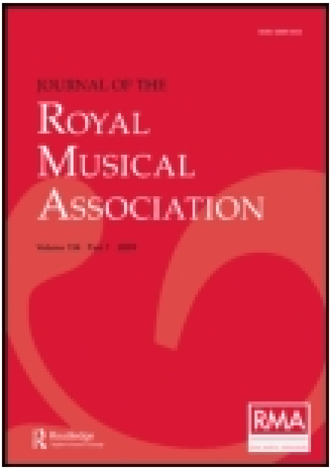


Proceedings of the Musical Association

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/rrma18

Communication Respecting a Point in the Theory of Brass Instruments

D. J. Blaikley Esq.

Published online: 28 Jan 2009.

To cite this article: D. J. Blaikley Esq. (1877) Communication Respecting a Point in the Theory of Brass Instruments, Proceedings of the Musical Association, 4:1, 56-60, DOI: 10.1093/jrma/4.1.56

To link to this article: http://dx.doi.org/10.1093/jrma/4.1.56

COMMUNICATION RESPECTING A POINT IN THE THEORY OF BRASS INSTRUMENTS.

By D. J. Blaikley, Esq.

The investigations of the late Sir Charles Wheatstone on the subject of the powers of resonance of different masses of air enclosed in chambers of certain definite simple forms, were brought before us by Professor Adams in 1876, and it appeared to me that it might be a matter of interest to this Association to enter briefly upon the consideration of the resonance of brass wind instruments as illustrating Wheatstone's laws. There is very commonly a vagueness used in the description of such instruments which I submit is misleading; they being usually considered to be cones, or cones combined with cylindrical tubing, neither of which descriptions properly applies. And further, they are commonly considered to be of necessity in tune, that is, in just intonation, having the vibrational numbers of the notes that may be produced from them without altering their length, in the proportion of the numbers, 1, 2, 3, &c. As so great an authority as Prof. Helmholtz writes ('Sensations of Tone,' pp. 511, 641): 'Horns and trumpets have already naturally just intonation,' and 'brass instruments naturally play in just intonation, and can only be forced to the tempered system by being blown out of tune,' it seemed to me worth attention that this must be taken only as being particularly, and not generally true: that is, that though the ideal brass instrument has such characteristics, this ideal is not necessarily attained to in practice. The relative and absolute numbers of vibrations of the first eight tones required on a brass instrument, taking the 4 feet C of 128 vib. as the fundamental note, are here given, with the corresponding wave lengths:—

Velocity of sound {1,120 feet = 13,440 inches} per second at 60° Fahr.

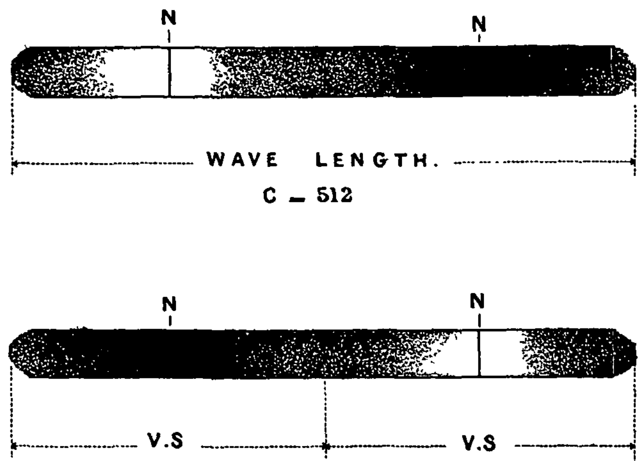
Note.	No. of Vibrations.		Wave Length.	
	Absolute.	Relative.	Relative.	Absolute.
c'''	1,024	8	$\frac{1}{8}$	13·125
b♭''	896	7	$\frac{1}{7}$	15·
g''	768	6	$\frac{1}{6}$	17·5
e''	640	5	$\frac{1}{5}$	21·
 *c''*	512	4	$\frac{1}{4}$	26·25
g'	384	3	$\frac{1}{3}$	35·
c'	256	2	$\frac{1}{2}$	52·5
c	128	1	1	105·

Diagram 7.

VIBRATION OF SOUND.

IN OPEN TUBE.

Scale — $\frac{1}{8}$ full size.



These are the notes of this bugle, and these four forks are tuned to the first four, *c*, *c'*, *g'*, and *c''*, which may be referred to as Notes 1, 2, 3, and 4. Having been struck with the paradoxical deviations from this succession of correct intervals, I endeavoured to determine, experimentally, the positions of the nodal points, or rather surfaces, in wind instruments, to give myself a basis for the further consideration of the subject, and the general result I will endeavour to illustrate to you.

For the purpose of leading up to the somewhat complicated condition of vibration especially before us, it may be well to give a few minutes to the consideration of some of the more simple forms. Diagram 1 roughly shows the characteristics of sound vibration in free air, or in a tube of equal section throughout. Points where the air is at rest, or nodal points, alternate with points where it is in a state of maximum motion, and the air at alternate nodes is in a state of maximum compression and maximum rarefaction (shown by difference of tint): the condition of any node varying with the motion of the air on each side of it, which is in contrary directions. The distance between any two nodes is a ventral segment, and the distance between two nodes that are in the same condition is the wave length, which, for any given note, is equal to the velocity of progress of the wave divided by the number of vibrations producing that note; the diagram is to scale for  512, $\frac{13440}{512} = 26{\cdot}25$ ins. A node being a point of no motion, but of reflection, a tube may be closed at such a point without influencing its note, but at no other point, and only those notes can be sounded on a closed tube which have a node in the position of the closed end.

Illustration.—Resonance of an open tube to the fork C 512, the tube being half the wave length and a nodal surface establishing itself in the centre of the tube. The position of the node can be proved by sinking the tube half its length in water; the resonance being at its maximum when the water-level corresponds exactly with the position of the node. By this method of experiment, which I believe is new, and is peculiarly applicable to tubes of varying section, the positions of the nodes in the cone and bugle shown on diagram 2 were determined. Combining four such half-wave lengths of C 512 we get a tube of the length represented in the diagram, which gives as its lowest note C 128 and also the notes 2, 3 and 4.

From this we find that the lowest note which an open tube reinforces has a wave twice the length of the tube, and that it also reinforces all notes whose vibrational numbers are 2, 3, 4, &c. times that of the lowest note; whilst the lowest note on a closed tube has a wave four times the length of the tube, and that such a tube gives only the notes having the vibrational 1, 3, 5, &c. There is another simple form, as well as the open tube, giving resonance to the notes 1, 2, 3, 4, &c., and this is the cone: a cone open at its base and complete to its apex, where it is of course closed, giving a fundamental note of the same pitch as an open tube of equal length, and the harmonics, or partial tones, in the same order of succession, 1, 2, 3, &c.

Diagram 2 shows the positions of the nodes and centres of ventral segments in an open tube and a cone of the same length, for the notes 1, 2, 3, 4, 1 being C 128, with wave length 105 in. The effect that the diminishing size of the cone has upon the position of the nodes may be traced. The numerals on the dotted lines above each figure grouped together and marked N show the position of the nodes, and those underneath, the positions of the centres of the ventral segments. Whilst the positions of the centres, or points of maximum vibration of the ventral segments remain the same as in the tube, the nodes are gradually farther and farther apart, until at the apex of the cone is a node common to all the notes. The centre of the ventral segment is thus no longer the centre of the distance between the nodes (compare open N 1 with cone N 1 &c.).

Before comparing these general results with the case presented by brass instruments, we may consider whether they are influenced appreciably by the action of the lips, and it will be found that whether the lips or a tuning fork be used the effect is the same.

Illustration.—A cylindrical tube 26 inches long, blown by the lips in the same manner as a bugle, gives the notes 1, 3, 5, 7, &c., the same as it would give as a closed tube excited by forks, and a small hunting horn with pitch c'' gives an excellent resonance to the fork c'' directly the mouthpiece is closed by touching the water surface. For musical purposes, such a tube as the one just tried (becoming, on being placed against the lips, a closed tube) is evidently unsuited, by reason of its poor tone, as well as by its giving only the odd intervals. The cone gives the required intervals, but it cannot be used by the lips in its complete form. It is approached very closely by the oboe, bassoon, and contrafagott, but these instruments are used with a double reed, which may be considered to be practically at the apex of the cone, the diameter where the reed is fixed being very small.

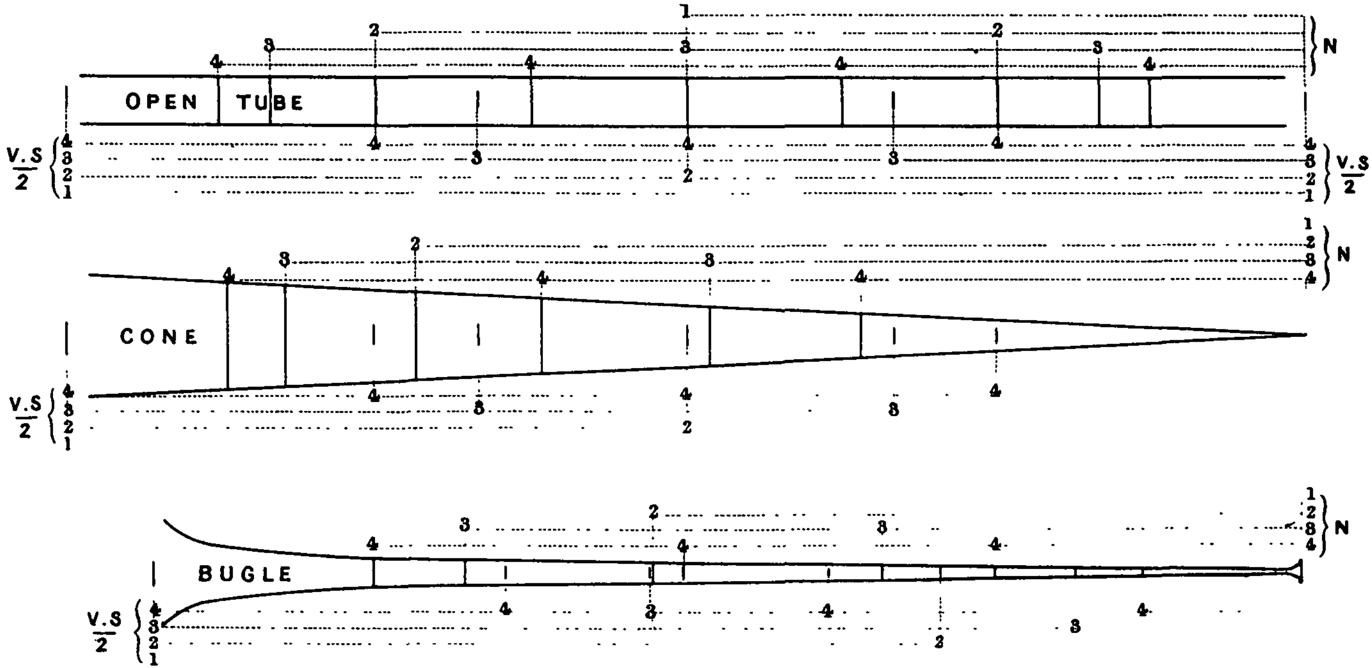
Adhering to the conical form, it would be necessary to cut off a considerable portion to get sufficient width for the action of the lips, and by so doing it becomes impossible to find a position which shall be a nodal point common to the various notes required, and the more nearly equal the two ends of the truncated cone are, the more nearly will the intervals on such a tube correspond with those of a stopped tube of equal section throughout.

Assuming the cone to be cut at the second node of note 4, and there closed by the lips, that note can still be sounded, but no other of the original series: the other notes that can be sounded may be regarded as the notes 3 and 2, made flatter by their nodes being drawn back, as it were, to the position of node 4: the original notes 2, 3, 4, becoming thus the first, second, and third notes of a new inharmonious series, with pitches approximately

Diagram 2.

NODAL POINTS.

Scale – 1/8 full size.



c♯, e♭′, c″: thus approaching the notes of a cylindrical stopped tube. Three illustrations may be given with tubes tapering in different degrees:

1st tube giving c♯, e♭′, c″.
2nd do. c′, c♯″
3rd do. c′, e″

From these experiments it may be seen that by using portions of cones of different proportions with their small ends closed, it is possible to get different series of intervals varying between those of an open and those of a closed tube: that is, the first interval varying between an octave and a twelfth.

One of the examples just shown, No. 2 c′, c♯″, appears to give intervals not very far removed from those required; it may be made use of to illustrate the effect of the combination of a cone with cylindrical tubing, such tubing being of necessity used in practice in connection with valves or slides to complete the scale. I will flatten this cone a fourth, from c′ to g, by adding tube, and it now gives the intervals g, e′, d″ in place of the g, g′, d″ required, or the ratios 1, $1\frac{2}{3}$, 3, in place of 1, 2, 3, the second interval being actually greater than the first; again, it may be altered by the addition of sufficient tube to give its original fundamental note, c′, as the second. This is done by adding half a wave length, so as not to disturb the position of the nodal point at the end of the cone. The intervals are now approximately b, c′, f♯′, c″, &c., quite sufficiently out of tune to be musically useless.

Seeing that a bugle, although it has a considerable diameter at the mouthpiece, may nevertheless be in tune, it appears that its various nodal points cannot be in the same positions as those in the cone. On diagram 2 is represented a bugle of the same pitch as the open tube and cone, with the positions of its nodes and semi-ventral segments as determined by experiment with tuning forks. Comparing on diagram the bugle and cone the fourth nodes of note 4 on each, it will be seen that on the bugle the node is farther from the open end than on the cone, in consequence of the bugle tapering more rapidly. The nodes of note 2 show this still more clearly (compare lengths from mouthpiece and apex, as well as from open end). From mouthpiece to node the length is more nearly equal to that between similar nodes on cylindrical tubing than to that between similar nodes on the cone, but from node to mouth or open end, is greater than on the cone, the bugle opening more rapidly. Thus, then, by altering the proportions of the different semi-ventral segments of which such an instrument may be conceived to be built up, the positions of the nodes may be so arranged that there is a node for every note at the mouthpiece as required, and according as that is more or less perfectly effected, will the instrument be more or less perfectly in tune. The question of quality of tone is intimately connected with this, but it would be impossible to enter upon it without taking up too much of your time. It was noticed just now that a wind instrument might be conceived to be built up of its various semi-ventral segments. This one is so divided for the note c'' 512 according to the diagram, and it will be found that by blowing at any one of the nodal points with any length of the bugle containing an odd number of semi-ventral segments, the note c'' can be produced. The total number of pieces and combinations that can give this note is 18, but a few illustrations will suffice.

In conclusion I would only say that in brass instruments it appears to me we have very interesting illustrations of some of the most beautiful points in the theory of wave motion.

° *The discussion of this communication was postponed until the following month, in consequence of the lateness of the hour.*