A Method of Analyzing High-Speed Films

PAPER M—7

By FRANZ TOPFER

When time-motion curves are plotted from high-speed films, the feeding steps of the tracing paper must be exactly proportional to the time interval between frames. Ordinarily the length of each feeding step must be determined by a preliminary measurement of the frame rate. This inconvenience is avoided by the procedure described here, which consists in photographing on each frame of the film a timing instrument with a rotating scale. The film analyzer is equipped with a duplicate of the timer dial, and the rotation of this duplicate dial is proportional to the movement of the tracing paper. As the film is advanced from one frame to the next, the paper is advanced independently until the dial on the analyzer stands at the same position as the image of the dial on the new frame of the film. The feeding step of the tracing paper is thus automatically proportional to the time interval between the new frame and the preceding one. The ratio of the rotation of the dial to the linear feed of the paper can be varied to give any desired time scale for the resulting time-motion curve.

For accurately analyzing high-speed films and especially for plotting time-motion curves, an analyzer of the general type shown in Fig. 1 is ordinarily used. Each frame in turn is imaged on the translucent screen facing the operator in such an orientation that the motion of the image of the body under study takes place forward and backward with respect to the operator. The motion of the body is thus represented by the ordinates of the resulting curve. This curve is drawn on a strip of tracing paper that is moved sideways between frames by a distance that is proportional to the time interval between frames in the camera. The abscissas of the curve therefore represent time.

The projector shown in Fig. 1 was especially designed for motion analysis of this sort. The beam coming downward from the projector lens is reflected to the back of the translucent screen by a first-surface mirror. A rotatable Dove prism placed before the lens enables the image on the screen to be rotated so that the motion under study will be accurately normal to the direction of movement of the paper. The film speed can be varied at will, and no flicker is seen even at 2 frames/sec. The film can also be advanced frame by frame by means of a pedal.

Making a time-motion curve obviously involves a knowledge of the time interval that corresponds to each frame interval. To enable this to be determined, a common procedure is to make a periodic mark on the film in the camera as shown in Fig. 2. This can be done by means of a small glow lamp fed by a stabilized generator that produces, say, 1000 pulses/sec. Then the distance between the start of one mark and the start of the next represents 1 msec (millisecond) and the speed of the film in units of distance per second is 1000 times this distance.

The importance of determining this speed is indicated by Fig. 3, which shows the speed at each point of a 30-meter film as a function of distance along the film for three cameras of different characteristics. For even the best camera (curve 1), the speed increases rapidly until about a third of the film has been wound off and is still rising slightly even when the film ends. The camera represented by curve 3 hardly even gets up to its final speed when the film ends; and the camera represented by curve 2 shows a quite different characteristic — the speed attaining a maximum when the film is half used and then decreasing for the rest of the run.

The method of determining film speed just described is clumsy and becomes time consuming when a large

Presented on October 21, 1960, at the Fifth International Congress on High-Speed Photography in Washington, D.C., by Franz Topfer, 15 rue Sohet, Liège, Belgium.

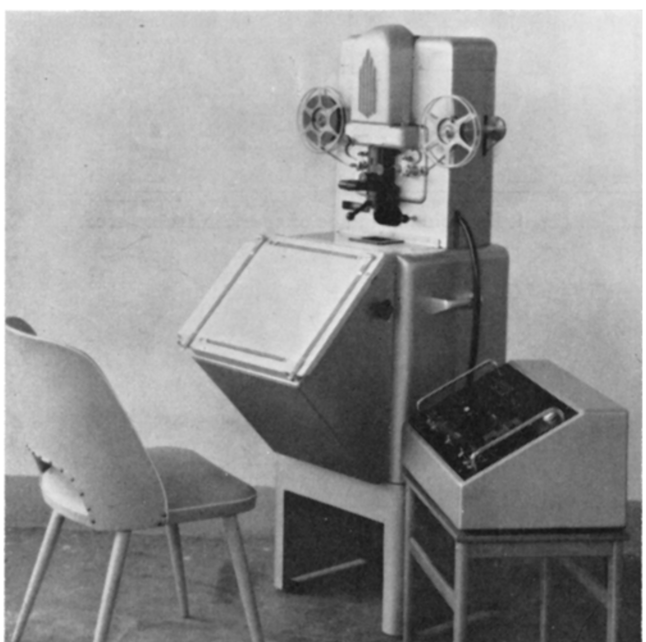

Fig. 1. The film analyzer.

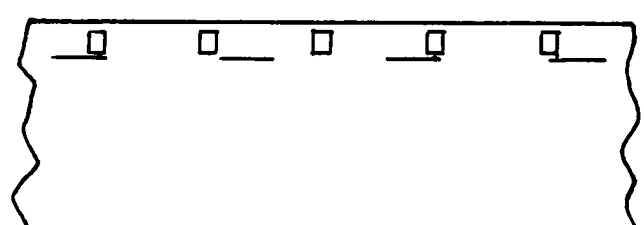

Fig. 2. Typical time marks on film.

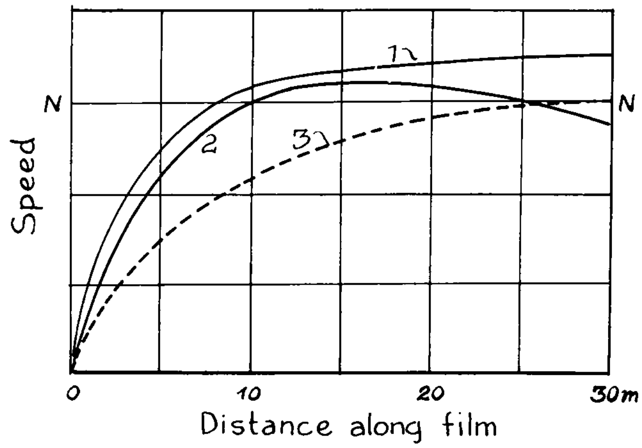

Fig. 3. Curves of film speed vs. distance along the film, for three different cameras.

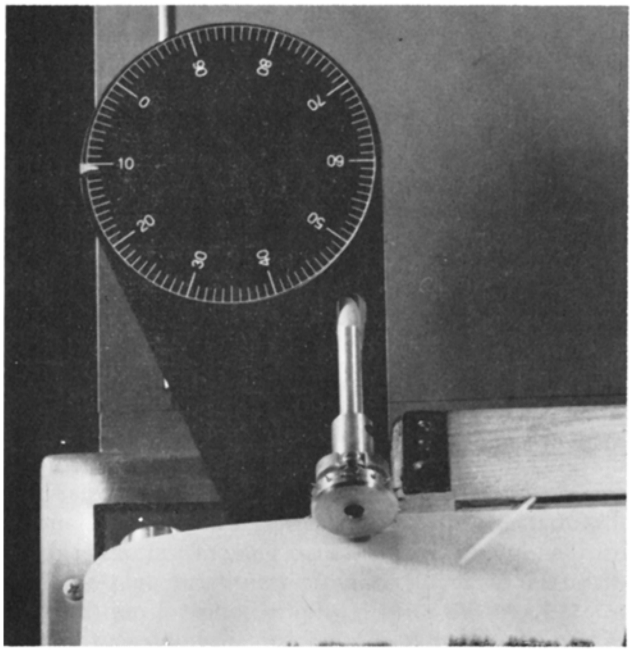

Fig. 5. Duplicate dial that indicates the extent of the advance of the paper.

amount of film is to be analyzed. The necessity for making calculations is entirely avoided by photographing on each frame the rotating dial shown in Fig. 4 and using a suitable analyzer. This type of time registration was commonly used before the timing-light marks were adopted; the novel part of the procedure is the device used on the analyzer to obtain the proper stepping distance for the paper without making computations.

The rotation of the dial must, of course, be steady, but it has been found that the speed of a synchronous motor is adequately constant. The speed of the dial is determined by a suitable gearbox. The most appropriate speeds have been found to be 10, 20 and 40 rps so that each division represents 1, 0.5 or 0.25 msec. It is not even necessary to photograph the entire dial, only a small region around the index being of interest.

In the film analyzer (Fig. 1) the tracing paper (not shown) unrolls from a feed spool on the righthand side of the translucent screen, crosses the screen, goes over an

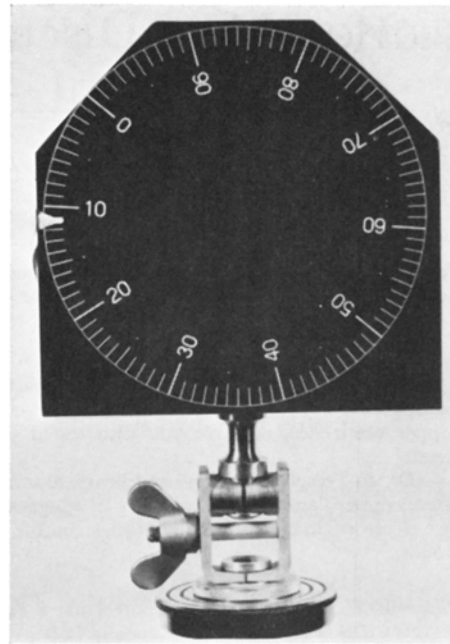

Fig. 4. The rotating dial, photographed on each frame.

idler and is wound up on the take-up spool at the left. The paper is advanced manually by rotating a knob on the end of the take-up spool. The tractive stress is made very slight to avoid stretching the paper and thus deforming the curve.

The calibrating device is the dial shown in Fig. 5, which is an exact duplicate of the dial that was photographed in Fig. 4. This dial is turned by means of the shaft shown in the middle of Fig. 5. This shaft terminates in a sprocket wheel that presses on the idler over which the paper passes so that its rotation is proportional to the distance traveled by the paper.

Plotting time-motion curves is now very simple and rapid. The paper and film are fed into the machine, and the dial of the analyzer is set to correspond to the image of the dial photographed in the first frame. As each frame is brought into view, the paper is moved until the dial of the analyzer again corresponds to the image of the dial on the frame being studied and a new point is plotted.

The dial on the analyzer is connected to the shaft of the sprocket wheel by means of an adjustable gearbox that makes one division of the dial correspond to an advance of 1, 2 or 4 mm of paper. Since one division of the dial in the image represents 1, 0.5 or 0.25 msec, the time scale of the time-motion curve is known directly and is constant regardless of the speed of the film. Moreover, when the motion being plotted does not change rapidly with time, any number of frames can be skipped and the paper will still be in step with the film if a modicum of care is taken to avoid skipping complete turns of the dial in counting.

This film analyzer has been patented in several countries and a license has been given for manufacturing it. It has been found to be very satisfactory for tracing time-motion curves with high precision and, since no measurements or calculations are needed, with astonishing rapidity.