$$\frac{\Sigma n H_{T=1 \atop v=1}}{4\,571} = C',$$

into which for this case equation (22), in which $\Sigma n = 0$, passes.

The calculation yields:

$$\Sigma n H_{T=1 \atop v=1} = -\ \mathbf{10.3} \text{ and } -\mathbf{10.3}.$$

If we now compare the values which the direct determinations of the watergas equilibrium have yielded, with the values which are calculated from the constants of the water and carbonic acid equilibrium, we find:

TABLE VIII.

| Carbonic acid | | Water | | Watergas | | | |
|---|---|---|---|---|---|---|---|
| | | | | Calculated | | Direct | |
| $C'$ | $\Sigma n H_{T=1 \atop v=1}$ | $C'$ | $\Sigma n H_{T=1 \atop v=1}$ | $C'$ | $\Sigma n H_{T=1 \atop v=1}$ | $C'$ | $\Sigma n H_{T=1 \atop v=1}$ |
| +2.25 | +20.2 | −2.43 | −1.19 | −2.34 | −10.7 | −2.26 | − 10.3 |
| +2.22 | +20.1 | −2.44 | −1.23 | −2.33 | −10.7 | −2.25 | −10.3 |

This agreement proves that the observations on which table VII is founded, correspond sufficiently well with those of the tables V and VI. This, however, cannot be advanced as a proof of the accuracy of the used expressions for the specific heats, as such an agreement may also be obtained on other assumptions concerning the specific heats.

*Inorganic Chemical Laboratory of the University of Amsterdam.*

**Physiology.** — "*The effusion of acoustic energy from the head, according to experiments of* Dr. P. NIKIFOROWSKY". By Prof. ZWAARDEMAKER.

(Communicated in the meeting of December 30, 1911).

In the months just past, Dr. P. NIKIFOROWSKY from St. Petersburg has carried on in the Physiological Laboratory at Utrecht an investigation as to the effusion of acoustic energy from the head whilst the sound was introduced, either from the head or from the vocal organs or from the crown of the head along the stem of a vibrating tuning-fork which had been placed there. The intensity of the sound produced, was about uniform, which appeared from special measurements (in the case of voice comparatively, by testing the sound at a microphone placed in a camera silenta and connected with a small string-galvanometer, in the case of the diapason vertex by measuring the amplitudes of the oscillations).

The problem which the experimenter has set himself, and which he has solved is the following: how does the vocal energy amounting uncorrected to from 1 to 7 megaergs per second according to an investigation made in collaboration with A. DE KLEYN (see my Leerboek der Physiologie, Haarlem 1910 Vol I p. 82) distribute itself over the natural egresses (mouth, nose and ears) and the hard and soft parts of skull and face. For obviously not only from the lips but also from all other parts the head will yield sound to its surroundings.

The sound when issuing forth was received in closely fitting leaden funnels or by ear-pieces and was led by sound-proof leaden channels to a microphone, placed in a leaden chamber with very thick walls. The current-fluctuations, produced in the microphone, manifested themselves, after having been transformed in the manner usual in *telephony into an induction apparatus, at a string galvanometer with* a gold string 5 $\mu$ thick and about 30 mm. long. The tension of the string was regulated in such a manner that it reverberated distinctly at all vowels and produced a vibration the double amplitude of which could be easily read off on the scale of the instrument. Provided we restrict ourselves to the comparison of sounds of the same pitch, it may be assumed that in spite of the multiple resonance of the system (sound-channels, microphone, transformator, string) the intensity of the sound acting upon the microphone was proportionate with the squares of the amplitudes measured. Sounds of different pitches, however, cannot be compared, as the manifold repeated resonatory strengthening, which the sound undergoes, is very different for different pitches; this became manifest when the micro-telephonic system after it had been constructed was tested, in the manner usual in the Laboratory, by means of a series of uniformly tuned organ-pipes, ranging from $a_1$ to $e_3$. If necessary a comparison of the various vowels might have been attempted with the aid of this supplementary investigation, but on account of the numerous sources of mistakes it gave rise to, the idea was relinquished.

On comparing the values of the same column in the above tables, we become aware of considerable differences in intensity, the more so if we remember that the actual strength of the sounds has been proportionate with the squares of the deviation of the galvanometer. The cause of this great difference will probably have to be sought in the co-operation of two causes:

TABLE I.

Intensity of the sound flowing away, calculated per cm², the chest voice being the sound-source.

| Place whence the sounds were transmitted to the micro-telephone-apparatus | Double amplitude whilst the vowels were being pronounced | | | | | Remarks |
|---|---|---|---|---|---|---|
| | *a* | *o* | *oe* | *e* | *i* | |
| Nose | 84 | 84 | 168 | 84 | 168 | leaden ear-pieces |
| Mouth | 168 | 168 | 84 | 168 | 84 | " " |
| Ears | 4 | 4 | 8 | 4 | 8 | " " |
| Zygomatic arch (temp. part) | 0.4 | 0.4 | 0.8 | 0.4 | 0.8 | leaden funnels |
| Supra meatum | 0.3 | 0.4 | 0.4 | 0.2 | 0.4 | " " |
| Proc. mastoid. | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | " " |
| Zygomatic arch (middle) | 0.4 | 0.4 | 0.8 | 0.4 | 0.8 | " " |
| Forehead (side part) | 0.4 | 0.4 | 0.4 | 0.2 | 0.4 | " " |
| Forehead (middle) | 0.2 | 0.4 | 0.8 | 0.2 | 0.8 | one funnel |
| Os parietale | 0.4 | 0.4 | 0.4 | 0.2 | 0.2 | leaden funnels |
| Crown | 0.4 | 0.4 | 0.8 | 0.4 | 0.8 | one funnel |
| Nape | 0.1 | 0.1 | 0.2 | 0.1 | 0.2 | one funnel |
| Cheek | 4 | 4 | 8 | 4 | 8 | leaden ear-pieces |
| Sides of the nose | 4 | 2 | 2 | 2 | 1 | " " |
| Planum submentale | 4 | 4 | 8 | 4 | 8 | " " |
| Chin | 4 | 4 | 8 | 4 | 8 | " " |

*a.* the timbre of the various vowels is different, even when pronounced at the same pitch,

*b.* the width of the mouth-cavity is different in the pronunciation of different vowels, for in the case of the wide vowels of BELL-SWEET the effusion of energy through the mouth will be promoted, in the narrow vowels impeded, in inverse proportion of which the effusion of energy by other channels takes place (*a* and *e* are open vowels, *œ* and *i* are closed ones).

From the tables it appears that the greater part of the acoustic energy of the voice leaves the head by the lips, a much smaller part by the nose, and a still smaller part by the auditory canals.

A totally different result is arrived at, if it is not the voice that produces the sound, but if the acoustic energy is derived from a tuning-fork set vibrating by means of electricity, and placed on the

TABLE II.

Intensity of the sound flowing away calculated per cm², the falsetto voice being the sound-source.

| Place whence the sounds were transmitted to the micro-telephone-apparatus | Double amplitude whilst the vowels were being pronounced | | | | | Remarks |
|---|---|---|---|---|---|---|
| | *a* | *o* | *oe* | *e* | *i* | |
| Ears | ? | 0 | 4 | 0 | 4 | leaden ear-pieces |
| Zygomatic arch (temp. part) | 0 | 0 | 0.3 | 0 | 0.3 | leaden funnels |
| Supra meatum | 0 | 0 | ? | 0 | ? | " " |
| Proc. mastoideus | 0 | 0 | ? | 0 | ? | " " |
| Zygomatic arch (middle) | 0.16 | 0.2 | 0.4 | 0.2 | 0.4 | " " |
| Forehead (side part) | 0.1 | 0.16 | 0.4 | 0.16 | 0.4 | " " |
| Forehead (middle) | 0 | ? | ? | ? | ? | one funnel |
| Os parietale | 0 | 0 | 0 | 0 | 0 | leaden funnel |
| Crown | 0.2 | 0.4 | 0.4 | 0.2 | 0.2 | " " |
| Nape | 0 | 0 | ? | 0 | ? | " " |
| Cheeks | 2 | 4 | 8 | 2 | 8 | leaden ear-pieces |

crown of the head. In this case mouth and nose orifice get hardly any share at all, the rest of the effusion being thus:

TABLE III.

Intensity of the sound flowing off calculated per cm², the sound-source being a diapason vertex.

| Place whence the sound was transmitted to the micro-telephone-apparatus | Double amplitude | Remark |
|---|---|---|
| Ears | 32 | The experiments were made with the aid of a tuning-fork of EDELMANN with running-weights at the ends. The double amplitude amounted there uninterruptedly to 1 mm., sustained by electro-magnetic motive force. |
| Zygomatic arch (middle) | 8 | |
| Forehead | 6 | |
| Supra meatum | 4 | |
| Nape | 4 | |
| Nasal bone | 4 | |
| Soft parts of the nose | 1 | |
| Cheeks | 2 | |

We have not succeeded in any other way than the one described above, in introducing an amount of sound-energy into the head, sufficient to import enough intensity to the sound which flowed off, to measure it by means of the microtelephone apparatus and the string-galvanometer. Only very strong sound-sources such as MARAGE's "sirène à voyelles", when one places oneself before it with open mouth, or a loud speaking telephone, led directly to a nostril, produce enough sound to bring about a measurable deviation of the galvanometer, and that only when the sound is derived from both ears i.e. in the most favourable condition. If we leave out of consideration sounds introduced by actual contact, the sound of one's own voice is evidently the only one which penetrates the skull in great intensity. The sound transmitted by the air to which we listen in ordinary life, acquires only its well-known preponderance by the structure of the middle-ear, eminently calculated to conduct sounds. In itself a tone passing through the air and piercing the skull, is always weak.

It also seemed desirable to make an absolute determination of the sound issuing from the head. For this purpose that which escapes from between the lips when we pronounce the vowel "a" was received into a phonograph (as this was done in the camera silenta, the sides of which are covered with thick horse-hair, absorbing sound, better results were obtained than before). Then the impressions made on the wax cylinder were measured according to the method of BOEKE and analyzed according to the method of FOURIER. Finally on the ground of this investigation the vowel was imitated in exactly the same strength by means of organ-pipes[1]). The total strength of the imitating sound appeared as follows:

TABLE IV. Vowel "a".

| Partial tone | Dominating components | Pitch (v. d.) | Depth of glyphic in $^1/_{200}$ mM. | Consumption of air in cM³. | Pressure in cM. of water | Energy (volume in cM³. × press. (in dynes) | Energy in megaergs | Total energy of voice (uncorrected) |
|---|---|---|---|---|---|---|---|---|
| 6 | a sharp$^2$ | 804 | 1.035 | 107.5 | 2 | 210915 | 0.04 | 2.45 |
| 7 | b sharp$^2$ | 938 | 1.71 | 308 | 16 | 4834368 | 2.4 | Megaergs |
| 8 | $c^3$ | 1072 | 0.825 | 107.5 | 2 | 210915 | 0.014 | pro sec. |

1 Megaerg = $10^6$ ergs

Hence it appears that the intensity of Dr. NIKIFOROWSKY's voice

[1]) ZWAARDEMAKER and MINKEMA. Arch. f. Anat u. Physiol., Physiol. Abteilung 1906 p. 433.

issuing from his lips when loudly sounding "a" amounted to 2.35 megaergs per second. According to this standard the effusion of sound from the other parts of the head may be determined. This is set forth in Table V.

TABLE V.

Acoustic energy emitted by the head per second whilst "a" was pronounced with chest-voice.

| Regiones | Energy per $cM^2$ in megaergs | Extent of the surface in $cM^2$. | Total energy in megaergs per sec. | Remarks. |
|---|---|---|---|---|
| Nose | 0.131 | 1.1 | 0.144 | both nostrils together |
| Mouth | 0.524 | 4.4 | 2.306 | |
| Ears | 0.000297 | 0.475 | 0.00014 | both ears together |
| Bony parts | 0.0000297 | 2233 | 0.066 | |
| Soft parts | 0.000297 | 559 | 0.166 | |
| | | | 2.68 | |

The total effusion of sound amounted therefore in the above experiment to 2.68 Megaergs per second. Of this the greater part viz. 2.45 Megaers left the head by the mouth and the ears, an extremely small part by the auditory passages and about $^1/_{10}$ by the hard and soft parts together. These data we offer uncorrected i. e. without an estimate of the efficiency of a well-regulated organ-pipe. Not all the energy imparted to the pipe is transformed into sound. Some of it is lost in the vortices of air. Hence our values are greater than the real acoustic values. Though the latter according to a recent publication by ZERNOV [1]) may be esteemed of about the same order, yet it seems to me that the importance of Dr. P. NIKIFOROWSKY's figures lies in the mutual relation of effusions which differ topographically.

**Mathematics.** — *"On partial differential equations of the first order"*. By Prof. W. KAPTEYN.

1. When a partial differential equation of the first order

$$F(x,y\,z,p,q) = 0 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

is transformed by a tangential transformation, the new equation will generally show the same form. Sometimes however the transformed equation will be linear. In this case the complete primitive of the

[1]) ZERNOV, Ueber absolute Messungen der Schallintensität. Die Rayleighsche Scheibe. Ann. d. Physik. (4). Bd. 26 p. 79. 1908.