area.. One of the best woods for this purpose is balsa wood. The balsa tree is grown in the tropics and due to its rapid growth the grain of the wood is very porous. It contains over 90% of air. This wood is very light in weight. Its main use is for packing food products in cold storage.

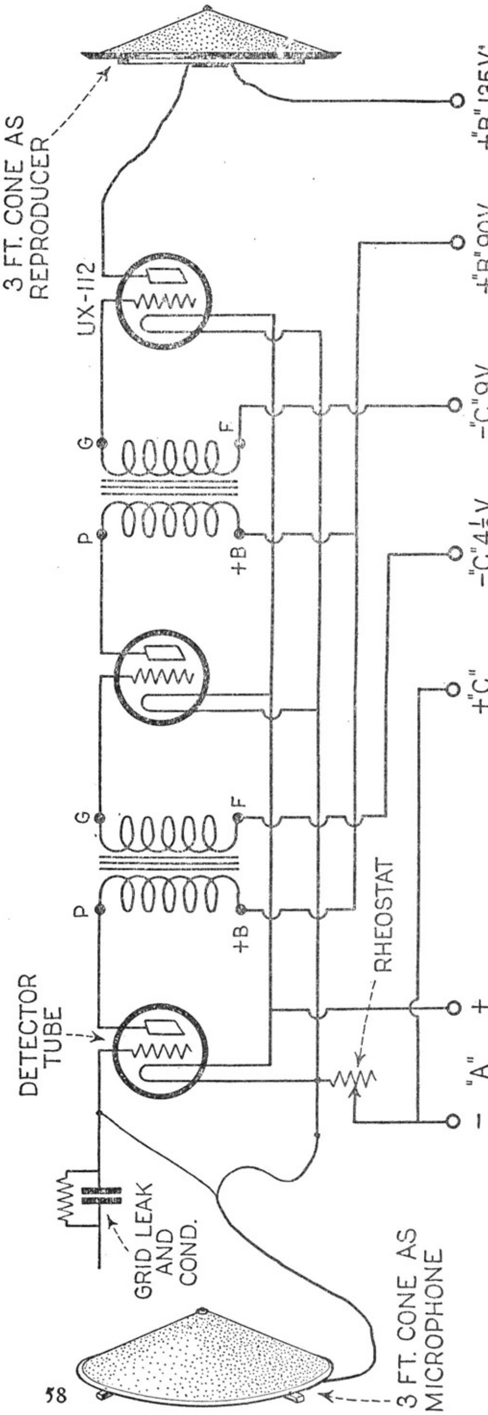



Fig. 9. Schematic diagram showing the use of two cones. One is used as a magnetic driven "pick-up," actuating the grid of the detector, the other is used as the output or reproducer.

# HINTS ABOUT THREE-FOOT CONES

## *A Few Tips Which Will Help Their Constructors*

IT has always been the aim of the radio expert to develop a loud speaker that would actually respond to the full frequency range covered by musical instruments; and not merely to the higher frequencies or the higher harmonics of the lower frequencies, which is the case with many loud speakers. A good loud speaker should respond to the lowest tone of the bass viol which, in the international pitch, is about forty cycles. Of course the piano keyboard extends to a lower range, the lowest note having a frequency of 27.188 cycles; but it is doubtful if any broadcasting stations transmit frequencies as low as this and consequently there is no advantage in having a loud speaker that would operate on them.

It is easy to build a loud speaker that will operate on the higher frequencies. Practically all the horns and small cones do this. The difficulty has always been to make a loud speaker that would operate on the lower frequencies as well as the higher. This has been accomplished in some of the larger cone speakers, about three feet in diameter. It seems that a large cone is required in order to get the bass notes. At the same time the unit which drives the cone should be matched to suit it, so that both high and low notes come through with more or less equal fidelity.

On account of the size of these speakers they are now furnished in kit from for convenient home assembly. But there are many little details of construction which might seem very simple and unimportant, yet in reality have a great bearing on the quality of reproduction. We must remember that the mechanical vibrations applied to the cone by the unit are in the order of one or two one-thousandths of an inch in amplitude, and therefore a slight change in the design of the instrument will produce very noticeable results.

### Types of Mounting

While the three-foot cone may be mounted on the wall, ceiling, pedestal, or in a console cabinet, the wall and ceiling types are the most popular; and the type shown in the various illustrations, in which a single cone only is used, is the best for home assembly, from the standpoint of not only mechanical simplicity but also accoustical superiority. Remember that the back of the cone should be entirely open and free, and therefore the finished wall cone should be spaced a few inches from the wall for best results.

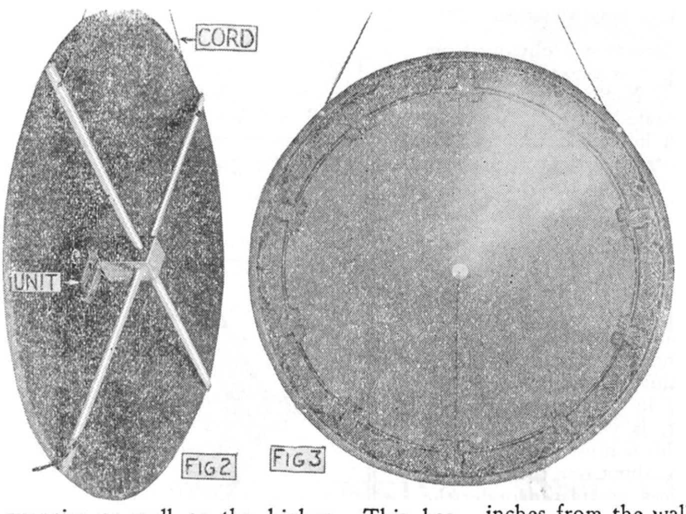



**Fig. 2, at the left, shows the rear view of a completed three-foot speaker, with the driving unit in place on the central wooden block.**

**Fig. 3 is the front view of a completed cone, of the model described in this article.**

Fig. 1 shows details of the frame construction for the wall- or ceiling-type cone. This should be built first, and the arms should be well fitted and glued into the center block to prevent rattling. Vibrations are transmitted to the frame as well as to the cone, and any looseness in the frame will cause disagreeable noises.

Fig. 2 is a rear view of the assembled speaker with the cone and unit mounted on

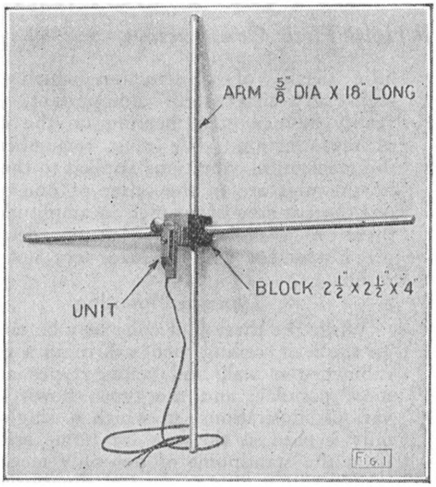



**Fig. 1. Constructional details of a central frame, for either the wall- or the ceiling-type three-foot cone speaker. The arms should be carefully fitted and then glued into the center block to eliminate any vibration.**

the frame. The construction is obvious from the illustration. Fig. 3 is the front view of the same instrument. Note the pleasing appearance of the decorated cone. It will harmonize with the best home interiors, so that the purchaser can install one without inviting domestic dissension.

### Tips on the Assembly

In assembling one of these speakers, the unit should be mounted to the frame before the cone is made. On the drive pin of the unit are two metal cones which are used for clamping the apex to the large cone and making a tight mechanical connection. One important point in this part of the assembly, which is overlooked in practically all cones now on the market, is what we may term "cushion drive." This is illustrated in Fig. 4.

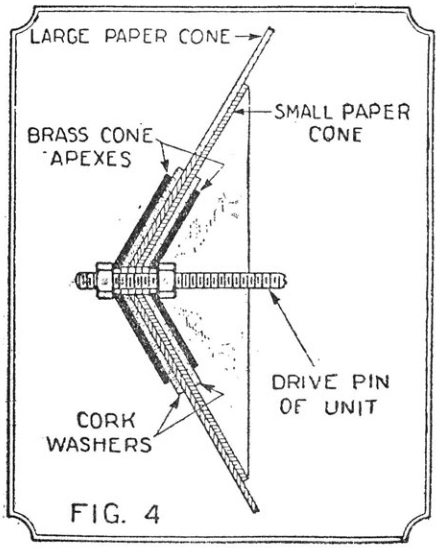
Two cork washers, about one thirty-second of an inch in thickness, are placed under the metal cones. Thus the vibrations from the unit are transmitted through cork to the large cone. The purpose of the cork is to absorb extremely high frequencies which produce harsh disagreeable noises and which are caused by the fundamental periods of vibration of the metal parts of the unit, such as the drive pin and the metal cones themselves. Even though you now have a cone speaker, it is very advisable to procure a large cork, slice off two thin washers with a safety-razor blade, and clamp them under the metal cone attachments. You will immediately note a difference in tone, due to the elimination of the harsh overtones and an increased amplitude of the fundamental bass tones.

The cone material is usually furnished in the form of a square sheet rolled up in a small package. The cone is made by cutting on the lines indicated and gluing into shape. The small cone printed in the upper right corner of the sheet is to be cut out and glued to the apex of the main cone for strengthening purposes. (See Fig. 3 on Page 55). The flange is bent towards the apex along the line indicated. It is advisable to scratch or indent the surface of the paper along this line with a blunt tool before bending. This flange strengthens the cone and makes it sufficiently rigid to be self-supporting.

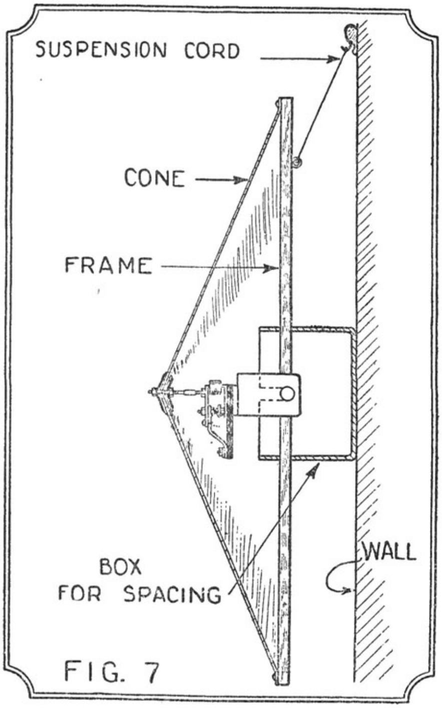
When assembling the cone to the unit and frame, make sure that it is in good alignment and that the cone is clamped to the drive pin where it naturally falls; so that no mechanical strain is placed on the pin. Thumb tacks are used to attach the cone to the four arms of the frame as shown.

### Adjustment

The unit employed on this particular speaker is illustrated in Fig. 6. The extension pin for the drive rod and the cone




**Method of mounting the paper diaphragm to the shaft of the unit. The resiliency of the cork damps undesirable vibrations.**

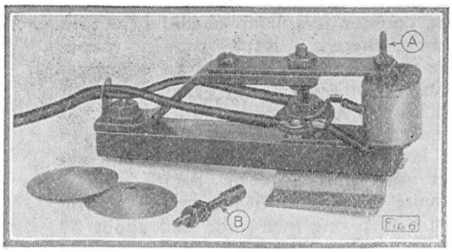



The method of keeping a cone away from the wall by means of a small cardboard box.

apexes are shown in this illustration. While it is adjusted for the average set, a slight readjustment may be necessary after the speaker is assembled; this can be made by means of the two lock nuts. Loosening the upper one and tightening the lower widens the air gap which is located at the center of the solenoid coil.

In operation the coil will stand voltages up to 200; so that it is safe to use it on a 171-type power tube without the use of an output filter. In this case the terminals of the speaker must be connected in the manner from which loudest results are obtained; as the unit is polarized.

It was stated before that, for best results from the wall-type speaker, it should be spaced a few inches from the wall. A simple method of doing this is illustrated in Fig. 7. A small cardboard box has a slot cut in each of the four sides so that it fits on the back of the frame. This box is sufficient for spacing. The ceiling-type cone is, of course, the same as the wall type; except that the suspension cord is attached to the center block, so that when the cone is suspended it balances in a horizontal position. This type gives better results, as it can be hung ten or twelve inches from the ceiling and the sound will be distributed. As it is, for the most part, reflected from the ceiling, the distribution is more uniform. A person entering the room has difficulty in locating the source of the sound.




The driving rod, A, is attached to the paper diaphragm by means of the rod, B, which is threaded.

The location of the speaker in the room also has a decided bearing on the quality output. This is more noticeable with the three-foot cone than with smaller ones; as the larger cone has greater carrying power, although the volume is apparently less. Good results on the wall type cone are obtained by suspending it in the corner of the room, as this gives more open space behind the cone in which the air vibration may build up.

# AN INEXPENSIVE CONE TYPE LOUDSPEAKER

*The Latest Type of Conical Loudspeaker, Designed for the Experimenter with a Modest Purse*

MANY ardent radio fans will be indebted to **Jay Hollander** for the constructional data of this cone type speaker without the necessity of pledging the family jewels. Mr. Hollander tells his story in **Radio News**, New York, as follows:

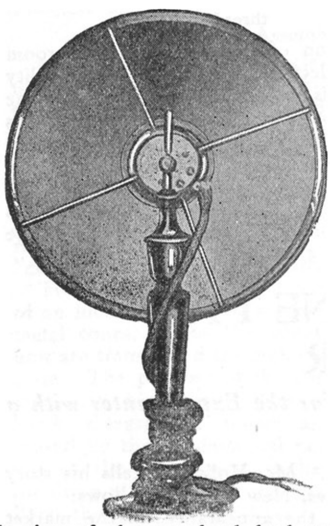
Ever since the appearance on the market last season of the cone type loud speaker with paper diaphragm, it has taken the premier place among such apparatus and has proved to be the best reproducer of speech and music to put in an appearance on the radio market.

But the price of the commercial types is pretty high, high enough, in fact, to make them almost out of the reach of the ordinary fan. For some time the writer contemplated the problem of getting together sufficient cash to buy one of these units, and finally, having discovered that such was almost impossible, decided to build one as the only possible way in which he might get the desired purity of tone from his radio set. (He has, of course, a resistance-coupled radio amplifier on a super-het.)

Having purchased a great deal of his radio supplies at the five-and-dime, he was wandering over near the radio counter one day, dreaming of the cone loud speaker, when he was hit by the great idea. Here it is: On that counter is a lamp shade; here is a candlestick; there's a lot of drawing paper at home and an old receiver—ergo, the great corporation won't get thirty "bucks" out of me and I'll still have a cone loud speaker.

Here is how the trick is turned:

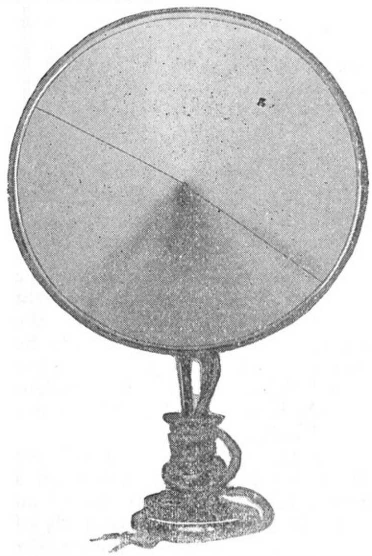
The lamp shade gave the idea, the remainder was simple. The details follow. First secure a piece of heavy brass sheeting and cut a strip one inch wide and about 37 inches long—this dimension is for a cone about 12 inches in diameter, which is a good size. For perfect reproduction, any smaller size will not give the best results. As a matter of fact, if absolutely perfect reproduction is desired, the cone would have to be at least eight feet in diameter. This is out of the question, however, and for the smaller sizes we must depend upon the formation of harmonics for the reproduction of the very low notes.



**Back view of the completed loud speaker mounted on a candle stick.**

Back again to the construction. After the strip of brass has been cut, it is rolled into as nearly a perfect circle as possible. The ends are connected by soldering a small piece under them.

The supports are then made for the phone unit. These consist of three or four heavy wires, soldered to the under side of the ring and run in toward the center, where they are again soldered to a second brass ring much like the first, except that its diameter is such as to fit snugly around the case of the unit to be used.

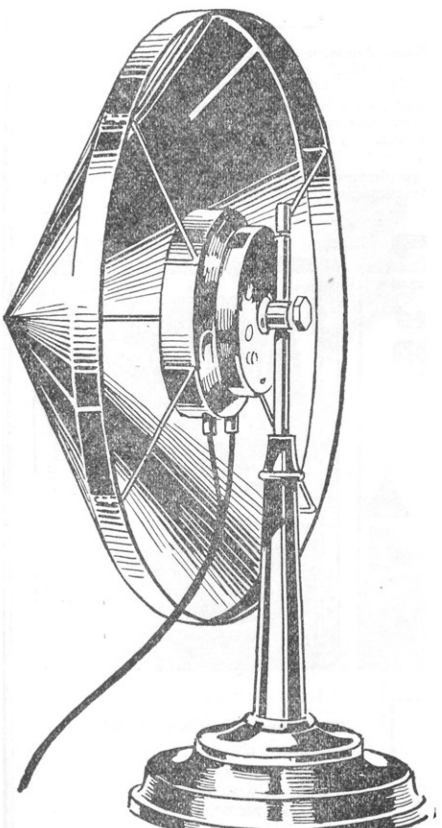


**Front of loudspeaker. The total cost of this speaker should not exceed $5.00.**

This second ring need not have its ends soldered together, but it may have a jumper fixed around the rear and equipped with a set screw for adjusting the tension of the diaphragm. The writer tried this idea on his first speaker, but found it unnecessary for good operation.

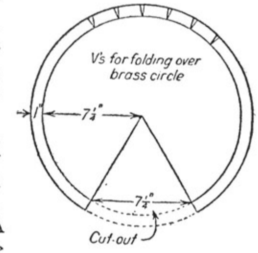
The cone is then made. If the diameter of one foot is being adhered to, the cone must be 8¼ inches in radius. This gives the completed cone a pitch of about four inches, deep enough for practice. After the circle is cut, another circle is marked with a radius one inch less; this marks off the point at which the paper is to be folded over the brass ring. Now, on this dotted line measure a distance across a chord of 7¼ inches. This marks the points at which the paper is to be cut to form the cone. Lines are drawn through these points to the center and then the paper is cut along them.

For fastening the paper to the brass ring, small V's are cut in the edge about every thirty degrees around the circumference from the edge of the paper to the dotted line, which is one inch closer to the center. A large number of very small V's will give better results than a small number of big ones, so do not be afraid of cutting the V's.



Above is a clear schematic constructional diagram of the loud speaker.

Following the completion of the speaker thus far, the next point is the installation of the connecting rod between the cone and




**The layout of the paper cone which forms the vibrating member of speaker.**

the unit which is to be employed. A piece of bus bar will serve admirably, if there is not an available piece of brass rod around the work-bench. The matter of attaching it to the diaphragm of the phone is very simple. Be careful that a good, tight connection is made but that, at the same time, the area covered by the connection is as small as possible. That is to say, see to it that the solder used covers as little of the diaphragm space as possible.

The attachment to the cone is not quite so simple a matter. The writer used two small brass cones two inches in diameter, one on the outside of the apex of the paper cone and the other on the inside. Then the connecting rod was attached to these cones with a suitable threaded end by means of nuts.

Now for the unit. The second brass ring was made to fit snugly around the outside of the receiver case. The receiver slips into this and the diaphragm with the extension installed. Remember that if the connections to the cone and to the diaphragm are not made at absolute right angles, trouble in plenty is liable to result.

When in operation, the chances are that the diaphragm will constantly rebut itself against the pole pieces of the magnets, giving a nice, metallic twang. This is corrected by the installation of a couple of thin shims of copper or brass placed between the edge of the diaphragm and its bearing around the receiver case.

The thinnest possible metal sheet should be used for this purpose. If there is some old shielding material around the house, it will come in handy. Keep the diaphragm as close to the pole pieces as possible, so long as it does not strike when the town's prize prima donna takes her high C.

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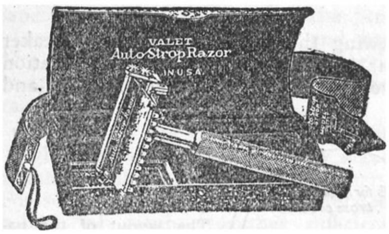


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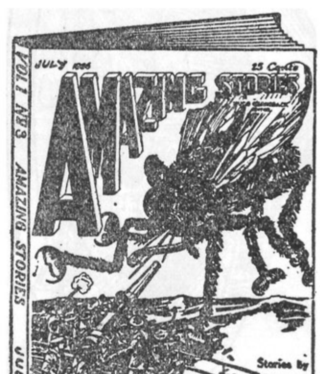


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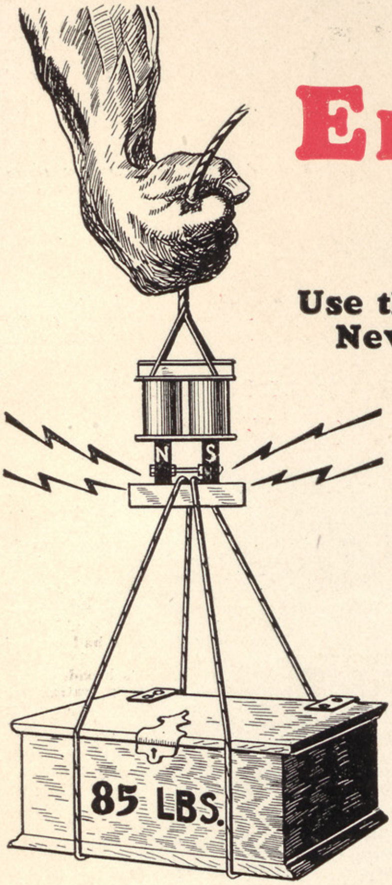


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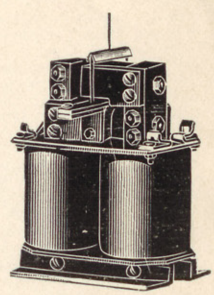

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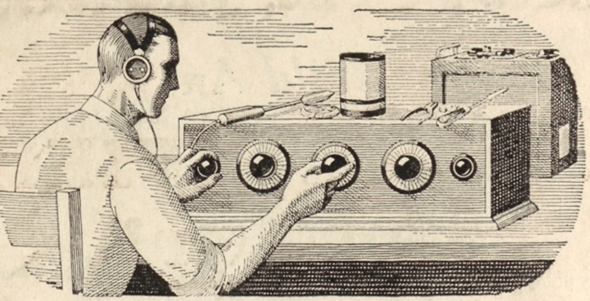

*If all the Radio sets I've "fooled" with in my time were piled on top of each other, they'd reach about half-way to Mars. The trouble with me was that I thought I knew so much about Radio that I really didn't know the first thing. I thought Radio was a plaything—that was all I could see in it for me.*

# I Thought Radio Was a Plaything

## But Now My Eyes Are Opened, And I'm Making Over $100 a Week!

$50 a week! Man alive, just one year ago a salary that big would have been the height of my ambition.

Twelve months ago I was skimping along on starvation wages, just barely making both ends meet. It was the same old story—a little job, a salary just as small as the job.

If you'd told me a year ago that in twelve months' time I would be making $100 and more every week in the Radio business—whew! I know I'd have thought you were crazy. But that's the sort of money I'm pulling down right now—and in the future I expect even more. Why, only today—

But I am getting ahead of my story. I was hard up a year ago because I was kidding myself, that's all—not because I had to be. If you've fooled around with Radio, but never thought of it as a serious business, maybe you're in just the same boat I was. If so, you'll want to read how my eyes were opened.

When broadcasting first became the rage, I first began dabbling with Radio. I was "nuts", like many thousands of other fellows. And no wonder! There's a fascination—something that grabs hold of a fellow—about twirling a little knob and suddenly listening to a voice speaking a thousand miles away! In those days many times I stayed up almost the whole night trying for DX.

I never seemed to ge very far with it though. So, up to a year ago, I was just a dabbler—I thought Radio was a plaything. I never realized what an enormous, fast growing industry Radio had come to be—employing thousands and thousands of trained men. I usually stayed home in the evenings after work, because I didn't make enough money to go out very much.

And as for the idea that a splendid Radio job might be mine, if I made a little effort to prepare for it—such an idea never entered my mind. When a friend suggested it to me one year ago, I laughed at him.

"You're kidding me," I said.

"I'm not," he replied. "Take a look at this ad."

He pointed to a page ad in a magazine I'd seen many times but just passed up. This time I read the ad carefully. It told of many big opportunities for trained men to succeed in the great new Radio field. With the advertisement was a coupon. I sent the coupon in, and in a few days received a handsome 64-page book, telling about the opportunities in the Radio field and how a man can prepare quickly and easily at home to take advantage of these opportunities. Well, it was a revelation to me. I read the book carefully, and when I finished it I made my decision.

What's happened in the twelve months since that day seems almost like a dream to me now. For ten of those twelve months, I've had a Radio business of my own. At first, of course, I started as a little proposition on the side, under the guidance of the National Radio Institute, the outfit that gave me my Radio training. It wasn't long before I was getting so much to do that I quit my measly little clerical job, and devoted my full time to my Radio business.

Since that time I've gone right on up, always under the watchful guidance of my friends at the National Radio Institute. They would have given me just as much help, too, if I had wanted to follow some other line of Radio besides building my own retail business—such as broadcasting, manufacturing, experimenting, sea operating, or any one of the score of lines they prepare for you. And to think that until that day I sent for their eye-opening book, I'd been wailing, "I never had a chance!"

Now I'm making, as I told you before, over $100 a week. And I know the future holds even more, for Radio is one of the most progressive, fastest growing businesses in the world today. And it's work that I like—work a man can get interested in.

Here's a real tip. You may not be as bad off as I was. But think it over—are you satisfied? Are you making enough money, at work that you like? Would you sign a contract to stay where you are now for the next ten years—making the same money? If not, you'd better be doing something about it instead of drifting.

This new Radio game is a live-wire field of golden rewards. The work is fascinating, absorbing, well paid. The National Radio Institute—oldest and largest radio home-study school in the world—will train you inexpensively in your own home to know Radio from A to Z.

Take another tip—not matter what your plans are, no matter how much or how litle you know about Radio—clip the coupon below and look their free book over. It is filled with interesting facts, figures, and photos, and the information it will give you is worth a few minutes of anybody's time. You will place yourself under no obligation—the book is free, and is gladly sent to anyone who wants to know about Radio. Just address J. E. Smith, President, National Radio Institute, Department 7L2, Washington, D. C.

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Dear Mr. Smith:

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