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COLUMN LOUDSPEAKERS

by F. Langford-Smith

Column loudspeakers have been briefly described in the Radiotron Designer's Handbook, under the name "line source loudspeakers" (Ref. 1). A column loudspeaker consists of a number of loudspeakers mounted close together in a straight line. A column loudspeaker gives greater directionality in the vertical plane than in the horizontal plane. If the individual speakers in the column are tapered in strength so that the sound from each speaker varies linearly from a maximum at the centre to zero at either end, the directionality is improved. Better results may be achieved, as in St. Paul's Cathedral, London, by the use of two columns, a long one for the low frequencies and a shorter one (one-quarter the height of the long one) for the high frequencies with a crossover network giving a crossover frequency of 1000 c/s (Ref. 2). Best directional effects are achieved when small loudspeakers are used (say 5 to 8 inch) when they are mounted as closely together as possible.

The speakers are totally enclosed by the column, and it is necessary for the inside of the enclosure to be heavily damped to eliminate box resonance; in some cases this result is partly achieved by electrical tone compensation to reduce the response at the resonant frequency. The purpose of this is largely to reduce the likelihood of acoustical feedback at this frequency, and also for better tonal qualities. The cross section of the column is often made rectangular, but any irregular shape can be used even more effectively. With the rectangular form the best position for the damping material is somewhere in the middle. Underfelt up to 1 inch thick (uncompressed) may be used as a damping material, although there are other possible materials.

The design of a single "tapered" column by L. L. Beranek has recently been published (Ref. 3). The details are given in Fig. 1 while the measured directionality in both vertical and horizontal planes are shown in the form of curves in Beranek's article. These curves have been used to derive the information tabulated below, in terms of the response at specified angles from the axis, to the response on the axis:

Vertical plane:

	500 c/s	1000 c/s	2500 c/s	6000 c/s
15°	—4	—10	—15	—8db
30°	—10	—17	—18	—12
45°	—18	—23	—20	—17
90°	—29	—28	—31	—30

Horizontal plane:

	500 c/s	1000 c/s	2500 c/s	6000 c/s
15°	0	0	0	—5
30°	—5	—7.5	—7	—14
55°	—8	—8	—8	—19
90°	—8	—11	—17	—23

Difference between vertical and horizontal planes:

	500 c/s	1000 c/s	2500 c/s	6000 c/s
15°	—4	—10	—15	—3
30°	—5	—9.5	—11	+2
45-55°	—10	—15	—12	+2
90°	—21	—17	—14	—7

The difference between the vertical and horizontal planes is from 10 to 15db over a frequency range from below 1000 to about 3000 c/s, over almost any angle up to 90°. This result is well worth while for difficult applications where it will minimize reflections from the ceiling, while there is the added feature of concentrating the sound in a beam in the direction where it is most needed and thus increasing the effective efficiency. In most large halls the

References.

1. Radiotron Designer's Handbook. 4th ed. (other than first impression) pp. 866-867.
2. Parkin, P. H., & J. H. Taylor, "Speech Reinforcement in St. Paul's Cathedral", W.W. 58.2 (Feb., 1952) 54; 58.3 (March, 1952) 109.
3. Beranek, L. L., "Sound systems for large auditoriums", Jour. Acoustical Society of America, 26.5 (Sept., 1954), 661.

column would be inclined so that the axis of the middle loudspeaker is pointing to the seats about three-quarters towards the back of the hall. If echoes are not troublesome, better uniformity of the sound will be achieved by directing it to the back row of seats.

A cheaper form.

If it is not necessary to obtain the full directional effects of a properly designed column, quite useful improvements may be obtained by the simplest forms of column loudspeakers, both in halls and in the open air. The minimum useful length is about 4 feet, and the minimum useful number of loudspeakers is 4. In such cases the speakers should be spread uniformly over the height of the column and no "tapering" in volume is necessary, so that all speakers may be connected in parallel.

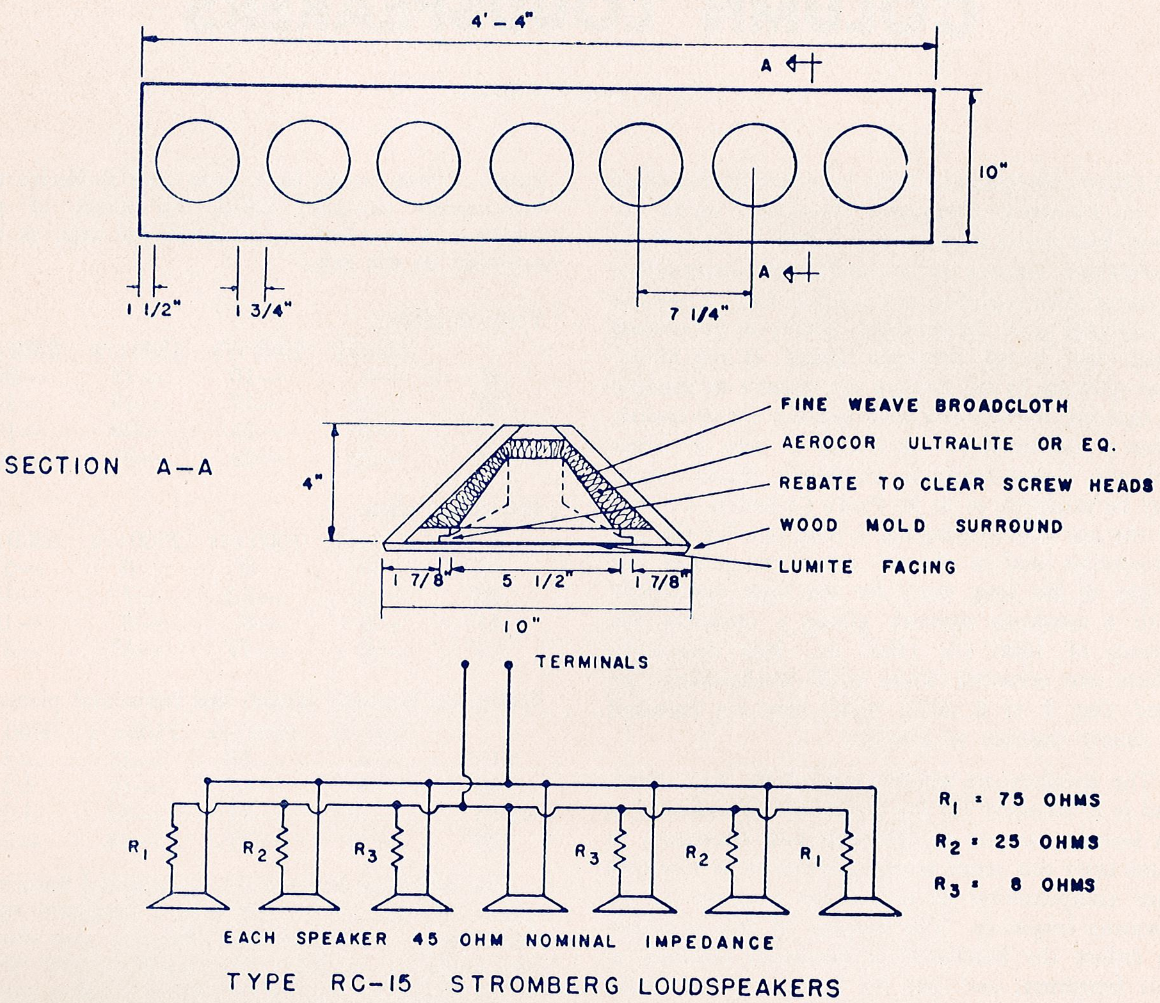


Fig. 1. Constructional details and circuit diagram for loudspeaker "column" using seven 5 in., 45 ohm Stromberg loudspeakers, after Beranek. Reproduced by permission from Journal of Acoustical Society of America. (RT53.)

ANALYSIS OF TWO GENERATORS FEEDING A LOAD

by F. Langford-Smith

In a previous article (Ref. 1) reference was made to some of the effects of two generators feeding a load, in that case the generators being the plate and screen of a pentode working with the "Ultra Linear" connection of the screen.

The following treatment is quite general, treating the effects of two generators feeding a resistive network. In Fig. 1 there are two constant voltage generators E_1 and E_2, each in series with a resistance

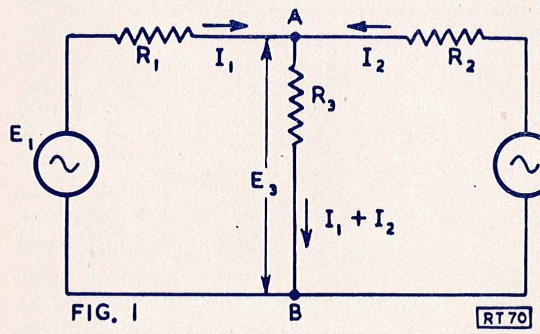


Fig. 1. Network fed by two generators (RT70).

(R_1 and R_2 respectively), feeding a load resistance R_3. The case treated here is when both generators are supplying power in the positive direction; it does not cover the case where one generator is being driven "backwards" by the other.

Power generated by $E_1 = E_1I_1$

Power generated by $E_2 = E_2I_2$

Total power generated $= E_1I_1 + E_2I_2$

Power loss in $R_1 = I_1R_1$

Power loss in $R_2 = I_2R_2$

Power dissipated in $R_3 = E_3\,(I_1 + I_2)$

Power in R_3 contributed by $E_1 = E_3I_1$

Power in R_3 contributed by $E_2 = E_3I_2$

Let the power in R_3 contributed by E_2 be represented in the alternative form $I_2{}^2R$, where R is the load resistance into which E_2 works.

Then $I_2{}^2R = E_3I_2$

$R = E_3/I_2$

$$R = \frac{E_3}{I_1 + I_2} \times \frac{I_1 + I_2}{I_2}$$

finally $$R = R_3\,\frac{I_1 + I_2}{I_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

Eqn. (1) shows that the load into which E_2 works is not R_3, as might be expected, but a resistance greater than R_3. Taking a numerical case for illustration, $E_1 = 120$ volts, $E_2 = 110$ volts, $R_1 = 250$ ohms, $R_2 = 500$ ohms, $R_3 = 1000$ ohms. It is shown in the Appendix that $I_1 =$ 80 mA, $I_2 = 20$ mA and $I_1 + I_2 = 100$ mA.

Applying equation (1), the load resistance into which E_2 works is given by

$$R = 1000\ (100/20) = 5000 \text{ ohms.}$$

Thus in this case, with E_2 contributing one-fifth of the total current, the load resistance into which E_2 works is 5 times R_3.

Appendix

In. Fig. 1, let $E_1 = 120$ volts, $E_2 = 110$ volts, $R_1 = 250$ ohms, $R_2 = 500$ ohms, $R_3 = 1000$ ohms.

$E_1 = I_1R_1 + (I_1 + I_2)\ R_3 \quad \ldots\ldots\ldots\ldots \quad (2)$

$E_2 = I_2R_2 + (I_1 + I_2)\ R_3 \quad \ldots\ldots\ldots\ldots \quad (3)$

$E_1 - E_2 = 120 - 110 = 10 \text{ volts} = I_1R_1 - I_2R_2$

$I_1R_1 = 10 + I_2R_2$

$I_1 = (10/250) + I_2\ (500/250)$

$I_1 = 0.04 + 2I_2$

$I_1 + I_2 = 0.04 + 3I_2 \quad \ldots\ldots\ldots\ldots \quad (4)$

Applying (4) in (3):

$110 = 500\ I_2 + (0.04 + 3I_2)\ 1000$

$110 = 3500\ I_2 + 40$

$I_2 = 70/3500 = 20$ mA.

$I_1 = 0.04 + 2 \times 20/1000 = 80$ mA.

$I_1 + I_2 = 100$ mA.

References

1. F. Langford-Smith and A. R. Chesterman, "Ultra Linear Amplifiers"—Part 3, Section 2, Screen Power Output, Radiotronics 20.7 (July, 1955), 78.

LOUDSPEAKER ENCLOSURES

We have pleasure in reprinting, through the courtesy of the Altec Lansing Corporation, the following article on loudspeaker enclosures. This includes some very useful information which has not been published in any other periodical and is not generally accesible to our readers.

The design of the Model 606A cabinet has a number of excellent features, particularly the break-away from the conventional rectangular construction with its strong standing waves.

A close equivalent to "Fiberglass" is found in the Australian-made "Koldboard" manufactured from "Fibertex" and available from Bradford Insulation Pty. Ltd., 66 Reservoir Street, Sydney. Koldboard is supplied in sheets 36 x 12 x 2 inches thick and weighs 9 to 10 lbs./cu. ft.

Where it is not necessary to have a self-supporting wedge, "B.I. Fibertex" (spun slagwool fiber) may be used to give greater acoustical absorption at less cost. The normal thickness is 3 or 2 inches, but it can be cut to 1 inch, sheets being either 23 x 17 or 36 x 12 inches. This weighs about 3 lbs. per cubic foot.

—F. Langford-Smith.

In the construction of a speaker enclosure Altec Lansing recommends that the user confine himself to the bass reflex type enclosure. The many reasons for this recommendation are thoroughly covered in Mr. Badmaieff's article.

It is possible to construct satisfactory enclosures of types other than the bass reflex, however the possibilities of obtaining excellent results from these other types are not good. The frequency response curves made in Altec's acoustic laboratory on many types of commercial enclosures on the market clearly illustrate the difficulties often found in types other than bass reflex. Undoubtedly the lack of acoustical laboratory facilities to provide accurate measurements is the major contributor to the number of poor commercial enclosures now on the market.

Speaker enclosures serve the twofold purpose of providing a good appearance and producing a good bass response. Unfortunately, in an effort to achieve good bass response, many designers overlook the troubles that may be created by the enclosure in the mid-frequencies. These mid-frequencies are much more important than extreme low frequency response. Altec Lansing maintains that no cabinet should be constructed where good bass response is attained at the cost of good-mid-frequency response.

In the design of your custom system and enclosure, the phase relationship between sound sources is of major importance. Proper phase relations are difficult to establish in a two-way (woofer and tweeter) speaker system and the problem is practically impossible with three or four-way systems. Improper phase relationship can result in sound cancellation between speakers with resulting irregularities in frequency response. For this reason two-way systems that, like all Altec Lansing two-way systems, cover the entire audible frequency range are to be preferred over any system having a greater number of limited rang speakers.

Excellent results may be obtained by constructing the Altec 606 cabinet shown or by carefully following the article for size, shape, calculation of port size, construction details and interior treatment.

—Altec Lansing Corporation.

RESUME OF LOUDSPEAKER ENCLOSURES

ALEXIS BADMAIEFF

Research Engineer — Altec Lansing Corporation

During the present trend to high-fidelity speaker systems, a lot of attention is focused on speaker enclosures. This is due to the fact that the enclosure is designed not only for appearance, but also to serve as a component of an acoustical system. A properly designed cabinet, however, cannot make a poorly designed speaker operate satisfactorily, nor can a well designed speaker perform efficiently when housed in an inferior enclosure. The speaker and the cabinet both must be of good design and work together as a unit. When this is accomplished, the result is that the response of the system is uniform and the efficiency is good down to very low bass.

The prime reason for an enclosure or baffle is to separate the sound radiated from the rear of a speaker diaphragm so that it does not interfere with the radiation generated by the front of the cone. Since these two sound sources differ by 180° in phase, cancellation takes place when the wave length is long in comparison with the diameter of the cone. If a baffle is placed to separate the two sides of the cone, the distance between the sources is increased, thereby permitting cancellation to occur at a lower frequency. An infinite baffle, then, is a separator that increases the distance between the sources of front and back of the diaphragm to such dimensions that the wave length of the lowest useful frequency is small in comparison to the distance of separtion. This ideal condition, however, is not practical because a board 15 feet square or larger is too large for common use. For this reason, other expedients must be used to reduce the bulk and at the same time, achieve the same or better results.

To outline the present-day speaker enclosure types, it is first necessary to separate them in four categories:—

A. Enclosures that perform as infinite baffles.

B. Enclosures that synthetically provide a bass boost.

C. Enclosures that beam the radiation from a speaker.

D. Combinations of the above.

All of the above devices perform satisfactorily within limits provided that proper choice and good design are carried out. The good and bad features of each type will be discussed in this article.

In Category A, the common example is a large box that totally encloses the radiation from the rear of the cone. The size of the box is important because the volume of air it contains is a capacitive reactance. Since this reactance adds stiffness to the cone suspension system, the diaphragm natural resonance is raised, which again produces a falling-off at the low frequency. If, however, the box is made large enough, say about 15 cubic feet in volume, the reactance becomes negligible in comparison with the stiffness of the cone's suspension system.

Another example, and perhaps a better one, is a speaker mechanism mounted in a wall so that the front of the diaphragm radiates into the listening room, but the rear of the cone radiates into another room separated by the wall. The volume of a small room behind the speaker is certainly large enough to produce negligible effect upon the resonance of the speaker. The coupling of the cone-to-air, however, is not good in the low bass range, due to increasingly high ratio between the wave length and the cone diameter. This effect produces a loss in bass response due to insufficient air loading of the cone.

In Category B, the best and most widely used example is the bass reflex or ported cabinet. It is probably the most satisfactory and economical of all enclosures, occupying a small space and yet capable of performance superior to an infinite baffle or a closed box. This, of course, is true only if this type of enclosure is carefully designed to fit the characteristics of the speaker with which it is to be used, to prevent boominess associated with high Q acoustical circuits. Instead of separating the radiation of the back from the front of the cone, the rear low-frequency sound is shifted in phase and made to combine in phase with the front radiation. Because both energies are additive, this reinforces the bass response and extends the reproduced low frequencies below the resonance of the cone, which is an improvement over the infinite baffle type of enclosure.

The design considerations of this type of cabinet are more stringent and involved than in the case of closed cabinets. The volume of the cabinet and the size of the port opening must be computed so that the resonance of the enclosure occurs at substantially the same frequency as the cone resonance. By doing this, the cone resonance is effectively damped because of loading by the port which prevents hang-over effects. The effect of the port in an 8 cubic foot ported enclosure acting on the cone resonance is shown in Fig. 1. Curve A is an impedance response of an Altec 602A speaker,

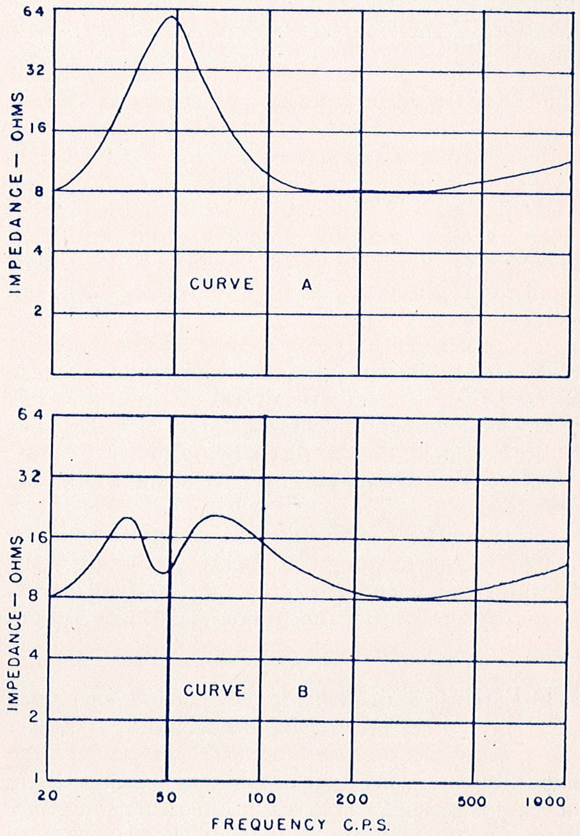


FIG. 1
602A SPEAKER IMPEDANCE VERSUS FREQUENCY
CURVE A—SPEAKER ONLY
CURVE B—SPEAKER IN A PORTED ENCLOSURE

having a resonance at 45 cycles. Curve B is the same speaker is an enclosure, having a port adjusted to produce a dip at 45 cycles. This combined effect produces a double peak which is much lower in amplitude. To the listener, this means a more faithful reproduction of low frequencies. The transient response of such a system is excellent which means that any shock excitation due to a complex wave is critically damped. This permits the cone to follow a complex wave shape without overshooting beyond the instantaneous signal limit.

In designing the ported enclosure, the Q of the cabinet-plus-port combination must not be made too high. If high Q values are encountered, a new effect occurs, which is a resonance of the system similar to a Helmholtz resonator. For this reason, the volume of the box must be chosen to provide the correct value of pressure amplification. If the box is made too large, the Helmholtz effect will be too great to be balanced by the Q of the cone's suspension system and its mass. If, however, the volume is made too small, the port will have less effect because the pressure amplification will be too small in reference to the Q of the cone. The optimum is achieved when the volume is about 8 cubic feet for a cone such as Altec's 601A, 602A or 604C. Fig. 2.

Curves A, B, C and D in Figure 2 are approximate curves for 90-70, 70-60, 60-50 and 50-40 cycle resonance of the loudspeaker cone suspension system. Before deciding on which curve to use, one should

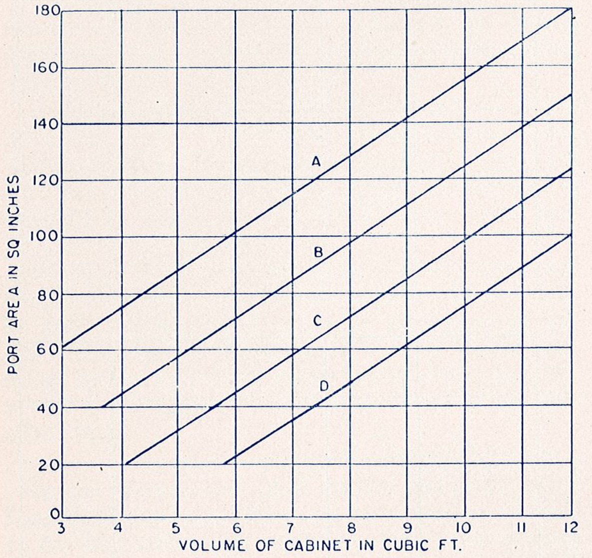


FIG. 2
RELATION BETWEEN VOLUME AND PORT AREA IN BASS REFLEX ENCLOSURES

know the resonance of the cone suspension system of the loudspeaker for which the enclosure is being designed. If, for example, a loudspeaker is purchased having a resonance of 45 cycles, Curve D should be chosen. On the other hand, if a smaller loudspeaker mechanism having an 8″ cone is to be mounted in an enclosure, and having its resonance at about 80 cycles, Curve A should be chosen.

Boxes that approach the shape of a sphere are ideal. Therefore, one should strive for a box that approaches a cube. This, however, is often undesirable for esthetic reasons. An approach, however, should be made to fulfill this condition by designing an enclosure having its depth no less than one-third of the width; and height or width no less than twice the diameter of the loudspeaker.

A corner cabinet such as the Altec 606 has an additional advantage. It even further approaches the ideal condition of a sphere, and in addition uses the corner walls of the room as a crude horn, which again improves the loading on the cone. Figure 3 shows two design suggestions, one for a rectangular enclosure and the other for a corner type.

The location of the port in reference to the loudspeaker cone opening in an enclosure is not too important, since the wave length of the frequencies in which the port opening is effective are much longer than the normal dimension of the whole enclosure. It is wise, however, to have the port opening as close to the speaker as possible without endangering the ruggedness of the baffle. Usually the port opening starts about 2″ from the rim of the loudspeaker. The shape of the port can also be varied. Its aspect ratio should not be higher than 5:1, otherwise the port can be square, rectangular or circular, provided that the area is correctly computed from the curve shown in Figure 2. In some instances it may be esthetically wise to divide the port in 2 areas. This can be done by designing the baffle with two ports, the sum of which is equal to the total port area required for the enclosure.

Success will be achieved if the foregoing design data is adhered to. The choice of port resonance, as shown by curves in Figure 2, will depend on speaker cone resonance. For 8″ speakers, such as Altec's 400B and 755, Curve A in Figure 2 should be chosen. (For 12″ speakers, Altec 600B and 601A, use curve C. for 15″ like Altec's 602A and 604C, use curve D.)

Much has been discussed about horn type enclosures. In this category (C), the enclosures should be sub-divided into two types.

(1) front loaded horn (2) back loaded horn

The front loaded horn system is usually composed of a low-frequency driver with a large horn and a high-frequency source. The sound radiated from the back of the cone is completely enclosed in a properly designed cavity. The mid-range and the high frequencies are reproduced by a smaller horn and one or more high-frequency drivers. A crossover network is provided to separate the two frequency ranges. Because the horn, to reproduce the bass frequencies efficiently, must be quite long (over six feet), it is usually folded to conserve space. These bends in the horn act as low pass acoustical filters and, therefore, sharply attenuate frequencies above approximately 300 cycles.

The low-frequency source of this loudspeaker system will be further away than the high-frequency unit along the axis of projection due to additional length in the folds of the horn. The phase between the signals from these two sources in the crossover region then shifts due to the relation between the fixed physical displacement and variable wave length. At some point, if that difference in distance is equal to one-half wave length, cancellation occurs producing a sharply pronounced dip in the response. An obvious way to minimize this effect is to design a crossover filter having very steep crossover slopes. This is expensive and may also consist of high Q electrical components. Such high Q electrical networks produce apparent peaks due to hang-over effects. To minimize this apparent effect, crossover networks are usually designed to have slopes of no more than 12 db per octave.

Another expedient, but one that makes it necessary to enlarge the high-frequency horn and therefore its cost, is to design the system having a low enough crossover point so that actual distance of separation between the high- and low-frequency drivers is small in comparison to one-half wave length at the crossover region. In practical applications, this crossover frequency is usually below 200 cycles.

The second classification in Category C is the back loaded folded horn. This type of enclosure serves two purposes; it reinforces the bass by utilizing the back radiation from the cone and projects it by means of a folded horn, and also permits the front of the cone to radiate normally as it does in an infinite baffle. The mid-range and high frequencies are reproduced by a wide range single cone or a duplex concentric speaker mechanism. This condition at first appears to be ideal, but upon examining the complex phase conditions that exist in this case, the system becomes extremely complicated to design. Instead of correcting the phase at only the crossover region, corrections have to be made along most of the range up to the mid-frequencies. Since the distance between the front and the back of the cone along the axis is very different, the phase will shift between the two sources as the wave length is varied. To illustrate, Fig. 4 shows this condition. The back wave, whose path is D, must travel that distance before it combines with the front radiation of the cone. Since the two radiations are 180° out of phase, the length of path D must be equal to one-half wave length for the two radiations to be additive. If, however, the wave length is equal to the distance D, complete cancellation takes place, because the two energies are 180° out of phase. At some point, usually between 200 and 500 cycles, a pronounced dip in the response is observed. This dip is inherent in this type of system because no crossover network is present between the two sides of the cone. The only way to eliminate this interference is to provide an acoustical low-pass filter in the back loaded horn. This filter would then attenuate frequencies above, say, 150 cycles, so that the intensity of the sound from the back of the cone, amplified by the horn, would be negligible in comparison with the direct cone radiation. The acoustical filter may consist of a capacitive reactance in a form of a cavity behind the cone and a fine mesh screen in the entrance to the horn. This provides an acoustical LC circuit forming a low-pass filter. The design of such a system is quite involved which is evidenced by the fact that only rarely was a system of this sort really successful. A well-designed back loaded folded horn, using a concentric speaker, having a tweeter and a network, is really a three-way speaker system. The horn and the back of the cone reproduce all the extreme bass notes up to 150 cycles, the front of the cone reproduces up to say 3,000 cycles, and the tweeter from 3,000 cycles on up to the highest treble.

Combinations of any one of the foregoing systems are possible, and have been on the market for a long time. One of the best known speaker systems of that type is Altec's "Voice of the Theatre" line. The other, which is a home version of large theatre systems, is the Altec 820, which is used for large listening rooms. These systems make use of short,

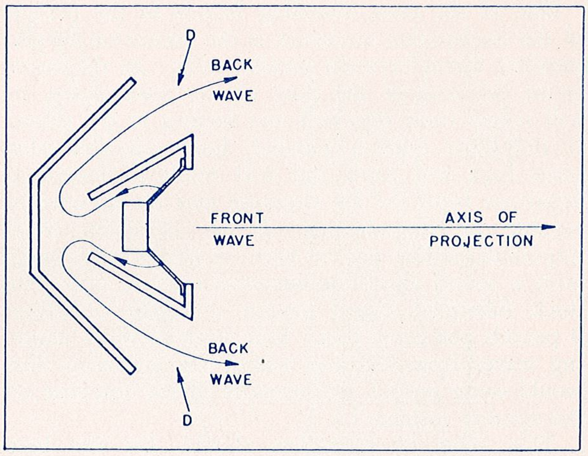


FIG. 4
DIAGRAM OF A BACK LOADED FOLDED HORN

direct radiating, front loaded horns plus ported enclosures to reproduce the low bass range, using two or more cone drivers. The mid-range and treble are reproduced by a smaller horn with one or more driver units. The efficiency of such systems is high, with excellent transient and frequency response down to the lowest bass note. Since the distance to the high- and low-frequency drivers is the same along the projection axis, perfect phasing is possible throughout the crossover range.

Other unusual speaker enclosure systems appear from time to time. The description of these is beyond the scope of this paper. In short, however, one general class could be described here: Enclosures that make use of two or more highly resonant cavities that are either coupled to the speaker or to each other to give an illusion of good bass response. The drawback is immediately evident from the foregoing explanation of transients. Such systems have high distortion, irregular response, and worst of all, violent hang-over effects. The purpose of systems like these is to conserve space, but at a sacrifice of faithful reproduction of good music.

In designing and building any enclosure in any category, it is important to adhere to general rules that will decide the success of the product. Any panel or baffle that is part of an acoustical system should be rigid. This is accomplished by using sufficiently thick wood panels (at least ½ inch) and reinforcing them with wooden strips, such as 1" x 2" glued and nailed on edge. This will prevent drumming and resonances in the structure which would otherwise alter the response. and reduce the efficiency of the acoustical system. As an example, any surface that is more than 3 square feet in area should be divided in two smaller areas by a reinforcing strip. This strip should be glued diagonally from corner to corner if the dimension of the surface is approximately a square. If the aspect ratio is less than 3:4, the strip should be glued across the smaller dimension, thus dividing the larger dimension in two equal areas.

One of the most offending factors in the design of the loudspeaker enclosure is the formation of the standing waves between parallel walls. As the wave leaves the rear of the cone of the loudspeaker, it will reflect from one wall and bounce to the other. If the other wall is parallel, bouncing will take place back and forth and will result in a serious departure from the flat response that the speaker is capable of reproducing. It is, therefore, very important to line one or both of any parallel walls with a sound absorbing material such as one inch thick Fiberglass board having a weight of about 9 pounds per cubic foot. This layer prevents standing waves from forming within the enclosure that would cause serious irregularities in the response of the speaker system.

This layer of Fiberglass should, for the best performance, extend from all edges of the parallel wall so that no hard surface is exposed. It is easy to apply by using any one of the commercial adhesives available on the market today, and insuring the permanence by reinforcing the Fiberglass layer with nails and fairly large washers tacking the Fiberglass to the wood. It is, however, unnecessary to line all the walls of an enclosure, since sound is absorbed if any one of the two parallel walls are lined with sound absorbing material. In the case of a closet or an unused room into which a loudspeaker is backed, some means of sound absorption should be provided to prevent standing waves. If for instance a closet is used, the normal hanging of clothing is sufficient to break up standing wave patterns. In rooms larger than a closet, ordinary drapery and carpeting is usually sufficient to prevent serious disturbances due to standing waves.

Only acoustically transparent grille cloth should be used in front of the speaker. The transmission of high frequency radiation is greatly attenuated through dense materials, such as drapery cloth or other closely woven fabrics. Decorative grills should be chosen that are coarsely woven and have a rough, clean surface without a fuzzy texture and that are as transparent to light as can be tolerated.

APPENDIX

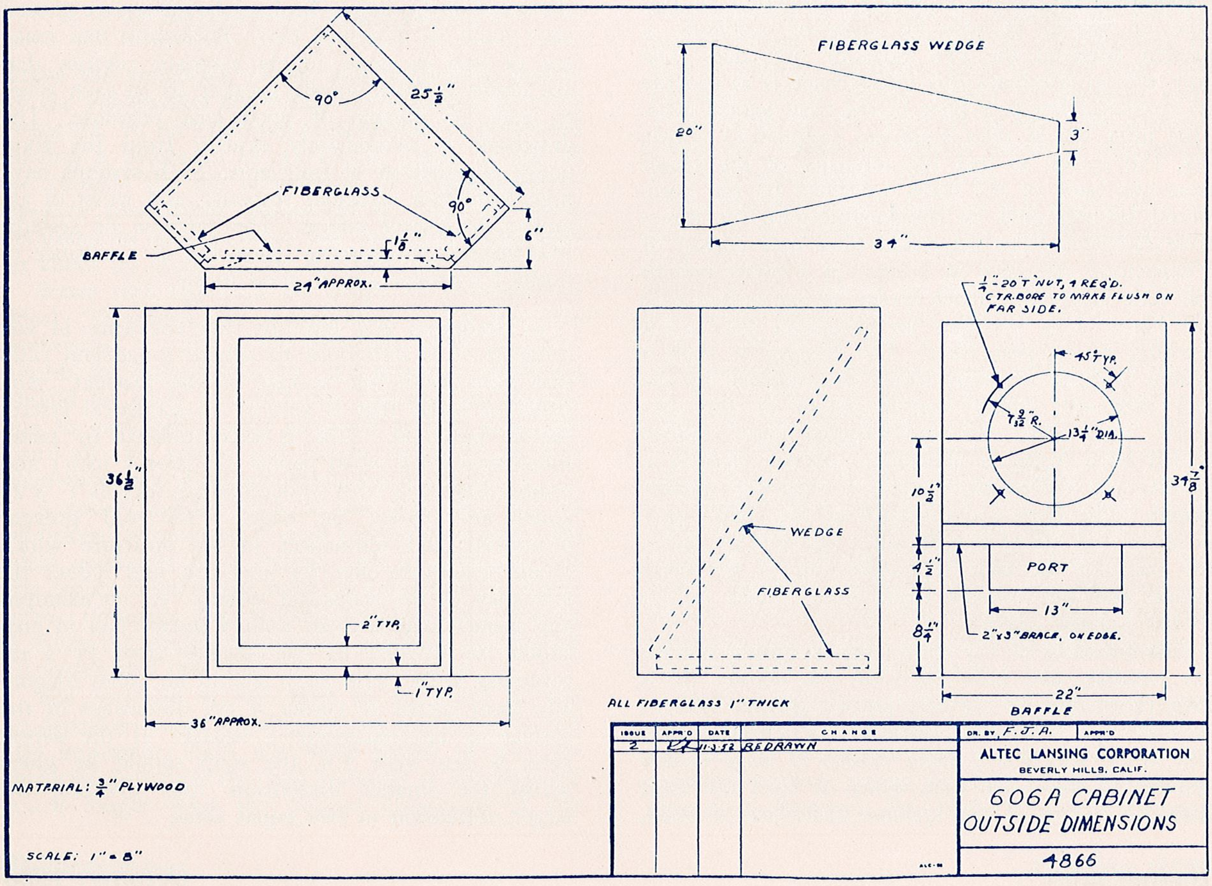
For the advanced experimenter who would like to have design charts and mathematical data to design various enclosures described in this paper, the references below will aid greatly.

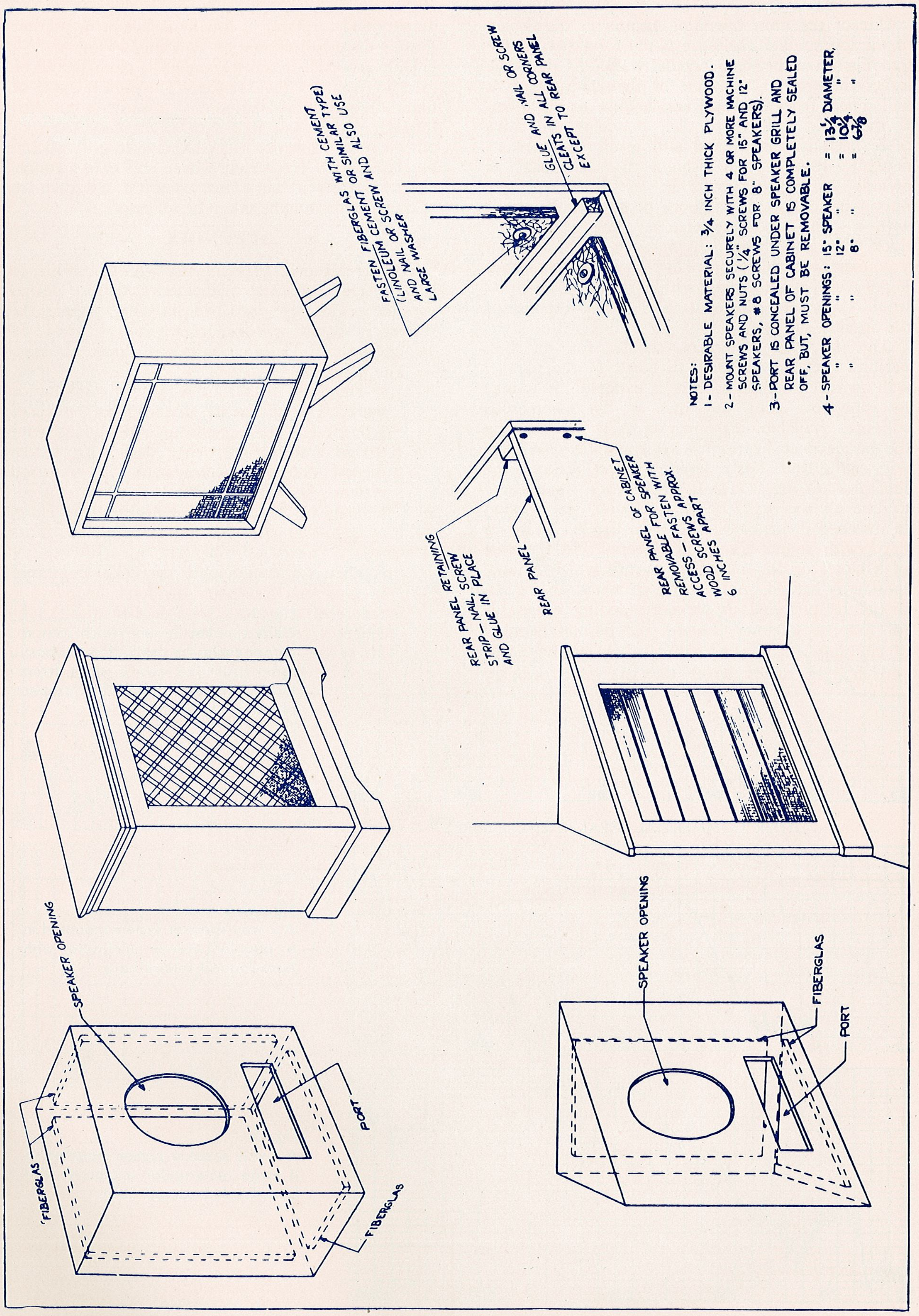
1. "Accoustical Design Charts" by Frank Massa — The Blakiston Co., Pa.

   These design charts save most of computation work. The charts are intended for advanced acoustical work as a source of quantitative design information. They deal with fundamental design of components in acoustical systems.

2. "Elements of Acoustical Engineering" by Harry F. Olson — D van Nostrand Co., New York City.

   This is a textbook for acoustical engineers. It is a practical book on fundamentals and theory of acoustics. Good mathematical knowledge is required to make use of this book. However, chapters and parts of the text will be of value to anyone interested in sound.




FIBERGLAS
SPEAKER OPENING
PORT
FIBERGLAS
FASTEN FIBERGLAS WITH CEMENT (LINOLEUM CEMENT OR SIMILAR TYPE) AND NAIL OR SCREW AND ALSO USE LARGE WASHER
REAR PANEL RETAINING STRIP—NAIL, SCREW AND GLUE IN PLACE
REAR PANEL
REAR PANEL OF CABINET REMOVABLE FOR SPEAKER ACCESS—FASTEN WITH WOOD SCREWS APPROX. 6 INCHES APART
GLUE AND NAIL OR SCREW CLEATS IN ALL CORNERS EXCEPT TO REAR PANEL
SPEAKER OPENING
FIBERGLAS
PORT
NOTES:
1- DESIRABLE MATERIAL: 3/4 INCH THICK PLYWOOD.
2- MOUNT SPEAKERS SECURELY WITH 4 OR MORE MACHINE SCREWS AND NUTS (1/4" SCREWS FOR 15" AND 12" SPEAKERS, #8 SCREWS FOR 8" SPEAKERS).
3- PORT IS CONCEALED UNDER SPEAKER GRILL AND REAR PANEL OF CABINET IS COMPLETELY SEALED OFF, BUT, MUST BE REMOVABLE.
4- SPEAKER OPENINGS: 15" SPEAKER = 13 1/4 DIAMETER,
" " 12" " = 10 1/4 "
" " 8" " = 6 7/8 "

REPRESENTATIVE ALTEC SPEAKER ENCLOSURES

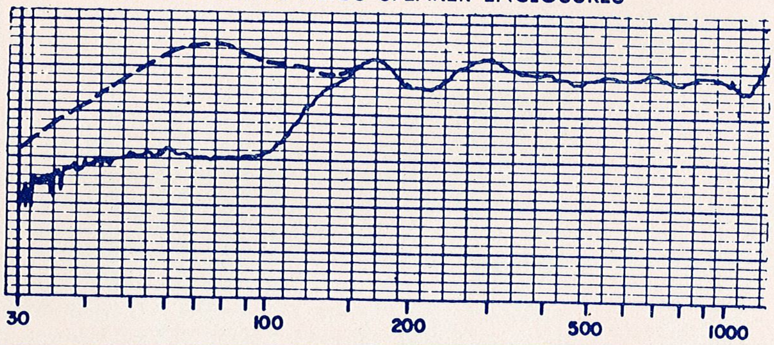


Fig. 1
602A Duplex Speaker mounted in 606A bass reflex corner cabinet.

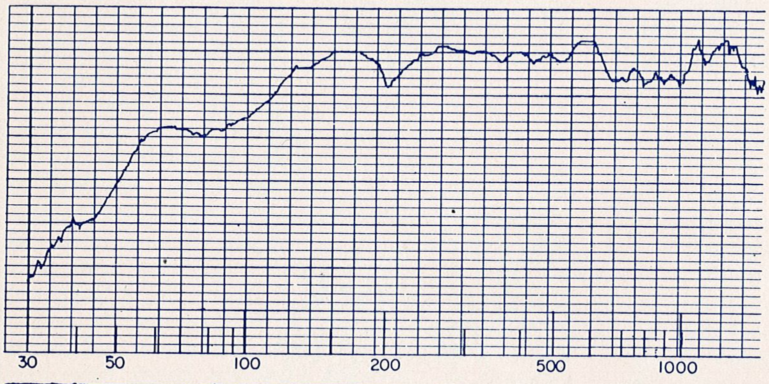


Fig. 2
604C Duplex Speaker mounted in the rectangular bass reflex cabinet, Model 607A

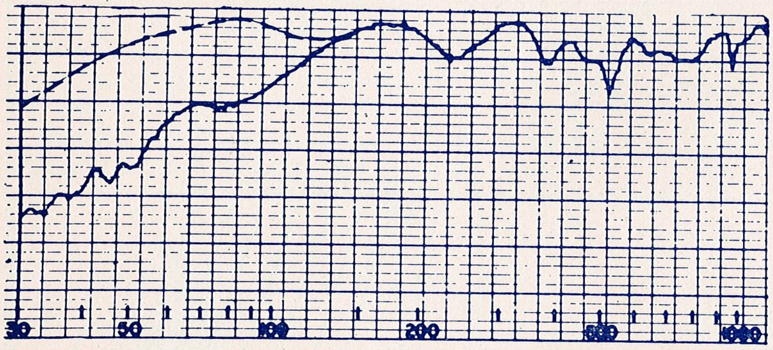


Fig. 3
820A speaker system which uses a corner enclosure combining the bass reflex principle and a short front loaded horn designed for proper phasing conditions.

OTHER COMMERCIAL SPEAKER ENCLOSURES

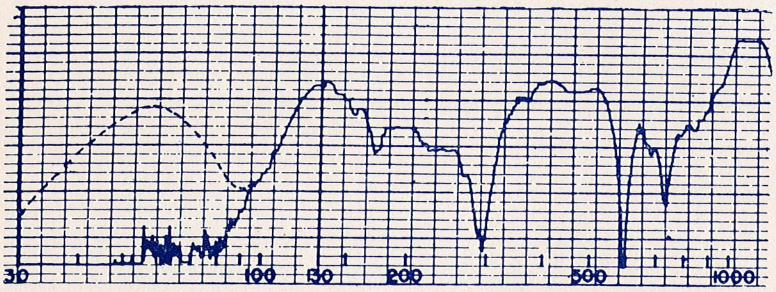


Fig. 4
A 2-way speaker system mounted in a popular corner enclosure with back-loaded folded horn.

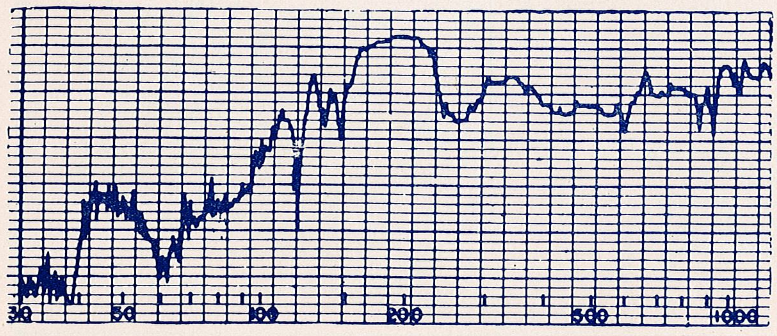


Fig. 5
A 3-way speaker system mounted in a large rectangular enclosure with back-loaded curved horn.

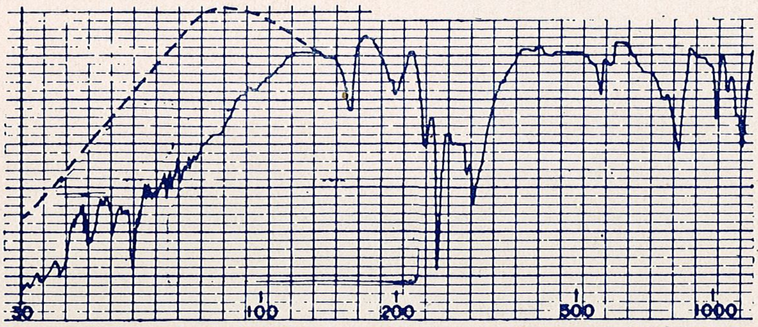


Fig. 6
601A Duplex speaker mounted in another popular corner enclosure with back-loaded folded horn.

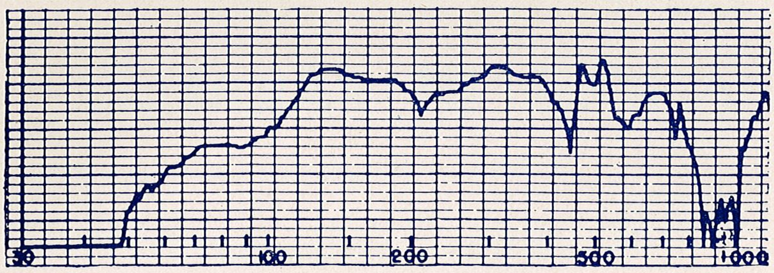


Fig. 7
A 2-way speaker system mounted in a bass reflex rectangular enclosure.

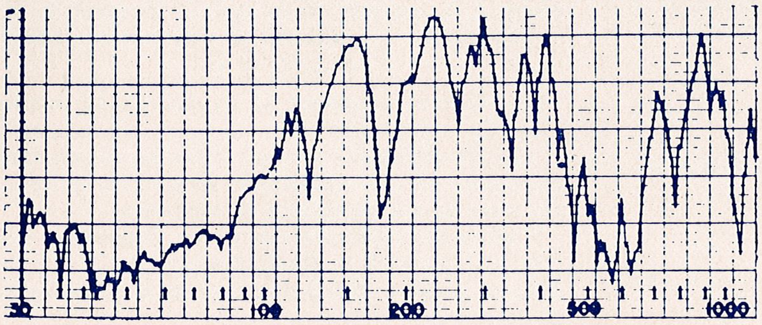


Fig. 8
600B speaker mounted in a vertical tuned pipe enclosure.

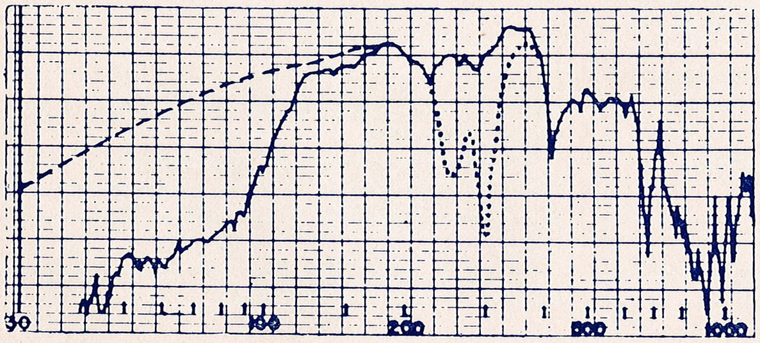


Fig. 9
A popular corner enclosure using a front loaded folded horn (low frequency speaker only). Dotted line indicates interference hole when used with H.F. horn using 300 cycle cross over.

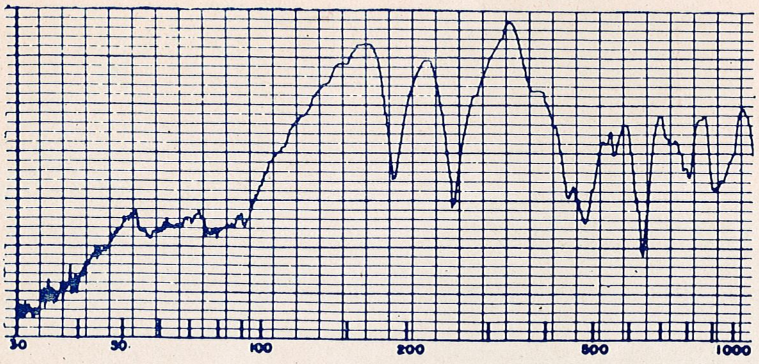


Fig. 10
A patented enclosure currently enjoying considerable popularity.

These curves cover only low and mid frequency range and are intended to show the effect of speaker enclosure on frequency response rather than any differences or comparisons between speaker units.

All curves were run in the Altec Lansing anechoic chamber. The dashed curves on corner enclosure types represent bass response when enclosure is placed in the corner of an average room.

TWO IMPEDANCES IN PARALLEL

Two cases are considered:

(1) *It is sometimes required to find the value of an impedance to shunt across a known impedance to produce a specified resultant impedance.*

Taking the resistive case as an illustration, it is well known that the resultant of two resistances R_1 and R_2 in parallel is given by

$$R = \frac{R_1 R_2}{R_1 + R_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

If R and R_1 are known we can readily derive R_2.

$$RR_1 + RR_2 = R_1R_2$$

$$R_2(R - R_1) = -RR_1$$

$$R_2 = \frac{R_1R}{R_1 - R} \quad \ldots\ldots\ldots\ldots \quad (2)$$

From eqn. (2) we can readily calculate the resistance R_2 to be shunted across a resistance R_1 to produce a resultant resistance R.

For example, suppose that we wish to have a resistance of exactly 1000 ohms, but that the nearest resistor is 10% high, that is 1100 ohms.

Thus we have R = resultant = 1000 ohms
R_1 = 1100 ohms

and from eqn. (2) we derive

$$R_2 = \frac{1100 \times 1000}{100} = 11{,}000 \text{ ohms.}$$

This same principle can be applied to inductances:

$$L_2 = \frac{L_1L}{L_1 - L} \quad \ldots\ldots\ldots\ldots \quad (3)$$

where L is resultant of L_1 and L_2 in parallel.

The formula for capacitances may also be derived:

$$C = C_1 + C_2$$

where C is the resultant of C_1 and C_2 in parallel. Thus $C_2 = C - C_1$. .... (4)

(2) *An alternative method of finding the resultant impedance of two impedances in parallel, based on the ratio of one impedance to the other.*

Taking the resistance case as an illustration, suppose that we wish to derive the resultant of R_1 and XR_1 in parallel. From eqn. (1) it may readily be derived that

$$R = R_1 \frac{X}{X + 1} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (5)$$

where X is the ratio of the two resistors, X being greater than unity.

For example, to find the resultant of $R_1 = 1000$ ohms in parallel with $XR_1 = 10{,}000$ ohms. Here $X = 10$ and therefore $R = 1000 \times 10/11 = 911$ ohms.

In most cases this may be applied mentally, without the use of a slide rule.

Editor .... D. Cunliffe-Jones
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