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MARCH 6, 1876.

JOHN HULLAH, Esq., LL.D., VICE-PRESIDENT, IN THE CHAIR.

ON STANDARDS OF MUSICAL PITCH.

BY DR. W. H. STONE, F.R.C.P., M.A.

DR. STONE said he did not intend to go into the question of any particular pitch, but rather to deal with the difficulties of keeping to a pitch when it was obtained. This was a constant source of difficulty, particularly in orchestras, where the wood instruments were constantly varying. In almost all cases the pitch tended upwards. The process of ascertaining with exactness the number of vibrations per second, either by means of the siren or any other instrument, was long and tedious; but in taking the French pitch as a standard, there was this advantage, that it had been ascertained once for all, by very competent men, and tuning forks had been made in accordance with it which varied very little, and could be produced in great numbers with considerable accuracy. Such forks, therefore, formed a good practical standard for experimental use, because, if you set two forks in vibration the beats were clearly perceptible. On the other hand, they had disadvantages. In the first place, the sound was very feeble and evanescent, and in the noise of an orchestra almost inaudible; besides which the beats, on account of the pure and rather dull character of the tone, were very faint at a distance; and after all it was by means of beats that tuning must be accomplished. Temperature again affected these forks very much. He had on the table several common tuning forks, such as were generally supplied by the trade, and although they were not so well made as the French, still they were very fair. There was a slight amount of beating usually perceptible between two of the same pitch arising from defective workmanship; but on warming one fork even to the temperature of the body, the difference became greatly increased.* A tuning fork, then, was not absolutely accurate. Their evanescent tone might be made more permanent by exciting it with a fiddle bow; but with an ordinary high-pitched fork you rapidly wore away the hair of the bow without producing much effect. There was no doubt a better way which deserved to be tried, although he had not been able yet to carry it out, namely, to put them in vibration by means

* Perronet Thompson showed that a fork giving treble c or middle c at freezing point flattened by the third of a comma when dipped in boiling water.

of galvanism. On passing an intermittent current through them you might obtain a permanent tone ; but it would require care to bring it to pitch. Helmholtz had succeeded in doing this, and it was no doubt sufficient for the purposes of the physical cabinet, but for an orchestra, or for tuning an organ, it was hardly practicable.

The next thing which suggested itself was the string, but strings of course were eminently affected by temperature, even if made of metal, and those of catgut were also very much affected by moisture, so that they not only varied in consequence of heat, but also in thickness, being swelled by moisture, even that of a damp hand. A violin string therefore could never be for two moments exactly of the same pitch, and this was fortunate in one respect, because it compelled the player to depend entirely on his ear, which thus had to be cultivated very specially. Ultimately no instrument gave so accurate intonation as the violin. He would now repeat an experiment which he brought some time ago before the Physical Society of London, for showing the difference in the tone of strings caused by variation in temperature. It was well known that when a current of electricity passed through an insufficient conductor, the latter became heated according to definite laws : when a metal string was heated it lengthened, and its elasticity also became to a certain extent altered. On the table was a sonometer, with two strings upon it of different metals, very nearly in unison, the beats being only about one per second. But on passing a current of electricity through one of them, the tone immediately began to alter, not only in pitch but in quality. The pitch varied very nearly an octave : a difference no one would have expected to arise from such a comparatively slight variation in temperature. That result was obtained with a brass string ; on repeating the experiment with a steel string, heated by the electric current, it soon sank far beyond an octave, a result which as a musician he should *a priori* not have deemed possible. It would be recollected that some time ago Mr. Baillie-Hamilton, in a paper read before the Society, described coiled springs which he had invented, and which appeared to possess very valuable properties, one being that they varied very little in tune. Now by this method of experiment that quality could be tested. This he would proceed to do. The coiled string was found to vary very slightly in pitch, sinking barely half a tone.

In wind instruments they had a much more complicated problem to deal with, because in such instruments there was a sort of compensating action under the influence of warmth and climate. In the first place, the material of the instrument, especially if it were metal, expanded with heat, and thus the whole instrument became flattened ; in this way, when taken out to hot climates, they were found to decline in pitch very much ; but brass instruments in this country, where the climate was generally cold, whilst they enlarged slightly by heat and thus flattened,

the air passing through them, especially if it were the human breath, became rarefied, and the tone in consequence was raised or sharpened. In this country the latter action predominated. Not long ago he obtained conclusive evidence on this point. A full brass band was sent out to India, the instruments being very carefully tuned beforehand to orchestral pitch, by a competent person. When they arrived in India an intelligent bandmaster, who had the means of ascertaining their pitch very accurately, took charge of them, and he found them far below the proper pitch. The fact was, the metal in that warm climate, which ranges generally above 100° , expanded, and there was no compensatory action going on at all, because the normal temperature of the healthy human body does not vary much, being generally about $98^{\circ}.4$, whilst it seldom, even in the hottest climates, rises above 99° , so that there a cold player was blowing into a hot instrument, instead of what occurred in England, a hot player blowing into a cold tube. A French horn, for instance, was really about 26 feet in length, though ingeniously coiled up into a small compass; hence it sank very appreciably with heat, owing to the expansion of the metal.

In speaking of organ pipes, he should point out that the expansion and rarefaction of the air caused considerable sharpening of tone: not that they varied so much as orchestral instruments, because in ordinary cases they were played with wind at ordinary temperatures; but still, as they all knew, they were sometimes exposed to extraordinary variations—sometimes falling as low as 32° , and at others as high as 80° ; the differences in pitch were very much greater than might have been expected. He had constructed a simple apparatus for the purpose of illustrating this effect. It consisted of a voicing bellows, the air from which passed through two vessels, in each of which was a spiral pipe; one of the vessels contained ice and the other boiling water, so that there was a definite difference of temperature of 100° centigrade between the two. The effect of thus cooling or heating the air on the resulting tone in an organ pipe was very remarkable. It was shown in the first instance by means of a flue pipe, which being attached to the orifice whence the air at 32° was issuing and tuned in unison with a wooden stopped pipe, was then transferred to the hot air tube, when the beats became very marked indeed. The same experiment was next tried with a metal stopped pipe, which underwent a slightly different course, taking rather longer for the effect to be produced, but still it was quite as perceptible ultimately. He attributed that to the fact that the upper part of the pipe kept cooler than in the open flue pipe. Metal and wood of course differed decidedly in variation, because pine wood, such as was used for organ pipes, was very little sensible to expansion, and the whole effect was due to the included air. The difference in pitch caused by rarefaction was also shown in another way, by affixing a pipe to a receiver in which hydrogen gas was collected, when a total change both in pitch and quality of tone

was at once noticeable. Good organ tuners were perfectly aware of this effect of heat on pipes, and were always careful not to handle them much in voicing, finding that if they were tuned when warm they would not be in tune when cold. On the possibility of tuning an organ by means of temperature, he did not think enough use had been made. Mr. Lewis some years ago told him that the very beautiful little organ which he put into the Hanover Square rooms would not speak at all until he opened a large grating into the open air at the back of the room, which ventilated the room and allowed the hot air from it to pass through the organ, warming and drying it. He suggested that the same process should be applied to the large cumbersome, unwieldy organ at Exeter Hall. The pipes there drew their supply of air from the cold corridors at the back, the stone passages which made one almost shudder in passing through, and the organ itself suffered in its own way. He was accustomed to play a large bass reed in the orchestra there, and found the alterations considerable; the organ at first was down very low indeed, but as the air of the hall became warm, at length even the corridors got warm also, and the organ rose gradually in pitch, sharpening during the whole evening. It was shifting perpetually, which was very trying to the instruments in the orchestra. If, instead of drawing air from the back, it were drawn from the roof by some kind of wind-sail or tube, it would be a great improvement.

Reed instruments followed a somewhat different course, because the vibrating reed, the dominance of which was so great, expanded appreciably, and therefore when in good condition they ought not to vary much. As a matter of fact, the reeds in an organ were known by every organist to be extremely unruly. He believed, however, that much of the blame cast on the reeds as to getting out of tune was really due to the flue pipes altering; reed pipes were sensitive to moisture more than flue pipes, though not so sensitive to heat and cold, as he would show by experiment, blowing the reed pipe and a flue pipe in unison with hot and cold air, and then transposing them. The influence of moisture or vapour of any kind was very great on reeds. This he had proved by introducing into one of those pipes a little chloroform, which had a very heavy vapour, and caused the pipe to sink in pitch. That experiment, however, he must ask them to take upon trust. His next observation would be upon orchestral instruments; he would choose the clarinet as the type, because it varied the most. In cold weather an ordinary B $\flat$ clarinet sank very considerably. He went on one occasion to Kingston with the Wandering Minstrels during a severe frost, having to sit outside the coach and carrying his instrument. When he went into the orchestra for rehearsal the conductor accused him of having the A clarinet instead of the B $\flat$; the fact being that the cold air had lowered the instrument a full semitone. But when it was put before a warm fire it recovered its equanimity. This was shown by sounding the note A on a cold clarinet in unison with a French

pitch tuning-fork ; and then blowing hot air through it, it was found to rise considerably.

Lastly, he would refer to harmonium reeds, which were found to vary very little, and somewhat differently, according to the material of which they were made. He had had some constructed of steel, of brass, and of German silver ; the last he found to be least liable to be affected, whilst the steel were worst of the three. On sounding them first with cold air, and next with hot, they were found to change very slightly, but a great advantage in their use as a standard of a pitch was that their beats were so very perceptible. Many persons might notice that a tuning fork was very flat or sharp without the beats being distinctly audible, but he would defy the hardest headed fiddler in existence to be out of tune if he had an harmonium reed for tuning to. It could also be kept constantly sounding. For both reasons he believed it would prove the most effective standard of pitch for the orchestra.

DISCUSSION.

MR. DE PONTIGNY said heat and moisture had a great effect upon drums ; the heat of a warm room rendered the skin drier, and consequently sharpened the tone.

MR. BOSANQUET said he had paid a great deal of attention to the subject Dr. Stone had so admirably brought before them, especially with regard to organ pipes. He did not know whether Dr. Stone had seen General Perronet Thompson's investigations on the change in pitch of organ pipes and tuning forks by variations in temperature. He there directed particular attention to one point which Dr. Stone had not alluded to, namely, that the effect of temperature on pipes of a high pitch and a low pitch was not the same ; in fact, that the pipes of high pitch separated in a body from the bass. Probably the same thing would apply to a smaller extent in tuning forks. He might also mention that General Thompson devised an ingenious mechanism, consisting of bars put across the mouths of the pipes, by which this variation in tone was got rid of. He had noticed in Dr. Stone's experiments that it was difficult to separate the effect due to temperature from the effect of the bellows, and this was a difficulty which all acoustic experimenters constantly encountered. He should like to know, therefore, whether the common inverted rib bellows was really found to be sufficiently accurate for these experiments, or whether some additional arrangement might not be desirable for the purpose. He had constantly used harmonium reeds in questions of

absolute pitch, and he thought they might be trusted for anything except real physical accuracy. Their beats were very easily heard, and they were easily manipulated. He had a little tuning machine in which he could put a number of reeds and file them to the exact pitch required, with the greatest ease. He had hoped to hear a little more about the determination of absolute pitch, because, after all, they could not always get the French standards, nor was it always easy to work from a French standard tuning fork. It was very desirable, therefore, that they should have some accurate and tolerably easy means of determining the pitch of harmonium reeds, and anything which enabled them to count the total number of beats between notes, constituting an accurately tuned interval, would meet the difficulty. If you tuned two notes to a major tone (C—D), by making them perfect fourth and fifth to a third note (G), and then interpolated between them so many other notes that you could count the beats between each successive pair, and then added all the beats together, a simple arithmetical rule gave you the absolute pitch of the C with considerable accuracy.* The only thing required, then, was an instrument for observing the beats. This could be done to some extent with a pendulum arranged for the purpose; but he was constructing a metronome, which he exhibited at the recent *soirée*, though it was not yet quite finished. He thought something of that kind must be the basis upon which the ordinary observer must depend, and by its means, with a few harmonium reeds, they could always secure an absolute pitch.

Dr. STONE said he agreed with everything Mr. Bosanquet had stated; but he had not been able to go into the important question of the separation of the bass from the treble in organ pipes, because it would have taken too long.

Mr. STEPHENS inquired in which direction the difference took place. Was it to sharpen or flatten the tone? If it were the latter, it might be accounted for by the greater weight of metal in the larger pipes.

Mr. BOSANQUET said it was found the small pipes were most affected, and became sharper. General Thompson proposed a somewhat more workable method than the one he had himself adopted for getting over the difficulty; namely, as the variation in the pitch of the pipes, arising from the strength of the wind, followed very nearly the same law as that arising from variations of temperature, it was possible that the difference between the treble and bass might be compensated by altering the weights of the bellows, if the pipes were so voiced as to speak under a variable amount of wind.

Mr. STEPHENS asked if Mr. Bosanquet had formed any hypothesis as to the physical reason for this change. Pre-

* The sum of all the beats that would be heard in eight seconds is the vibration number of the C.

conceived notions would rather have led one to suppose that the change would have taken place in the larger pipes.

Mr. BOSANQUET said he thought in organ pipes the air was the most material cause of the change in pitch. The whole question was very complicated, and very little as yet had been done to determine it.*

Dr. STONE said that in his own experiments he had used a much larger reservoir of air than he had been able to bring down for the purposes of the present paper.

Mr. CHAPPELL said that if we start with thirty-two vibrations for the lower C, we can never have the F in perfect tune, because the ratio of F in the scale of C will not allow it. This is also an objection to the French pitch; at the same time, it is nearly right.

Mr. STEPHENS asked why they could not take the French pitch and reckon downwards.

Mr. CHAPPELL said in that case we can neither have the lower octaves nor the C in perfect tune.

Mr. BOSANQUET did not quite understand the objection.

Mr. CHAPPELL explained further that, in the scale of C, if we start with 33 vibrations, the octave above will have 66; then F, a true fifth below, will have 22, and its octave 44; thus we have perfect scales for F and for C. Whatever variations we may make in the temperament of certain intervals, we should start with mathematical accuracy; and if the calculation were made it would be found, taking those figures, that the A would have 880 vibrations instead of the 870 of the French pitch. We can neither arrive at French pitch from C with 32 nor 33 vibrations. Again, if we take 870 for the upper A, its octave below will have 435 vibrations. If halved again, the note must be out of tune, because we cannot halve a vibration.

Mr. BOSANQUET said the objection amounted to this, that the French pitch did not coincide with either of the theoretical pitches proposed.

Mr. CHAPPELL said that ten vibrations in a high note was a very small difference, but one which ought to be taken into account by men of science in settling perfect intonation. This was very much insisted upon by French men of science at the time the pitch was established in France. In a pamphlet, reprinted from *Concordia*, he had included the two harmonic scales, C and F, showing that C would have 528 vibrations, starting with 33, the present pitch: a more complete scale of C would be had by starting from 32 vibrations, but as long as we have F in the scale, we cannot take any ratio which would exactly agree with it. If we take 33 we can make the F coincide.

* General Thompson refers this effect to the increase of scale in the smaller pipes. He states that the effect of heat varies inversely as the length, and directly as the diameter; so that for pipes of constant scale the effect should vanish. But this requires confirmation.

Mr. BOSANQUET said he had no fear of fractions in these matters. What was required was practical convenience.

Mr. CHAPPELL said it was not a question of fractions, but of sound; fractions are divisible, but we cannot split a vibration into parts. The cycles will continue, and non-coincidence must ensue.

The CHAIRMAN, in proposing a vote of thanks to Dr. Stone, said he never heard a lecture on acoustics without being left in a state of absolute astonishment that there could be any music in the world which was at all tolerable. When one considered the vast difficulties there were in ascertaining what was in tune and what was not, about which no two people seemed to agree, he thought they could only rejoice that they got as near practical perfection as they did.