NOTE ON OVERBLOWN PIPES.

PART I.

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SYNOPSIS.

Minimum Pressures to Excite the Fundamental Note and Octave of a Pipe with Lip at Various Distances from the Edge.—It is well known that as the blowing pressure is increased first the fundamental is excited, then the octave appears, then after an interval of beating the octave alone is heard. With the pipe tested (fundamental pitch 490), as the lip distance was increased from 8 to 12 mm., the minimum pressures for the fundamental and octave, respectively, increased from 0.4 to 0.9 cm. and from 2 to 25 cm. of Hg.

Change of Pitch of a Pipe with Blowing Pressure.—This phenomenon is well known. For a particular pipe, studied with the help of phonodeik records, the fundamental pitch increased from 490 to 505 as the pressure was increased from 6 to 32 cm. of water. For 50 cm. of water the pitch (octave) was 1052.

THE experimental data necessary for working out the mathematical theory of the fluid motion near the mouth of an organ pipe seem to be wanting. Whatever accounts we have are scattered and incomplete. The present note describes a few quantitative results on (1) The variation of pitch with increase of pressure, (2) The minimum pressure necessary to excite the fundamental and the octave at various distances of the lip from the edge. The effect of the increase of the blowing pressure is to increase the pitch and the intensity, quantitative determinations of which are given in a paper in the PHYSICAL REVIEW.[1] The change in pitch with increase of pressure has been determined by the late Lord Rayleigh.[2] He employed resonators to determine the rise of pitch with increase of pressure. In order to be more accurate it was thought best to dispense with resonators and employ a photographic method for the determination of the pitch. For this purpose the record of the aërial vibration was obtained by a Phonodeik simultaneously with the trace of a vibrating fork on a sliding photographic plate. The frequency was determined by counting the number of waves. The following table shows a typical case.

The amount of variation in pitch is the same as observed by Lord Rayleigh. The important point to be noticed in the table below is the jumping of the pitch to the octave and, further, it must be noted that

[1] PHYSICAL REVIEW, Sept., 1920.

[2] Scientific Papers, Vol. II, p. 92.

the frequency at 38 cm. of water is double that of the note just at the next lower pressure. At about 30 cm. of water the octave is clearly heard with the fundamental. With the rise of pressure the octave

Table I.

Distance of Lip from Edge .8 cm.

Pressure in Water Column.	Frequency.
6 cm.	490 Fundamental
10 "	495
20 "	500
32 "	505
38 "	1050 Octave
50 "	1052

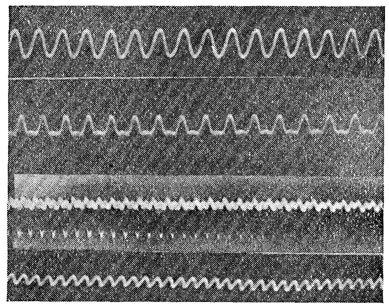
increases in prominence, and just before the note settles down to the octave only, there is beating as noticed by Raps,[1] Rayleigh and Lough.[2]

§ II. Experiments with Different Positions of Lip and High Pressures.

The lip was placed at different positions and made air tight. Compressed air was blown into the pipe, and the pressure near the mouth was recorded by a mercury manometer. It was found that the sequence of the phenomena is the same whatever be the position of the lip. The difference lies in the enormous pressure required to excite the pipe. We have observed in Table I. that the fundamental is elicited at a pressure of 6 cm. of water when the distance of the lip from the edge is about .8 cm. When the distance is 1.2 cm., the pressure necessary to excite the fundamental is 0.9 cm. of mercury (12.2 cm. of water). As the pressure is increased the pitch rises, but more slowly than the case when the lip was at .8 cm. from the edge. With the rise of pressure, the note develops its octave which is so strong that even an unaided ear cannot fail to detect it. As the pressure is further raised, the beat tone appears when on a slight increase of pressure the beat tone disappears, giving place to a steady octave. The necessary condition for obtaining the octave is the beat tone which is always obtained at a pressure depending upon the distance of the lip from the edge. Beyond the octave very little rise of pitch is obtained with increase of pressure. The addition of pressure increases the intensity considerably. In plate I. a few vibration curves which were obtained at high pressures are shown. Fig. 1 shows the fundamental, Figs. 2 and 3 show the gradual development of the octave clearly. Fig. 4 represents the octave which is more or less simple in character like the fundamental.

[1] Ann. der Phys., Vol. 1, p. 193.

[2] Phil. Mag., Jan., 1922, p. 72.



Figs. 1–4.

Fig. 5 shows the relation between the minimum pressures (ordinates in the figure) necessary to excite the fundamental at various positions of the lip. It will be observed that the minimum pressure increases slowly with increasing distance, then becomes rapid.

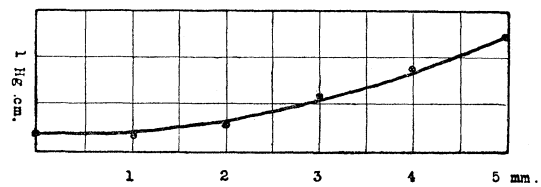


Fig. 5.
Origin representing .8 cm. from the edge.

Fig. 6 exhibits the relation between the pressure necessary to excite

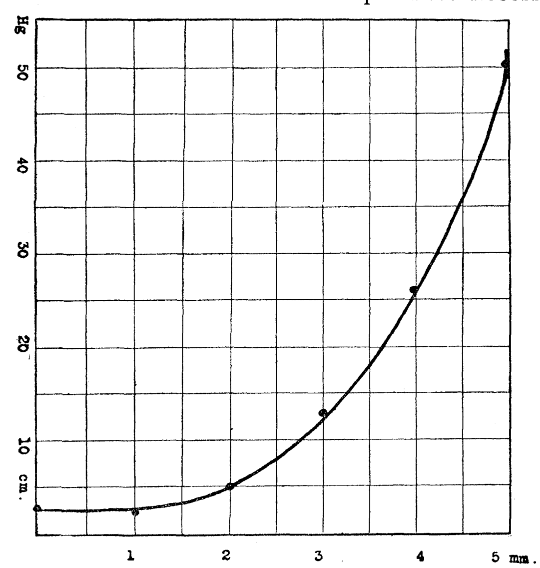


Fig. 6.
Distance of lip from the edge at the origin is .8 cm.

the octave at various positions of the lip. It is evident from the curve that the increase of pressure to change the note to the octave becomes greater as the lip distance increases. The curve is almost logarithmic to the distance axis.

§ III. Discussion of Results.

Since the rise of pitch with increase of pressure, the presence of the octave, and the beat tone, and finally the jumping to the octave, are quite general, *i.e.*, obtained at any position of the lip, it is evident that the hydrodynamical problem is quite definite. The fact that a certain minimum pressure is necessary to start the pipe, shows that the length of the air jet must be such as to allow it to flow past the edge. When the jet flows past the edge, it wafts to one side or the other delivering a puff at each journey. The maintenance is effected by the energy supplied by blowing. But this elementary view does not explain the gradual rise of pitch with increase of pressure. The effect of the increase of pressure is to produce a vortex motion whose effect is to diminish the effective inertia of the system, *i.e.*, the oscillating air jet, thus reducing the period. This qualitatively explains the rise of pitch. The presence of the octave and the beat tone can be explained on lines suggested by Lough.[1]

If we assume that the vortex motion has a certain natural period depending upon the pressure and decreasing with the increase of pressure then the phenomenon can be easily explained. Initially the period of the air jet is the same as that of the vortex pulsations. So that the two forces conspire, and produce the maximum effect. As the pressure rises, the period of the air jet decreases but more slowly than the pulsations, and in a short time they become discordant, when the fundamental is weakened. Finally the forces due to the pulsations excite in the pipe the next higher mode of vibration independently, *i.e.*, the octave, which becomes prominent, and the fundamental dies out. It will be observed from the above discussion that the pitch of the note on increase of pressure will jump to the octave of the note obtained at the next lower pressure.

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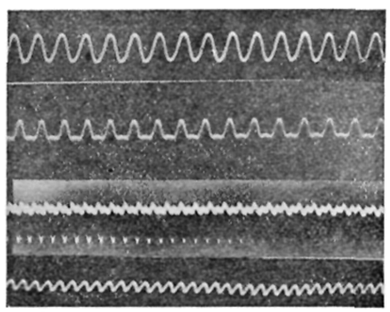
[1] Lough, loc. cit.



1

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3

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Figs. 1–4.