AN ORGAN PIPE SONOMETER.

By W. LECONTE STEVENS.

The discussion of just intonation in connection with the development of the laws of vibration of stretched cords does not occupy much time in the usual course of instruction in acoustics, partly because it is considered as the musician's specialty, and partly on account of the tedious tables of vibration numbers to which the student's attention must be invited. The subject in its relation to the intonation of chime-bells has been well presented quite recently in this jonrnal by Mr. John W. Nystrom.* Some time ago I devised a method of presenting it with the aid of the sonometer, by adjusting division marks on one edge of the sound board to give the proper cord lengths for the natural scale, and on the other edge for the scale of equal temperament. In doing this no attempt was made to adjust the cord lengths of the tempered scale to produce vibration numbers in arithmetical progression with constant differences in different portions of the octave, as recommended by the Stuttgart Congress and criticised by Mr. Nystrom. I deduced the formula, and calculated by aid of logarithms a table of vibration numbers and cord lengths, identical with part of what Mr. Nystrom has just published, assuming that the geometric ratio,

$$r = \sqrt[12]{2} = 1{\cdot}059462,$$

which I had readily obtained, was in general use.† The reciprocal of this,

$$r' = {\cdot}943877$$

gives the common ratio for the geometrical series of cord lengths, by which the twelve semi-tone intervals of the scale of equal temperament are secured. My sonometer was described at the Cincinnati meeting of the American Association for the Advancement of Science, a brief abstract of the description having since been incorporated in the journal of proceedings. The instrument has been still further improved, and a description may now be worth giving.

The resonance-box consists of a double organ-pipe made of spruce,

* This journal, May 1882, p. 367.

† Airy on sound, p. 224. Macmillan, 1871.

which is rested horizontally on the lecture table. The two embouchures are on opposite sides, one being turned toward the operator, as in Fig. 1. The air-blast, from either the lungs or a pair of bellows, may be forced into either one or both pipes at will through India rubber tubes. The interior dimensions of each pipe are 52 mm. by 62 mm., the length being adjusted to give as fundamental note, C, 132 vibrations per second; the effective length is hence a little over 125 cm., which is the length of the sonometer. At the side of the open end of one pipe is a sliding plate (a), by which it may be thrown out of unison with the other, thus producing beats. A stop may be thrust, by means of its handle, half way into one of the pair, converting it at will into a stopped pipe whose fundamental is the same as that of the open pipe of double its length. The union of double organ pipe

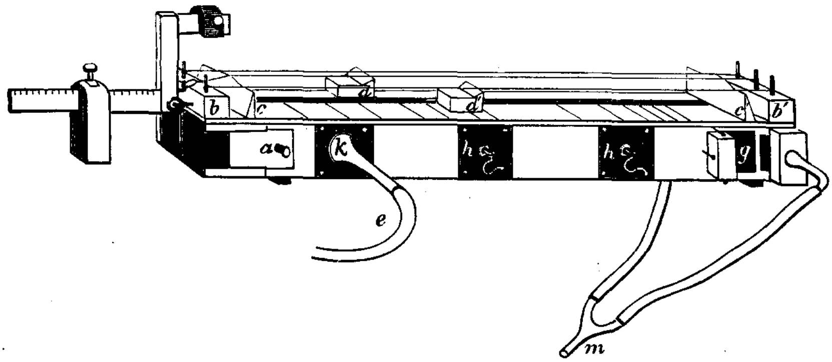

Fig. 1.

with sonometer is attended with some advantages, particularly in connection with the exhibition of Bernoulli's laws, since every note of the harmonic series can be secured with certainty from the stretched wire; and if this be tuned into unison with the fundamental of the organ pipe, a ready standard of pitch is close at hand for comparison with the corresponding harmonics of the organ pipe, which are not always obtained with equal ease, or with entire purity of tone.

The upper wall of the double pipe consists of a single plate of spruce, 5 mm. thick, that forms the sound board of the sonometer. Firmly fixed at each end is a block of hard wood (b, b'), into which piano pins have been driven for attachment of three steel wires which pass over the fixed bridges (c, c'). The latter are exactly one metre apart, in contact with the ends of a strip of wood divided at each edge into millimeters, and occupying the middle of the sound board. Such a strip may be obtained for a trifle from the American Metric Bureau; it not only serves as a guide for the movable bridges (*d d′*), but makes it easy to mark off the division lines at their proper places. A longitudinal line divides its surface into two equal parts; that on the side toward the operator is marked off to give cord lengths for the natural scale, by changing the fractions $\frac{8}{9}$, $\frac{4}{5}$, $\frac{3}{4}$, etc., into decimals. The results are indicated, correct to three places, on the millimeter scale. Three octaves in succession are thus marked off: the lines for the first octave extending across to the edge of the sound board, as in Fig. 2, which represents a part of the instrument viewed from above. By multiplying each of these lengths successively by $\frac{135}{128}$ and $\frac{128}{135}$ we obtain cord lengths for the chromatic intervals of the natural scale. These are marked off for two octaves, the lines extending half way to the edge. The other side of the central strip (*e e′*, Fig. 2) is marked off through two octaves, to give cord lengths for the scale of equal temperament. There are hence 21 division lines to each octave on one side, and 12 on the other side of the central strip.

Of the three wires, the two outer ones are kept permanently unisonant, or as nearly so as possible, sounding the same note, C, as the fundamental of the organ pipes. That in the middle terminates at the left in a stiff ring, so as to be detached in a moment from the hook against which it is ordinarily kept pulled. The ring may then be attached to a hook projecting from a bent lever, such as is employed with the sonometer constructed by Mr. Ritchie, of Boston, to show the law of variation in tension.

Since the tension of the outer wires is kept constant, each division mark in both natural and tempered scales is distinctly labeled, as shown in Fig. 2. The movable bridges are painted black at their front edges, so as to contrast strongly with the white spruce on which they slide. Suppose the bridge, *d′*, to be adjusted so that its wire sounds E of the natural scale, while its companion, *d*, is adjusted to give E of the tempered scale. The difference in pitch is nearly a comma, and can be detected at once by a good ear. But this is additionally made visible by turning the sonometer toward the audience and resting it on its narrow side; the difference in position of the two bridges being easily detectible even when the ear fails to distinguish between the two sounds. Every note in the two scales can thus be compared in a few moments, starting with C as key note.

The necessity for temperament, and yet the unavoidable error of a tempered scale, is still better shown by taking some derived key for comparison; for example, that of G. For this purpose a separate strip (*f*, *f*,′ Fig. 2), properly marked off, is placed at the side of the central strip, the movable bridge being grooved below to slide over it. It is prepared by marking a strip whose length is $\frac{2}{3}$ metre at distances $\frac{8}{9}$, $\frac{4}{5}$, $\frac{3}{4}$, $\frac{2}{3}$, $\frac{3}{5}$, $\frac{8}{15}$, $\frac{1}{2}$, and then discarding the unmarked half. Placing the initial extremity of this scale in contact with the division mark, G, of the tempered scale, which in this case sensibly coincides with that of G on the natural scale, it is seen that the second note, if correctly tuned, would be a trifle higher than tempered A, and decidedly higher than natural A; the third would be lower than tempered B and unisonant with natural B; the fourth unisonant with both tempered and natural C, etc. Such a strip can be constructed for each one of the derived keys employed in music, though the principle is sufficiently shown with but one.

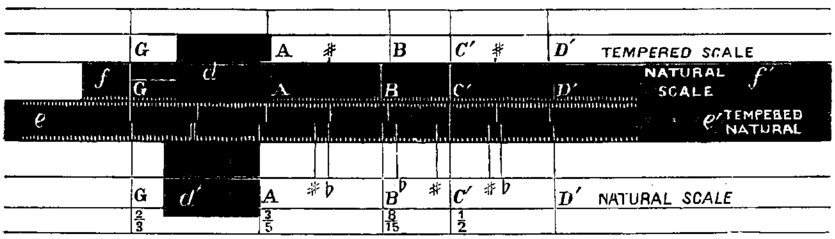

Fig. 2.

The division marks, $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, $\frac{1}{5}$, $\frac{1}{6}$, etc., each labeled with the name of the corresponding note, C′, G′, C″, E″, G″, etc., as well as with the figures composing the fraction, render it easy to obtain with quickness and accuracy the first dozen notes of the harmonic series, besides facilitating experiments on co-vibration.

To obtain the harmonic series from the open organ pipe it is found convenient to modify the size of the embouchure, and also the diameter of the pipe. For this last purpose a piece of wood, 120 cm. long, 6 cm. wide, and 2 cm. thick, is thrust into the pipe next the operator, thus diminishing the volume of air set in motion, and increasing the ratio of length to width. A sliding plate (*g*, Fig. 1) of thin sheet-iron serves to narrow the embouchure at will. Eight or ten successive notes of the harmonic series are thus secured and compared at the same time with those obtained by aid of the wire and labeled scale.

The stop can then be thrust into one pipe, and several of the odd series of harmonics elicited.

The wall of the pipe next the operator is perforated with three small holes, at distances approximately $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, from the open end. These are kept stopped with plugs, which may be removed at will. Immediately around them the wall is covered with sheet rubber (*h, h,*) to secure an air-tight fit for the mouth of the funnel (*k*) from which a tube (*l*) conveys waves to a manometric capsule. The position of nodal points in the air column is thus shown. By fitting the tube (*l*) upon a Y-tube, like that shown at *m*, and interposing between this and another Y-tube a pair of India rubber tubes, one of which is longer than the other by a half wave length, making allowance for friction, the apparatus is readily utilized for illustrating interference, with the aid of the manometric flame.*

New York, May 4, 1882.

ANALYSIS OF HELVITE FROM VIRGINIA.

By Reuben Haines.

[Read before the Chemical Section, Franklin Institute, May 2, 1882.]

The writer was requested by Mr. Henry Carvill Lewis to analyze a mineral he had lately found among others at the mica mines, near Amelia Court House, Virginia, a locality which has become remarkable for its rare minerals. It appears to be Helvite, a rare mineral hitherto found only in Europe; in Saxony, Norway and Finland. It is a silicate of glucina and manganese, containing ferrous sulphide and manganese sulphide. It occurs in yellow crystals and crystalline masses associated with orthoclase and garnet.

The following mineralogical determinations were made by Mr. Lewis. The crystals were shown by the polariscope to be isometric, but were not sufficiently perfect for angular measurement. Hardness about 6; color sulphur yellow; lustre somewhat resinous; partially translucent; fusibility about 4, with intumescence to a brown glass. The mineral gives no water in closed tube; with fluxes reacts for manganese; soluble in hydrochloric acid with evolution of hydrogen sulphide and separation of gelatinous silica.

The specific gravity which I determined myself was 4·306.

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* We are indebted to *Am Jour. Science and Arts* for the use of the cuts illustrating this article.