Reprint with additions from p 61 of "Chemistry, Biology, &c" volume of the South Kensington Conferences in 1876 (in connection with Loan Collection Scient. Instr.)

See also Catalogue of the Loan Collection No 689, page 178.

GALTON'S WHISTLES

For determining the upper limits of audible sound in different persons,

SOLD BY

S. C. TISLEY & Co.,

172, Brompton Road, London, S.W.

Printed by H. & W. Brown, at 261, Brompton Road, S.W

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BY

FRANCIS GALTON, F.R.S.

The base of the inner tube of the whistle is the foremost end of a plug, that admits of being advanced or withdrawn by screwing it out or in; thus the depth of the inner tube of the whistle can be varied at pleasure. The more nearly the plug is screwed home, the less is the depth of the whistle and the more shrill does its note become, until a point is reached at which, although the air that proceeds from it vibrates as violently as before, its note ceases to be audible.

The number of vibrations per second in the note of a whistle or other " closed pipe " depends on its depth. The theory of acoustics shews that the length of each complete vibration is four times that of the depth of the closed pipe, and since experience proves that all sound, whatever may be its pitch, is propagated at the same rate, which under ordinary conditions of temperature and barometric pressure may be taken at 1120 feet, or 13440 inches, per second,—it follows that the number of vibrations in the note of a whistle may be found by dividing 13440 by four times the depth, (measured in inches) of the inner tube of the whistle. This rule however supposes the vibrations of the air in the tube to be strictly longitudinal, and ceases to apply when the depth of the tube is less than about one-and-a-half times its

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diameter. When the tube is reduced to a shallow pan, a note may still be produced by it, but that note has reference rather to the diameter of the whistle than to its depth, being sometimes apparently unaltered by a further decrease of depth. The necessity of preserving a fair proportion between the diameter and the depth of a whistle is the reason why these instruments having necessarily little depth, are made with such small bores.

The depth of the inner tube of the whistle at any moment, is shewn by the graduations on the outside of the instrument, The lower portion of the instrument is a cap that surrounds the body of the whistle, and is itself fixed to the screw that forms the plug. One turn of the cap increases or diminishes the depth of the whistle, by an amount equal to the interval between two threads of the screw. For mechanical convenience, a screw is used whose pitch is 25 to the inch, therefore one complete turn of the cap moves the plug one twenty-fifth of an inch, or ten two hundred-and-fiftieths. The edge of the cap is divided into ten parts, each of which corresponds to the tenth of a complete turn; and, therefore, to one two-hundred-and-fiftieth of an inch. Hence in reading off the graduations the tens are shewn on the body of the whistle, and the units are shewn on the edge of the cap.

The scale of the instrument having for its unit the two-hundred-and-fiftieth part of an inch, it follows that the number of vibrations in the note of the whistle is to be found by dividing $\frac{13440 \times 250}{4}$ or 84000, by the graduations read off on its scale.

A short table is annexed, giving the number of vibrations calculated by this formula, for different depths, bearing in mind that the upper lines cannot be relied upon unless the whistle has a very minute bore, and consequently a very feeble note. The largest whistles suitable for experiments on the human ear, have an inner tube of about 0.16 inches in diameter which is equal to 40 units of the scale. Consequently in these instruments the theory of closed pipes ceases to be reliable when the depth of the whiste is less than about 60 units. In short, we cannot be sure of sounding with them a higher note than one of 14000 vibrations to the second.

Scale Readings (One division = $\frac{1}{250}$ of an inch.)	Corresponding number of Vibrations per Second.
10	84000
15	56000
20	42000
25	33600
30	28000
35	24000
40	21000
45	18666
50	16800
55	15273
60	14000
65	12923
70	12000
75	11200
80	10500
85	9882
90	9333
95	8842
100	8400
105	8000
110	7591
115	7305
120	7000
125	6720
130	6461

The following popular account of these instruments was given at one of the Conferences held in connection with the Loan Collection of Scientific Instruments at South Kensington in 1876. It is reprinted with a few verbal corrections, from the published Reports of those Conferences. (Physical Science Section, p. 61).

Mr. GALTON: I thought it would be of convenience to experimenters, that I should exhibit some little instruments I have contrived for ascertaining what the upper limits of audible sound may be in different persons of the same race, and in individuals of different races, and in different kinds of animals. It is, of course, a matter of great interest to know whether insects and such small creatures can hear sounds, and can in any sense of the word, converse in language which to our ears is utterly inaudible. When I first desired to make experiments, I was checked by the great difficulty of finding instruments that vibrated with sufficient rapidity for the purpose in question. Dr. Wollaston (to whom we are indebted for the first experiments ever made on this subject, and for the knowledge of the fact that vibrations exist which the ear is incompetent to seize and render into sound) found very great difficulty in making his small pipes. I tried several plans for obtaining acute notes, and the one I finally adopted was this: I made a very small whistle, whose internal diameter was much less than one-tenth of an inch—I have many such here, made for me by Messrs. Tisley and Spiller, Opticians, 172, Brompton-road,—with a plug at the bottom, which plug is screwed up by a graduated screw. The graduations are marked on the side so that when you use the instrument you know the depth of the tube, and knowing what that is, it is a matter of calculation to learn the rate of vibration. There is, however, a good deal of uncertainty in the matter, because there must be some fair proportion between the length and width of the tube in order that the calculations should give a correct result. A short whistle with a diameter exceeding two-thirds of its length, will certainly not give a note whose shrillness is governed wholly by its shortness. Therefore in some of my experiments I was driven to use very fine tubes indeed, not wider than those little glass tubes that hold the smallest leads for Mordan's pencils. It occurred to me, in order to produce a note that should be both shrill and powerful, and so correspond to a battery of small whistles, that a simple plan would be to take a piece of brass tube and flatten it, and pass another sheet of brass up it, and thus form a whistle the whole width of the sheet, but of very small diameter from front to back. I have such a whistle here, it makes a powerful note, but not a very pure one. I also made an annular whistle by means of three cylinders, one sliding within the other two, and graduated as before. I find that when the limits of audibility are approached, the sound becomes much fainter, and when that limit is reached, the sound usually gives place to a peculiar sensation, which is not sound but more like dizziness, and which some persons experience to a high degree. I am afraid it is of little use attempting to make the audience hear these small instruments; but I will try, beginning by making rather a low note. (It was found that there was great variability in the audience, in their powers of hearing high notes, some few persons who were in no way deaf in the ordinary meaning of the word, being wholly insensible to shrill sounds that were piercingly heard by others.) I find that young people hear shriller sounds than older people, and I am told there is a proverb in Dorsetshire, that no agricultural labourer who is more than forty years old, can hear a bat squeak. The power of hearing shrill notes has nothing to do with sharpness of hearing, any more than a wide range of the key-board of a piano has to do with the goodness of the sound of the individual strings. We all have our limits, and that limit may be quickly found in every case. The facility of hearing shrill sounds depends in some degree on the position of the whistle, for it is highest when the whistle is held exactly opposite the opening of the ear. Any roughness of the lining of the auditory canal appears to have a marked effect in checking the transmission of rapid vibrations when they strike the ear obliquely. For my part, I feel this in a marked degree, and I have long noted the effects in respect to the buzz of a mosquito. I do not hear the mosquito much as it flies about, but when it passes close by my ear I hear a "ping," the suddeness of which is very striking. Mr. Dalby, the aurist, to whom I gave one of these instruments, tells me he uses it for diagnoses. When the power of hearing high notes is wholly lost, the loss is commonly owing to failure in the nerves, but when very deaf people are still able to hear high notes if they are sounded with force, the nerves are usually all right, and the fault lies in the auditory canal. I have tried experiments with all kinds of animals on their powers of hearing shrill notes. I have gone through the whole of the Zoological Gardens, using a machine of the kind that I hold in my hand. It consists of one of my little whistles at the end of a walking stick, that is in reality a long tube; it has a bit of india-rubber pipe under the handle, a sudden squeeze upon which forces a little air into the whistle and makes it sound. I hold it as near as is safe, to the ears of the animals, and when they are quite accustomed to its presence and heedless of it, I make it sound, then if they prick their ears it shows that they hear the whistle, if they do not, it is probably inaudible to them. Still, it is very possible that in some cases they hear but do not heed the sound. Of all creatures, I have found none superior to cats in the power of hearing shrill sounds. It is perfectly remarkable what a faculty they have in this way. Cats, of course, have to deal in the dark with mice, and to find them out by their squealing. Many people cannot hear the shrill squeal of a mouse. Some time ago, singing mice were exhibited in London, and of the people who went to hear them, some could hear nothing, whilst others could hear a little, and others again could hear much. Cats are differentiated by natural selection until they have a power of hearing all the high notes made by mice and other little creatures that they have to catch. You can make a cat, who is at a very considerable distance, turn its ear round by sounding a note that is too shrill to be audible by almost any human ear. Small dogs also hear very shrill notes, but large ones do not. You may pass through the streets of a town with an instrument like that which I used in the Zoological Gardens, and make nearly all the little dogs turn round, but not the large ones. At Berne, where there appear to be more large dogs lying idly about the streets than in any other town in Europe, I have tried this method for hours together, on a great many large dogs, but could not find one that heard it. Ponies and cattle, too, are sometimes able to hear very high notes—much more than horses; I once frightened a pony with one of these whistles in the middle of a large field. I can produce no effect on ants, nor on the great majority of insects, though there are some apparent exceptions about which, however, I am not yet prepared to speak.

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