the liquid is not crystalline, but is one in which molecular mobility is permitted and the resulting peaks represent the most probable spacings. A name is proposed for this non-crystalline, space-array state. The noun is *cybotaxis* and the adjective *cybotactic*.

This conception of the liquid state gives a description of a "solution" and contributes to various theories in connection with liquids. The experiments and discussion will soon be published in full.

[1] Debye and Scherrer, *Nachr. Gesell. Göttingen* (1916), p. 6.

[2] Vide Hewlett, *Phys. Rev.*, **20** (1922), p. 688 and others.

[3] Müller and Saville, *Journal Chem. Soc.*, **127** (1925), p. 599.

[4] Adam, *Proc. of Roy. Soc.* (1921), (1922), (1923).

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*PINHOLE PROBE MEASUREMENTS WITH MASSIVE CYLINDRICAL AIR COLUMNS**

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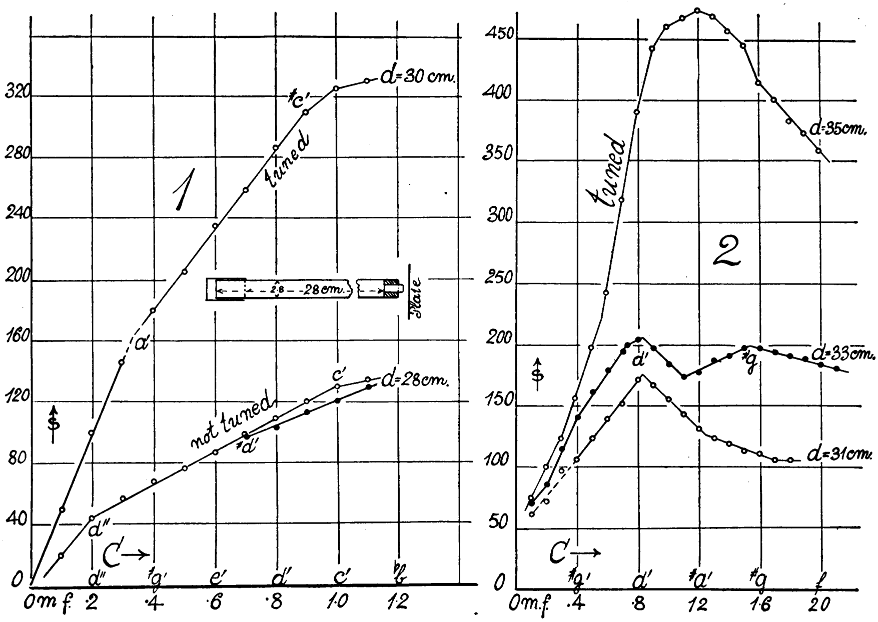
1. *Introductory*.—After completing the work with the broad horn of my last paper,[1] similar experiments were made with a long slender horn (40 cm. long) and with cylindrical tubes (28 cm. long, 2.8 cm. diam.). The results in the former case are too complicated to be given here. In the latter (tube), the nodal pressure-capacity (s, C) graphs of the transformer (electric oscillation) consisted of a group of nearly straight and parallel lines, running close together, so long as the pinhole lay below the middle (d = 14 cm.) of the tube. After this (d = 15 cm. to 0) the slopes decreased rapidly. There were no marked crests, but rather noise increasing continuously with the capacity, C, or falling pitch. The break circuit (electric siren) graphs, however, showed the usual cuspidal crests (here at a', e'', a'') with long intervals of relative silence between. As far as the middle of the pipe, the crests were about of the same nodal intensity, s. Hence these data accentuate the results already described for the horn. In the s-d graphs, the a' and a'' crests lay at about d = 7 cm. and near the bottom, while the e'' crest was marked near the middle d = 15 cm. of the pipe. From this it appears both the a' and a'' of the motor break (siren) evoke the first overtone a'' of the d' closed organ pipe; whereas in the case of the e'', the pipe with a telephone plate at one end vibrates as an open organ pipe with a node near the middle.

2. *Extensible Pipe*.—Since there are three vibrating systems in the transformer method, two of them should be made adjustable if the third is given, to obtain the largest acoustic pressure values (s). An extension

was, therefore, added to the pipe (insert, figure 1) so that its length could be increased continuously, from $d = 28$ to 35 cm. By setting this for the maximum s at any capacity, C, the remainder of the curve was then worked out. A remarkable result presented itself, with an important bearing on the pinhole probe, inasmuch as the graphs now consisted of right line elements, between breaks.

In figure 1 the largest s was first found for the pipe depth near $d = 30$ cm. by tuning (the probe being at the bottom of the tube as usual). The graph obtained for varying C (0 to 1.1 m.f.) starts with a linear sweep as far as $C = 0.3$ m.f. (a'), then bends abruptly to a second linear sweep

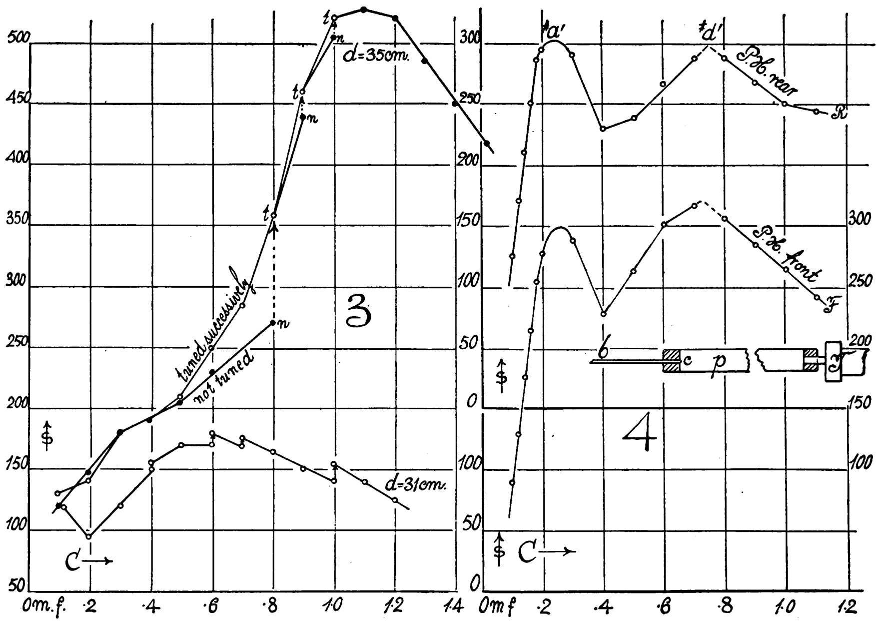


as far as $C = 0.9$ m.f., after which the course is curved to the crest beyond the figure. It would seem that each of these lines corresponds to a given kind of vibration; i.e., to a given overtone which breaks abruptly into the next available.

The behavior of the untuned pipe ($d = 28$ cm.) for the given spring tension is shown in the lower curve. There is a break at $C = 0.2$ (d'') and at $C = 1.0$ (c') m.f. In the repetition (black dots) the break at $C = 0.7$ (# d') is probably an accidental small change in the tension of the electrical spring break. Between these points the graph is strikingly linear.

After the tube was further elongated to the pipe depth, $d = 35$ cm., now adequately in resonance with the spring break, a second and much stronger maximum, figure 2, appeared. The rectilinear progress between C = 0.1 to 0.3, 0.4 to 0.5, 0.6 to 0.8, 1.0 to 1.2, 1.3 to 1.5, 1.6 to 2.0 m.f., is marked throughout. Even near the crest C = 1.2 the tendency is still observable. This relatively enormous crest (s = 475) is in keeping with the near resonance of break, pipe and electric oscillation.

It seemed worthwhile to test the case further with untuned lengths between d = 28 cm. and d = 34 cm., and throughout large C ranges (0 to 2 m.f.). Examples of the graphs are given in figure 2 for an altered transformer spring tension. Broken rectilinear paths are the rule particularly for d = 31, 33, where the roof-like crests are striking.



Finally in figure 3 for the optimum d = 35, the successively tuned pipe (open circles) is compared with the untuned pipe (black circles). Below C = 0.5 the divergence is not large, both starting under tuned conditions. Thereafter the divergence rapidly increases, the tuned pipe naturally being in excess. From C = 0.8 on, passage of the untuned (n) condition to the tuned condition (t) is indicated by arrows. To get the maximum s-values it is thus necessary to re-tune the pipe at all pitches. The successive tuning (resonance throughout) has raised the crest to nearly s = 550, an acoustic pressure of over 0.4 mm. of Hg.

The same figure shows the corresponding behavior at the smaller maximum at d = 31. Linear progress is interrupted by the tuning indicated by the arrows.

3. *Closed Organ Pipe.*—The open-mouthed organ pipe is very noisy, so that in this respect the doubly closed organ pipe shown in the insert, figure 4, is preferable. Here p is the pipe 27 cm. long in the clear, T the attached activating telephone and bc the pinhole probe. The point c may either be thrust to the rear, near the telephone, or (as in figure) the pinhole c may be near the front of the tube. This should make no difference in the acoustic pressure, s, other things being equal. The telephone, T, was activated by the transformer method, as the specific results of this method are particularly in question.

The graphs R and F (the former raised for clearness), for the same tense spring break adjustment left unchanged, but with the pinhole, respectively, in the rear (bottom) and in the front of the doubly closed tube, are practically identical. They again consist of linear parts (as above) with abrupt breaks. Each exhibits two crests, respectively, above a' and $\# \, d'$.

4. *Alternating Current.*—The attempt to energize the primary of the induction coil by an alternating current proved unsatisfactory for the reason that while the induction is relatively feeble as compared with the break circuit methods used heretofore, the heating effect of these continuous currents is out of all proportion.

5. *Remarks.*—In my work heretofore, I have associated the fringe displacement, s, i.e., the nodal intensity or acoustic pressure with the usual energy (E per unit of volume) equation. If n is the frequency and a the amplitude of the sound wave, we may, therefore, write $E = p + \rho v^2/2 = Ks + (\rho/2)(2\pi a n)^2$. At the mouth of the tube s is zero and a the maximum; at the bottom or node a is zero and s a maximum. The expectation that a similar equation could also be used to interpret the fringe displacement at a given point for different frequencies is not warranted. For if we put $4\pi^2 n^2 = 1/LC, p = Ks$ and assume E to be constant along the linear elements of the graphs, the result is $-(s-s') = (\rho/2KL)(A^2/C - A'^2/C')$ whereas the graphs suggest $\Delta s \propto \Delta C$ simply, along each element.

The view that the oscillation frequency (n) of the organ pipe is impressed on the oscillation frequency (n') of the secondary actuating the telephone plate is also unsatisfactory. For if Y is the amplitude of the electric circuit under a harmonic electromotive force $E \cos \omega t$

$$Y = E/\sqrt{(\omega'^2-\omega^2)^2 + K^2\omega^2}$$

where $\omega = 2\omega n$ and $\omega' = 2\pi n'$ are the angular frequencies of the free and frictionless acoustic and electrical circuits, respectively, and K is the coefficient of friction. This may as usual be reduced to proportionalities in the form $y = 1/\sqrt{(1-x^2)^2 + \alpha^2 x^2}$ where $x = \omega/\omega'$, $\alpha = K/\omega'$, $y = Y/(E/\omega'^2)$. This y has a crest for $x^2 = 1-\alpha^2/2$.

If $\omega' = 1/LC$ and K is relatively very small, the equation reduces to

$$Y = \frac{ELC}{1-\omega^2LC}\left(1-\left(\frac{K\omega LC}{1-\omega^2LC}\right)^2/2\right)$$

approximately, where ω, K, L are constant and C variable. Hence, even if we neglect the term in K and associate Y with the fringe displacement, s, an equation in this form is not serviceable in identifying $\Delta s \propto \Delta C$ along linear elements, unless ω^2LC is small compared with 1. This would not be the case with the fundamental or any harmonics of the cylindrical pipe. Even if ω refers to the frequency of the spring break taken at pitch a, the equation remains inapplicable.

This suggests a simpler approach through the capacity equation $Q = CV$ whence $\Delta s \propto \Delta i = (dV/dt)\Delta C$; or the slopes of the linear elements of the graphs are to be associated with the effective time rate at which the potential of the condenser changes. The value of dV/dt depends on the form of residual wave on which the new impulse is superimposed. Moreover a reason for the broken linear relations of s and C is now apparent; for the fringe displacement s measures the difference of level of the surfaces of mercury in the U-gage. It, therefore, also measures the potential energy localized in the stationary wave at the point of the pinhole probe, though it does this with a coefficient which may be either positive or negative. The stream lines run from the outside to the inside of the pinhole embouchure.

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

[1] These PROCEEDINGS, 13, pp. 52–56, 1927.

ATOMIC LATTICES AND ATOMIC DIMENSIONS

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By means of the concept of a spherical atom W. L. Bragg[2] and W. P. Davey[3] have independently computed the radii of atomic spheres of influence from the distances of closest approach obtained from X-ray measurements on crystals. In this paper these spherical atoms are specialized and the cubic atom proposed by Lewis and developed by Langmuir is extended to simple polyhedrons inscribable in spheres. It is shown in detail how these simple models can be built up into various types of observed cubic and hexagonal lattices and how the lattice constants are geometrically related to the atomic radii. From these relations *possible atomic radii* are computed and tabulated.