MEASUREMENT OF VELOCITY WITH GRAFLEX CAMERA

ROSCOE E. HARRIS

Lake Forest College, Lake Forest, Illinois

The problem of using the distortion introduced into a picture of a moving object because of the relative motion of the object and focal plane shutter to determine the velocity of the object should be attacked, first, by making proper measurements of the distortion, and second by measuring the speed of the shutter along the plate.

The relative motion of the shutter and the object may be (1) at right angles, (2) in opposite directions, or (3) in the same direction. If the object is completely unknown, the only parts whose true geometry may be depended upon are the wheels. These are distorted into ellipses, either (1) leaning forward at the top, in the direction of the object speed "v", (2) flattened in the direction of the speed, or (3) elongated in the direction of the speed depending upon which of the above relative motions is employed.

In the first case, if "s" is the shutter speed and "v" the speed of the object, the ratio

$$\frac{v}{s} = \frac{\text{horizontal displacement of wheel center}}{\text{diameter of wheel}}$$

$$= \frac{x}{y} \; .$$

The wheel center is a point easily observed upon the picture. The point of contact of the wheel and ground or track is easily estimated. Thus x and y are measurable to about 2 per cent accuracy.

In the second case,

$$\frac{v}{s} = \frac{\text{diameter of wheel — apparent width}}{\text{apparent width}}$$

$$= \frac{y - x}{x}.$$

y is measurable with sufficient accuracy but the sides of the wheel are considerably blurred, introducing great probable error in the x measurement. This error is aggravated by the operation entering into the numerator. This case is not subject to sufficient accuracy of measurement. In case 3,

$$\frac{v}{s} = \frac{x - y}{x}.$$

Even greater diffusion exists at the sides of the wheel, but the error is not now aggravated by the arithmetical operation. The final probable error is about as great as in case 2. Case 1 is judged best.

To reduce diffusion, the shutter aperture must be the smallest and the tension as great as the light conditions will permit. The distance from the object should be regulated by its speed. A short distance introduces greater distortion, but also greater diffusion. Hence the greater "v", the greater the distance for optimum measurement. A distance of 18 feet gave a good negative upon a freight train going 50 miles per hour, the photographic measurement differing from the distance time measurement by 2%, while the same distance from a fast train (90 miles per hour) yielded results differing by 10%. However, when the distance was 47 feet from the fast train, results checked to 1%.

The actual measurements are best made by projecting the negative upon a large cross sectioned screen. Judgment of the contact point of wheel and track depends upon observation of shadows and streaks over the entire wheel. Attempts to make this judgment thru telescopic or microscopic instruments always results in large error.

The second part of the problem, determination of shutter speed, was finally solved by using a "Strobotac" after many other methods were tried. A vertical slot about 1 cm wide was put across the face of the Strobotac and the camera focussed upon this slot from a distance of about 3 feet. Flashing frequencies of 233, 200,

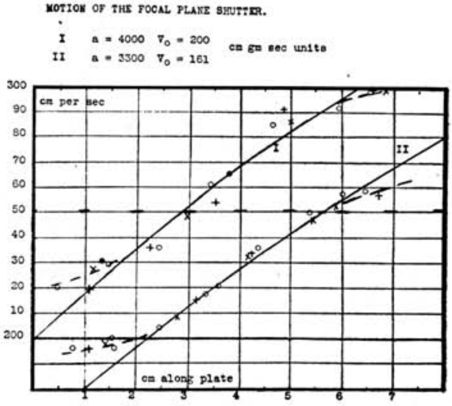

FIG. 1.—VELOCITY OF FOCAL PLANE SHUTTER AT VARIOUS POINTS ALONG THE PLATE

Different exposures are indicated by different characters. Uniform shutter behavior is indicated by these all falling along the same curve. Curve I for /1000 rating. Solid line represented by
acceleration = 4000 cm/sec/sec.
initial velocity = 200 cm/sec.
measured exposure time = /900 sec.
Curve II for /500 rating. Solid line,
a = 3300 cm/sec/sec.
V_o = 161 cm/sec.
Calculated exposure time = /760 sec.
Both curves show greater initial velocity than given by uniformly accelerated motion, probably caused by elasticity of the shutter material. Near the leaving edge, the acceleration decreases. The middle half of the plate exhibits uniform acceleration.

150, and 100 times per second were employed. Very sharp images of the shutter aperture at these intervals were recorded upon the negative. The length of the flash in this instrument is very short. Precision measurements of distance to velocity were possible. Different exposures all gave the same results. As a precaution the shutter was wound and tripped several times at the speed to be tested just before each exposure. Results obtained are indicated in the accompanying figure.

From these curves, the shutter speed "s" may be obtained for that portion of the plate where v/s is measured. The ground in the picture plane may be scaled before making the exposure. Short crayon marks at 2 feet intervals are convenient. Image velocity in cm per second may then be transformed to object velocity in feet per second.