KOENIG'S TUNING-FORKS AND THE
FRENCH "DIAPASON NORMAL"

HAVING had occasion to measure a series of Koenig's tuning-forks, kindly lent me for that purpose by Professors Tyndall and Guthrie, by means of Appunn's tonometer, now in the South Kensington Museum, I was much struck, and for a time puzzled, by finding that though the forks were perfectly consistent with each other, they did not answer to their names, that is, the numbers of single vibrations marked on them, did not answer at all to the double vibrations measured by Appunn's tonometer. The workmanship of Koenig's forks is so good and the intervals between them so exact, that one might be at first inclined to suspect the accuracy of the absolute numbers of the reeds on Appunn's instrument. But there can be no doubt of the accuracy of the differences of the number of vibrations between any reed and any other, for these admit of ready control by counting, and I have counted them all. Hence such a thing as this is quite certain. The difference of the vibrations of C 256 and G 384 is 128 vibrations, as on Appunn's instrument; but the difference in the vibrations of Koenig's corresponding forks is 129·2 vibrations. Now, I have no doubt about the perfection of Koenig's fifth C to G. If then his C make x vibrations, his G makes $x + 129·2$ vibrations. Putting this = $\frac{3}{2}x$, we obtain $x = 258·4$ as the number of the vibrations of his C, and this is the precise number furnished by Appunn's tonometer, according to a very careful measurement made by Mr. A. J. Hipkins, of Messrs. Broadwoods, who has had great experience in counting beats, and myself. The discrepancy, therefore, becomes an excellent proof of the perfection of Appunn's instrument. But how could Koenig have hit on this strange number 258·4, in lieu of 256? It was some little time before the solution presented itself to my mind, but I believe that this, which is decidedly sufficient, will prove substantially correct.

The French normal A was settled at 435, and since Lissajous superintended the publication of the fork of the French Commission in 1859, the whole world has accepted that fork as having exactly 435 vibrations. Now the French Commission gave to Messrs Broadwoods, in return for their courtesy in sending them their forks, an authorised copy of this fork, stamped with their stamp (a lyre between D and N, at the end of each prong) and made by Secretan. This fork I assume to be an authentic representative of the French diapason normal, made at the time. I have examined many others made by Secretan, and also officially stamped, and one by Koenig, and they mostly agree within two- or three-tenths of a vibration in a second. Two of Secretan's, however—one bought in Paris by the Society of Arts, and one sent to that society officially in 1869 through the Foreign Office, as representing the French pitch used in the Grand Duchy of Baden, differ as much as six-tenths of a vibration, the extreme difference observed in authorised forks. Other copies differ as much as two vibrations. But I take as my standard the copy given to Messrs. Broadwoods (which through the kindness of Mr. Hipkins I have carefully measured), and the one made by Koenig (which Dr. W. H. Stone was so obliging as to allow me to measure). These differ only by one-tenth of a vibration, and that tenth may be my own fault in counting. All these forks show that the real French diapason normal is A 439, that is, four vibrations sharper than was supposed. This is really a result of prime importance as brought out by Appunn's instrument, and it fully accounts for Koenig's differences as follows:—

Koenig having to make a C 256, observed (I suppose) that a major sixth above it would be $A 426\frac{2}{3} = \frac{5}{3} \times 256$, and that this would beat $8\frac{1}{3}$ times in a second with A 435, which he assumed to be given by his diapason normal.

Constructing such a fork by beats, which is easy enough, he necessarily obtained one exactly four vibrations too sharp, that is, A 430 $\frac{2}{3}$. From this, by the Lissajous figures most probably (certainly *not* by interposing new forks and counting the beats, for that would have shown him his error), he obtained first the correct major sixth below it, C 258·4 = $\frac{2}{3} \times 430\frac{2}{3}$, and then got his other forks by true intervals obtained also by Lissajous' figures. This makes all Koenig's forks harmonics of C 64·6, instead of C 64, as he intended and as he marks his forks.

Since Koenig's forks are extensively used by physicists, and also for the purpose of obtaining other pitches from them either for musical or for counting purposes, I think it will be convenient to add a little table of the harmonics of 64·6, with the marks on the forks observed (all of which had Koenig's monogram) and the pitches as actually measured by Appunn's tonometer. I am quite willing to allow the small differences to be set down to my bad counting and not to defective workmanship of either Koenig or Appunn.

No. of Harmonic.	Double Vibrations of Harmonic.	Marks on Koenig's Forks, V.S.	Meaning in English Notation.	Measured by Appunn's Tonometer.
1	64·6	—	—	—
2	129·2	—	—	—
3	193·8	—	—	—
4	258·4	Ut ₃ 512	C 256	258·4
5	323·0	Mi ₃ 640	E 320	323·1
6	387·6	Sol ₃ 768	G 384	387·6
7	452·2	—	—	—
8	516·8	Ut ₄ 1024	C 512	516·7
9	581·4	—	—	—
10	646·0	Mi ₄ 1280	E 640	646·0
11	710·6	—	—	—
12	775·2	—	—	—
13	839·8	—	—	—
14	904·4	7. 1792	B _{flat} 896	905·0
15	969·0	—	—	—
16	1033·6	Ut ₅ 2048	C 1024	1033·6
17	1098·2	—	—	—
18	1162·8	Re ₅ 2304	D 1152	1163·3
19	1227·4	—	—	—
20	1292·0	Mi ₅ 2560	E 1280	1292·0

The last four forks were difficult to measure. Those left blank were not found either at the Royal Institution or the School of Mines. The 11th, 13th, 17th, and 19th harmonics would not be easy to tune by Lissajous' figures. Appunn's instrument gives them with perfect ease. I may observe here with regard to the question of forks and reeds, that though forks may be the most permanent and portable records of pitch, reeds have a great advantage in the number of their upper partial tones, which allow of an extraordinary variety of verifications without any assistance beyond the instrument itself. I have found this reed tonometer easily checked and invaluable in measurements. But the above table would allow any tuning-fork maker to tune exactly to C 256, or from C 254 to C 265, by means of beats from Koenig's forks.

In trying forks to-day at King's College, Prof. Adams drew my attention to the fact that Koenig's organ-pipes are much flatter than his forks. On account of the difficulty of getting a steady blast on the organ pipes, it was not possible to measure them satisfactorily by Appunn's tonometer (a copy of which is in the physical laboratory there, and should be in all physical laboratories, as it is the best instrument for illustrating the nature of sound, partials, beats, and chords that I have yet seen), but they seemed to give very nearly C 250, about eight vibrations flatter than the forks. I cannot account for this, as this would be about Koenig's 248. ALEXANDER J. ELLIS

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