having a resistance of 400 ohms and a sensitivity of 6.02×10^{-11} amps./mm. as now used. In this work it has been critically damped. The deflections for illuminations such as used ran as high as 100 cm. The contacts used were very heavy strips of copper, about 2″ by 10″ and $^1/_8$″ thick; they were blackened by smoke from burning naphthalene except at the point of contact, and were pressed firmly against the crystal by weights placed on them. The crystals were natural and several specimens were used, obtained from the following localities: Frieberg, Saxony, Germany; Schneeberg, Saxony, Germany; Batopilas, Mexico; and Arispe Sonora, Mexico.

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*POSITIVE AND NEGATIVE PINHOLE RESONATORS**

BY CARL BARUS

DEPARTMENT OF PHYSICS, BROWN UNIVERSITY

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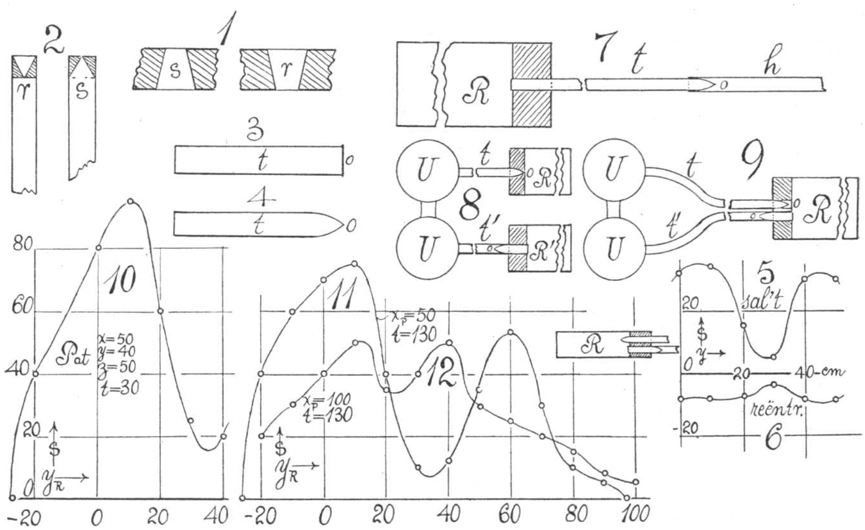
Improvement of the Pinhole Resonator.—The plan immediately suggesting itself was the trial of an adjustable needle valve pinhole. The apparatus was made of $^1/_4$ inch brass tube, with a conical point carrying the pinhole at its end. The tube was closed by a long nut in which a waxed screw terminated by the needle was movable. The pinhole could thus be completely closed, or opened in any degree by approaching or withdrawing the screw. The new pinhole was inserted into the tuned resonator, as usual. After many trials, nothing was obtained with this promising apparatus, until the needle was completely withdrawn. In fact the best pin holes obtained for the resonator, were made from glass quill tubes drawn to a blunt closed cone. It is necessary to open and enlarge the hole by grinding; or to close the conical end by gentle fusion and regrinding when cold.

To throw further light on this intricate subject, it seemed advisable to operate with pinholes in soft sealing wax, as these could be more easily shaped. In this way much information was obtained. A thin sheet of wax was spread on thin-paper closing the end of the quill tube. When the wax was punctured by a needle from the inside of the tube, producing a conical hole as exaggerated at S in figure 1, the fringe deflections were positive and reached a maximum with the right size of hole. But when the thin wax sheet was punctured from the outside of the quill tube (suggested at r fig. 1.), the deflection obtained was to the same degree negative. In other words, in passing from the salient pinhole to the reëntrant pinhole, acoustic pressures pass to acoustic dilatations; or the pressure excess is on the reëntrant or concave side of the conical pinhole. It follows therefore that a cylindrical pinhole must be inactive, if used with a resonator.

The remarkable efficiency of glass quill tube probes, with the pin hole at a conical end, ground off, thus finds its explanation; for these are in conformity with *s*, figure 1.

To further verify the new results, holes were bored with a fluted conical reamer in small discs of brass and these were then soldered to the ends of quarter inch-brass tubes, as shown at *r* and *s* in figure 2. The cones ended in pinholes, drilled from within and without, respectively, by fine needles. The case *s* gave positive deflections, *r*, negative deflections. It was found that on enlarging *r* from within with a needle, the deflections became positive; on further enlarging the pinhole, now from without, it became



negative again. This proves, conformable with the earlier evidence, that only a very small depth of pinhole (probably of the thickness of a piece of paper) is effective and the remainder of the cone without importance.

Fine slits cut in wax behaved similarly to the pinholes above mentioned, producing pressure for a salient wedge, and the reverse. The fringe deflections, *s*, of figure 5, in which a resonator with a salient pinhole moves in *y* when tested with a reëntrant pinhole resonator, supplied the results shown in figure 6. The maxima and minima are throughout negative. Both salient and reëntrant pinholes function in the same way, with an inversion of sign, but without change of sign for the same pinhole.

The question is thus adduced, as to whether the pinhole resonator with a reversed cone, figure 7, will also produce a reversal of fringe deflections. On trial an affirmative answer was obtained at once. As a rule the negative deflections are numerically smaller than the positive deflections. It was further found that the negative deflection decreases with the length of connector tube *t*, from the bottom of the resonator *R* to the reëntrant pinhole O, figure 7, the pipe h beyond being the rubber connection to the U-gauge. The negative pinhole resonator runs down in sensitiveness much more rapidly (if treated in this way, pinhole remote), than if the pinhole is fixed in the bottom of the resonator, and a connector h of any length, communicates with the U-gauge.

Positive and Negative Pinhole Resonators Coöperating.—It is obvious that the positive (pinhole cone O salient) and negative (pinhole cone O' re-entrant) pinhole resonators, R and R', figure 8, must add their respective pressure effects at the gauge U U', if they are provided with independent connector tubes t and t'. A large number of such experiments all indicated that the separate deflections may be added, at least very nearly. The sensitiveness may thus be nearly doubled. It is probable moreover that two resonators will interfere less with each other than two positive or two negative resonators (i.e., two identical resonators, generally), if placed a short distance apart. The deflection in fact, falls off slowly and does not quite vanish even with a mere crevice between the mouths. If the two resonators are parallel, side by side and mouth near mouth, the conditions are even better. Hence if R R', figure 8, are placed side by side, and the connector tubes t, t' are of pure rubber, elongated if necessary, the twin apparatus is available for exploration.

With short connectors t t' in the interest of greater sensitiveness, I made a number of tests to find the maximum distance for which the twin resonators (fig. 8) would respond. They were able to hear an organ pipe to a distance of 6 meters, the deflection being then about a fringe.

Although a single resonator with a branched tube is ineffective, the suggestion of using the bottom of the resonator R figure 9, as a branch point for the connector tubes t t' to the gauge U U', seems highly promising. One and the same resonator here functions in both (positive and negative) capacities. The design succeeded with, as it seemed, but little sacrifice of sensitivity. Figure 10 shows the fringe deflections S, obtained along y, for the case of short connector tubes t t' (30 cm. long), with the pipe (at $x = 50$, $y = 40$, $z = 50$ cm.), near the center of the table. In figure 11 the same result is extended with long connector tubes ($t = 130$ cm.). In curve 12 finally, the results refer to a more distant pipe at $x = 100$ cm., $y = 40$, $z = 50$ cm. All curves fall off quite abruptly at the two edges of the table $y = -27$ and $+93$ cm. The extreme importance of tuning was noteworthy throughout; mild notes frequently giving large deflections, sometimes out of field, whereas strong notes of the same pitch to the ear dropped the fringes back to zero. A variety of experiments were made with this $\pm$ resonator with results like the above which need not therefore be reported.

* Advance note from a Report to the Carnegie Institution of Washington, D. C.