IMPROVED DESIGNS OF SOUND CONDENSERS.

ARTHUR L. FOLEY, Indiana University.

The writer has shown in former papers that a number of the generally accepted theories in regard to the passage of sound through tubes[1] and the action of horns[2] are not tenable. The theory that when a horn is used as a sound "condenser" all or even the greater part of the energy entering the large end is condensed at the small end is far from the truth. Sound waves do not pass through a horn, like shot or water poured into a funnel. The energy condensed at the small end of a conical or flared horn is not even approximately equal to that entering the large end. If the horn is one of large angle, the condensed energy is usually but a small fraction of the entering energy. The major part of the entering energy is lost by reflection; it backs out of the horn at the end it entered.

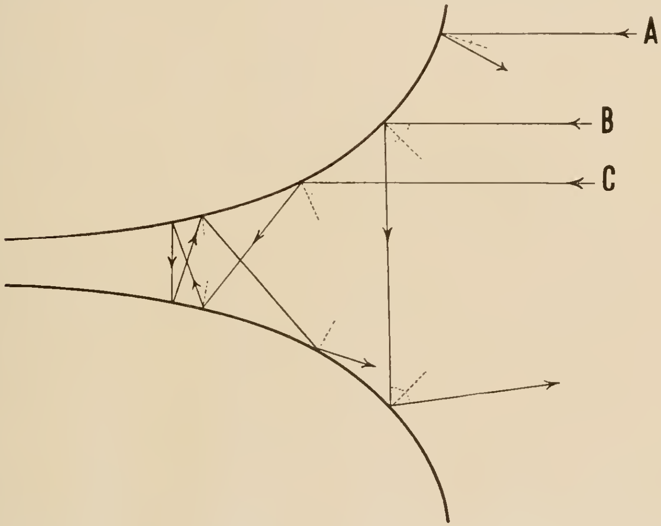

Fig. 1. Cross section of flared horn, showing how wave energy is reflected backward and out of the large end.

Owing to the fact that sound waves are long, compared to light waves, one can not—using sound reflecting surfaces of usual size, expect close agreement between optical and acoustical phenomena. Sound diffraction is a most disturbing factor. However, there is no reason why Huygen's theory should not be applied to determine the direction

[1] The Speed of Sound Pulses in Pipes. Phys. Rev., N.S., Vol. XIV., No. 2, Aug., 1919.

The Velocity of Sound Waves in Tubes. Proc. Ind. Acad. Sci., 1919.

[2] A Photographic Study of Sound Pulses Between Curved Walls and Sound Amplification by Horns. Phys. Rev., S.S., Vol. XX, No. 6, Dec., 1922.

"Proc. 38th Meeting, 1922 (1923)."

of the main portion of a reflected sound wave. For this portion of wave the law that the angle of incidence equals the angle of reflection is as true as it is in the case of light. The writer has proved this statement in the case of sound pulses from electric sparks, by photographing such waves in various stages of reflection from surfaces of several different shapes.

Let us apply the law to the case of a plane sound wave entering the large end of a flared horn, as in figure 1. The portion of the wave which is lettered A is reflected back and out at the end it entered, after but a single reflection. The portion lettered B backs out after two reflections, while C does so after six reflections. Reference to the photographs published in the author's papers referred to above, shows clearly and conclusively that this is exactly what happens. The data therein

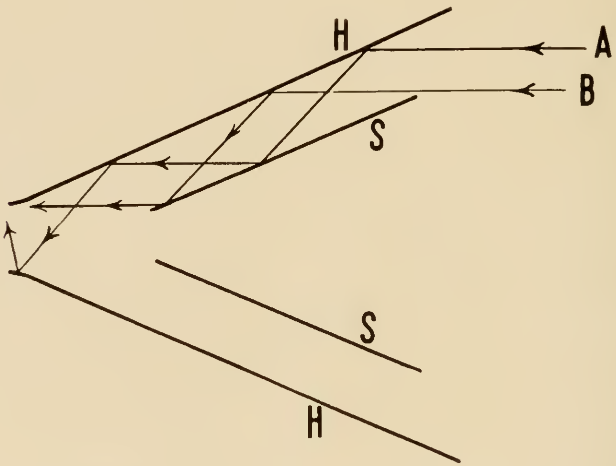

Fig. 2. Cross section of a multiple conical horn, showing how wave energy may be reflected to the small end of the horn, resulting in increased amplification.

published shows that a horn of wide angle "condenses" very little more energy than one of small angle.

Suppose now that we take an ordinary conical horn H, shown in cross section in figure 2, and place within it and coaxial with it a similar but smaller horn S. Then the portion of a sound wave A, instead of backing out of the horn after one or two reflections, is reflected first from the inner surface of the outer horn H, then from the outer surface of the inner horn S, then again from the inner surface of H, thence to the small end of the horn. Likewise, the portion of the wave lettered B, and therefore all portions of the wave between A and B.

To take care of the energy falling on the *inner* surface of the horn S, a third and still smaller horn may be placed within S, and so on. Thus, by using a number of nested, and spaced horns the energy condensed at the small end is materially increased over anything possible with a single horn.

The shape of the external horn is not necessarily conical, nor is it entirely arbitrary. It is determined by the use to which the horn is to be put, to its length, aperture, and small end diameter, to the distance to the sound source, to the extent it is desired to make use of the horn as a sound resonator, and to the pitch and quality of the sound to be amplified or condensed.

Figure 2 shows both horns, H and S of the same shape. This is not always the most efficient design. The shape of the outer horn having been decided upon, the inner horns are so shaped as to condense the maximum amount of energy at the small end. They are supported by radial strips of sheet metal placed with the plane of the strips parallel with the common axis of the horns, in order to give minimum interference to the passage of sound waves through the system.

The writer is still experimenting with multiple horns of different designs, in order to determine the one having the maximum efficiency. An account of this work, with data, will be published later.

LOCOMOTIVE WHISTLE EXPERIMENTS.

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A study of the amount of steam, and consequently the amount of coal, required to blow an ordinary locomotive whistle, the probable average time per day the whistle is blown, and the total number of locomotives in use, convinces me that we "pay dearly for the whistle". Is it not possible to reduce the cost and the coal waste?

In the first place, it would seem that the position of the whistle is bad. It is almost always behind the smoke stack, and frequently behind or at the side of the steam dome, bell or sand box. Sound shadows are not pronounced like light shadows. Nevertheless sound shadows actually exist. The intensity of the sound along the track in front of a locomotive is certainly somewhat lessened by placing the whistle behind the smoke stack or other objects. But it is much further reduced by the hot gases coming from the smoke stack, which act like a dispersing cylindrical lens. Moreover, the currents of hot air about the walls of the smoke stack and rising from the boiler are both absorbing and dissipating for sound energy. That such conditions are undesirable can not be questioned. The question concerns the magnitude of their effect. Is the reduction in the intensity of the sound along the track sufficient to warrant placing the whistle in front of the locomotive smoke stack, as is the case with the headlight?

A second question. Can one devise a sound reflector that will increase the sound intensity along the track where it is needed and decrease it in other directions where it is not only not needed, but is usually a nuisance?

It has been argued that sound waves are relatively so long that a reflector of ordinary size would have little or no effect. Certainly we should not expect results anything comparable to what we have in