A NEW TYPE OF SOUND AMPLIFYING HORN.

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A vibrating tuning fork held in the hand produces little sound. The volume of the air thrown into vibration by the prongs of the fork is small. When one places the handle of the fork against a table top or anything else that can be set into vibration by the fork the intensity of the sound is increased. The fork has been forced to work "harder" (to spend its energy more rapidly) in causing the vibrations of the table. The table top does not of itself produce any sound. It merely forces the fork to produce more.

People generally do not seem to understand that the principle stated above applies to all kinds of sound amplifying devices, including phonograph and radio horns and cone loud speakers, even though the action of the latter and the table top amplification is practically identical. The case of the horn is a little more difficult to visualize. When the diaphragm of the phonograph reproducer or radio receiving unit vibrates in the open the resistance offered by the free air is so small that the diaphragm dissipates energy very slowly. However, if the air about the diaphragm be confined, as by a horn, it offers more resistance and the diaphragm is called upon to do more work, the rate being dependent upon various factors, amongst which are the length, shape and cross section of the air column in the horn. The maximum amplification results when the horn dimensions are such that the diaphragm is called upon to work at its greatest possible rate. Like an electric motor, for the highest efficiency it should be neither under nor over-loaded.

It is well known that an air column has more or less selective resonance and consequently selective tone amplification. The trombone player produces the particular tone he wants by adjusting the length of the air column. A flute player does the same thing. In one case the air column is curved, in the other, straight. The curves in the trombone are so gentle that the sound waves follow the tortuous path through the horn without suffering very much internal reflection. But if there were an abrupt turn, more or less of the sound wave energy would be reflected backwards at that turn. This would tend to set up a stationary vibration in the horn of a wave length different from that which is produced by reflection at the far end of the horn. The net result would be that the intensity of the resonance due to the stationary waves set up between the two extreme ends of the horn would be diminished, and the intensity of the sound corresponding to the stationary vibrations between the abrupt turn and the end of the horn would be increased. By the use of this principle in the design of a horn, it may be made resonant to a greater number of tones than if the axis of the horn were straight.

If the walls of a horn are smooth and rigid, the quality and degree of resonance is independent of the material of which they are made.

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But inasmuch as most materials do not possess these characteristics, considerable loss of sound energy may result from their use. But if the walls of the horn be made of a material that approaches what we call perfect elasticity, they may absorb large quantities of sound energy without decreasing the intensity of the total output. The energy which they absorb throws them into vibration and they in turn throw in vibration the air with which they are in contact—an action similar to the table top experiment above mentioned. The writer has made use of this principle, as well as that of internal reflections, in the design of the horn briefly described as follows:

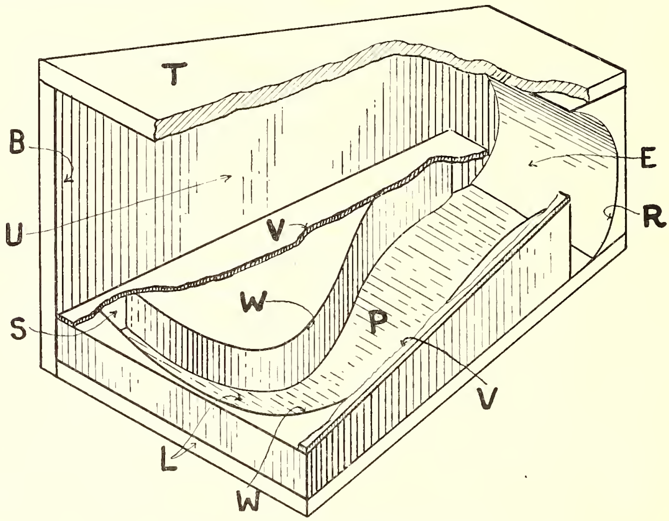

Fig. 1. Sound Amplifying Horn.

Figure 1 is a perspective drawing of a horn in which the near side and most of the top T and the partition V, hereafter called the vibrator, have been cut away to show the details of the interior. The curved baffles W form the side walls, while the lower wall of the horn L and the vibrator board function as the other two walls of a curved sound passage P. Sound enters the passage at the small end S and on emergence at the large end E strikes a curved reflecting surface R which reflects much of it into the upper passage U between the vibrator and horn top from which it emerges at the bell end of the horn B. But not all the energy passing through P is reflected at once into U. A portion of it (re-entrant) is reflected back into P, thus tending to set up stationary vibrations in P corresponding to waves of higher frequency than the vibrations set up between the extreme ends of the horn S and B. Likewise, some of the energy reflected back into U from the open end B is again reflected at R into U, causing stationary waves between B and R. Both sections or segments of the horn therefore have their own resonance frequencies which by properly designing the horn, can be made different from one another and from the resonance frequency of the horn as a whole.

We have spoken of the resonance frequency of P as if it were a single and definite frequency. It would be so if P were straight or but gradually curved. But with the rather sharp curves which the horn actually has (much sharper than the drawing suggests) sound entering P is variously and multiply reflected from the side walls before reaching the reflector R. The actual distance the sound must travel in passing from S to R is thus considerably increased and as a consequence the pitch of the lowest resonant tone is correspondingly lowered. The net result is that the resonance of P for a particular frequency is reduced while the range of frequencies which this segment of the horn amplifies is correspondingly broadened.

The cross section area of the passage P being relatively small the sound waves (compressions and rarefactions of the enclosed air) tend strongly to produce vibrations of the walls of the passage. The two side walls W and the lower wall L are made massive and stiff. The upper wall, called the vibrator, V, is of thin elastic material and is of such a shape that it can readily vibrate in unison with the sound waves passing underneath. The vibration of V sets up waves which pass across the horn (transverse to the horn's axis) where they are again transversely reflected by the top T to the vibrator board. Several such reflections may take place before the waves finally emerge at B. This multiple reflection again greatly increases the effective length of the horn and increases the frequency range of its resonance. Note that the wider end of the vibrator V is at the rear end of U and that it naturally vibrates at a lower rate than the narrow portion of the vibrator near B. The lower pitched waves produced at the rear must travel farther before emergence than the higher pitched waves generated near B, in both cases a necessary condition for amplification. It should be noticed that the vibrator board, as a sound amplifier, functions much as the disk of a fixed edge cone.

It may be seen that the horn described is not a simple air volume resonator, but that it is a combination in a single instrument of a series of air resonators, a reflex horn, a straight horn, a curved horn, a re-entrant horn, and a resonating diaphragm or sounding board, and that it makes use of both multiple and cross resonance, all in the effort to secure as nearly as possible uniform tone amplification. Such a horn (designed as a radio loud speaker) 12 inches long and only 8 by 8 inches outside at the larger end gives sound volume and quality quite comparable to that produced by any other horn the author ever tested, regardless of size.

Within the last year or so many manufacturers, in order to satisfy what the writer believes is but a passing mood, have gone to the extreme in designing phonograph and radio horns to accentuate the lower tones. The "empty barrel" tones are over amplified, usually at the expense of the higher tones. Remembering that even a low tone has many *higher harmonics that must be amplified just as strongly as the fundamental* in order to give the tone its true quality, it is evident that over emphasis of tones of low pitch (or of any pitch) is something to be avoided. In the opinion of the writer that amplifier is best which most nearly reproduces the original sound, whatever be its character.