Theater Sound in a Small Package

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Part 2. Continuing the description of a speaker enclosure which is claimed by the designer to be superior to any other type with which he has had experience. Constructional details are given in this installment.

IN THE PRECEDING ARTICLE, the writer discussed the many practical and technical reasons why he believes this system to be the only completely satisfactory means of properly reproducing classical music in the average-size living room, and this installment is devoted to the construction. The first assembly is illustrated at various stages during the building, but the views shown are just suggestions. The dimensions and proportions can be varied to fit the particular speaker and other materials at hand.

The first woofer had such a large field coil that the cabinet had to have considerable depth from the front, or face, back into the corner of the room. This meant that the face was wider also; as you can see, the base of an equilateral triangle increases with the altitude. The second assembly was built around a woofer with a permanent magnet and was scaled down somewhat in dimensions because the smaller magnet could be fitted into the corner more snugly.

The woofer may be built up by removing the frame from the permanent magnet structure of an old 12- or 15-in. speaker and replacing it with a sturdy 8-in. frame. However, a high-quality field-coil magnet can be used, if available, provided it has adequate wattage so as to provide a large magnetic flux—somewhere around 10,000 lines per sq. cm. It is necessary that the structure selected have a deep voice-coil slot, and that the pole pieces are long axially. The voice-coil diameter should be at least 1¼ in., and 1½ in. or more would be even better.

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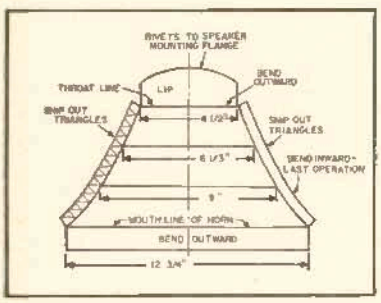

Fig. 3. Detail of one side of the metal horn covering the range from 450 to 1000 cps.

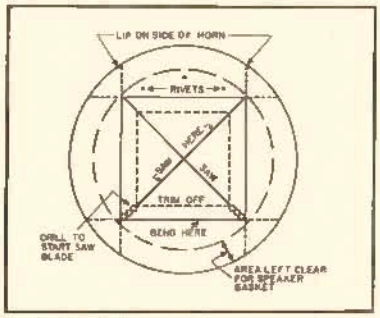

Fig. 4. Detail of the speaker mounting ring to be attached to the horn of Fig. 3.

Suitable speaker frames—including the magnet structure—can usually be obtained for a relatively low cost from a shop which specializes in reconing speakers. While many of the modern high-flux-density speakers would provide an ideal magnet for this purpose, it would be futile to suggest disassembling one of them for the special type of woofer we desire. It was stated previously that such speakers were relatively expensive, and that this design was economical.

Having secured a suitable magnet structure, it might also be possible to obtain from the same source a frame or "basket" for an 8-in. speaker. Remember that this basket should be as deep as possible—the one used on some of the earliest dynamic speakers is the type to obtain. Assuming that you succeed in obtaining a permanent magnet unit, be sure to cover the voice-coil opening immediately with Scotch tape—either the cellophane type or that known as masking tape—to preclude the slot being filled up with metal particles. Once these particles become lodged in the voice-coil slot, it is almost impossible to remove them—although one of the most effective ways to "try" to get them out is to fold a piece of this same tape over the end of a thin strip of metal, which can then be used to "wipe" the slot. A large percentage of the filings can be removed in this manner, although some are almost certain to remain.

After you have mounted the smaller frame on the magnet the rest is up to the speaker reconing expert. He must design a steep cone of stiff parchment, such as phenolic impregnated paper, and a voice coil to handle the wattage required for a small woofer. To match the average horn tweeter and utilize smaller capacitors in the dividing network, the voice-coil impedance should be around 16 ohms at 400 cps. This isn't critical, however; a value of 8 ohms is still usable.

The most critical item is the suspension of this cone. It will have a much greater excursion than any normal 8-in. speaker, so both the center spider and outer surrounding ring should be of some plasticized cloth fabric or soft leather rather than the usual molded mat of paper. These suspensions must be free in movement (not stiff) but able to stand the punishment of the greater flexing. The effective working diameter of the cone proper—its outside diameter—will probably be around 6 in.

The Intermediate Horn

Bolted to the mounting ring of the 8-in. woofer is the direct-radiating intermediate horn. Through this horn passes the major portion of the fundamental notes and the drum and cymbal crashes, etc. For the low notes of the outside horn, the shape of the walls is not so important but for this intermediate horn we must carry the flare out in a smooth exponential curve.

To meet all requirements, a throat opening of 4½ in. square works out best. Take a sheet of paper and draw an axis across the center. Then plot points on it starting with the 4½-in. throat, so that you will have a side elevation of the horn standing on its mouth, as in *Fig. 3*. Measure off three divisions of 1⅛ in. each along the axis and strike off a chord at each division, perpendicular to the axis. The area of the throat opening is 20.25 sq. in. By doubling this area and extracting the square root, it is found that the span along the side at the first chord will be 6-1/3 in. Plot

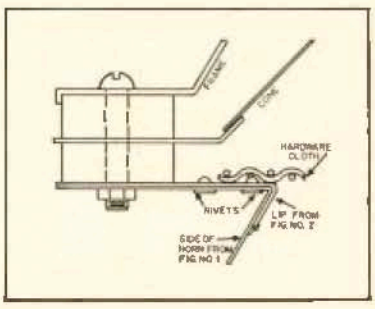

Fig. 5. Detail of the mounting of the speaker on the flange and horn.

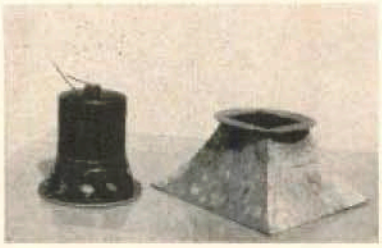

Fig. 6. Completed horn, shown with the early electrodynamic driver unit used in the first model.

half of this distance along the chord to each side of the axis. At the next chord the dimension will be 9 in. and at the mouth it will be 12¾ in.

Next, trace a smooth curve through the four points plotted on each side of the axis. This is best done with a "French Curve;" you may not find a curve that falls exactly on all four points but retrace the different sectors to get it as close as possible. Then use a flexible rule to measure the length of this curve to determine how long to cut the sheet metal side from throat to mouth.

To make these sides, get some 22 or 24 ga. furniture steel. 20 ga. is a little stiff for shaping but would give greater rigidity of the horn walls. On the steel, draw the axis again and then lay off the distance along the axis that was measured around the curve. Divide this distance into three equal divisions for the chords and lay off the former distances across the chords for the points of the curves.

The curves will be the same for all four sides of the horn, but two of the sides must have a ½-in. strip added along the edge as shown in *Fig.* 3. At the mouth of these two sides leave an extension of an additional 1 in. to bend over. At the throat of all four sides, leave an extended lip as shown. Cut out the two pairs of sides as drawn, and then snip out little wedge-shaped pieces from the ½-in. extended edge left along the curves of two of the sides.

The flange shown in *Fig.* 4 must be made from furniture steel of at least 20 ga. or heavier. Cut out a circular piece the same diameter as the outside edge of the 8 in. speaker frame. Scribe a circle on it which will just clear the inner edge of the speaker gasket where it bolts on to this flange. Then mark off the 4½ × 4½-in. square in the center of this circle and saw across the diagonals with a hacksaw, as shown. Drill two rows of ¼-in. holes at the corners for starting a saw blade in the cuts.

Clamp the circular edge in a vise so that a 4½-in. side of the square is flush with the edges of the vise jaws. If the vise does not have jaws wide enough, the width can be extended by two small pieces of angle iron. Bend the triangular piece, between two diagonal saw cuts, inward to a 90-deg. angle against the vise jaw. Then trim off the triangle to leave a ½-in. lip as shown. Bend over the next triangle, being careful to choose the side that will let the tin snips clear the first lip just cut. Continue around for all four triangular segments so that a 4½ × 4½-in. mouth opening with ½-in. lips results.

The lip extensions, at the throat line of the horn sides, should be cut to match the portion of the flange they mate with, around the mouth. These lip pieces may be bent over at approximately 90 deg. and the extensions on the bottoms of two sides may be bent over in the same direction, to an angle of approximately 45 deg. Then the two sides without serrated edges may be clamped against the flange, facing each other, with the ½-in. lip of the throat extending inside the horn and their upper lip pieces against the flange on the side away from the speaker gasket, as in *Fig.* 5.

While these pieces are clamped along the edges, drill small holes and rivet small tinner's rivets or nail stubs, so that they fall within the circle you drew to clear the speaker gasket. After riveting the two sides on, they can be carefully shaped over a large pipe or other cylindrical surface, for the horn flare curvature. Next, form the horn flare in the two remaining sides and then bend over the saw-teeth edges to the proper angle with pliers.

These saw-teeth are to reach along the outside of the other two sides and

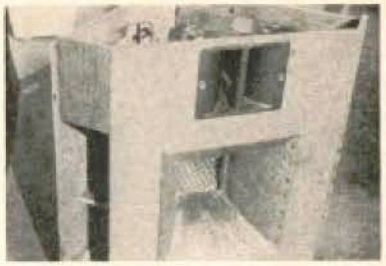

Fig. 9. Method of mounting horns to front of cabinet structure.

allow the soldering iron point to apply heat effectively and to flow the solder between mating edges. After you are sure every thing fits properly, these remaining two sides may be riveted to the flange at the speaker end. Some mechanics like to tin the mating surfaces before assembling. Use a little "cut" muriatic acid on the edges and solder with half-and-half solder and a large soldering iron. Solder an inch or two at a time while clamping the edges in snug position with "C" clamps or other suitable means.

After all corners are well soldered, place the throat opening over a flat extension of the vise or an anvil and use a hammer lightly to shape the inner ½-in. lip back against the inner surface of the horn for soldering. For riveting in tight places or for this shaping procedure, a stiff bar or angle iron can be clamped to extend out from a strong vise. This lip should be soldered to the horn wall to kill any chance for spurious vibration between the horn and flange sections. *Figure* 6 shows the finished appearance.

When you are through soldering there must be no visible air leaks up the corners of the horn or where the flange is attached. The speaker mounting ring must have a continuous gasket to mate with this horn flange, for completing this air-tight effect. Before the speaker is bolted to the horn, solder a piece of light hardware cloth across the throat of the horn flange, leaving no free edges to vibrate.

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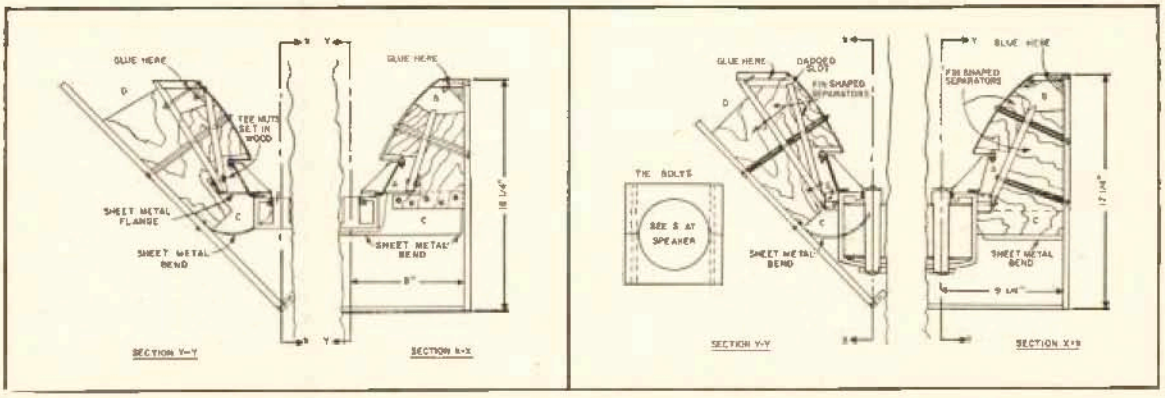

Fig. 7 (left). Horizontal and vertical sections through the center of the speaker unit for the second model, using a PM dynamic driver. Fig. 8 (right). Sections through first model, using the driver shown in Fig. 6.

THEATER SOUND

(from page 31)

Design of the Main Case

The surest way to cut and assemble the sections of the wood cabinet without mistakes is to make a plan drawing of its assembly to scale, similar to *Fig. 7* or 8. This is especially true if the plywood is of different thicknesses. In the cabinets we constructed we used ½-in. plywood throughout, but the front of the cabinet, sides, top, and bottom could be made of thicker plywood if it is on hand. All pieces must be at least ½-in. thick, however.

Figure 9 shows the metal horn attached to the front by wood screws but this was our first assembly. In later models, the fin-like separator pieces project at right angles from the center of each side of the sheet metal horn, to act as struts between partitions, and they are slotted across one side to let the 3/16-in. truss rods pass through them. These pieces must be shaped to fairly well match the surfaces they are to push against, and to obtain a snug fit so that partitions will not be sprung out of position as truss rods are tightened.

A truss rod passes from the side of the sheet metal horn to the outside of the cabinet in each of the four directions, at the center of the sound passages. After partitions for folded horn sound passages have been cut and shaped to fit together correctly, these fin-like separators must be lined up with the direction of sound and tacked in place with small brads. As the horn partitions are assembled, a 3/16-in. rod (such as steel welding rod) can be threaded through the group to help line up the separators while they are tacked in place.

Finally each truss rod may be cut to length and threaded on each end. Screw a nut on one end with a thread or so sticking through; clamp the rod in the vise with the nut resting on the jaws; and rivet the end with a ball peen hammer. This end is used at the outside of the cabinet with a large washer to keep the nut from seating into the wood with the vibrations. The other nut is screwed on the end which sticks into the sheet metal horn, with a good lock washer to keep it from working loose. Allow plenty of thread on this end for tightening.

In installing an 8-in. speaker frame on the larger magnet an additional 16-ga. metal flange can be included in the assembly, as shown in *Fig. 7*, to form a tie or hub for the partitions of the sound chamber. This member seals off the passage of sound to the rear and gives a more direct support for the heavy magnet. With our first woofer we used a wooden collar, fabricated by glueing two layers of ⅝-in. plywood together, as shown in *Fig. 8*. One layer was given ¼-in. slots to let a 3/16-in. tie rod pass through on each side of the speaker magnet.

Where the metal horn fits through the front panel and where the partitions were fit to the wooden collar around the speaker, a thin layer of plastic (non-hardening) putty was applied between surfaces. This was to seal from passage of air and to prevent any spurious vibrations at joints.

No. 8 wood screws, of different lengths, were used in our first cabinet. Lengths were chosen so that 1 in. or more of thread was seated in the holding member and they were spaced 1½ in. apart in short runs and 2½ or 3 in. along the main sides. A small hole was drilled to guide each screw and prevent splitting of edges of panels. Then the hole through the held piece was enlarged for the shank and countersunk. A bit of floor wax was used to ease each screw home in its long run.

Arranging Inner Passages

In computing the sound passage area past the speaker mounting flange, the cross sectional area between partitions, at A in *Fig. 7*, is figured and the circular area of the speaker flange deducted. It will be seen that the sound waves have to turn a 90-deg. angle at the space marked A before departing from this chamber back of the mounting ring. Thus frequencies of the intermediate range are filtered out by acoustical resistance before they can cause much distortion in the folded horn passages.

Continuing along the inner sound passages, the cross sectional area at each change of direction is figured for doubling every 12 in. in axial length. Since there is no continuous 12-in. run in any part of it, this can only be a rough approximation, by proportions. Remember to allow for the same degree of expansion as the sound bends around the end of partitions because it may travel four or five inches axially in these bends. Leaving the sound chamber at A, the low notes pass toward the front of the cabinet and are bent back at B to pass rearward along the top and bottom panels to C.

Many corner speaker cabinets depend on the walls of the room to form the final folded passage, but this design uses complete side panels with the truss rods terminating in them. Pieces of ¼-in. hair felt were glued along the outside of these panels to prevent their making vibrating contact with walls of the room. Rubber feet were installed on the bottom. Thus, there is practically no sound transmission through the room walls at normal operating levels.

Curved inserts of sheet metal were bolted to the side walls and center separator to help the sound around the last bend at C and prevent possible distortion in this large chamber which surrounds the magnet. This sheet metal may be any gauge from 28 to 22, for easy shaping. Use lock washers on all bolts, which are 8-32 machine screws in most locations.

Before tightening the truss rod nuts in the metal horn, on the final assembly, twist a turn of small wire under each nut and allow the two ends to reach out the front like hairpins. Then take an old gauze or lace curtain and wad it up and pack it loosely in the horn to fill it almost to the mouth. Place a piece of light hardware cloth over this curtain and secure in place with these hair pins. If the hardware cloth is not light and pliable, its ends may receive vibrations from touching the metal horn.

The purpose of this curtain wad is twofold. Naturally, the direct radiated sound is much more effective than the lower notes which have to traverse the folded horn. So this material acts as a mute to cut down the intensity of the emerging notes and provide a distortion-free coupling with the outside air. Thus a fair balance can be obtained between the two horns and further experimenting may be resorted to in order to suit the needs of the particular speaker and horn assembly.

Don't be too concerned about the looks of the sheet metal horn or other features around that part of the cabinet because it will have to be covered with some cloth or other finishing. Picture molding was used to form open louvers over the horn on our first cabinet. There are many ways to dress up this cabinet to fit in with the surrounding environment. Do not run any wide molding up the edge of the horn opening against the wall at D, *Figs. 7* and 8. Any molding which extends into this opening from the wall would curtail the annular movement of the lowest notes along this outer wall.

Like most experimenters, we have never gotten around to finishing our cabinet because we are too busy on other projects. Louvers should not be used over the tweeter and any cloth used over its opening should be of fairly loose weave and hard, wiry thread, preferably plastic.

Both the tweeter and the center horn must be mounted flush with the front surface of the panel (disregarding louvers which extend beyond). The reason for this is, of course, to avoid any discontinuities in the sound path where the horn joins the open air.

Sounds like a lot of work, doesn't it? It has taken years of struggling to achieve this ideal and the real listening satisfaction for a true music fanatic. Let's put it this way: A sextet of saxophones of different ranges can imitate the brass choir, but the comparison in texture is about the same as comparing an ordinary 12- or 15-in. resonator-boxed speaker with our system—except that the saxophones are a little muddier than the box speaker.

In the final article of this series, we will discuss the controls that go with the dividing network.

[To be concluded]