# 18.

## ON SYAKUHATI.

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*Syakuhati*, one of the popular Japanese wind-instruments, derives its name from its length, being 1 *syaku* and 8(*hati*) *sun* for the key *itikotu* (d). It is cut from a well-seasoned bamboo near its root, such that the both ends correspond to the knots. Interior of the pipe which slightly contracts toward the lower end is cleared of the partitions at the knots and well varnished. The pipe usually curves forward slightly. The front edge of the upper end is partially cut down with an angle of about 30° to the direction of the length, forming a sharp knife-edge. In playing, the upper end is applied between the lower lip and the chin so that a narrow arcuate aperture is left between the lip and the knife-edge to which the jet of air from the mouth is directed. Among five lateral openings, the uppermost one is situated on the rear and the rests on the front side of the tube.

*Syakuhati* is to be considered as a form of organ-pipe whose effective length is varied not only by means of the five lateral openings as in other wind-instruments of the kind, but also by adjusting the area of the mouth at which it is blown. The latter adjustment which characterizes this pipe is usually made by changing its inclination relative to the player's head, thus causing the change of the aperture between the lip and the edge of the pipe. The angle through which this adjustment can be made is ca. 10°, producing the change of note of about a whole tone. By means of this peculiar adjustment, the instrument may speak in any note within its limits, notwithstanding the small numbers of the lateral openings. In this respect, *syakuhati* is to be compared to a string instrument rather than

the pipes and flutes of the kind.

How much the note of this pipe is influenced by the change of the area of the mouth, may be shown by the following simple experiment. The mouth of the pipe is brought to the lip as in the playing; bring a proper vibrating tuning-fork near the mouth and adjust the aperture till the resonance is maximum. If the pipe be slightly inclined from this position, or if we move the lower lip, the resonance at once falls.

For ordinary organ-pipe of circular section, the addition of the effective length due to the ends is, according to the result of CAVAILLÉ-COLL, $3\frac{1}{3}\,R$, where $R$ is the radius of the pipe. Lord RAYLEIGH pointed out that the chief part of it is due to the mouth at which it is blown. In the case of *syakuhati*, this opening is very narrow, being an arcuate passage between the lip and the sharpened edge of the instrument, so that the addition of the length due to the mouth may be expected to be very great. Indeed, as may be seen later, it is more than ten times the radius of the pipe.

Instead of experimenting with the pipe directly, the following case was investigated, which is essentially similar to the actual one and convenient for studying the effect of the mouth only, apart from the complicated influence of lateral openings.

A glass tube of 4 cm inner diameter was fixed vertically, whose upper end was open and the length of the air column inside could be adjusted by means of water in the lower part of the tube. A thin plate of zinc, 0·4 mm thick, was brought on the open end to cover the opening partly, leaving a segment between its straight edge and the side of the tube. In order to secure the close contact between the plate and the polished end of the pipe, a small quantity of grease was used. The area of the opening was calculated from the arrow of the segment which was measured by a glass scale.

A series of tuning-forks were successively brought near the opening,

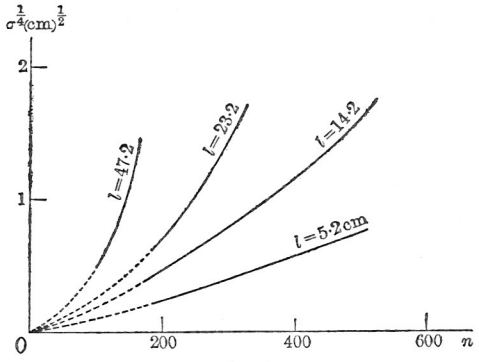


Fig. 1.

the zinc plate was adjusted till the resonance of the tube is maximum and the length of the arrow was measured for each fork. Next the length of the pipe was changed and similar experiment was repeated. The result of the experiment is to be seen from Fig. 1, in which $n$ denotes the number of vibration per second, $\sigma$ the area of the opening and $l$ the length of the air column. From the diagram it is to be noticed that as long as $l$ is small, $n$ varies very nearly with $\sigma^{\frac{1}{4}}$.

The pitch of a simple resonator whose three dimensions are comparatively smaller than the wave-length and which communicates with the external atmosphere by a small opening in its surface, has been investigated by many eminent physicists. HELMHOLTZ obtained theoretically for a circular aperture,

$$n=\frac{a\sigma^{\frac{1}{4}}}{2^{\frac{1}{2}}\pi^{\frac{5}{4}}S^{\frac{1}{2}}},$$

where $S$ is the volume and $a$ the velocity of sound in air. SONDHAUSS obtained experimentally

$$n=52400\,\sigma^{\frac{1}{4}}S^{-\frac{1}{2}}.$$

These results have been discussed by RAYLEIGH in his classical paper on resonance. Though in the present case, the length of the pipe is by no means small compared with the wave-length, it is to be observed from the above result that for $l=5$ cm, $n$ is very nearly proportional to $\sigma^{\frac{1}{4}}$. For somewhat greater values of $l$, the curves are nearly straight and seem to converge toward the origin with a small curvature. On the other hand, the diagram showing the relation between $n$ and $l^{-\frac{1}{2}}$ for different values of $\sigma$ presents a similar aspect; the curves which are nearly straight in the region investigated, seem to converge with a slight curvature toward the origin.

If the above result may be applied to the actual case of *syakuhati* with a proper modification, we may deduce approximately the mode of aereal vibration in this pipe and the influence of several lateral openings in the following manner.

The pipe investigated was of the following dimensions: length=49·2 cm; mean inner diameter=1·9 cm; diameter of lateral openings=0·8 cm; length between the mouth and the centres of lateral openings=23·4, 28·3, 33·3, and 38·2 cm. Now, closing all lateral holes, the note is about $C_1^{\#}$ for a moderate area of the mouth, so that the correction for the length due to the mouth is about 10·2. It is well known that for a similar resonator the pitch is inversely proportional to its linear dimension, so that the above result may be reduced to the case of *syakuhati* if $n$ and $l^{-1}$ be multiplied by

(diameter of the glass pipe)/(diameter of the *syakuhati*) and $\sigma^{\frac{1}{2}}$ by (the same ratio)$^{-\frac{1}{2}}$. From the diagram thus reduced, we find the value of $\sigma$ for which $\frac{\lambda}{4}-l$ for $C_1^{\#}$ is about 10·2 cm. Trace the curve $l$ to $n$ for this value of $\sigma$, whence the correction for the mouth corresponding to different notes is obtained. In this way, the distance $N$ of the apparent node from the mouth is determined.

$$N=\frac{\lambda}{4}-\left(\frac{\lambda}{4}-l\right)=l.$$

$N+\frac{\lambda}{4}$ from the mouth gives the position of apparent loop for each note. Distance of this loop beyond the opened hole is to be regarded as the correction due to the opening.

Among various combinations of the five lateral openings, a number of cases were investigated which are shown schematically in Fig. 2.

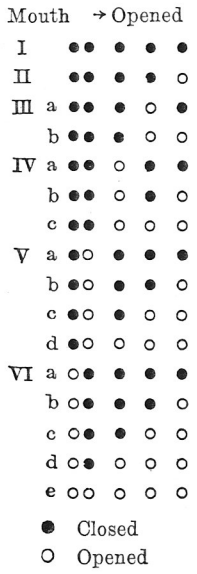


Fig. 2.

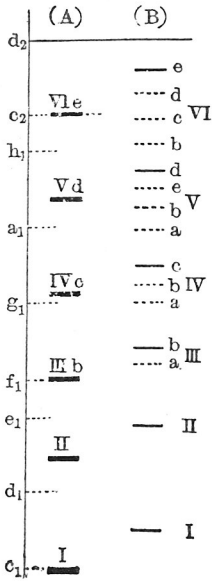


Fig. 3.

Corresponding pitches are also tabulated in Fig. 3, in which the column (A) corresponds to the narrow mouth and (B) to moderately wide one. It will be seen from this table that the opening of another hole nearer to the open end raises the pitch by about a quarter of a whole tone. Corresponding positions of apparent nodes and loops are as follows:

Here $d$ denotes the distance between the centre of the opened hole nearest to the mouth and the apparent loop. A glance at the table will show that the addition of the length due to one hole only diminishes as the hole approaches the open end of the pipe. Opening of another hole nearer to the open end diminishes this addition by ca. 1 cm. These facts may be explained qualitatively by considering the reduced resistance due to the introduction of another hole near the principal one. The complete explanation, however, must be postponed till the action of lateral opening has been thoroughly studied.

| Position of holes | $N$ in cm | $d$ in cm |
|---|---|---|
| I | 20·4 | — |
| II | 17·6 | 5·0 |
| III a | 15·6 | 5·3 |
| b | 15·1 | 4·6 |
| IV a | 14·0 | 6·8 |
| b | 13·4 | 5·7 |
| c | 12 8 | 4·9 |
| V a | 12·0 | 7·8 |
| b | 11·5 | 6·5 |
| c | 10·9 | 5·3 |
| d | 10·2 | 4·2 |
| VI a | — | — |
| b | 9·8 | 6·9 |
| c | 9·3 | 5·8 |
| d | 8·8 | 4·8 |
| e | 8·3 | 3·8 |

The fact that in *syakuhati* the change of the *interval* of the note, *not* the *difference* of $n$, due to a given change in the mouth, is nearly the same for different position of lateral openings, corresponds to the result of our experiment with the glass tube that the longer the tube the steeper is the curve $n$ to $\sigma^{\frac{1}{2}}$.

The above should be regarded only a step toward the solution of the complicated problem respecting the aerial vibration in the instruments of the kind.