# PHYSICS

XXIV. ON THE INTENSITY OF SOUND
J. H. CLOUD
Oklahoma A. and M. College

It is a simple matter to measure the intensity of a source of light and express it in candle power. Students in elementary laboratories measure the intensity of an electric current accurate to one part in ten thousand, but until quite recently the intensity of sound was almost meaningless. Qualitative measurements have been sadly lacking. So far as the writer is aware the Rayleigh Disc and the Webster Phonometer are the only instruments so far devised for the measurement of sound intensity.

Apparatus

The apparatus selected for the first part of this work was that of a Rayleigh disc suspended in the throat or neck of a compound resonator. The disc considered of a cover glass used on microscope slides. The diameter of the disc is 15 mm., thickness 0.1 mm. and weight, after being heavily silvered by a modification of the Brashear Method, about 12 mg.
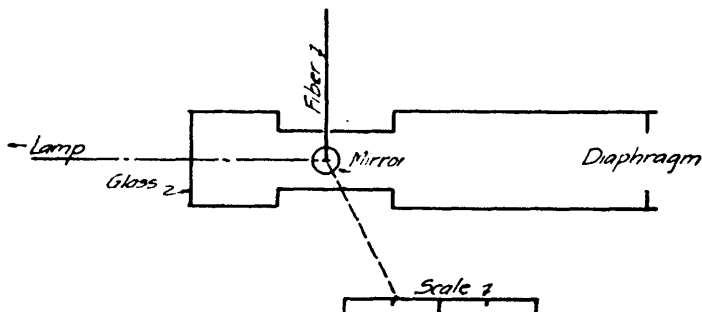
The resonator was made of two metal cylindrical chambers 12.5 cm. and 3.2 cm. long respectively and each 4.8 cm. in diameter, connected by a smaller tube 2,8 cm. in diameter and 8 cm long. The tubes were soldered together as shown. The outer end of the smaller chamber was closed by a piece of glass. The opening at the outer end of the large chamber could be varied by means of an iris diaphragm which was surrounded by a flange extending 20 cm. beyond the tube. The throat had two open-

ings, one at the top to admit the suspension, and one at the side, covered with glass, to allow light reflected from the disc to pass to the screen.

Various suspensions were tried. A single strand of unspun slik fiber being found most sensive. Hair was also tried but fine quarts threads (diameter—0.0022 cm.) gave the most nearly dependable zero reading and were otherwise less troublesome, though less sensitive, than the silk.

In the theory of sound it is shown that the angle of deflection of the disk is proportional to the sound energy per unit volume of the vibrating medium. Thus the angle of deflection is a measure of the intensity of the sound.

Different sources of sound were tried including various forms of whistles, auto horns and electrically-driven tuning forks. The one best suited to the above described resonator was an organ pipe blown by air under constant pressure. The constant pressure was obtained by forcing air from a foot bellows into an inverted cylindrical vessel surrounded by a similar vessel, the space between them being filled with oil. The tank was 75 cm high and 38 cm in diameter. The stop-cock openings were of such dimensions that a pressure of 2 cm of mercury, caused a consumption of air, when operating the organ pipe, of 340 cubic centimeters per second.

Experiments

An attempt was made to map the distribution of energy around an organ pipe blown with constant pressure. As it was much easier to move the source of sound than to move the resonator the latter was left fixed in position and the organ pipe moved about it. The room was practically 12x16 feet with a 12 foot ceiling. It was possible to find positions for the pipe in which it would produced almost no effect upon the resonator.

Doubtless this result was brought about by a node being established at the resonator, due to reflections from the plastered walls of the room. Moving either the source or the resonator one foot the usual large deflection would result when the pipe was sounding. At some positions when the fundamental failed to cause a deflection an upper partial might still cause one. This proves that both the intensity and the quality of sound heard in a small room depend upon the position of both the source and the hearer.

The experiment was continued in a larger room approximately 30x50 feet with the result that with no flange at the mouth of the resonator, the source might be carried completely

around the resonator with no appreciable change in the deflection. With a large close-fitting flange surrounding the resonating tube at the mouth end the deflection was about five per cent greater when the source was in front of the aperture than than when it was the same distance behind it.

Readings taken with the source close to the resonator were found to vary somewhat with the distance, but when the distance was as great as 15 feet the deflection was no greater than when the source was moved to the farthest corner of the room 30 feet away. This shows that within a room of this size the inverse square law does not apply.

A further attempt was made to eliminate reflection and interference by moving the whole apparatus out in the open air. A level tract of land covered with grass, and with neither buildings nor trees near was selected. It was found impossible to obtain trustworthy readings when a strong wind was blowing but on the calmest days the zero reading of the spot of light on the scale was fairly constant and repeated readings differed by not more than about five per cent. The whole apparatus was protected from the wind by means of light frame covered with cheese cloth and four thicknesses of the same material were loosely placed over the mouth of the resonator and held in position by means of rubber bands. This layer of cheese cloth did not appreciably diminish the response of the resonator.

The conclusions reached agreed with those of indoor experiments, viz, that when the distance between the source and resonator was constant, the source could be carried completely around the resonator without appreciably changing the deflection. The small difference detected indoors by using the flange was so small as to be within the limits of the error of the outdoor readings.

No anemometer was available but with even a "gentle breeze" blowing it was impossible to obtain a deflection with the pipe (source) more than 40 feet on the leeward side of the resonator, while a readable deflection was produced at a distance of 100 feet on the windward side.

A circle of ten-foot radius was drawn with the reasonator as center. The circumference was divided into arcs of 45° each, the points of division being lettered A, B, C, D, E, F, G, and H. "A" designated the point directly in front of the reasonator and E, directly behind it. With the centimeter scale at a distance of 180 cm from the mirror, readings were taken when the pipe was blown at A, B, C, and so on in succession around

the circle. The circle was then expanded to radii of 20, 30, 40 and 50 feet in succession and the readings repeated. This was done several times. The average readings are recorded in table I

Table I

Radius in			Scale deflection cm.					
feet	A	B	C	D	E	F	G	H
10	28	28	26	25	25	26	25	28
20	12.5	12	12	10	10	10	11	12
30	7.5	7	6	6	6	6	6	7
40	4	4	3	3	3	3	4	4
50	2	2	1	1	1	1	1	1

The decreased readings at D and E were perhaps due to the wind which was from that direction rather than to any flange action. Readings were repeated with the flange removed and the differences were found to be so small as to be easily attributable to variations in wind velocity or to other incidental causes.

Even a cursory glance at the readings in Table I shows that the inverse square law is not at all applicable. The average deflection at a distance of 10 feet is 26 scale divisions while at 20 feet the average deflection is still 11 instead of 6.5 as it should be if the inverse square law held.

For out door work it was found that shorter fibers were less troublesome and gave better results than the longer more sensitive fibers used inside. The suspension used to get the data shown in Table I was 15 cm long, 0.079 cm in diameter, and had a mass of 0.080 grams and a period of 2.3 seconds.

An approximate calculation showed that for each unit of sound energy in the fundamnetal at a distance of 40 feet from the pipe, 20,000 units of energy were expended at the gas tank. This is, indeed, a very low efficiency.