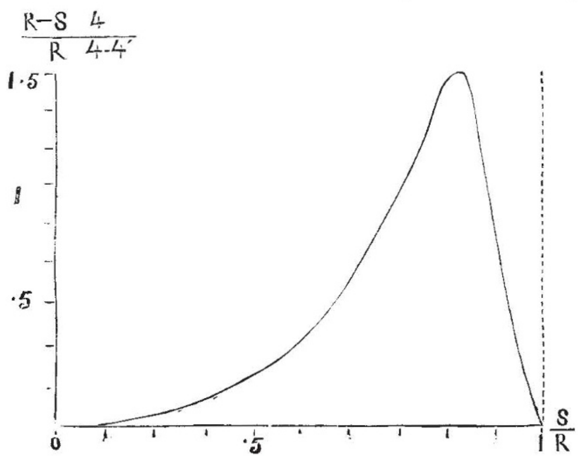
been had the whole aperture been employed. The improvement in definition, then, due to the expanding shutter acting as a stop is given by the expression—

$$\frac{R-\rho}{R} \cdot \frac{L_1}{L-L_1}.$$

The curve below shows the improvement in definition calculated from this expression, the abscissæ being proportional to $\frac{\rho}{R}$. It has a maximum value of 1·5 nearly when $\frac{\rho}{R}$ is about ·8, but falls away rapidly on either side of this value.

Thus when a stop of ·8 times the full aperture is sufficient to secure definition, the square expanding aperture may be said to answer the purpose. But a better result with less exposure could be obtained by the use of shutters of type (4) with a separate stop of the right size; for it may be shown that with the square expanding aperture the amount of light admitted while more than eight-tenths open is not more than 8 per cent. of the whole, and not more than 8 per cent. of the light would be lost if a ·8 stop were used. But a shutter of type (4) admits nearly 40 per cent. more light than the expanding square, so that there would be a gain of something more than 30 per cent. in light by using it.

This is rather understating the case, for the efficiency of a shutter as defined above is increased by the use of a stop,



the whole aperture of the stop being uncovered for a finite time while the whole aperture of the lens is only uncovered for an instant.

To see what effect an unbalanced shutter has on the steadiness of the camera and definition of the image, the mass of the unbalanced moving part of the shutter, the mass of the camera, its period of vibration on its support, and its radius of gyration must be taken into account, as well as the time of exposure. The exact investigation of the motion is very much like that given by Helmholtz of the motion of a pianoforte-wire when struck by a hammer. But without entering into mathematical details it is easy to approximate to the required result in a large group of cases, viz. where the time of exposure is short compared with the natural period of the camera on its supports. This will apply to cameras held in the hand for all exposures which could be effectively used with such a support, and in most other cases when the exposure is less than a fiftieth of a second.

The camera and shutter may now be compared to a fly-wheel free to turn with a small load on its rim, which, by some mechanism on the wheel, can be made to vary its position. If the fly-wheel is at rest to begin with, the motion of the system when the load is caused to move is given by the condition that the moment of momentum of the fly-wheel and load together is nothing, which implies that

$$\frac{\text{velocity of rim of wheel}}{\text{velocity of load}} = \frac{\text{mass of load}}{\text{mass of rim}}$$

Suppose that the camera is replaced by a fly-wheel which has the same moment of inertia and a radius equal to the distance of the centre of oscillation of the camera on its support from the shutter, the mass of the equivalent fly-wheel will be less than that of the camera on account of its distribution, so that the angular motion of the camera about the centre of oscillation will be somewhat greater than

$$\frac{\text{mass of shutter} \times \text{travel of shutter}}{\text{mass of camera} \times \text{radius of oscillation}}$$

As an example, suppose the ratio of the masses to be 1/100 and the travel of the shutter one inch, if the radius of oscillation lies between one foot and six inches, the augular movement of the camera will be between three and six minutes of arc, or from one-tenth to one-fifth of the apparent diameter of the sun or moon.

In the case of drop-shutters acting by gravity, the camera begins to move upwards at the moment the shutter is released, and will go on moving upwards until it is as much above the new position of equilibrim which it would assume on the removal of the weight of the shutter as it was below it when the latter was attached. So that if the time of exposure be half as long as the natural period of the camera, the whole extent of the angular motion will show on the sensitive plate.

I have recently made some experiments to see how, when the camera was held in the hand, the accidental motions of the support compared with those due to the action of the shutter. It would, I think, at first sight be supposed that the former were the more important of the two. The experiments were made by weighting a piece of looking-glass to represent the camera, and then, holding it as the camera would be held, reflecting the sun on a distant screen and noting the displacement of the patch of light. I found it in my own case to be continual, vibrating at a rate of something like four per second, through an angle of about one in six hundred to one in eight hundred, implying, of course, half this motion in the camera; that is, from three to two minutes of arc. The time of the whole vibration being about one-fourth of a second, if the time of exposure was as much as one-eighth of a second the whole of this would show on the plate, but for exposures of one-twentieth of a second the loss of definition from this source would hardly be appreciable. The weight of the camera in this case was small—little more than a pound—and so unfavourable for steadiness.

The general conclusions to be gathered from the foregoing remarks are: (1) That there is room for great improvement in the photographic efficiency of shutters; (2) that all the ordinary kinds shake the camera when the exposure is rapid; but that (3) for comparatively long exposures, say more than one-tenth of a second, almost any kind of shutter will do when the camera is mounted on a stand; and (4) that for cameras which are to be held in the hand, in order to secure fine definition the shutters must be dynamically balanced or exceedingly light.

A. MALLOCK

ON SOME PHENOMENA CONNECTED WITH THE FREEZING OF AËRATED WATER

THE elimination in the gaseous form, on the freezing of liquids, of the air and gases held in solution presents some features in its process which may be worth recording.

Bubbles in ice are familiar; but their arrangement and progressive development in the process of freezing-over present some points which I do not think have been generally observed.

Aquatic plants at the bottoms of ponds give off oxygen gas, and marsh gas is emitted from decaying vegetable matter. These two sources of supply will, to some extent, account for the entanglement of bubbles in ice on a pond surface, but only to a very small extent, and may be left out of consideration in dealing with the development of air-bubbles in ice. This takes place independently of any extraneous source of supply other than atmospheric air, and may be as well seen in a glass or earthenware vessel as over a weedy pond surface.

The following facts must be noticed :—

(1) Ice over deep water invariably contains fewer bubbles of included air and gas than ice formed over shallow water, and probably from this cause ice obtained from over deep water is more durable for storage than ice obtained from shallow pools.

(2) The upper or surface portion of a coating of ice invariably contains less included air than its under or lower portion, and this is more obvious in ice formed over shallow than in that over deep water. In each case there is a fairly regular gradation in the quantity of entangled air, increasing from the surface downwards. I ascertained that the included air from the upper surface (*a*, Fig. 1) of

Fig. 1.

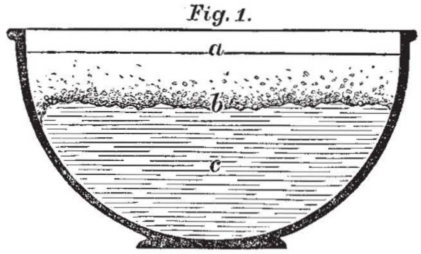
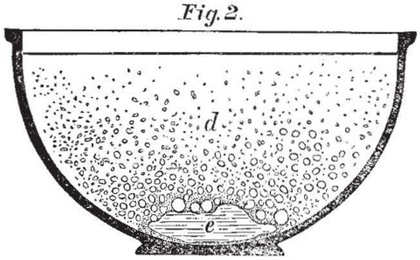


Fig. 2.



a thin coat of ice was scarcely appreciable in quantity, and one pound weight from its lower surface (*b*, Fig. 1) contained 0·08 of a cubic inch of entangled air.

(3) There is more included air in ice formed over water in a small vessel (Fig. 1) than in ice formed over a large body of water.

(4) There is more included air (weight for weight of ice) in an entirely frozen mass of ice (Fig. 2, *d*) than in surface ice from a partly frozen vessel of water. In an entirely frozen mass (Fig. 2, *d*) 1 pound of ice contained 0·59 cubic inch of included air; and surface-ice (*a*, *b*, Fig. 1), over unfrozen water, one pound weight contained 0·15 cubic inch.

(5) In freezing separately the water from which the first frozen coat of ice had been removed (Fig. 1, *c*), the ice contained a much larger proportion of included air (0·89 cubic inch) than either the surface ice (Fig. 1, *a*, *b*) or the ice obtained from entirely freezing a body of water (Fig. 2, *d*).

(6) On re-freezing water which had been frozen and thawed, there was but a very slight further release of air, which had been almost entirely released in the first freezing: one pound of the second ice contained but 0·005 cubic inch of air.

(7) In completely freezing a vessel of water (Fig. 2), not only does the entangled air increase in quantity downwards, but at the base of the frozen mass occurs a large air-cavity (*e*, Fig. 2).

All these facts, and the results of the experiments, seem to point to the fact that, in the process of freezing, the elimination of the air and gases in solution is taking place in two directions: (1) a part of the air is taken into solution by the *un*frozen water as it is progressively rejected by the thickening coat of ice; and (2), a part of it is extruded as bubbles of air, which become entangled in the ice.

If each stratum of ice eliminated the whole of its own proportion of air in solution in the gaseous form, the bubbles would be distributed with fair regularity throughout the collective mass, but their progressive increase in a descending direction exactly agrees with the continuous surcharging of the underlying unfrozen water with the air in solution rejected by the ice above, till, at the end of the freezing process of the mass, the remnant is extruded as one large bubble (Fig. 2, *e*) at its base.

The rejection of the air into continued solution would seem to take precedence of its extrusion in the gaseous form, and would go on as long as there was a sufficient body of adjacent water in a condition to receive it; but the gradual surcharging of a limited body of water with the rejected air is necessarily accompanied by its progressively increased extrusion in the gaseous form.

The comparative absence of air-bubbles in ice over deep water is accounted for by the fact of there being a sufficient body of adjacent water in a condition to receive the rejected air into solution in preference to its extrusion as gas.

To briefly recapitulate the experimental results:—(1) In a thin ice-coating, the upper or surface half contains barely a trace of eliminated air, whilst its under or bottom half contained 0·08 cubic inch of air in each pound of ice. (2) A surface coating of ice $1\frac{1}{2}$ inch thick contained 0·15 cubic inch of air in each pound weight, whilst an entirely frozen mass contained 0·59 cubic inch of air in each pound weight. (3) The freezing of a limited body of water which had been first frozen over and the surface ice removed points still more strikingly to the concentration of air in solution; for this contained 0·89 cubic inch of air in each pound weight, compared with 0·15 cubic inch in surface ice, and 0·59 cubic inch in an entirely frozen mass.

The water employed in these experiments was from the East Surrey Waterworks. GEORGE MAW

NOTES

THE following notice of motion has been given by Mr. Howell, M.P. :—"To call the attention of the House to the subject of technical education, and to move the following resolution :—'That, in the opinion of this House, it is essential to the maintenance and development of our manufacturing and agricultural industries, in view of the rapidly increasing competition of other nations, both in home markets and abroad; and in consequence of the almost universal abandonment of the system of apprenticeship; that our national scheme of education should be so widened as to bring technical instruction, the teaching of the natural sciences, and manual training, within the reach of the working classes throughout the country.'"

IT is stated that in consequence of the financial difficulties of the Bristol College, and lack of endowments, the salaries of all the Professors will be reduced by the Council, and some Chairs are to be abolished. The course pursued by the Council has given rise to much correspondence in the local papers during the past month. It is earnestly to be hoped that circumstances may yet