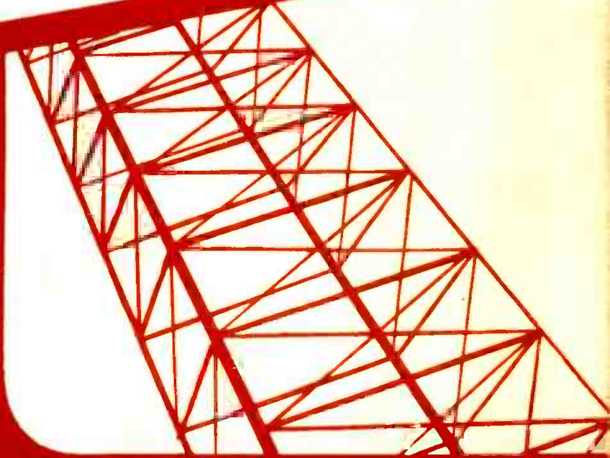
LOUDSPEAKERS

Lesson RRT-2



DE FOREST'S TRAINING, INC.
RADIO
TELEVISION
ELECTRONICS

DE FOREST'S TRAINING, INC.

2533 N. Ashland Ave., Chicago 14, Illinois

RRT-2

Radio Reception
and Transmission

LESSON RRT-2

LOUDSPEAKERS

CHRONOLOGICAL HISTORY OF RADIO AND TELEVISION DEVELOPMENTS

1779—Volta completed the development of his voltaic pile, the first form of electric battery to convert chemical energy into electrical energy. This marked the beginning of our modern electrical science.

1808—John Dalton, an English chemist, announced the first version of his atomic theory and the atomic structure of matter.

1820—Prof. Ampere of France released several articles on the nature of the electric current and how it is related to magnetism. The ampere, unit of current, was named after him.

1820—Prof. Hans Oersted of Copenhagen discovered that a conductor carrying a current is surrounded with a magnetic field, thus establishing a relation between electricity and magnetism.

DE FOREST'S TRAINING, INC.
2533 N. ASHLAND AVE., CHICAGO 14, ILLINOIS

RADIO RECEPTION AND TRANSMISSION

LESSON RRT-2

LOUDSPEAKERS

INDEX

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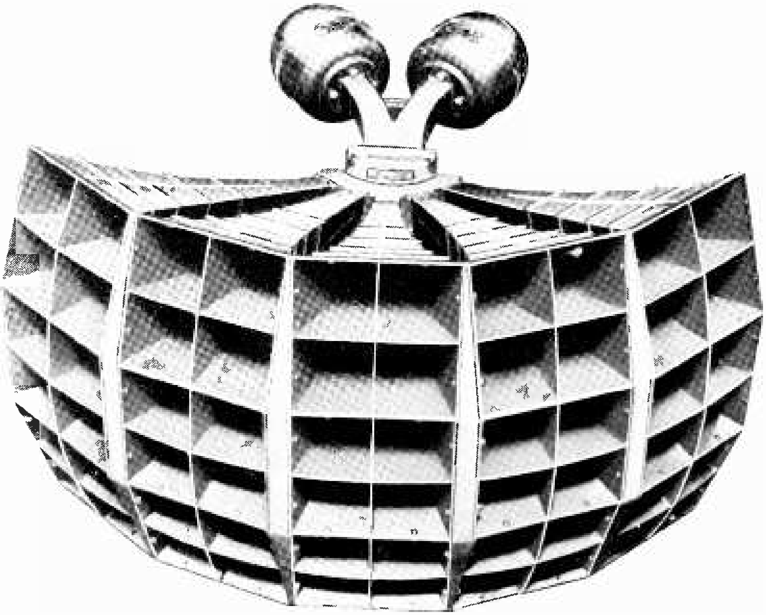
Work is the true elixir of life. The busiest man is the happiest man. Excellence in any art or profession is attained only by hard and persistent work. Never believe that you are perfect. When a man imagines, even after years of striving, that he has attained perfection, his decline begins.

—Selected

LOUDSPEAKERS

In all electronic communication systems, the original sound waves are converted into corresponding changes of electrical energy and, as such, are amplified, transmitted and received. At the receiver, the changes of electrical energy are amplified again and finally converted back into sound waves which duplicate those of the original signal. Thus, in addition to its electronic parts, the complete system includes two important energy conversion units.

At the transmitter the sound is converted to electrical energy by means of a "microphone", the action of which will be explained in a later Lesson. At the receiver, the electrical energy is converted to sound by means of a "loudspeaker" or speaker, the action of which will be described in this Lesson. In general, the speaker converts the electrical energy to magnetic energy which causes mechanical motion or vibration. These vibrations are transferred to a diaphragm or cone which sets up the sound waves in the air.



A large multicellular horn fed by two dynamic driver units. Such an installation gives excellent sound distribution and good volume.
Courtesy Jensen Manufacturing Company

The two general types of loudspeakers in use today are the direct radiator and the horn type. In the latter, the vibrating membrane or diaphragm, is efficiently coupled to the outside air by means of a tube, called a horn, which gradually increases in diameter from the speaker unit to the open end. The membrane, or cone, of the direct radiator loudspeaker is coupled directly to the air, a somewhat less efficient arrangement than the horn speaker.

SPEAKER ACTION

By far the most commonly used loudspeaker mechanism consists of a radiator or membrane rigidly attached to a "voice coil", which is located in a strong, steady magnetic field and the assembly suspended by flexible supports in such a way that it can move in a direction parallel to the axis of the coil. Carried by the voice coil, audio-frequency electric currents set up a magnetic field which continually varies in strength and direction in accordance with the a-f currents producing it. This varying field alternately aids and opposes the steady field and results in a force which causes the voice coil to vibrate at the frequency of the applied audio signals. Rigidly attached to the voice coil, the diaphragm receives these vibrations and, in turn, imparts them to the air. This arrangement is known as a "moving coil" or "dynamic" type loudspeaker.

Other speaker mechanisms which have been developed consist of:

(1) a diaphragm which forms the moving plate of a condenser, the other plate being fixed. A steady polarizing voltage is applied to the two plates, and when the a-f signal is applied to them, the movable plate vibrates to and from the fixed plate in accordance with the variations in electric charge between them, as caused by the signal. The moving plate acts as the speaker diaphragm and causes similar vibrations in the surrounding air. The arrangement is limited by problems of polarizing potentials and satisfactory electrical coupling to the driving amplifier.

(2) A system in which the a-f signal is applied to a Rochelle salt crystal which is mechanically attached to a diaphragm. The resulting movements of the crystal cause the necessary vibrations of the diaphragm; but the amount which the crystal can move without fracturing, limits the low frequency response of the system.

(3) A flexible reed or ribbon of magnetic material, placed in a magnetic field, vibrates and acts as a radiator of sound energy when the field is varied by the

audio signal. However, with this system it is difficult to obtain efficient coupling to the air, and therefore such units are not widely used.

An older magnetic type, called the "balanced armature" speaker, employed a movable iron shaft which was pivoted and mounted inside a stationary coil. This, in turn, was located inside a large permanent magnet. The variations of the a-f currents in the coil caused corresponding changes in the magnetic force applied to the armature. Mechanically connected to the armature, the speaker cone or diaphragm, was caused to vibrate with the movements of the armature.

46-490M

High-fidelity 12-inch electrodynamic concert speaker.
Jensen Manufacturing Company

DIRECT RADIATOR LOUDSPEAKERS

The direct radiator type loudspeaker has the advantages of simplicity of construction, small space requirements, a relatively uniform frequency response, and low cost; and for these reasons, has attained almost universal use. The construction of a typical unit of this type is shown in Figure 1. The field coil which supplies the steady magnetic field, is located around a central core or pole piece and is energized by direct current when the unit is in operation. The outer case, called the "pot", provides a path of low reluctance for the magnetic flux from one end of the pole piece around the outside of the field winding to the other end.

Mechanically fastened to the pot is the "basket", a strong metal frame work which supports the "cone", or diaphragm, at its outer edge by means of the ring clamp.

At its inner edge, the cone is fastened to the voice coil, and both are centered in the air gap around the pole piece by means of a flexible device called a "spider". The air gap in which the voice coil is suspended is very short, so that the total reluctance of the magnetic circuit is low and the flux density high. With this close spacing, the free movement of the voice coil may be retarded by the presence of any small particles that happen to get into the gap, therefore the central opening is covered with a soft piece of cloth called the "dust cap".

LOUDSPEAKER CONES

Practically all direct radiator loudspeaker diaphragms or cones, are made of paper. They are produced by means of a system called "felting", in which a mixture of pulp and water is drawn through a master screen that has the desired shape of the diaphragm. After drying, the cone is finished and can be removed from the screen. Most felted cones are circular, although in certain applications it is possible to obtain a greater diaphragm area by making them elliptical. However, the latter shape results in a particular directional radiation pattern which is not always desirable. Other shapes have been made but the circular design has proved to be the most efficient and generally satisfactory.

Dynamic driver unit for various types of horns and trumpets.
Courtesy Atlas Sound Corporation

Many cones are made of special types of paper. Where efficiency in the transfer of audio power is desired at the expense of smooth response, very hard papers are best while softer, more flexible papers are used to obtain high quality reproduction. Sometimes a compromise is made between mechanical strength and smooth response by employing closely spaced annular rings in which the fibrous structure of the cone material is deliberately broken down.

The frequency response of a speaker may be smoothed (high peaks and dips eliminated) still further by use of very soft material similar to blotting paper, but this results in the loss of the high frequencies. Another compromise is obtained in a cone which is divided into three bands of equal width, each having a different degree of hardness, with the material nearest the voice coil being the hardest and that near the outer rim being most soft.

The three types of cross sections employed for speaker cones are shown in Figure 2. That of Figure 2-A is called the conical shape, while the flared shape of Figure 2-B is somewhat more rigid, causing its radiation pattern to be very much sharper for the higher audio frequencies. The corrugations in the cone of Figure 2-C increase the radial rigidity and result in a broadening of the radiation pattern.

CONE SUSPENSION SYSTEMS

One method by which the speaker cone is supported at its outer edge is shown in Figure 3-A where the suspension system has been felted as part of the cone and is fastened to the supporting basket with cement. This system, although simple and inexpensive, has the disadvantage of not permitting the cone to move with equal freedom at all frequencies or amplitudes, and thus introduces distortion into the sound waves.

This type of distortion can be reduced by means of the improved system of Figure 3-B in which the double supporting arrangement decreases the stiffness of the suspension system so that even small light cones will have a fairly low fundamental frequency thereby increasing their low-frequency range.

A fairly recent development is the so-called "accordion cone" speaker in which the outer edge of the cone floats without contacting the metal basket. Similar to the arrangement of Figure 3-B, a supporting structure of cone material is folded back accordion-wise and has just enough stiffness to provide centering for the cone. This type of folded edge support extends the lower frequency limit of a speaker down to at least one octave below that obtainable with conventional construction.

Three methods of suspending the speaker cone at its inner edge and keeping the voice coil properly centered in the air gap are shown in Figures 3-C, 3-D, and 3-E. The inside slotted centering suspension of Figure 3-C is usually made of some type of fiber, and the slots shown in the top view decrease the stiffness of the disk and permit greater amplitude of voice coil travel. Figure 3-D shows an inside corrugated centering suspension which is made of felted paper. Both this and the slotted disk are usually used in speakers in which the amplitude of vibration is relatively small. For greater amplitudes, a very low value of suspension-system stiffness is obtained by employing the felted-paper outside corrugated centering suspension of Figure 3-E.

SPEAKER VOICE COILS

The details of loudspeaker voice coil construction are shown in the partial section views Figure 4. In Figure 4-A, the coil is wound on a cylindrical paper form which is cemented to the speaker cone. Cement is also used to bind the adjacent turns of wire together and to bind the voice coil to the form. The ends of the coil are brought out to points on the cone where they are soldered to a pair of very flexible leads which complete the signal circuit when they are connected to the audio-amplifier output or speaker matching transformer.

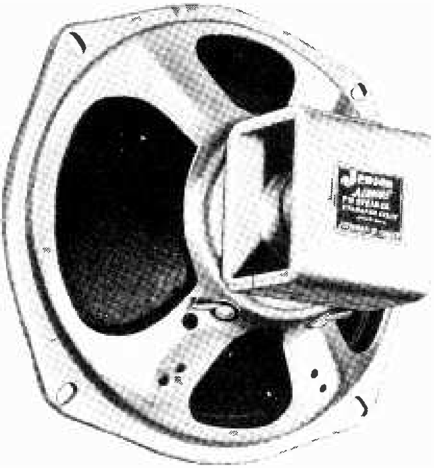
The efficiency of the speaker can be increased by reducing the air gap, to lower the reluctance of the magnetic circuit and allow a stronger field, and by reducing the weight of the voice coil to permit it to respond more readily and accurately to the changes of flux.

As shown in Figure 1, the air gap between the pole piece and pot must be large enough to accommodate the voice coil and permit it to move in and out freely without rubbing on either side. Thus, the dimensions of the voice coil determine the size of the air gap. In the common arrangement of Figure 4A, the coil is wound with conventional round wire on a paper cylinder, therefore the air gap must be wide enough to accommodate both the cylinder and the wire.

By the use of self-supporting voice coils, which are held together with cement as shown in Figure 4B, the paper coil form can be eliminated, therefore the required width of the air gap can be reduced. Also, to provide the same current carrying capacity in less space, the round wire of Figures 4A and 4B can be replaced with the edge wound ribbon of Figure 4C or the square wire of Figure 4D. To reduce the weight of the voice coil, the conventional copper wire may be replaced by aluminum wire.

SPEAKER FIELD MAGNETS

Either an electromagnet or a permanent magnet may be used to supply the steady field in a moving coil speaker mechanism.



Alnico 5 permanent-magnet dynamic speaker. Jensen Manufacturing Company

Providing the fields are of equal strength, the operation of the speaker is the same for both types of magnets. Speakers employing electromagnets are called electrodynamic speakers, while those using permanent magnets are known simply as "permanent magnet", or "p-m", speakers.

As shown in Figure 1, the electromagnet consists of a coil of wire wound around a core. To create a magnetic field of the required strength, a sufficiently high voltage must be applied to overcome the electrical resistance of the winding and produce the proper value of direct current in the coil. Besides the voltage applied, the field strength depends upon a number of other factors, such as the number of turns in the field coil, and the area of the core or pole piece.

For any particular unit, the magnetic field is produced by the power dissipated in the field coil, and this in turn, is generally approximately equal to the audio-frequency power to be handled by the voice coil. If this value is known, and the d-c resistance of the coil measured, the required field-coil current and voltage to be applied for proper exitation can be calculated. For example, suppose it is desired to determine the proper field coil current and voltage of an electro-dynamic speaker that is to operate at 4 watts of audio power, and that an ohmmeter shows a d-c field coil resistance of 2500 ohms.

Assuming a field-coil power requirement of 4 watts, the voltage which should be applied is:

$$\begin{aligned} E &= \sqrt{WR} \\ &= \sqrt{4 \times 2500} \\ &= \sqrt{10{,}000} = 100 \text{ volts.} \end{aligned}$$

The current in the field coil should then be:

$$I = \frac{E}{R} = \frac{100}{2500} = .04 \text{ amps} = 40 \text{ ma.}$$

The d-c power for the field coil is obtained either from the power supply of the equipment with which the speaker is being used, or from a separate small power supply called a "field exciter", which operates on the 115 volt a-c power lines. Since the field coil has inductance as well as resistance, it is often placed in series with the d-c plate supply of a radio or audio amplifier, thus serving the dual purpose of providing the magnetic field for the speaker and acting as a power supply filter choke.

Projector equipped with dynamic driver unit, suitable for outdoor and indoor music distribution and calling systems.
Atlas Sound Corporation

Under these conditions a small a-c ripple voltage may appear in the d-c power supplied to the field and the resulting pulsating flux will induce a corresponding voltage in the voice coil. That is, the field winding will act as the primary and the voice coil as the secondary of a transformer. This induced voltage will be entirely independent of any signal voltage that may be impressed across the voice coil and will produce undesirable hum.

To overcome this effect, it is common practice to wind on the field another coil with the same number of turns as the voice coil. The hum voltages induced in this coil will be of equal amplitude to those induced in the voice coil and by connecting them series opposing, the voltages will exactly neutralize each other. This extra field winding is known as a "hum bucking" coil and has no appreciable effect as far as the signal voltages are concerned.

As mentioned previously, the field flux of a dynamic type speaker may be produced by an electromagnet or a permanent magnet. Originally, the required high density field flux was obtained only by means of an electromagnet but due to recent developments in magnetic materials, permanent magnet loud speakers now are available with magnetic field strengths identical to equivalent models using field coils.

Two types of field structures used for p-m speakers are shown in Figure 5. In Figure 5-A, to permit the employment of a large magnet which provides a strong field a ring-shaped magnet has its magnetic path completed through the circular disk which supports the central pole piece. Lower power p-m speaker employs the smaller, centrally located, slug magnet of Figure 5-B with the pole piece mounted on top of the magnet, and the magnetic circuit completed through the pot.

Permanent magnets are made of combinations or alloys of various metals such as aluminum, nickel, cobalt, steel, etc., and are given various trade names according to their composition. One of the best known, Alnico, is made of the first three substances mentioned and the name is usually followed by a number, such as Alnico V, designating the exact chemical formula. The ability of the magnet to hold its magnetism after being magnetized at the factory, depends upon its chemical formula and the extent to which it is magnetized. The magnetic materials in use today are capable of holding their magnetism for years without showing any signs of appreciable decrease in the strength of their field.

The weight of a permanent magnet depends upon its chemical composition, and, of two magnets having the same chemical formula, the larger of the two will be the heavier and will have the stronger magnetic field. Likewise, of two magnets having the same size and structure, the heavier unit will generally possess the stronger field. For this reason, manufacturers usually include the size and weight of the magnet in the specifications of their p-m speakers.

With both electromagnetic and p-m speakers, a low reluctance path must be provided for the magnetic field around the outside from one end of the magnet to the other such as the pot of Figure 5-B. If this pot were absent, there would be a large leakage of magnetic flux, and the field in which the voice coil lies would not be as uniform nor as concentrated as it should. This would result in a decrease of the speaker efficiency and give rise to distortion.

Among the many factors which must be considered in choosing between the electromagnetic and permanent magnet field structures for any particular speaker application, the cost of the unit is often of vital concern. Generally speaking, very small p-m loudspeakers cost from the same amount to about 10% more than equivalent electromagnetic units. The larger sizes employed for public address systems and large radios may cost as much as 50% more than their field-coil equivalents, while, for very large installations, such as in theatres, etc., the p-m unit may cost more than twice as much as the electromagnetic type.

To offset the greater cost, the p-m speaker requires but one comparatively low voltage circuit to the voice coil while the electrodynamic speaker requires a second comparatively high voltage circuit to the field coil. This second circuit is a greater disadvantage in larger systems in which the speakers are located at a distance from the audio amplifier or a D-C supply.

EFFICIENCY

Efficiency of a loudspeaker is a measure of its ability to convert electrical energy to acoustical energy. It is very difficult to obtain the necessary data for determining speaker efficiencies, and usually such calculation is performed only by the manufacturers in the research laboratories. However, it may be surprising to learn that loudspeaker efficiencies range from about 5 to 10 per cent for direct radiator types up to as high as 30 per cent for the horn types. These figures are general deductions based on the use of a 400 cycle test note, which approximates the most predominant frequencies in musical reproductions.

The efficiency of a loudspeaker may be defined as the ratio of the sound power output to the electrical power input, expressed as a percentage. As might be expected, the efficiency of a speaker varies over the audio band, and each unit has its own particular point at which it is most efficient. This is illustrated in Figure 6 where the efficiencies of three different direct-radiator speakers are compared by means of curves.

The solid line curve, "A", is that of a large speaker with a cone diameter of 16 inches. The second speaker, curve B, has a cone diameter of 4 inches, while for curve C, the speaker cone has a diameter of 1 inch. These values are typical of loudspeakers in actual use today, and in general, the larger the cone diameter, the lower the frequency of maximum efficiency.

FREQUENCY RESPONSE

The frequency response of a loudspeaker is a measure of the sound pressure produced at a designated point or points in the vicinity of the speaker, with specified electrical power input, frequency, and surrounding acoustic conditions. With present day methods, variations in the specifications of the test conditions exist in different laboratories, and, therefore, comparisons of the response curves of different speakers are meaningless unless the compared units were tested under identical conditions. For this reason, most speaker manufacturers do not publish response curves along with the other specifications of their speakers.

To give an idea of the differences in the response of different sized speakers, the frequency-vs-output curves of the three units mentioned above, having cone diameters of 16 inches, 4 inches, and 1 inch, respectively, are given in Figure 7. As curve A shows, the largest speaker has a response which extends farthest into the low-frequency region, while the best high-frequency response is obtained with the smallest unit as shown by curve C. These curves are in general agreement with the calculated frequency-per cent efficiency curves of Figure 6.

SPEAKER POWER CONSIDERATIONS

The maximum a-f power input which may be applied to a given speaker generally is determined either by the power which can be handled by the unit before an appreciable amount of distortion sets in, or by the physical ability of the voice coil to dissipate a given amount of power in the form of heat. For ordinary speakers, the distortion is not very noticeable, and it is often possible to damage the voice coil before the distortion becomes objectionable. In the case of the high-

Loudspeaker unit with circular deflecting plates for producing 360° horizontal sound distribution.

Courtesy Atlas Sound Corporation

fidelity types, where high-frequency response is flat above 5000 cycles, objectionable distortion usually will be produced before the temperature of the voice coil has risen to a point where permanent damage will occur.

Special cabinet with the built-in base reflex principle for extension speakers in homes, hotels, theaters, etc
Jensen Manufacturing Company

The factor which limits the sound power output of a given speaker, is the maximum amplitude of vibration which its diaphragm may have at the lowest frequency to be reproduced. For a specified power output, the vibration amplitude required increases with a decrease in frequency. Also, the larger the diameter of the cone, the smaller the vibration amplitude needed for a given output at a particular frequency. Therefore, for the same maximum vibration amplitude, the speaker having the largest diameter cone will produce the lowest frequency at a given value of power output.

A common misunderstanding is that a speaker rated at a high power-handling capacity, such as 25 watts, and having a large cone 15 to 18 inches in diameter, cannot be driven satisfactorily by a small audio amplifier. The fact is, however, that the more efficient a speaker, the more sound output it will deliver for any given electrical input power. For example, suppose a certain amplifier is used normally with a 10 inch speaker having an efficiency of approximately 5 per cent. This same amplifier can be used with an 18 inch speaker having power handling capacity of 25 watts or more at an efficiency of 20 per cent, with the result that besides the improvement in low frequency response, the sound output from the larger speaker will be about four times that obtained from the 10 inch speaker. This is due to the fact that a highly efficient speaker requires less input power to drive it to a given acoustical output than does a smaller less efficient speaker.

DIRECTIVITY

With any speaker, the greatest amplitude of sound is projected in the direction of the axis of the cone. As the angle between the axis and the path by which the sound reaches a listener is increased, a gradual drop-off of volume is observed. A graph showing the relative response of a speaker at various angles from its axis, is termed a directional pattern, and drawn on the general plan of those shown in Figure 8.

The origin of the curve is at the lower center with the relative response measured along the straight radial lines. The central vertical line represents an extension of the cone axis while the outer circular scale indicates the angles in respect to the axis. For example, the approximate readings of Figure 8B are 100% response at the 0° axis, 85% at 30°, 30% at 60° and 15% at 90°.

It has been found that the directional pattern depends principally upon: (1) the diameter of the cone, (2) the frequency, and (3) the angle formed by the sides of the cone. It is affected to a lesser degree by the cone material (type of paper), the processing during manufacture, any corrugations in the cone, the voice coil diameter, and the suspension system.

The effect of frequency is shown by the patterns of Figures 8-A, B, and C, which indicate the response of a single speaker having a cone diameter of 4 inches, at 1000, 5000 and 15,000 cps, respectively. Thus, it is seen that a listener located directly in front of the speaker would hear with equal volume all frequencies that are within the flat response range of the speaker, while a listener located at an angle from the axis would note a considerable reduction in the volume of the high frequencies. The larger the angle, the greater the reduction. This "beaming" of the sound, Figure 8-C, is termed directivity; and as the curves indicate, a speaker is more "directional" at the high frequencies than at the lows. For comparison, Figures 8-D, E, and F show the directional patterns of 250, 1000 and 5000 cycles per second, respectively, of a second speaker having the same cone angle but with a cone diameter of 16 inches. The patterns show that the directivity of this unit increases with frequency as in the case of the smaller speaker. However, by comparing their respective patterns at 1000 cycles, Figures 8-A and 8-E, the speaker having the larger cone is more directive than the one with the smaller cone. This is shown also by their respective patterns at 5000 cycles, Figures 8-B and 8-F.

The cone angle affects the directional pattern in such a way that the greater the angle between the sides of the cone of a given unit, the less directional the speaker response at any particular frequency. Thus, in summary, it may be stated that the directivity of a direct radiator type loudspeaker varies directly with frequency and cone diameter, and inversely with the cone angle.

HIGH FIDELITY

True high fidelity reproduction of music by a loudspeaker system requires a wide-range frequency response such that the "tone quality" produced is indistinguishable from the original as heard in the concert hall. It is this tone quality, or timbre, which distinguishes one instrument from another when both are playing the same fundamental note, and it is determined by the nature and number of the harmonics or overtones, which are being produced along with the fundamental. Though the range of fundamental tones employed in music extends only to about 4000 cps, the overtones may have a frequency of several times this value; therefore, the loudspeaker and its driving a-f amplifier should have a frequency response which is substantially flat up to ten or fifteen thousand cycles per second.

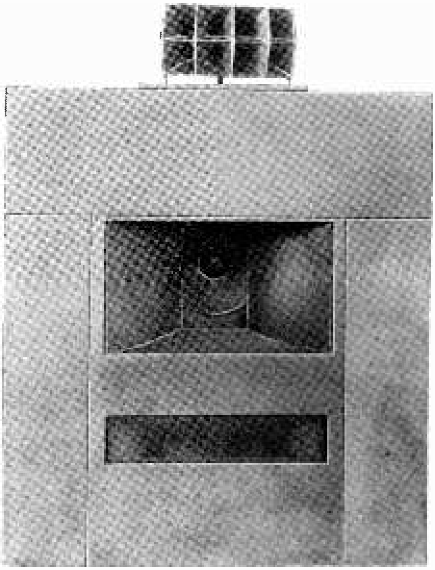
METHODS OF OBTAINING WIDE-RANGE RESPONSE

In preceding explanations it was shown that the two extreme ends of the audio band are difficult to reproduce with an efficiency equal to that obtained in the mid-frequency region. At the low frequencies, the lower efficiency is due primarily to the smaller mechanical resistance presented to the speaker cone by the air. As in all electrical and mechanical systems, the greatest transfer of energy takes place when the impedance of the load (in this case the air) is equal to that of the source (the speaker cone). A larger mechanical radiation resistance may be obtained with a large diameter cone which presents more surface to the air.

The efficiency at the high frequencies is limited by the mechanical reactance due to the mass of the vibrating cone and voice coil. Thus, to obtain adequate power handling capacity and uniform response at the lower frequencies requires a relatively large diameter, heavy cone, and a large voice coil; whereas a relatively small diameter, light cone and light voice coil are needed to obtain good efficiency at the higher frequencies. For applications where it is desired to obtain adequate reproduction over a wide range of frequencies, a number of speaker arrangements have been developed. Usually these arrangements include one, two, or all three of the following: (1) specially designed speakers, (2) combinations of two or more speakers, and (3) employment of suitable baffles or cabinets.

DOUBLE-CONE SPEAKERS

For purposes of comparison, a simplified cross-sectional drawing of an ordinary loudspeaker is shown in Figure 9-A. This type of unit usually has a fairly uniform axial frequency response from approximately 70 up to about 5000 cycles per second, above which its output drops off rapidly. An increase in the high frequency range is obtained by use of the double cone unit of Figure 9-B which includes the voice coil and large cone of Figure 9-A. The large cone, A, and the small cone, B, are separated by the compliance C, which consists of a corrugation near the inside rim of the large cone.

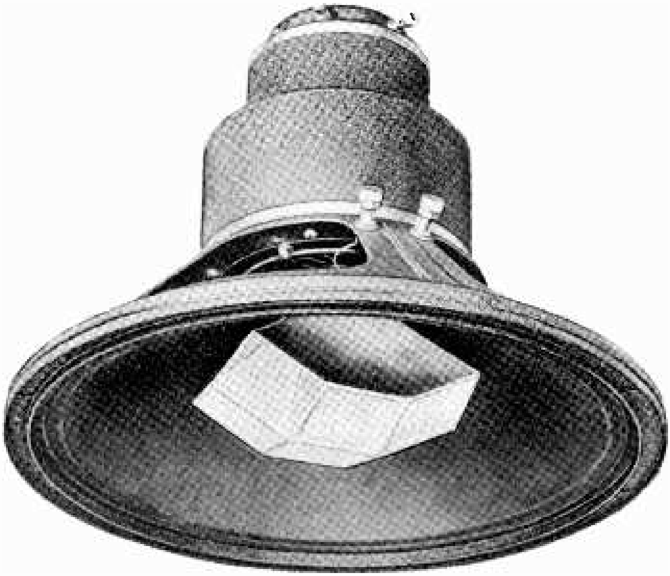


A full two-way speaker system for small auditorium and theatre use. Features claimed are true bass reproduction, good intelligibility and high acoustic efficiency.
Courtesy Altec Lansing Corporation

At high frequencies, the mechanical reactance of the compliance C is small compared to the mechanical impedance of A, therefore the small cone, B, moves, while A remains stationary. At low frequencies, the reactance of C is high compared to the impedance of A, and the entire system moves as a whole. Thus, the unit operates as a small cone speaker at high frequencies and as a large cone speaker at low frequencies, resulting in an extension of the high frequency range to about 8000 cps without any sacrifice of power handling capabilities.

DOUBLE-COIL SPEAKERS

Just as the compliance C permits independent movement of the small cone of the speaker of Figure 9-B, in Figure 9-C, a similar compliance separates the small voice coil, L_2, from the large coil, L_1. Here the electrical connections are such that the high signal frequencies are shunted around L_1 by means of a condenser. With this arrangement, the action is such that at high frequencies the mechanical reactance of C is low compared to the reactance of the mass of L_1.



Duplex speaker combining both high and low-frequency units in a compact two-way multicellular speaker. A dividing network of the constant impedance type with a crossover frequency of 2000 cycles is used for separating the power to each unit.

Courtesy Altec Lansing Corporation

Also, the electrical reactance of the condenser is small compared to that of L_1. Therefore, with signal currents in L_2 only, L_1 remains stationary while the cone is driven by the smaller coil L_2.

At low frequencies, the reactances of C and the condenser are high compared to the respective mechanical and electrical reactances of L_1, which, therefore, now carries the signal currents; and the action is the same as that of a single coil loud speaker. The indicated corrugations in the cone serve to counteract its increase in mechanical reactance, due to its mass, as the frequency rises. Thus, at the low frequencies the arrangement of Figure 9-C operates as a speaker having a large heavy cone and voice coil while at the higher frequencies, it acts as a lighter cone and small light voice coil with a frequency range up to 10,000 cps.

DOUBLE CONE—DOUBLE COIL SPEAKERS

Further improvements of high frequency response may be obtained by combining the features of the two units described above. Figure 9-D shows the cross section of a speaker employing a light coil L_2, connected to a small cone B, the two being coupled with compliance C to a heavy coil L_1, and a large cone A. Again, L_1 is shunted electrically by means of a condenser and as before, at low frequencies the reactances of C and the condenser are large, to cause operation as a single-cone, single-coil loudspeaker of large dimensions.

However, at high frequencies the condenser bypasses the signal current around L_1, which with cone A remains stationary, while the low mechanical reactance of C permits L_2 to vibrate independently of L_1 and thus drive the small cone B. This system provides a means of obtaining a frequency response which is flat up to about 14,000 cps, almost three times the range of the ordinary type of unit in Figure 9-A.

MULTIPLE SPEAKER ARRANGEMENTS

A system employing two separate speaker units to obtain a wide range of frequency response is shown in Figure 10-A. The upper high-frequency speaker, called the "tweeter", has a small voice coil and a small diameter cone; while the low-frequency unit, called the "woofer", employs a large diameter heavy cone driven by a large voice coil. Normally, such a "two-way system", as this is called, uses a filter arrangement in its electrical circuit for the purpose of applying the high frequency signals to the small speaker only and the low frequency signals to the large unit.

Filters of this type, often called frequency dividing networks, provide the desired action by the relationship between frequency and reactance. For example, in the circuit of Figure 11, inductive reactance L_1 and capacitive reactance C_1 are connected in series across the output of an a-f amplifier. At low frequencies, the inductive reactance is low and the capacitive reactance high, therefore, with voltage across the circuit, the drop across L_1 will be low compared to that across C_1. At high frequencies, conditions are reversed because the inductive reactance is high and the capacitive reactance low therefore the drop across L_1 will be high compared to that across C_1.

Similar conditions exist in the series circuit made up of capacitive reactance C_2 and inductive reactance L_2. Therefore the low frequency speaker is connected across condenser C_1 and the high frequency speaker is connected across choke coil L_2. Thus, at low frequencies, the voltage across the LF speaker will be high while that across the HF speaker will be low. As the frequency increases, the voltage across the LF speaker will decrease while that across the HF speaker will increase. Depending on the values of inductance and capacitance, at some particular frequency, known as the "cross over", both speakers will have equal voltage.

There are many variations of this basic circuit. For example, the value of low frequency voice coil inductance may be large enough to allow the omission of coil L_1 with circuit connections as shown by the dotted line. Choke coil L_2 may be omitted if the inductance of the high frequency voice coil is so small that practically all low frequency voltages are lost in the drop across condenser C_2.

The arrangement of Figure 10-A has a disadvantage, in that the speakers are separated, and hence a cancellation effect is produced in the "overlap" range of mid-band frequencies which are reproduced by both speakers. This effect can be reduced by locating the small speaker in the center of the large one, as shown in Figure 10-B. If the smaller unit is situated back of and inside the voice coil of the larger speaker, as in Figure 10-C, the large cone becomes a geometric continuation of the small one, the two then vibrating as a single cone, and the cancellation effects are completely eliminated.

In a case where the frequency range of a given small or medium-size speaker is adequate, but its power handling capacity is not, the latter requirement may be met by the use of several units mounted together on a panel as shown in Figure 10-D. Electrically, their voice coils will normally be connected in parallel or in a series-parallel arrangement and the number of units employed is determined by the total sound output required. The combined directional pattern may be broadened, if desired, by mounting the various units so that they are inclined at different angles.

Driver unit of the permanent-magnet dynamic type for use with different types of projectors. Courtesy University Loudspeakers, Inc.

SPEAKER PHASING

When more than one speaker is employed, in an arrangement like that of Figure 10D, the voice coils must be "phased" so that all cones move in and out in unison. This can be done by connecting a low voltage d-c source, such as a standard No. 6 dry cell, directly across the voice coil circuit and noting whether each cone jumps outward or inward as the circuit is closed. Individual voice coil connections can then be reversed until all cones jump in unison as the d-c voltage is applied. If the cones are out of phase, the sound waves produced by one will tend to cancel those produced by another especially if the speakers are mounted on a common baffle.

BAFFLES

The performance of a loudspeaker is greatly dependent upon the characteristics of the air masses which must be formed into alternate compressions and rarefactions to produce sound waves. The cone is affected not only by the air it must push during its forward movement, but also by the air masses behind it. Naturally, the sound waves produced at the back of the cone are 180° out of phase with those generated at the front, and will tend to cancel when the wavelength of the reproduced tone is equal to the length of the acoustical path from the back to the front. For the higher frequencies, with speakers having larger cones, the path length around the cone itself is greater than the length of the sound waves, and this cancellation does not occur; but at the lower frequencies, where the acoustic path is short compared to the sound wavelengths, this action is of great importance.

Generally the cancellation of low frequencies is prevented by the use of some type of baffle which can be defined as a parti-. tion or panel in which the speaker is mounted, and that serves to increase the length of the acoustic path between the front and back of the cone. Going back to Figure 10, the panels on which the speakers are mounted are good examples of simple baffles.

Just as the special structures of Figure 9 result in extensions of high frequency speaker response, the purpose of a baffle is to improve the low frequency response. To illustrate this action, the curves of Figure 12 show the effect on the low-frequency response of a direct radiator speaker with a 10 inch diameter cone when baffles of various dimensions are employed. Note that as the size of the baffle is increased, an extension of the response into the low frequency region is obtained.

Radial Reflex Speaker consisting of reflex air column horns with radial deflectors, designed with a dispersion angle of 360° for uniform sound distribution over wide areas.

Courtesy University Loudspeakers, Inc.

From this the conclusion may be drawn that, as far as the elimination of low frequency cancellation effects is concerned, the ideal mounting for a direct radiator loudspeaker is an infinite baffle. Practically, this can be achieved by mounting the speaker in a very large partition, such as a wall of a room, as shown in Figure 13-A. However, the impedance match between a direct radiator loudspeaker and the air is very poor, the condition of maximum efficiency being obtained when the ratio of the mass of the voice coil to the sum of the masses of the cone and the air load is equal to unity. Because the air offers such a low impedance, termed "radiation impedance", the speaker efficiency is necessarily low, and in general, anything that can be done to increase the radiation impedance will, of course, improve the efficiency.

For example, a speaker mounted near a corner of the room, as in Figure 13-B, will radiate about twice as much low-frequency energy as one located in the middle of a wall. This is because the adjacent wall, "n", restricts the movement of the air so that the radiation impedance in that direction is increased. This is due to the fact that at a given frequency, any particular point on wall n which is less than a quarter wavelength from the speaker, will cause a compression to build up and be reflected back to the speaker cone before the latter has completed the compression part of its cycle. This results in an impedance, greater than that of free air, being presented to the cone. The lower the frequency, the longer the wavelength; and the greater the likelihood that the distance from speaker cone to wall n will be less than a quarter wavelength. This is the reason the effect is most pronounced in the low frequency region.

The maximum increase in radiation impedance and low-frequency response, is obtained when the speaker is located at the junction of two walls and the floor (or ceiling), as shown in Figure 13-C. With this arrangement, a loudspeaker will radiate about 3 or 4 times as much low-frequency energy as one located as in Figure 13-A. In a practical case where the installation of Figure 13-C is difficult or impossible to achieve, a noticeable improvement in low-frequency radiation may be obtained by simply moving a standard console radio cabinet to a diagonal position across the corner of a room.

LOUDSPEAKER CABINETS

The conventional open-back cabinet which houses the radio chassis or phonograph mechanism is commonly employed as a housing for the loudspeaker also.

These cabinets, ranging in size from the smallest midget to the largest console type, all function as a baffle for the loudspeaker, as far as sound reproduction is concerned. In the case of the large console cabinets, good reproduction of low frequencies is obtained because of the sufficiently long acoustic path from the front to the back. However, this path length is short in the case of the midget type radio cabinets, and the low frequency sounds are not produced.

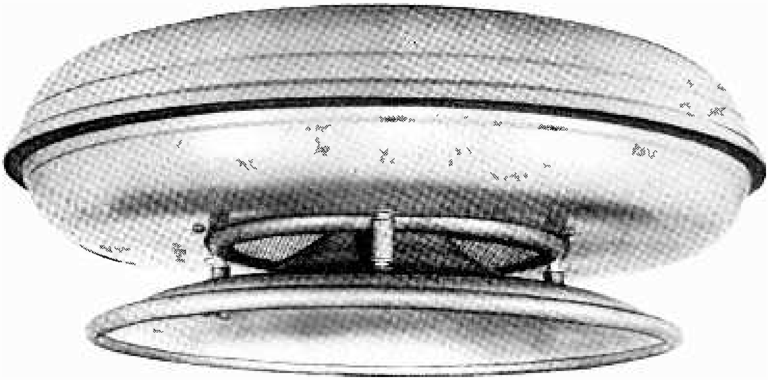
Three disadvantages possessed by both flat baffles and openback cabinets are: (1) large size required for adequate low-frequency response, (2) very poor low-frequency response at large angles from the speaker axis, and (3) limited opportunity for modification of response characteristics. Besides these, the open-back cabinet produces an undesired emphasis of the frequencies in the band from about 150 to 250 cycles due to the resonance in the enclosure back of the cone.

An arrangement that eliminates cancellation of low frequencies due to interaction of front and back radiation is shown in the completely enclosed speaker cabinet of Figure 14. The stiffness due to the compression of the air in the closed box acts as though the compliance of the speaker suspension system itself were decreased. The natural frequency of the speaker will depend upon the compliance of the enclosed volume of air and will, therefore, vary with cabinet size. If sufficient absorption is provided, together with a large enough cabinet, the resonant frequency may be located fairly low in the audio range where it becomes a desirable characteristic, thus eliminating the trouble due to cabinet resonance mentioned above for the open-back types. This type of totally enclosed cabinet is sometimes called an "infinite baffle"; however, this classification is inaccurate, for the behavior of the system is quite different from the arrangements of Figure 13.

A still more elaborate acoustic loading arrangement consists of the labyrinth type cabinet, shown in Figure 15. This amounts to an absorbent walled conduit which is made at a length equal to a half-wave at some desired low frequency. Due to the transmission time delay of the back wave through the labyrinth, at this frequency the wave emerging from the "mouth" of the cabinet will be exactly in phase with that at the front of the cone, and the two will reinforce each other, thus increasing the response of the system. The phase relationship and sound reinforcement, are about the same for a range of frequencies above and below that chosen for the cabinet design, and therefore the system produces a general increase of response in the low frequency region. The lining is made of material the absorption of which increases with frequency, and for this reason there is very little labyrinth transmission of frequencies higher than about 150 cycles.

An arrangement which is especially effective in increasing low frequency response is the acoustical phase inverter type cabinet shown in Figure 16-A. Popularly termed a "bass reflex" speaker, this system employs a cabinet which is completely enclosed save for a small port, called the "reflex opening", which couples the cabinet volume to the outside air. A relatively small amount of sound aborbing material is used, the object being to have as little absorption as possible at the low frequencies, while eliminating radiation of the high frequencies from the port opening.

The dimensions of the cabinet, the area of the port and its distance from the speaker are proportioned so that, at low frequencies, the phase of the back wave from the cone is shifted 180° and emerges from the port in phase with the front wave from the cone. Thus the low frequency output of the speaker is reinforced for increased output with low distortion. As there is no time delay in producing the required phase shift, to achieve comparable results, the bass-reflex cabinet need not be as large as the solid enclosure or labyrinth types.



Radial Cone Speaker Reflector consisting of an acoustic chamber for housing a cone speaker and a radial deflector for uniform 360° dispersion.
Courtesy University Loudspeakers, Inc.

To make a more direct comparison, the curves of Figure 17 show the frequency response of a 10 inch speaker when, at A it is mounted in an open back cabinet, at B in a solid enclosure, and at C in a bass-reflex cabinet. As shown above the curves, the overall dimensions are the same for all.

HORN-TYPE LOUDSPEAKERS

Since high-power audio-frequency amplifiers are quite costly, when large scale reproduction of sound is to be obtained, it is generally desirable to reduce the amplifier output requirements to a minimum by the use of high efficiency loudspeakers. As has been explained, the direct radiator type loudspeaker, used in a baffle or cabinet, is a relatively low efficiency device due to the poor impedance match which exists between the speaker cone and the air.

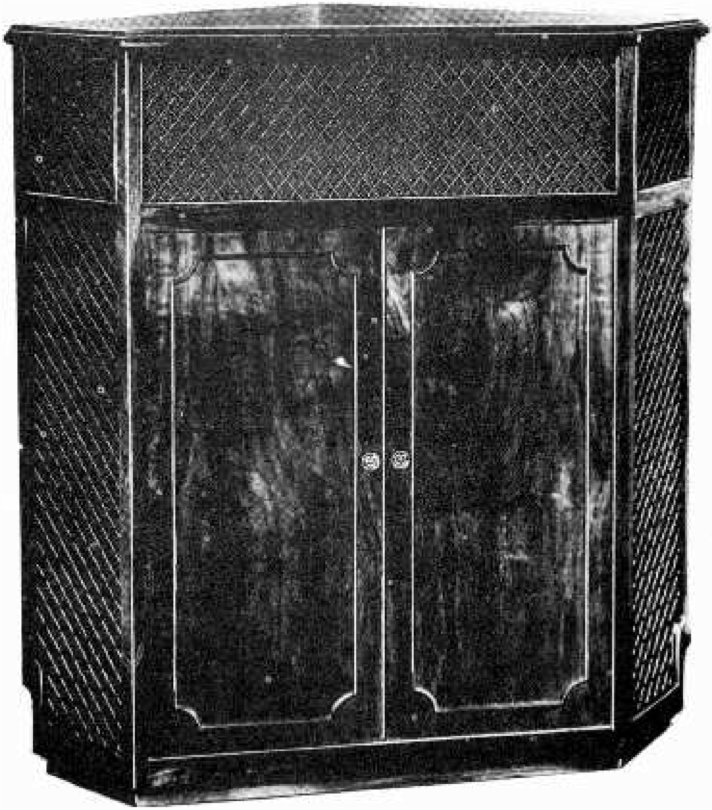
It has been mentioned that in any system, the maximum transfer of energy takes place when the impedance of the source is equal to that of the load. However, in the case where these impedances include reactive components, the reactance of the load must be equal to and of opposite sign compared to that of the source, while their respective resistive components are equal. This condition is indicated in simplified form in Figure 18 where, the effective circuit consists of two resistors in series, the net reactance being equal to zero.

With a direct radiator loudspeaker, this ideal condition is approached only at the speaker resonant frequency; while at all other frequencies the reactance of the speaker mechanism is much higher than that of the air load, resulting in considerable impedance mismatch between this load and the generator (speaker). The basic difficulty lies in the fact that the air is a poor tenuous transmitter of mechanical energy, and at low frequencies the largest practical loudspeaker cone simply is not capable of efficient generation into a large loose mass of air. Consider, for example, the difference between the area of a 15 inch speaker cone and that of a bass viol, or the sounding board of a piano.

Much better efficiency could be obtained if the area of the speaker cone could be increased without increasing its mass. This cannot be done with cone type loudspeakers, because as the area of the cone is increased, the mass also must be increased to maintain adequate rigidity. However, by using a horn structure along with a cone or diaphragm, the high impedance of the cone can be matched efficiently to the low impedance of the air load by virtue of the gradually increasing cross section area of the air column in the horn. Thus, the horn may be thought of as an acoustical output transformer which transforms acoustic energy at high pressure and low velocity to energy at low pressure and high velocity. The air in the mouth of the horn becomes a virtual diaphragm having the desired radiation characteristics of large area with minimum mass.

The complete unit, known as a horn loudspeaker, consists of a diaphragm driving mechanism coupled to a horn of some type. The driving mechanism may be a cone type speaker or may be a unit designed specifically for use with a horn and built on the general plan of the cross section views in Figure 19.

Figure 19-A shows a unit employing an electromagnet for its field, a permanent magnet is used



Corner console model Klipsch Speaker System.
Courtesy Brociner Electronics Laboratory

for this purpose in the mechanism of Figure 19-B while each has a metal diaphragm to which its voice coil is attached. Note that the diaphragms of these units are much smaller in diameter than the corresponding cones of the direct radiator type speakers. In general, it is customary to design horn driving mechanisms to have higher flux density in the air gap than in cone type speakers. To avoid cancellation and falling off of certain high frequencies, it is necessary that the distances from various points on the diaphragm to the throat do not vary by more than half a wavelength. To equalize these distances, annular plugs are employed as shown in Figure 19.

There are a number of variations of horn structures, three of the most common being shown in Figure 20. The simple trumpet or projector type of Figure 20-A, has a straight axis with the cross section area expanding according to a definite formula. In the folded or re-entrant type of horn, the axis along which the area expands is no longer a simple straight line. As shown in Figure 20-B, the area expands as a simple horn for a short distance and then becomes an annular area expanding back along the exterior of the first simple horn section.

Finally, the folding is repeated, with the last section expanding along the exterior of the second section. With various models, this type of folding may be carried even further. The advantage of this arrangement is that the length of the air column is increased without increasing the overall length of the unit.

As explained for Figure 8, the directional properties of loudspeakers become more pronounced with increases of frequency and this action is even more true for horn speakers than for direct radiator types. Therefore, to obtain satisfactory distribution patterns at high frequencies, many horns are constructed on the general plan shown in Figure 20-C. This type is known as a multi-cell horn, the total area being broken up into a number of sub-areas, each expanding individually. These individual cells may be formed by inserting partitions in a trumpet type horn, or they may be completely separate sub-horns assembled in an array. In fact, as far as high frequencies are concerned, the proper sound distribution is the most important function of the horn; whereas for low frequencies, its most important function is that of increased efficiency of energy transfer.

The design of a horn is a complicated mathematical engineering procedure, the type of response obtained depending upon the chosen shape formulas which include as factors: the diameter which the mouth of the horn is to have; the diameter of the throat; and the rate of expansion.

The lowest frequency to be reproduced, called the "cut-off frequency", fixes the minimum diameter which the mouth or bell may have. In practical cases, the bell diameter must be not less than two-thirds the wavelength of the cut-off frequency. An equivalent statement is that the product of this lowest frequency and the mouth diameter (in inches) should be not less than 4000. For example, if a horn has a bell diameter of 20-inches, the lowest frequency it will reproduce properly will be 4000 ÷ 20 = 200 cycles per second.

The area of the throat determines the air load placed upon the cone structure, or driver mechanism, as the case may be. When the area of the throat is smaller than the diameter of the diaphragm, the compression of air caused by the movement of the diaphragm is increased, with a resulting increase in speaker efficiency because of the heavier acoustic loading.

However, if the area of the throat is too small, excessive horn lengths are required, and the increased frictional losses introduce distortion due to excessive throat pressures.

Therefore, in practice the throat size is a compromise between the various factors mentioned, and most commercial driver units for use with a horn, have the proper size opening in the cover over the diaphragm, as shown in Figure 19.

The rate of expansion, or the taper, of the horn determines the nature of the mechanical resistance of the air in the throat, at frequencies just above the cut-off value. At high frequencies, several times cut-off and higher, this mechanical resistance remains constant. In an ideal speaker, the throat air resistance would be constant down to zero cycles per second; however, in the case of every known type of horn, this resistance has a very low value at the cut-off frequency f_1, then rises gradually and reaches its ultimate or high-frequency value at a frequency f_2 equal to several times f_1.

To approach the ideal condition, it is, therefore, desirable that the rate of expansion of the horn be such that the value of f_2 be as near to that of f_1 as possible. Many years ago, after investigating many horn shapes, Webster reported that most of them fell into three groups, one of which was the type now known as the exponential horn. In this type of horn the cross section area doubles for equal increases in length. Webster's evaluation of the throat impedance showed that the exponential horn has a throat resistance—frequency characteristic which, above the cut-off frequency, f_1, rises to its ultimate value, f_2, more rapidly than any other horn then known.

Thus, the exponential horn taper was considered the most desirable and has been the most popular type used for many years.

However, relatively recent investigations by the Jensen Radio Mfg. Co. have resulted in the development of a family of horns in which the throat air resistance can be made to rise much more rapidly, from its value at the cut-off frequency, than in the exponential type. These horns have been given the name "Hypex", and depending upon the value of a certain factor in their taper formula, the throat resistance may be made to rise very quickly to any given amount above the ultimate value to which it then falls. If desired, certain horns may therefore be designed to produce even more acoustic output in the low frequency region, just above cut-off, than over the remainder of their frequency range. As with other types, Hypex horns may be made in any form, such as straight, coiled, folded or reentrant, or multicell, and may have any cross section shape such as circular, square, or rectangular.

The high-frequency response limit of a horn is set by the mass of the driver mechanism and diaphragm structure. Also, it can be seen that the air column length which any particular horn must have is fixed jointly by the bell and throat diameters and the taper employed.

Figure 21 illustrates a type of "directional baffle" which is often used with a direct radiator type loudspeaker. This type of baffle concentrates the sound into a smaller angle, and thus increases the efficiency of the system in one area. The directional baffle, strictly speaking, is not a horn, the chief difference being the fact that the diameter of the throat is equal to or slightly less than that of the cone. Below the cut-off frequency of the baffle, the loudspeaker merely radiates in the same way as it would on a flat baffle of the same area as the "horn" surface. Thus, although small "flares", used as in Figure 21, may enhance the speech-frequency range, they add nothing to low-frequency response of the system.

COMBINATION LOUDSPEAKERS

To combine high efficiency, wide range response, and good high-frequency distribution, many large installations consist of a combination of units such as shown in Figure 22. This system employs a folded-horn low-frequency unit for reproduction from 40 to 300 cycles. The low-frequency horn is driven by a large diameter cone type speaker mechanism, and its area expands along two channels, each folded upon itself to save space, as in the arrangement of Figure 20-B. The high-frequency unit consists of a cluster of relatively small horns, like that of Figure 20-C, all coupled to a common throat and driven by a mechanism like those shown in Figures 19-A and 19-B. This multicellular horn is used in this case for frequencies from 300 to 8000 cycles. The frequency dividing the ranges of the two units, 300 cps in this case, is called the "cross-over frequency".

A combination horn and direct radiator loudspeaker is shown in Figure 23, with a side view at A and a top view at B. At low frequencies, the compliance of the air inside the horn is large compared to the mechanical impedance at the throat of the horn and thus the cone is coupled directly to the horn. However, above approximately 150 cycles, the output from the horn drops off, the major portion of the radiation issues from the front of the cone, and the system behaves as a direct radiator loudspeaker.

The use of the horn coupling makes it possible to obtain larger power output from a small diameter cone and the arrangement provides a good high-frequency response, due to the small cone speaker, combined with high efficiency and smooth response at low frequencies. When a direct radiator loudspeaker having a double voice coil like that of Figure 9-C is used, it is possible to obtain reproduction which is essentially flat from about 30 to 12,000 cycles.

As is illustrated in Figure 24, another horn and direct radiator combination consists of a unit employing a large cone for the reproduction of the low-frequency range, and a small horn loudspeaker for the high-frequency range. As shown, the "h-f unit" consists of a separate metal-diaphragm driving unit which is coupled directly to the hollow interior of the low-frequency unit pole piece that actually constitutes the small portion of the h-f speaker horn. A small, cellular section coupled to the small portion in the pole, completes the horn. By this co-axial assembly arrangement a saving of space is obtained without significant sacrifice of frequency range, and systems of this type have achieved much popularity. Of course, the entire assembly shown in the figure will normally be mounted in a baffle or cabinet.

LOUDSPEAKER DESIGN TRENDS

An improvement on the folded, or re-entrant, horns is the new two-way speaker developed by Klipsch, and illustrated in Figure 25. As shown in Figure 25-A, the front of this unit is a solid piece of wood, but the complete assembly occupies only 15 cubic feet of space, as compared to 60 or several hundred cubic feet for systems like that of Figures 22 or 23 when used in large theatre installations, etc.

The sound from the low-frequency unit, which extends down to 30 cps, is emitted from two vertical slots that run the full length of the cabinet. These slots are located one in each side at the rear of the cabinet, and as can be seen in the horizontal section view at Figure 25-B, are so designed that the walls of the room function as extensions of the horn. The enclosure houses a 15-inch cone type driver, and measurements have shown that this arrangement permits a low-frequency efficiency of 30% as compared with 2% when the same high quality speaker is mounted on a flat baffle. A wide-angle tweeter, mounted on the cabinet top, supplies the high frequencies.

IMPORTANT WORDS USED IN THIS LESSON

ACOUSTICS—The science that deals with the production, transmission, and utilization of sound.

AIR-GAP—The small space between the pole pieces of a speaker magnet and within which the voice coil moves in and out.

ALNICO—A highly magnetic alloy consisting chiefly of aluminum, nickel, and cobalt.

BACK WAVE—The sound wave liberated from the rear surface of a speaker cone.

BAFFLE—A flat panel or cabinet used with a loudspeaker to increase the length of the air path from the front to the rear of the speaker diaphragm or cone.

BASS RESPONSE—The ability of a speaker or reproducing device to generate low-frequency notes.

CABINET RESONANCE—A condition within the cabinet of a radio receiver or musical instrument, at which the sound waves of certain frequencies vibrate back and forth with greatest intensity. This over-emphasizes the sounds or tones at those frequencies, similar to resonance in an electrically tuned circuit.

COMPLIANCE—The readiness or ease with which a substance or an object responds to a displacing or distorting force. It is a result of elasticity, and is the opposite of stiffness. In an electric circuit it corresponds to capacitance.

CONCENTRICALLY—A term applied to a number of circular objects all of which have a common center.

DIAPHRAGM—A thin flexible sheet or elastic membrane used as the conversion unit between sound energy and electrical energy.

DIRECTIONAL PATTERN—A graphic representation of the relative amounts of sound projected by a speaker at various angles from the axis of the cone or horn.

DIRECTIVITY—The characteristic of a cone speaker that causes it to project maximum sound volume in the direction of the cone axis.

DIRECT RADIATOR SPEAKER—A type of speaker or reproducer in which the vibrating diaphragm imparts the sound energy directly to the air in the room or space in which the sounds are to be heard. Cone speakers are of the direct radiator type.

DYNAMIC SPEAKER—A type of loudspeaker in which the coil carrying the audio signal current is attached to the moving cone or diaphragm.

FIELD COIL—As used here, it refers to the winding on the center core of the magnet in an electrodynamic speaker. The d-c current that sets up the magnetic flux in the air gap is carried by this coil.

FRONTAL WAVE—The sound wave emitted in a forward direction from the front surface of the cone in a speaker.

HORN-TYPE SPEAKER—A type of speaker in which the column of air in a horn of increasing cross-sectional area couples the vibrating diaphragm to the volume of air through which the sound energy is to be distributed.

HUM-BUCKING COIL—A small coil mounted on the field of an electrodynamic speaker, but connected in series with the voice coil so that its induced voltage neutralizes or "bucks out" any hum that may be induced in the voice coil by variations of field current.

MECHANICAL IMPEDANCE—The combined effect of the reactance and resistance in a mechanical system, corresponding to impedance in an electric circuit.

MECHANICAL REACTANCE—The ability of an object or material to absorb and store up energy when subjected to a displacement force, and then to liberate this energy when the displacing force is removed. Mechanical reactance is a result of compliance, just as capacitive reactance is a result of capacitance.

MECHANICAL RESISTANCE—The ability of an object to radiate or dissipate energy. For example, the energy which the cone of a speaker converts into sound and dissipates into space can be considered its mechanical resistance or loading effect. It corresponds to the dissipation of electric energy in a resistor in an electric circuit.

MULTICELLULAR HORN—A type of speaker horn into which a number of separate tubes have been built in order to bring about a wider distribution of the emitted sound waves.

P-M SPEAKER—A dynamic speaker in which a strong permanent magnet is employed to provide the magnetic field.

POLARIZING VOLTAGE—A steady voltage applied to an electromagnetic circuit so that the latter will always be of the same polarity.

SHIM—A thin piece of paper, celluloid or metal used to center the armature or voice coil in a loudspeaker.

SOUNDING BOARD—A flat surface used with some musical instruments to increase the volume of air set into vibration.

SPEAKER ARMATURE—The small iron bar that vibrates between the magnetic poles of a speaker and sets the cone or diaphragm into motion.

SPEAKER EFFICIENCY—The ratio (expressed in per cent) of the sound power output to the electric signal power input.

SPIDER—A flexible punched washer, usually made of fiber and used to center the voice coil in the circular magnetic gap, without seriously interfering with its axial movements.

STANDING WAVE—The condition within a radio cabinet when the emitted sound wave and the wave reflected from the rear wall of the cabinet combine with each other to form a stationary or zero-motion wave.

TWEETER—A speaker designed to reproduce only the higher frequencies, from several hundred cycles to 15,000 cycles.

VOICE COIL—The small coil that is attached to the diaphragm or cone of a dynamic speaker and that moves axially in the gap between the pole pieces, in accordance with the signal currents that it carries.

WOOFER—A loudspeaker designed to reproduce low audio frequencies at high power levels.

STUDENT NOTES

STUDENT NOTES

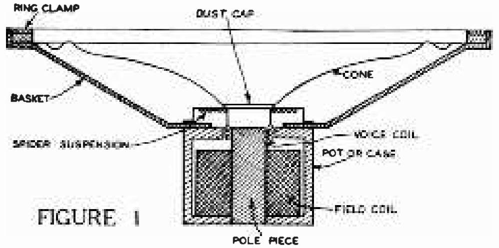


FIGURE 1

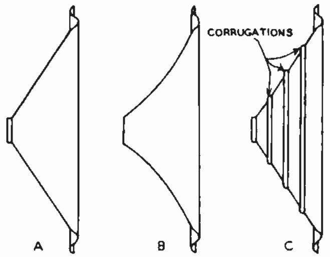


FIGURE 2

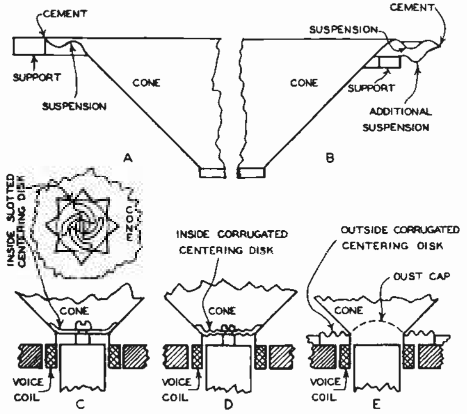


FIGURE 3

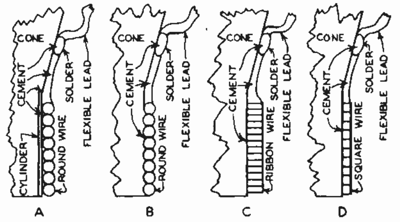


FIGURE 4

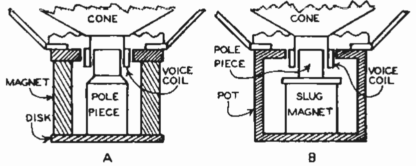


FIGURE 5

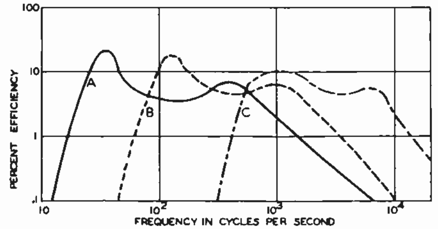


FIGURE 6

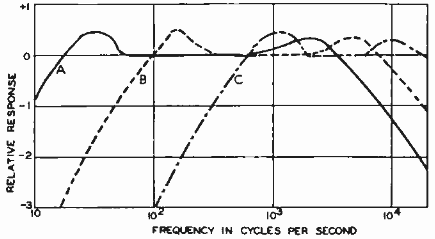


FIGURE 7

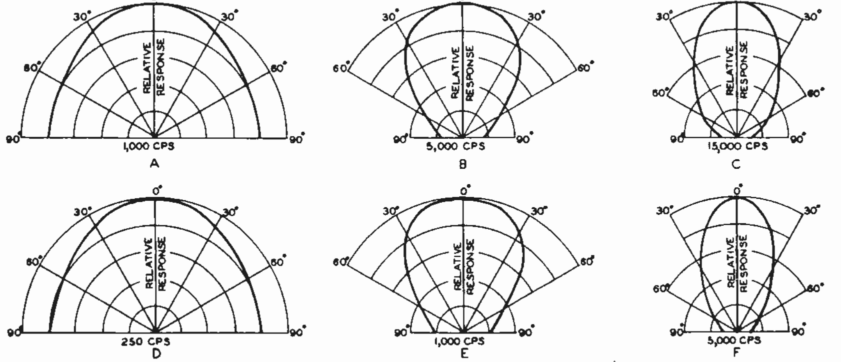


FIGURE 8

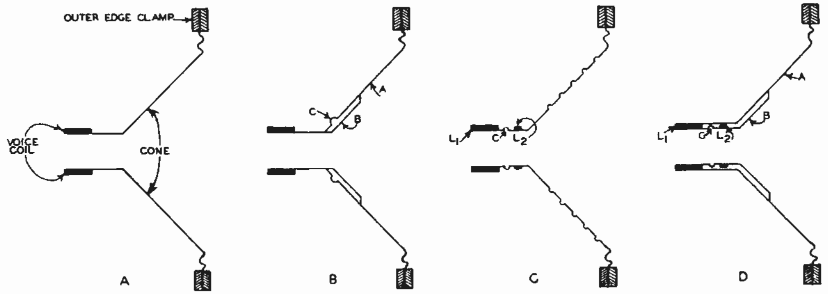


FIGURE 9

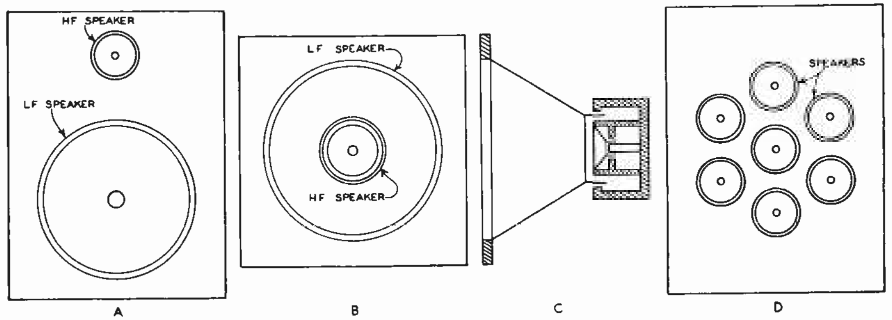


FIGURE 10

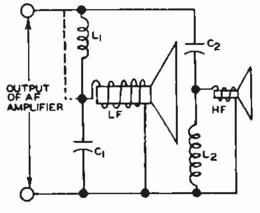


FIGURE 11

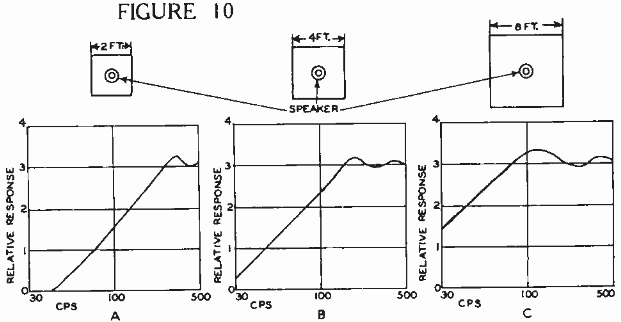


FIGURE 12

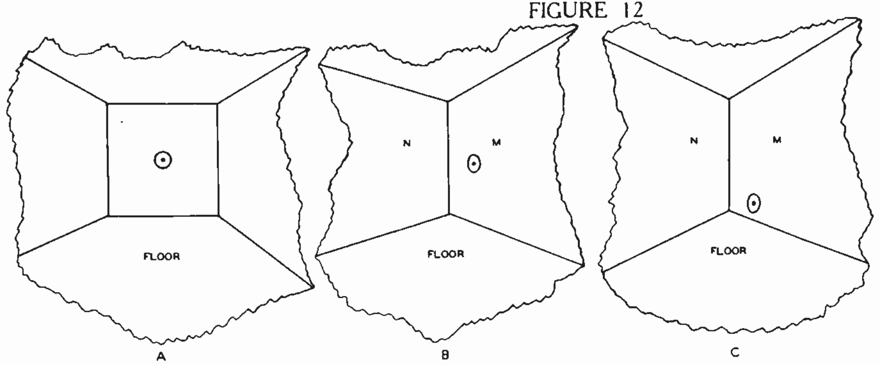
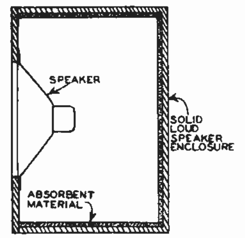


FIGURE 13



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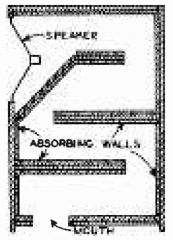

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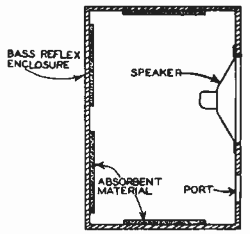


FIGURE 16

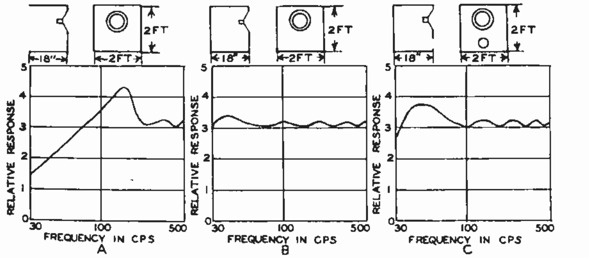
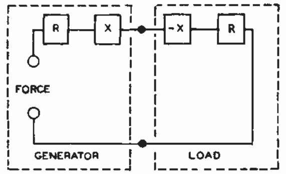


FIGURE 17



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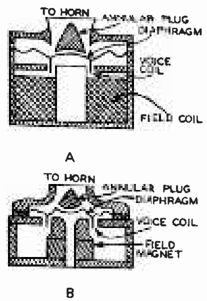


FIGURE 19

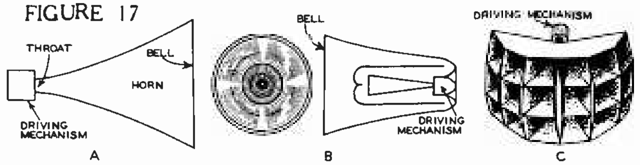


FIGURE 20

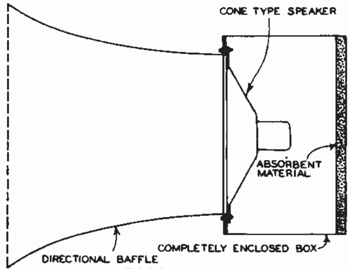


FIGURE 21

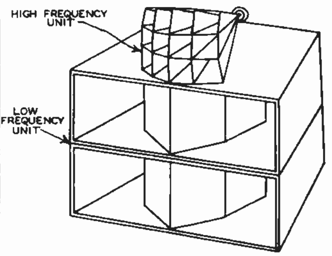
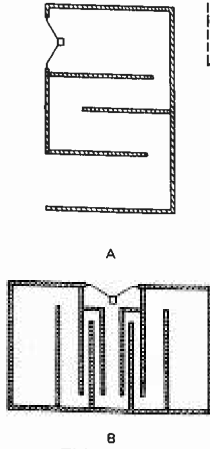


FIGURE 22



RRT-2 FIGURE 23

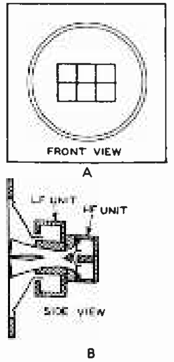


FIGURE 24

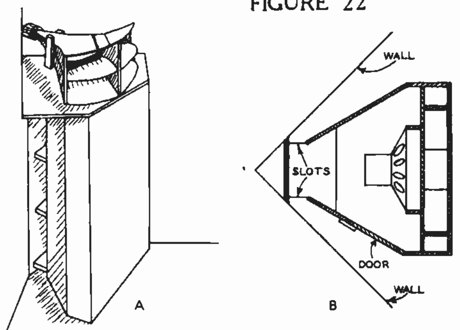


FIGURE 25

FROM OUR *President's* NOTEBOOK

LUCK

Our luck is to a great extent a matter of our own choosing. If we get satisfaction out of believing we were born under an unlucky star, then we naturally consider ourselves unlucky. If we get more satisfaction, however, out of meeting our problems and trying to work them out, other people will probably call us lucky. Luck is, therefore, largely a state of mind. The man who faces his problems and does something about them, is usually the one who forges ahead. Use his methods, and you will see how fast your bad breaks turn into good chances for personal achievement.

Yours for success,

E.B. DeVry

PRESIDENT

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