REPORT ON THE CONSTRUCTION OF A VOWEL ORGAN[1]

By E. W. SCRIPTURE

The attempt to construct an organ that could sing the vowels took its rise in connection with work on curves of speech and experiments in the production of artificial vowels. The Helmholtz theory that the physiological action in the vowels consists in reinforcing overtones of the glottal vibration was rejected because it had been proved to be incorrect by the results of analyses of vowel curves by Professor Hermann of Königsberg, and myself. Work was begun on the Willis-Hermann theory, namely, that a vowel consists of a resonance tone aroused by a series of sharp puffs from the glottis. The action of the glottis in producing sharp puffs and not smooth vibrations was supposed to be similar to that of striking musical reeds. The reed portion of a vox humana pipe was accordingly placed in connection with a bellows.

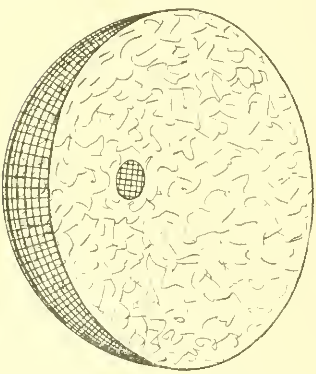

FIG. 56.—Wire frame with cotton for half of spherical water resonator.

A previous investigation had made it evident that a hitherto neglected factor must be introduced into any vowel theory, namely, the softness of the wall of the resonator. A reed pipe will respond only when the pipe cavity is harmonic to the reed; the vocal cavities would respond only to overtones of the glottal tone—if they were made of metal. The walls of the cavities are, however, soft and inelastic; it was necessary, therefore, to imitate this property. Water resonators were first used. To obtain spherical water resonators, wooden forms were made into which wire netting was pressed; the resulting series of pairs of wire hemispheres were lined with absorbent cotton (figure 56). For use the resonators were dipped in water; the cotton had

[1] This is the first report submitted by Professor Scripture on the results of his experiments on the subject indicated in the title. The researches were conducted under the auspices of the Smithsonian Institution, by the aid of a grant from the Hodgkins Fund.

absolutely no acoustic effect and the resonators were in fact hollow spheres of water. A more convenient form is the cubical water resonator built on a wire cube (figure 57).

These resonators were placed in succession above the reed with the result that a harsh *u* as *oo* in *boot* or *a* as in *father* could be obtained.

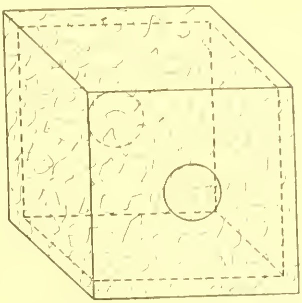

FIG. 57.—Wire frame with cotton for cubic water resonator, or with flesh.

The next step was to remove the harshness. This was accomplished by trying reeds of various kinds—mahogany, ebony, oak, cedar, hard rubber, celluloid, etc. With an ebony reed a pure and beautifully musical *u* and *a* could be obtained.

This result, however, was entirely independent of the size and character of the resonators: a large resonator or a small one would alike give *u* when nearly closed, and *a* when further opened; the different resonators merely changed the shading of the vowels a trifle.

These experiments indicated the inadequacy of the Hermann vowel theory. The possibility of the Lloyd theory was considered. According to this theory the vowel character is due to the relation between two tones independent of their pitch; for example, *i* as in *machine* would be heard if two resonance tones were produced in the relation of 1 :37, *a* if in the relation 1 :5, and *u* if only one were present, no matter how high or low the tones might be. Accordingly the resonators were tried in pairs, then in threes and fours; the result was the same, always *u* or *a*.

The experiments were then repeated with hollow spheres of gelatine, modeling wax, and putty, with cavities cut out of different vegetables and fruit, etc. The results remained essentially the same.

These experiments showed that some factor in vowel production must have been entirely overlooked. Since the fact of the softness of the vocal resonators had been overlooked by all previous investigators, it was natural to conclude that some other factor in the vocal cavities had not been considered. It was therefore decided to imitate as closely as possible the structure of the cavities above the larynx. A human skull was fitted with gelatine cheeks and other parts to replace the flesh. The lower jaw received a gelatine casting that filled the base of the mouth and represented the tongue; a series of such castings was made with the tongue in different positions. The result was the same as before.

It was now evident that the theory was defective in regard to the glottal tone itself. The first supposition was that the glottal tone might not be independent, but might change its character with every vowel. The glottal lips are soft tissues; might they not change the manner of vibration according to the resonance of the cavities around them? The reed was discarded and experiments were now made with rubber membranes held in wooden frames. Circular, square, and triangular openings (figures 58, 59, 60) were covered with

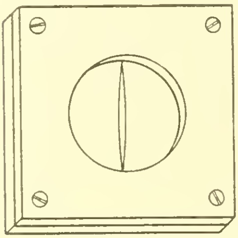

FIG. 58.—Circular rubber glottis.

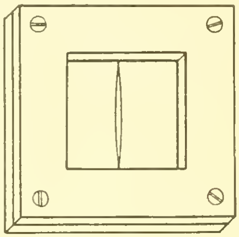

FIG. 59.—Square rubber glottis.

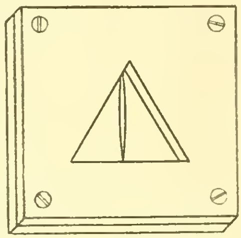

FIG. 60.—Triangular rubber glottis.

rubber membranes held at any desired tension; the air pressure caused the edges of the slit in the middle to vibrate. Such a membrane may vibrate on each side as a whole, or with any number of nodal lines concentric to the slit. The timbre of the tone of the membrane depends on its manner of vibration. Resonators of wood (hard walls) were introduced at this point, as the water and gelatine resonators were inconvenient for manipulation. These resonators could be used singly, doubly, triply, etc.; the rubber glottis could be introduced directly above the blast or between two resonators. The experiments were entirely successful. By proper combinations of two resonators of different sizes with the rubber glottis between them, all the vowels could be produced. Any change in the size of one of the resonators resulted in a slightly different shading of the vowel tone.

It was possible to look into the opening of the upper resonator and see the rubber glottis. Its manner of vibration could be seen to be different for different resonators. These experiments are a substantiation of the view that the action of the human glottis differs with different vowels; the reason, however, is, in my opinion, a different one for the human glottis. The glottal lips are not thin membranes like rubber, but masses of flesh; there is little possibility of their changing their vibrations in response to the reaction of the cavities around them. In my opinion the fibers of the *M. vocalis* which compose the lips, contract differently for each vowel, and therefore produce differences in tension throughout the mass; the slant fibers to the *Ligamentum vocale* can also create longitudinal nodes. My view is that the sound of each vowel is associated with certain sets of innervations to the fibers of the *M. vocalis* as well as with certain innervations of the muscles of the vocal cavities; these innervations differ for each vowel; the vowel is therefore formed at the glottis as well as in the mouth. This view, developed in the work for the Smithsonian Institution, was thereafter adopted as the basis of my work on speech curves for the Carnegie Institution; in many cases the curves became for the first time intelligible.

Although the change of the action with the rubber glottis has not the same cause as with the human glottis, the vowels produced were sufficiently good to make it advisable to keep to the principle of construction. The work was continued with them. To soften the tone, wooden resonators were tried with linings of butter, lard, etc. Tones of human softness could be obtained by felt-lined resonators.

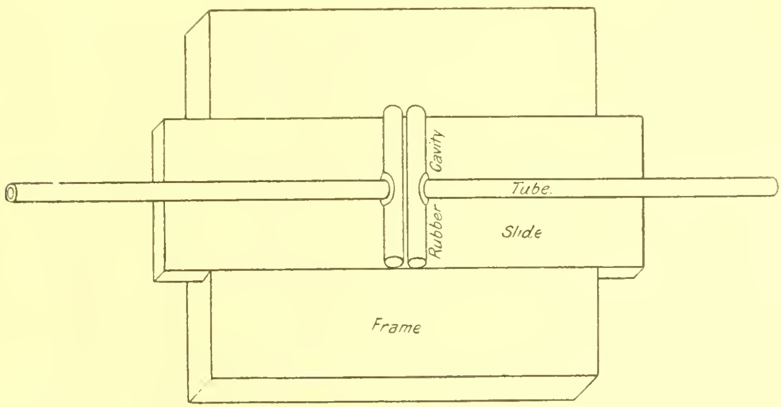

FIG. 61.—Adjustable rubber glottis.

In spite of a specially constructed metal holder for the rubber membranes, it was found impossible to tune them; moreover, they constantly got out of order. Work is now going on with a glottis of the form shown in figure 61. The wooden frame fits between two resonators. Each slide carries across its edge a tube-like cavity of very thin rubber. When the slides are pushed together the two rubber cavities touch with any desired closeness. The tension of the rubber cavity is regulated by blowing into and closing a supply tube above the slide.

With the felt-lined resonators in combinations of twos and threes, it is possible to imitate all the vowels and their variations. The problem at present consists in replacing the rubber glottis by something which changes its form of vibration for different vowels, but which can be accurately tuned and does not alter with time. When this can be done, a complete organ can be built that will sing the vowels, or a vowel register can be added to a regular organ. Eight vowels would be enough for most purposes; for a single octave with chromatic intervals, 124 vowel pipes would be needed. A vowel register of this size could be effectively used in church music.