44. Further Studies on the Acoustical Properties of the Japanese Wind Instruments, Syakuhati.\(^1\)

By Jūichi OBATA and Takehiko TESIMA.

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In a previous paper\(^2\) one of the present authors published the results of investigations on the tone-colour of the syakuhati, a very popular Japanese wind instrument. The sound of the syakuhati was found to contain a full series of harmonics, differing in this respect from the sound of a flute, which is known to be very simple, consisting mainly of the fundamental and a very weak octave.

In playing the syakuhati it is held vertically, the upper end, which is bevelled to a sharp knife-edge, being placed between the lower lip and the chin, and a jet of air directed to it from the player’s mouth. Thus, the upper end, the embouchure, is partly closed by the player’s lip. In the present experiment the instrument was held horizontally and blown artificially by compressed air using a special blowing contrivance, the embouchure being partially closed with a wedge-shaped piece of wood. After several trials with the shape and the size of the opening of the blowing pipe, as well as with its inclination to the embouchure, a rich tone, almost the same as those in actual playing, could be produced.

A condenser microphone or a Siemens Stabmikrofon were employed to record the sound-wave or to measure the sound intensity, and (1) the directional properties of the various components of the sound, and (2) the relation between the tone-colour and the blowing pressure were investigated.

The syakuhati is rotated about an axis perpendicular to its length, the microphone being placed in a fixed position, and the amplitudes of the various components were determined by analyzing the recorded sound-waves. It was soon found that the sound is emitted from both ends of the instrument. Thus, the sound field around the syakuhati consists of the effects of two sound sources which are always separated by half a wave length and have phases, either the same or opposite,

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according to the order of the harmonics. For the fundamental and odd harmonics the two sources are always in phase, while for even harmonics they are always out of phase. Besides this phase relation of the sources, phase-difference is further created, by the path-difference from them, between the effects at any point due to the two sources.

Figs. 1 and 2 show the directional properties of the sounds of the "ro" tone and the "ti" tone. The former (approx. pitch: d¹) is produced by closing all the lateral holes, and the latter (approx. pitch: a¹) by opening the three lower lateral holes. Polar curves at two distances, 65 and 100 cm. from the middle point of the pipe, are given, the length of the radius vector indicating the magnitude of the amplitude.

Briefly speaking, the sound intensity is distributed nearly uniformly all round for the fundamental, while for the even harmonics it shows so-called 8-figure pattern, owing to the fact that the effects due to both sources cancel out on the line that bisects the pipe perpendicularly.
Thus, it will be concluded that as the directional properties of the various components of the sound of the syakuhati differ according to the order of harmonics, the tone-colour of the instrument should differ with position. Hence, in broadcasting the sound of the syakuhati, special care should be bestowed on the position of the microphone. No such characteristic will be found in the sounds of a flute.

Fig. 3 shows the acoustic spectra of the “ro” tone for various blowing pressures. As shown in the upper two spectra, at pressures below 3.45 cm, water-column, the recognized pitch corresponds to the fundamental tone, notwithstanding the very small intensity of the fundamental itself (about 10% of the second harmonics in amplitude). By increasing the pressure the pitch jumps suddenly to the first overtone, and the spectra as shown in the lower two figures are obtained. Only those components which are multiples of the first overtone, not the multiples of the fundamental, are perceptible; the recognized pitch in this case, being of course, the octave of the “ro” tone.

![Fig. 3. Effect of the blowing pressure (Distance 65 cm. 30°).](image-url)