## A Physical Explanation of the Action of the New Singing Tube.

By Chas. T. Knipp and Jakob Kunz.

In the organ pipe energy is supplied by a stream of air which encourages the vibrations in a one-sided way, so that the vibrating column receives an impulse each time when the air moves upward towards the node in the middle of the pipe, and receives no impulse in the opposite motion. It looks as if a pendulum were kept in oscillation by receiving at one end of its path an impulse always in the same direction. If we would apply the momentum of the air jet at the center of the tube, vibrations of the column would be discouraged.

We can communicate momentum to a vertical open-air column by heating it. If we heat the air in a tube by a wire net placed in the lower half of the tube, we will obtain a uniform current of air upwards. If the air is vibrating then as it is moving inward its vibration is increased by the momentum of the upward stream of air, but not increased by moving downward. When we place the hot wire net in the middle of the tube it will tend to increase the pressure of the gas when it is a minimum, *i.e.*, it will discourage oscillations. The same will happen when we place the hot net above the middle. In order to encourage oscillations we have to add momentum in a position and at a moment such that the pressure in the node increases more than it would do because of the oscillations alone. If we put the hot wire net at the lower end of the tube, *i.e.*, in a loop, the effect will be very small or zero. The transfer of heat will depend upon the temperature of the air in contact with the wire net, being greatest when the temperature is lowest. But the temperature in the loop at the lower end does not vary, therefore, the transfer of heat in this position of the gauze does not give rise to oscillations. It tends only to raise the temperature of the gas uniformly. *Heat must therefore be applied between a loop and a node.*

If we cover the upper end of the tube, with the hot net in the most favorable position, the sound ceases, and if we heat by means of a Bunsen burner the outside at the top, we get no sound. This was considered by Rayleigh[1] as possible. But if we change the cross section of the tube at its middle, making the upper, closed part of larger diameter, then the tube will emit a sound. The pressure in the upper half of the tube will increase, partly because the air is heated, partly because of the condensations of the air in the node on the top. The air will expand and now the expansion in the narrow neck is aided by the air being heated by the wall. Here the oscillations are encouraged because each time when the air is expanding by the oscillation the expansion is increased by the heat. In each cycle the vibrating particle receives one push in the right direction. It is this one-sidedness of the action which encourages the oscillations. Moreover, as the heat here has the tendency to increase the pressure near the node, the oscillations will start very readily. A slight modification of this experiment is the glass blower's bulb with a long open

[1] Theory of Sound, Vol. II., p. 231.

neck below, which emits a sound when heated round about the neck. Instead of making the lower part of the tube narrower, we might have an annular area take the place of the narrow tube. Various other modifications are considered. In all cases, in the organ pipe, in Rijke's experiment (the second case) and in the other tubes, the oscillations of a column of air are maintained by a one-sided addition of momentum at the right moment and in the right place.

These experiments belong to a large variety of phenomena in which a direct motion is transformed into a periodic motion, electrically speaking, where direct current is transformed into an alternating current.

University of Illinois,
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## Theory of Acoustic Wave Filters: The Limiting Frequencies of Transmission.

By G. W. Stewart.

In a former abstract[1] the writer presented the description of an acoustic wave filter and an approximate formula for its cut-off frequency. The theory has been slightly modified and has been extended to include three types of filters.

*Definitions.*—Using complex notation, *acoustic impedance* is the complex ratio of the pressure difference applied and the rate of change of volume displacement.

If $X$ is the volume displacement, $P$ the difference of pressure applied in a portion of the line, the definitions of the inertance, $M$, and the capacitance, $C$, are as follows:

$$\frac{Md^2X}{dt^2} = Pe^{i\omega t}, \qquad \frac{X}{C} = Pe^{i\omega t}.$$

*Assumptions.*—The chief assumptions are as follows:

Any portion of the system consists of mass and stiffness and hence the volume displacement with a sinusoidal applied difference of pressure can always be expressed by $Ie^{i\omega t}$, wherein $I$ is complex.

The algebraic sum of the volume displacements at any junction is zero.

In the practical construction a short line is equivalent to an inertance and capacitance connected in parallel.

*Results.*—At least three filters are practicable, the single-band-pass filter, the low-frequency-pass filter and the high-frequency-pass filter. The following are the limiting frequencies of zero attenuation, for all three types:

$$f_1 = \frac{1}{2\pi}\sqrt{\frac{1}{M_2C_2}}, \qquad f = \frac{1}{2\pi}\sqrt{\frac{M_1 + 4M_2}{M_1M_2(4C_1 + C_2)}}.$$

All of these filters have been constructed and found to test out in remarkable agreement with the approximate theory.

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[1] Phys. Rev., March, 1921, p. 382.