polar area of depression in the higher regions of the atmosphere is shown by the movements of the higher clouds. Any one who will be at the trouble to chart out these phenomena will feel that the neat little orographical maps of the atmosphere with which some of our popular writers on weather would present us are exceedingly different from the realities.

The terms "col," ridge," "trough," &c., for a similar reason, while assisting the popular imagination, perhaps assist it in the wrong direction, and I would, though with much deference to better authorities, suggest that such terms as "arm," "band," "belt," "extension," &c., might be employed with a little more safety. To the terms "deep," "depth," "high," "height," might not my own respectable old words, "intense," "intensity," even now be found preferable? and for the word "shallow" the word "slight" in many cases be advantageously substituted? I am aware that in a magazine article or in a weather report some variation of terms and expressions is frequently desirable, but the cover has not yet been fairly drawn; and an abundance of useful words is still available, without recourse being had to terms either borrowed from foreign languages or expressive of incorrect ideas. W. CLEMENT LEY

NOTE ON INSTANTANEOUS SHUTTERS

THE introduction of rapid dry plates having made a general demand for mechanical shutters, a large variety are now offered for sale by the various makers. Many of these shutters are neat and ingenious, but nearly all have a tendency to shake the camera during exposure, and in the only one which I have seen for sale in which this mistake has been avoided the photographic efficiency of the arrangement has been impaired by the opening being made to assume the form of a gradually expanding and contracting hole; the idea being, I am told, that while the opening is small it will act as a stop and secure definition. This, of course, is true to a certain extent—how far, I will inquire presently.

I do not know whether the general theory of mechanical shutters has been discussed, but if it has it is certainly not well known, and perhaps the following remarks, which point out what the photographic efficiency of the various classes of shutters is and their effect on the steadiness of the camera, may be of some use.

Shutters may be divided into two chief classes, viz. those in which the principal moving part consists of a single piece, and those where the moving parts are multiple; the great difference between them being that, while the first class must exert either a force or a couple on the camera during exposure, the second class may be so designed as to exert neither. The first class consists of drop-shutters and revolving disks with an aperture which passes across the lens, and of those shutters where a sliding piece rises and falls or a hinged piece opens and shuts. Of the second class I only know of one as being in the market, though probably many amateurs may, like myself, have made them for their own use. In this shutter two plates, occupying the position of the ordinary stop in the lens, separate and come together again. Each plate has a deep V-shaped notch in it; the apex of each V when the shutter is closed being in the axis of the lens. The opening is therefore a quadrilateral figure which gradually expands and contracts.

The mechanical arrangements of nearly all the shutters, except those belonging to the revolving disk and drop-shutter class, are such as to make the motion of the shutter a simple harmonic function, or nearly so, of the time from the commencement of exposure, while in the drop-shutters and disks the aperture may be taken as moving across the lens with a nearly uniform velocity. This, of course, would not be true if the motion of the parts was quite free under the action of the driving force, but friction enters largely into the account; and even if it did not, no large error will be introduced in calculating the photographic effect of shutters of this class by assuming that velocity of the moving part is uniform during exposure and equal to its mean velocity.

The photographic effect of a shutter is measured by the sum of the products of each element of aperture brought into action by the shutter and the time for which that element acts. This measures the total amount of light which passes through the lens during exposure, but it does not necessarily follow that the light should be uniformly distributed on the sensitive plate. This, indeed, only happens when the shutter is at the optic centre of the combination.

In mathematical notation, if the path of a point in the shutter be along a line x, and if U be the area of the lens expressed in terms of x, and T_x the time for which dU, the element of area exposed in passing from x to $x + dx$, acts, then the photographic effect of the shutter is $\int T_x dU$, taken between the proper limits of x.

The photographic efficiency of a shutter may be taken as the ratio of this quantity to the whole area of the lens, multiplied by the whole time of exposure, or $T'U'$.

The result of integrating the above expression may always be put in the form

$$aT'U',$$

where a is a numerical constant, which therefore expresses the efficiency of the particular shutter considered.

I subjoin a few results showing the efficiency of several different types of shutter:—

	Efficiency
(1) Drop-shutter with circular aperture (uniform velocity)	$a = \cdot 43$
(2) Harmonic opening from one side (x proportional to cos pt)	$a = \cdot 5$
(3) Harmonic opening from centre, the opening being a circular hole of radius ρ (proportional to sin pt)	$a = \cdot 5$
(4)[1] Harmonic opening from centre, the aperture being formed by the edges of two plates which recede from a diameter of the lens and the boundary of the lens (x proportional to sin pt)	$a = \cdot 764$

It will be seen that as far as efficiency goes the drop-shutter is lowest on the list.

The next two have the same efficiency, but while the second has a tendency to shake the camera the third has not. If, instead of assuming that the aperture in this case was circular, we had made it square, as in the shutter before referred to, the efficiency would not have been quite as great as ·5.

No. 4 has the highest efficiency of any, viz. ·764, and differs from the last merely in having no V-shaped notches in the plates which close the aperture, so that the opening begins as a slit instead of a point. Thus by the adoption of the square expanding aperture nearly 40 per cent. of possible efficiency is lost.

The gain in definition caused by the aperture acting as a stop may be estimated by comparing the amount of light (L_1) admitted while the opening is small enough to make the definition good, with the total amount of light admitted (L) minus (L_1), remembering that the greater the aperture up to which the shutter may open without sensibly impairing the definition the less is the possible gain in definition from the use of a stop. Thus, suppose the greatest aperture consistent with good definition to be $\rho^2 \times$ full aperture (R^2). Then the use of a stop of radius ρ can only reduce the radius of the circle of confusion about the image of a point by $\frac{R - \rho}{R}$ times what it would have

[1] This is the form which I use, but I am not aware of any shutter of the kind being in the market.

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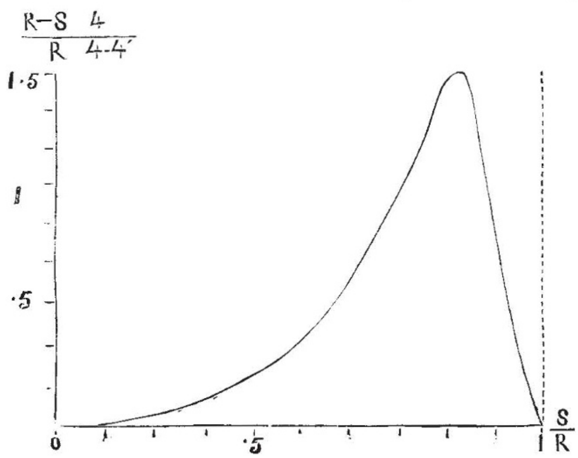
been had the whole aperture been employed. The improvement in definition, then, due to the expanding shutter acting as a stop is given by the expression—

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

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

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