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THE VIBRATION OF AIR IN TUBES CAPPED AT BOTH ENDS*

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1. *H-tubes.*—The arrangement is shown diagrammatically in figure 1 (inset), where tAt' is the tube, $2R = 2$ cm. in diameter. A is extensible, but like the whole region air tight. T and T' are two common telephones by which the air columns are actuated, the switch C allowing of reversal of the current in T relatively to T'. The junction of t with the mouthpiece of T and of t' with T', are rigidly cemented. The far ends of t and t' are closed with perforated corks, through which the conical pin-hole probes s (salient) and r (reëntrant) are inserted. One of them (here s) communicates by a short end of rubber tubing with a shank of the interferometer U-tube. Curiously enough it makes little difference whether both s and r are joined with the corresponding shanks, or whether one, r or s, is open to the atmosphere.

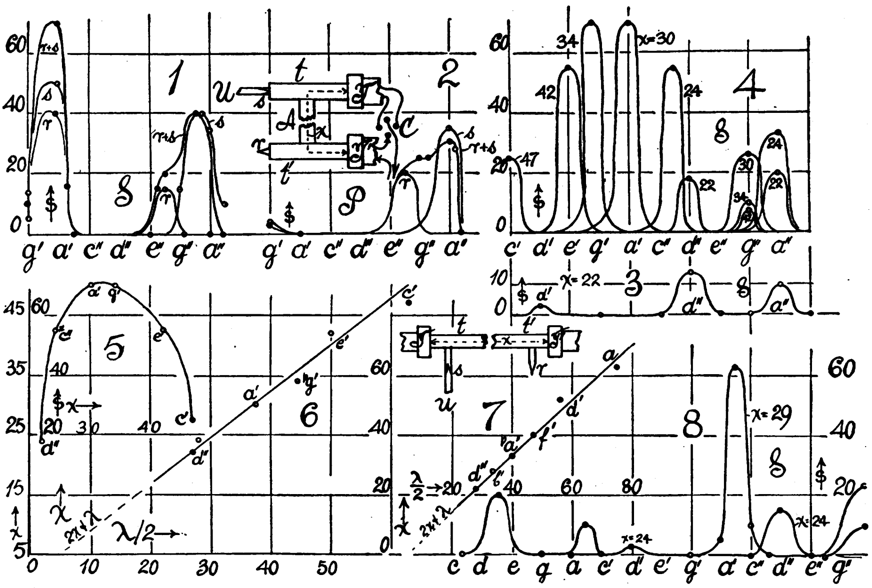
The telephones are energized by a small induction coil with a large resistance in circuit. A controllable break-circuit (electric siren) is in the primary.

In figures 1, 2, s denotes the fringe displacement of the interferometer U-tube and is proportional to the acoustic pressure generated at r, s (inset). S (sequence) shows that the telephone plates are vibrating in opposed phases, P that their phase is the same. The graph thus records the observed nodal intensities at the different frequencies (pitch) given by the abscissa.

To obtain the r curve, figure 1, the s pin-hole was plugged, and vice versa for the s curve; when both pin holes are used, the effect is here not quite summational at the g' to a' resonance; but it frequently is so. The upper separate resonances e''–g'', g''–a'' differ in pitch; consequently when r and s are used together $(r + s)$ there is an interesting multiresonance, or blend. One may note that for these wide tubes, $R = 1$ cm., a closed region shows acoustic pressure (curves r, s), even with a single pin-hole within.

In figure 1 the telephone plates are opposed in phase (sequence S), while figure 2 shows the corresponding results with the plates vibrating in phase (P). The g'–a' resonance has vanished, whereas the e''–g'', g''–a'' maxima retain their character except as to intensity. Consequently the g'–a' maximum must be associated with the axial tube length x (figure 1, inset) from plate to plate of the telephone. The upper (fixed) maximum will be found largely referable to the telephone.

Figure 4 shows what happens when the cross tube A (figure 1, inset) is elongated so that x = 22, 24, 30, 34, 42, 47 cm., in succession. The g''–a'' maxima remain relatively stationary, whereas the low pitch maximum moves from d'' to c'. In this march it passes an optimum of in-



tensity (x = 30–34), more fully exhibited in figure 5, which contains the relation of x and s. In figure 8 a more extended survey in pitch, for x = 24 and 29 cm. and from c to c''', is reproduced. In figure 3 the pin-holes r and s communicate with the atmosphere, while the U-tube is joined to the middle of A without a pin-hole. The registry of acoustic pressure is definite but low in intensity.

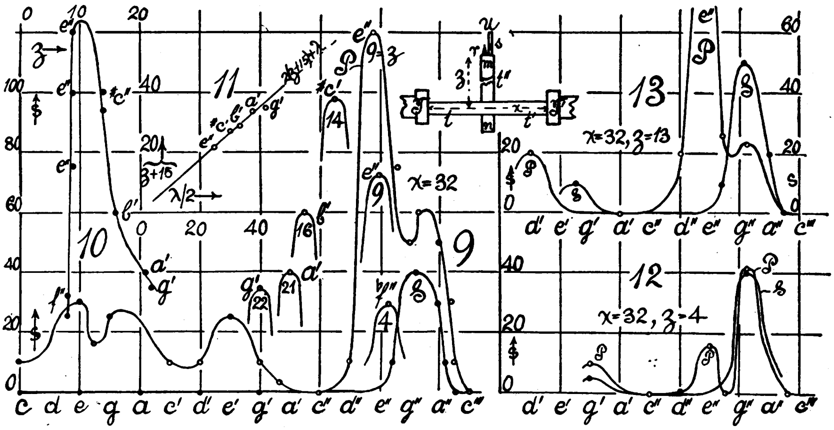
If the maxima of figure 4 be used to construct x in terms of the free wave length λ, the graph in figure 6 results, which is as nearly linear as anything else and equivalent to $2x = 0.79\lambda$. Thus there is a marked frictional effect[1] but no special frequency effect, such as would be anticipated theoretically.

Straight Tubes.—The adjustment is given diagrammatically in the inset, figure 7, r and s being the pin-hole probes very near the telephones

T and T'. The U-gauge is joined to s. The results, as a whole, were very similar to the preceding. I will only exhibit the relation of tube length x and λ which has the form $2(x + a) = b\lambda$, or $2(x + 4) = 0.92\lambda$, where a is the effect of the telephone mouthpiece expressed in length of tube. The coefficient here is considerably larger, a result to be anticipated since these tubes were both straight and smoother. Again there is no evidence of a special frequency effect.

Transverse Tubes.—The adjustment is shown in the inset, figure 13, T, T' being the telephone cemented to the straight tubes t, t', across the middle of which is the transverse tube mn of effective length z and carrying the pin-hole probes r, s at the m end, s being joined to the U-tube.

It is clear that the tube will now respond effectively when the telephone plates vibrate in phase (P). The S adjustment evokes the fixed telephone



resonance only. Examples of fringe deflection s in terms of pitch are given in figures 12 and 13, for $x = 32$ and $z = 4$ and 13 cm., the movable note being near e'' and tending toward an optimum. This is more fully shown in figure 9, in which the successive values ($z = 4$, 9, 14, 16, 21, 22 cm.) are attached to the maxima. The graph is fully worked out for $z = 9$ cm. for the P vibration. In the S vibration of the telephone plates, only the fixed g'' appears distinctly. Figure 10 is the (s, z) graph, indicating the very rapid tendency toward and from the optimum (max. s) as tube length increases. Finally in figure 11, the result $z + a = z + 15 = 0.88\lambda$ is exhibited. Thus since $a = x/2$ nearly, the vibration of the air column is from both T and T' plates toward m and return. The coefficient $b = 0.88$ agrees as closely with the preceding $b = 0.92$, as the ear can detect chromatically varying pitch.

* Advance note from a Report to the Carnegie Institution, Washington, D. C.

[1] Cf. Rayleigh's "Sound," Chapter IX, discussing the equations of Helmholtz and others.