AN INVESTIGATION OF THE FOLEY TELEPHONE MOUTHPIECE.

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One of the chief results of Dr. A. L. Foley's photographic studies of sound pulses through horns is the discovery that the condensing power of flared horns is considerably less than what has been taught by physicists heretofore.[1] The heretofore accepted theory is that the condensing power of such horns is inversely proportional to the areas of cross-section of the ends.[2] Researches by Foley, Cloud, and others at Indiana University have shown conclusively that such is not always the case. In fact, it was found that in flared horns there seems to be an

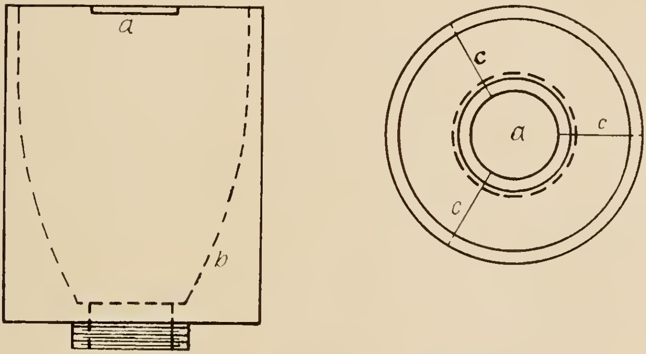

Fig. 1. Foley telephone mouthpiece.

actual "backing out" of some of the energy[3] which enters the wide mouth of the horn, instead of all passing through, as the old theory demands. It was also found that horns having a somewhat parabolic curvature as indicated in figure 1 seemed to have much greater condensing powers than those that are flared in the manner ordinarily found on telephone transmitters. The net result of all these studies was the Foley Telephone Mouthpiece shown in figure 1. As one would expect from the geometry of the parabola a marked advantage of this type of horn comes from the focusing effect of the curve. It was sensed that one very serious fault of the flared horn mouthpiece was the fact that all sound waves created in any instant did not arrive simultaneously at the diaphragm of the transmitter, due to the fact that some of them had to suffer reflections while others traveled directly in without impedence of any kind. This was overcome in the case of the Foley Telephone

[1] A Photographic Study of Sound Pulses Between Curved Walls and Sound Amplification by Horns. Phy. Rev., Dec., 1922.

[2] A. L. Kimball, College Physics. Revised Edition, pp. 196-197.

[3] *Ibid.* See 1.

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

Mouthpiece by suspending a small disc flatwise in the mouth of the horn as indicated in figure 1, *a*, so that all pulses striking the diaphragm would suffer one reflection, and therefore equal retardation. This improvement eliminates a large part of the buzzing and muffled tones common in telephones.

The arrangement of the apparatus used for taking the data in this report is indicated in figure 2, and is a modification of the "hook-up" employed by the Kellogg Switchboard and Supply Company in their common battery telephones.[4] A, A′ are telephone transmitters, shown in the diagram with the ordinary flared horn; R, R′ are adjustable resistances, R having a capacity of about 50,000 ohms and R′ about 10,000 ohms; L, L′ are induction coils (small telephone coils with cores); C is a

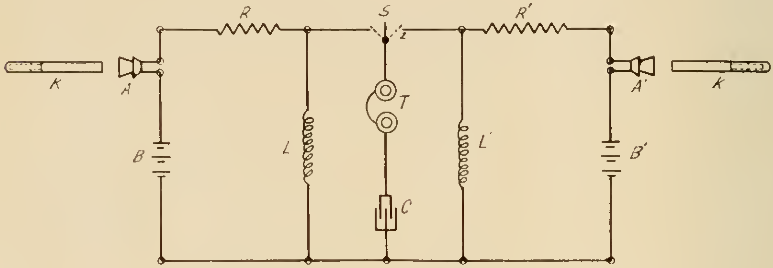

Fig. 2. Hook-up for the experiment.

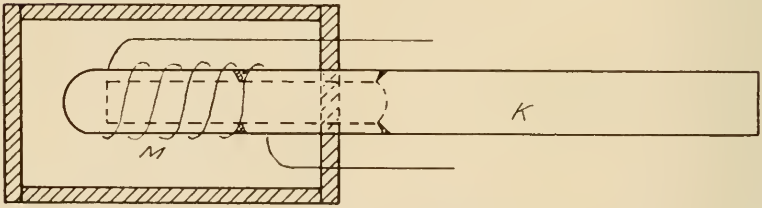

Fig. 3. Heating oven for Knipp Tube.

1/3 m. f. condenser; T a Baldwin mica-disc receiving set; B, B′ are 2 volt storage cells; and S is a double throw switch arranged so that either transmitter could be instantly thrown into the circuit.

In figure 3 are shown the details of the heating oven for the Knipp Singing Tube. M is a coil of three or four turns of No. 28 nichrome wire and was heated on the 110 volt circuit with about 5 amperes of current. The walls of the oven were made of asbestos sheeting, such as is ordinarily used to cover steam pipes, from which the hemp and sisal body had previously been burned so that it would not stain the glass tube. Knipp Tubes were chosen for the experiment because they came more nearly than any other sounding instrument to giving a point source of sound, while tests have shown that the tones[5] given off by

[4] "Principles of the Telephone," p. 99, by Jansky and Faber.

[5] New Standard of Sound Energy. C. T. Knipp. Phys. Rev., Feb., 1920. pp. 155-156.

them are almost pure. The tubes used in the experiments were so sensitive that it was only necessary to heat the wire to a dull cherry red temperature to make them sing in a smooth, loud tone. The especial advantage of the electric heating even over any open flame was that it gave an even temperature that did not seem to injure the tube by congealing the glass.

As would be expected, it was found that a proper balancing of the capacity and inductances in the telephone circuits gave the best results. Two common telephone coils at L and L′ against a 1/3 m. f. capacity at C seemed to give the best results of any arrangements tried.

Considerable experimenting with different telephone "hook-ups" was done before it was finally decided that the arrangement in figure 2 would be best for our purpose. The theory for the arrangement is as follows: With switch S on contact point 1 the circuit for transmitter A is complete. Any steady currents passing through transmitter A will pass unimpeded through the inductance L, but intermittent or A. C. currents would suffer considerable impedence. The intermittent or A. C. currents set up by the transmitter diaphragm will, however, readily discharge through the condenser and the receiver set. By this arrangement no direct currents flowing in the circuits ever disturb the receiving set T, but practically the whole energy of the A. C. currents created by the vibrations of the transmitter diaphragm will discharge through the condenser. You will notice that both the circuits A and A′ are just alike.

In taking data, one of the transmitters, assume in this case A′, was used as a reference transmitter. The tube K′ was set singing and resistance was "plugged in" in R′ until the sound was just audible in the receivers T, S being set on contact point 2. With this adjustment made the switch S was set on contact point 1 and the tube K set to singing. Resistance was now "plugged in" in R until no difference could be noticed in the intensity of the tone when the switch S was rapidly thrown from point 1 to point 2. (The tubes K, K′ were of practically the same pitch and as nearly the same size as it was possible to make them.) No change was made in the resistance R′ for any set of readings after once adjusted for minimum audibility. The first reading on each horn studied was made with the mouth of tube K just flush with the end of the horn on the transmitter A. Readings were then taken as the tube was moved back to various distances from the mouth of the horn. By placing different types of horns on the transmitter comparisons could be made of the relative intensities of the tones transmitted at any distance. In this research comparisons were made for *no horn*, ordinary *flared horn*, and the Foley Telephone Mouthpiece. The observations were made in an especially arranged, sound-proof room; the walls, floor, and ceiling of which were covered with felt about one inch thick. Long strips of this same felt about one foot wide were also cut and hung edge-wise along the walls and ceiling to break up any reflections that might occur. The singing tubes K, K′ were set at opposite ends of the room, a distance of about twenty feet, and the receiving apparatus was moved out into the adjoining hall. Observations were made at night, for noise during the day interfered with the hearing of the extremely low tones. All the curves shown have been checked on at least three different evenings and I am certain that the slope and relative intensities at the different distances are as nearly correct as the conditions of the experiment and the apparatus would permit.

Data:

No horn		Flared horn		Parabolic horn		Parabolic horn with disc	
D	R	D	R	D	R	D	R
0.0	30700	0.0	18000	0.0	33000	.5	20000
.5	17000	.5	13000	.5	26000	1.0	23000
1.0	8000	1.5	6000	1.0	23000	2.0	14000
1.5	7000	2.5	5000	1.5	21000	3.5	10000
2.5	4000	3.5	4000	2.0	20000	5.5	7000
3.5	3000	5.5	1600	2.5	18400	8.0	3000
5.0	2900	7.5	600	3.0	14000	11.0	1000
7.0	1400	11.0	200	3.5	11000	14.0	400
10.0	1000	15.0	000	4.0	7000		
13.0	200			4.5	5000		
16.0	100			5.0	4400		
				7.0	3000		
				9.0	2000		
				11.0	1000		
				14.0	1000		
				19.0	800		
				23.0	400		

Above is the data for the four curves shown in figure 4. D is the distance from the mouth of the horn to the nearest end of the singing tube. R is the resistance "plugged in" in the test circuit A to reduce the tone to the same intensity as that in the reference circuit A′.

It is noticed there is a marked superiority in the Foley Telephone Mouthpiece (parabolic horn) as is shown by the curves 3 and 4 (fig. 4), and that this superiority holds especially at the ordinary speaking distances of from 5 cm. to 10 cm. It was necessary to plug in almost twice as much resistance in the circuit at 5 cm. to reduce the intensity of the parabolic horn to minimum audibility as for the *No horn*, and the ratio is about 5 to 1 for the flared horn. This increased efficiency is probably due in no small part to resonance[6] in the horn and is as marked for the speaking voice as for the pure tone of the singing tube. When the small disc was inserted in the mouth of the horn so that the focusing effect was a maximum the efficiency was considerably increased for 4 cm. to 9 cm. as is shown by curve 4. This curve exhibits a freakish tendency to rise upward until a distance of about one centimeter is reached when the slope reverses and it drops off in a smooth curve. This tendency of the curve to rise for a short distance was probably due to the shielding effect of the disc when the source is near to it. The

[6] D. C. Miller. The Science of Musical Sounds. pp. 156-159.

high sensitivity of the *no horn* curve at zero distance is undoubtedly due to the fact that the diaphragm of the transmitter was almost adjacent to the tube so that the total energy given off at the source was almost all absorbed by the vibrating disc. The rapid falling off of the curves shows vividly how the energy falls off with distance out from the horn.

The apparatus was also used to make some investigations of the sound pattern about the mouth of the singing tube for which it seemed

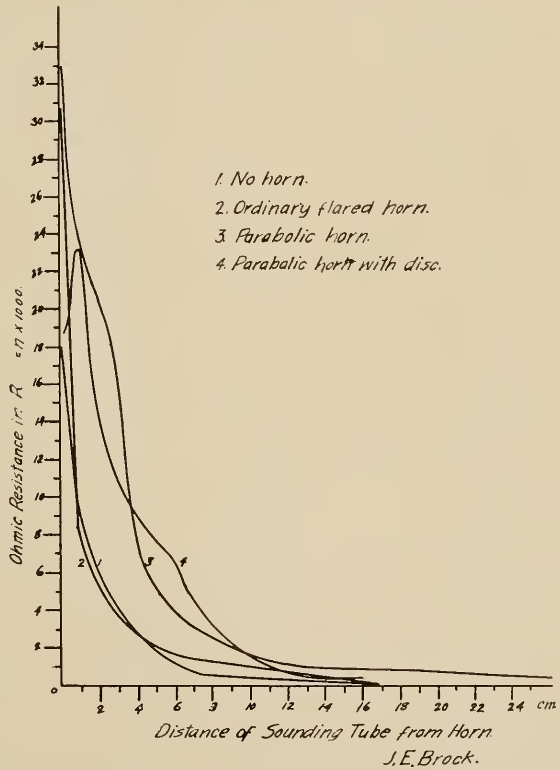

Fig. 4. Graph of curves showing superiority of the parabolic horn.

to be singularly well adapted. The energy given off by the singing tube seemed to be largely confined to a cone shaped region in front of the tube with the mouth of the tube at the apex. The boundaries of this sound cone seemed to be very sharply defined. It is hoped that in a short time enough data will have been secured so that more definite ideas may be formulated concerning the sound pattern of this cone.

In concluding I wish to express my thanks to Dr. A. L. Foley, of Indiana University, and Dr. C. T. Knipp, of the University of Illinois, for their kindly interest and many helpful suggestions offered during the progress of the experiments outlined in this research.