EFFECT OF FREQUENCY UPON THE END CORRECTION FOR CLOSED RESONANCE PIPES

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Introduction. There is no present mathematical theory to cover the end correction for an open unflanged pipe[1]. It is true that Rayleigh has experimented with unflanged pipes and has found the correction for pipes of small radius to be .62R. However, to secure this result, Rayleigh has used the mathematical theory for flanged pipes and by counting the number of beats between a pipe when flanged and unflanged has determined a relative value for unflanged pipes.

Blaikley has determined the correction for unflanged pipes experimentally and arrived at the conclusion that the amount of the correction is distinctly a function of the frequency of the note produced. Thus the correction must vary as the wave length varies. This is important because if the correction depended only on the size of the pipe it would not affect the relative pitch of the notes at all.

Most of the experimenting in sound in general, and upon this phase in particular has, up until this time, been of English origin. However there has recently been some work done in the United States on this subject and we are much indebted to the work of Anderson and Ostensen[2] in providing valuable guidance for the present experiment.

Since resonance in a closed pipe comes at the stages $\frac{\lambda}{4}$, $3\frac{\lambda}{4}$, $5\frac{\lambda}{4}$, etc., therefore the correction as determined by the first and second resonances would be $C = \frac{l_2 - 3l_1}{2}$; for the correction dependent on the first and third reading it would be $C = \frac{l_3 - 5l_1}{4}$. We have evolved a general formula for use in this experiment which serves for all resonances: $C = \frac{\lambda y - \left\{(2y-1)\,\lambda_1\right\}}{2(y-1)}$ where λ is the resonant length and Y is the rank of resonance.

Method. The present experiment was made in the Physics Laboratories of Indiana State Teachers College at Terre Haute during the summer of 1930. It was found that much better results could be obtained with pipes of larger bore than are ordinarily found in laboratories and that these pipes should be of a sufficient length to give several resonance stages.

For the purpose of the experiment we therefore secured two six foot lengths of galvanized iron tubing one piece 7.44 cm. in diameter and the other 10.04 cm.

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[1]Barton, E. H. Sound, McMillan & Co., London, 1914, 249-254.

[2]Anderson, S. Herbert and Floyd C. Ostensen, Effect of Frequency on End Correction of Pipes, Phy. Review. 31, Feb. 1928, 267-74.

in diameter. These tubes were equipped with small ¼ inch openings at the bottom by which the water level in the tubes could be regulated by means of a clear glass siphon tube. Resonance forks of from 256 vps. to 512 vps. were used and from three to five resonance points were determined depending on the fork in use. At each resonance point three readings were taken and the averages of the obtained, corrections were obtained by the general formula given above and these corrections expressed in terms of the radius (R) of the tube.

The readings are of course dependent on the interpretations of the human ear in detecting the correct resonant lengths and are subject to the limitations thereof. However, by obtaining the average of a large number of readings this error would not be so pronounced.

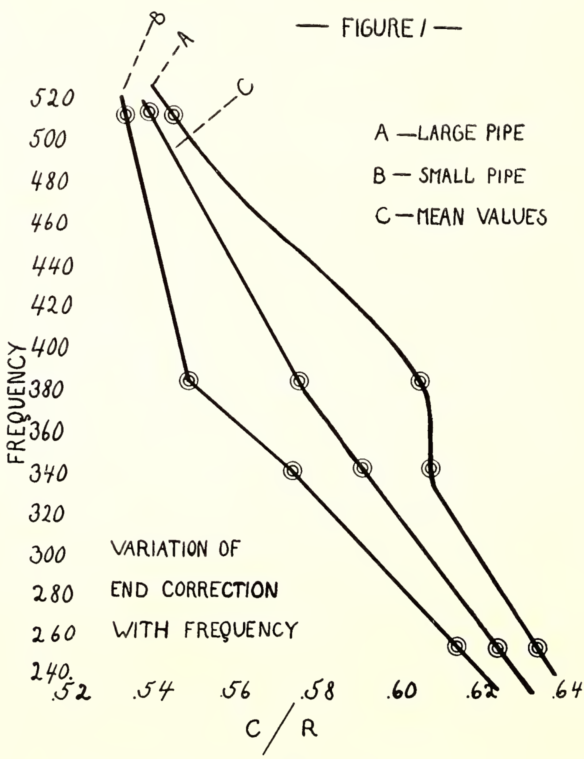

Fig. 1.

According to Blaikley four sources of error are possible in this experiment namely: (1) Position of fork. (2) Temperature changes. (3) Capillary action of water in pipes and (4) Humidity.

Anderson and Ostensen recognize three other possible sources of error: (5) The stationary wave pattern of the room (6) Resonance in the walls of the pipe and (7) Action of the resonator in "loading" the walls of the pipe.

It was found that the position of the fork had little effect on results as long as it was kept uniformly above the top of the pipe and within four or five cm. from it.

Temperature and humidity would have some effect on the various resonant lengths but no appreciable effect on the relative correction value.

The wave pattern of the room was changed by changing to different rooms, by opening windows, etc., but no difference in correction was noted.

The pipes were of such a size that the influence of capillary attraction was negligible although this would be a factor of some importance in a small pipe.

Resonance in the walls of the pipes made no difference but transverse vibrations causing lateral vibrations of the pipes was avoided by clamping the pipes firmly to a solid support at the open end.

We used no "pick-up" on the resonator and therefore "loading" of the pipes was absent.

Results are given in Table I while Fig. 1 is a graphical representation of the observed effect of frequency upon the correction. Curve A represents values for the large pipe, Curve B for the smaller pipe and Curve C, the mean values for both pipes. The latter curve seems to indicate that the end correction factor is a linear function of the frequency, tending to vanish as the frequency increases.

TABLE I—RESULTS

Frequency	Temperature	Radius (cm.)	1st Res. (cm.)	2nd Res. (cm.)	3rd Res. (cm.)	4th Res. (cm.)	5th Res. (cm.)	C/R
256	28.5	3.72	31.4 31.5 32.2 Ave. 31.7	99.2 99.2 98.9 Ave. 99.1	168.8 168.3 169.3 Ave. 168.8			.540 .688 Ave. .614
341	29.4	3.72	23.7 23.5 23.1 Ave. 23.4	74.6 74.5 74.4 Ave. 74.5	125.6 125.2 125.7 Ave. 125.5	176.5 176.7 176.6 Ave. 176.6		.578 .571 .574 Ave. .574
384	32.4	3.72	20.8 20.5 20.6 Ave. 20.6	65.3 65.4 65.8 Ave. 65.5	111.8 111.1 111.6 Ave. 111.5	156.3 157 157.1 Ave. 156.8		.511 .571 .564 Ave. .549
512	34.5	3.72	15 15 15 Ave. 15	48.9 48.8 48.7 Ave. 48.8	83.2 83.3 83.8 Ave. 83.4	117.8 117.2 118 Ave. 117.7	149.4 149.6 149.8 Ave. 149.6	.511 .564 .570 .491 Ave. .534
256	30.4	5.02	30.8 30.9 30.9 Ave. 30.9	98.8 98.7 98.75 Ave. 98.75	168 168.1 167.2 Ave. 167.8			.603 .662 Ave. .632
341	29.8	5.02	21.7 23 22.1 Ave. 22.2	72.6 72.2 72.4 Ave. 72.4	123.3 122.8 122.9 Ave. 123	174.9 173.9 175.4 Ave. 174.7		.577 .597 .641 Ave. .605
384	27.6	5.02	19.5 19.6 19.6 Ave. 19.6	64.8 64.7 65 Ave. 64.9	108.8 108.6 109.3 Ave. 108.9	157 157.2 157.1 Ave. 157.1		.607 .543 .660 Ave. .603
512	27.8	5.02	14.2 14.2 14.3 Ave. 14.2	47.6 47.9 48.1 Ave. 47.9	82.4 81.9 82.5 Ave. 82.3	115.6 115.4 115.2 Ave. 115.4	149.9 150.4 149.8 Ave. 150	.528 .563 .532 .553 Ave. .544

CONCLUSIONS

There is a distinct relation between the amount of correction and frequency, the correction decreasing as the frequency increases. This is in accordance with the work of Anderson and Ostensen on the subject although they find the decrease to be more pronounced at frequencies higher than we have attempted.

The correction is slightly higher for the larger bore pipe but the range of values is practically uniform for the two pipes; in the larger pipe there was a variation of 12 percent from the lowest to the highest frequency and in the smaller pipe a variation of 13 percent.

The mean of all observed corrections is .5819 R; this is in accordance with the value determined by Blaikley at .58 R but is slightly lower than Rayleigh's value of .62 R.

Helmholtz has found the correction to be $\pi/4$ R, a result that is higher than that given by most authorities. However he supports the generally accepted theory that for very short values of λ the correction would tend to vanish.

In a study of this kind a sound proof or nearly sound proof room would be a decided help in adding to accuracy. The tube should be firmly clamped in order to prevent vibratory motion in the walls of the pipe. The air in the room should be perfectly still as an air jet across the top of the open pipe would tend to decrease the volume of the resonance and to set up transverse vibrations in the pipe itself.

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