Techniques and Instrumentation for High-Speed Photography

By WILLIAM G. HYZER

MAX R. NAGEL, USA, discussed some of the pitfalls in the interpretation and extraction of information from motion-blurred photographic images (83).* Single photographic records often represent a considerable investment in scientific effort, but owing to camera or subject motion during exposure, information is masked by image blur. The size and shape of objects may be determined if certain precautionary measures are recognized. A simple experiment was described to demonstrate that the image trace is not equal to the sum of (a) image size, and (b) image motion during exposure. A rotating black disc on which a white sector has been pasted illustrates this phenomenon. In Fig. 1, which illustrates this point, the mathematical size of the image trace is within the dashed lines, the dotted lines bracket the visible size and the borders of the trace having a density of 0.1 above fog are shown by solid lines. Measured points are described by crosses. The reduced size of the image trace results from the limited or threshold sensitivity of the film. At the outer edges of the image trace the exposure threshold conditions are not met, so image density is not perceptible above background "noise." Nagel demonstrated, by an extension of this simple experiment, that the recorded motion blur is greater for an object against a bright background than for the same object against a dark background; or for brightly-illuminated objects as compared to darker objects. Asymmetric-motion blur between the leading and trailing edges of the object becomes apparent when the background of the leading and trailing edges of the object varies in radiance or when the exposure is asymmetric with respect to the midpoint of the exposure time. This latter condition occurs often in commercial shutters and also is a characteristic of electronic flash illumination.

The application of moiré grids to the measurement of very small movements was treated in a paper by G. H. Lunn, et al. (73), United Kingdom. It was pointed out by Lunn that parallel-line grids used to produce familiar moiré fringes can result in ambiguities in the measurement of displacement between the grids when the attempt is made to record fringe shift by the use of cinephotography. If the framing rate is insufficient to record a fringe shift less than $\frac{1}{2}$ fringe, doubt exists in tracking the movement whether the actual shift is $1\frac{1}{2}$ fringes or $n + \frac{1}{2}$ fringes. The actual direction of fringe shift is also a point of ambiguity. A pair of identical overlapping zone plates (each consisting of concentric annuli of equal area, alternately black and white) produce straight parallel-line fringes separated a distance inversely to the distance of plate separation. If d is the separation between the centers of overlapping zone plates, R is the radius of the innermost circle on each identical zone plate and S is the distance between fringes, then it can be shown that

$$d = \pm S/R^2 \qquad (1)$$

The fringe orientation is at right angles to the direction of relative displacement between the two overlapping zone plates. In this case, it is not necessary to track fringe shift. Fringe spacing and orientation determine both the distance and direction of displacement between the two overlapping zone plates. Fringe patterns produced by this technique are shown in Fig. 2.

In a paper presented by J. G. A. de Graaf, Central Technical Institute, TNO, Netherlands, high-speed photographic techniques were described for the testing of guardrail constructions for highways, seat belts for motor cars and different types of wind screens (85). This research was conducted by a team of technicians, physicists and medical men, using both qualitative and quantitative evaluation of the high-speed cinematographic results. High-speed films and slides were shown to illustrate results obtained in these studies.

Collision sequences (Fig. 3) were photographed at 500 frames/s using rotating-prism-type 16mm high-speed cameras mounted on towers 70 ft over the point of collision and on the ground 150 ft beyond the point of collision.

Seat belt tests were performed using test dummies, imitating both adults and children. The experiments were carried out on a test sled propelled by means of compressed air and stopped suddenly by a special oil damper, Fig. 4. Of the three types of seat belts used in the Netherlands, namely (a) the lap belt, (b) diagonal belt and (c) three-points belt, the lap belt was found best, owing to the ability of the hip to withstand jack-knife effects resulting from rapid de-

A paper to be presented during the Society's 99th Conference in Washington, D.C., May 1–6, 1966, by William G. Hyzer, Consulting Engineer, 205 Wall St., Janesville, Wis. (This paper was received on March 15, 1966.)

* Numbers in parentheses refer to the papers' numbers in the Congress Program as listed on pp. 353–355. The papers will appear in the *Proceedings of the Seventh International Congress on High-Speed Photography*, to be published by Verlag Dr. Othmar Helwich, D-61, Darmstadt, Hoffmanstr. 59, Germany.

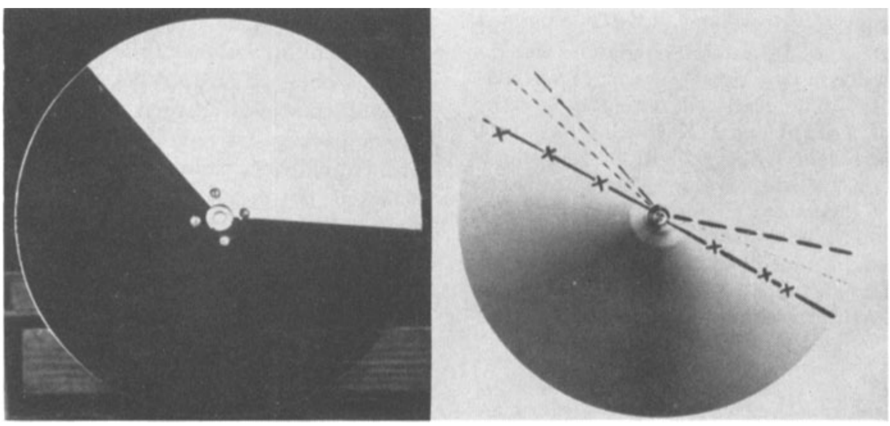

Fig. 1. Disc used to illustrate properties of motion blur in photographic images. Lines on diagram to the right are described in text.

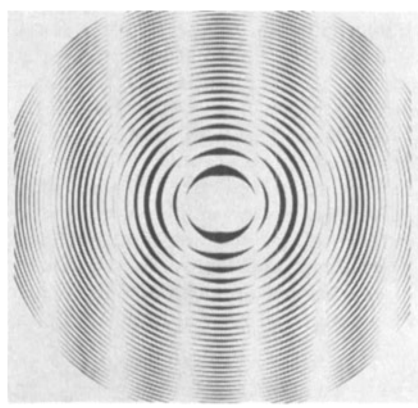

Fig. 2. Fringes produced by displacement between overlapping zone plates.

Fig. 3. Test collision between vehicle and test rail.

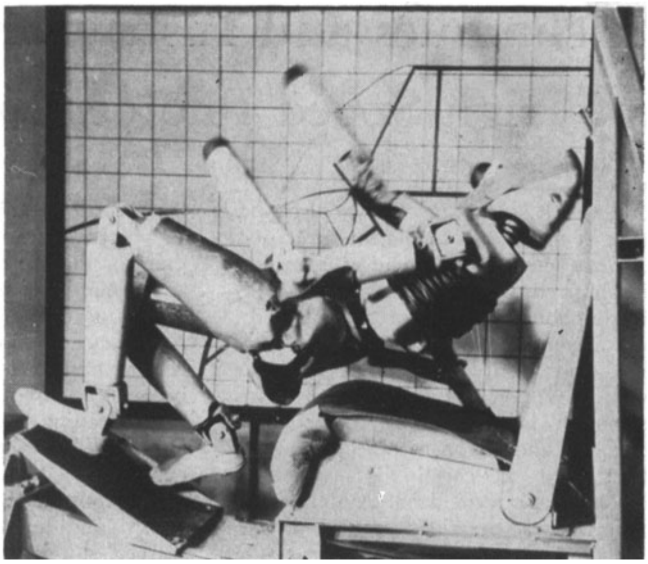

Fig. 4. Test dummy used to evaluate seat belts.

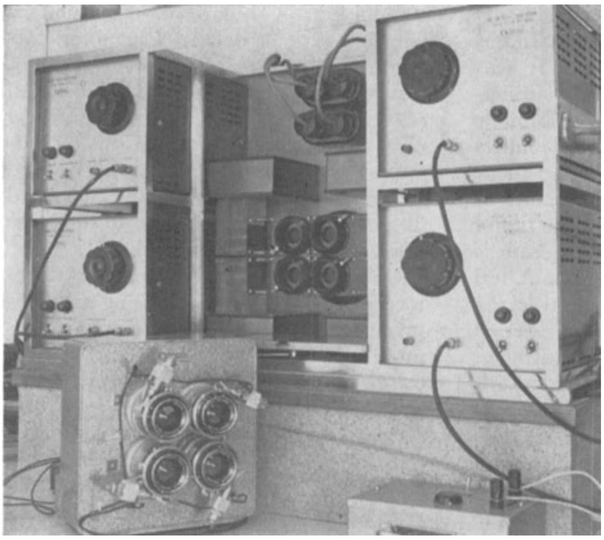

Fig. 5. Swedish Detonics Research Foundation Kerr-cell system and camera.

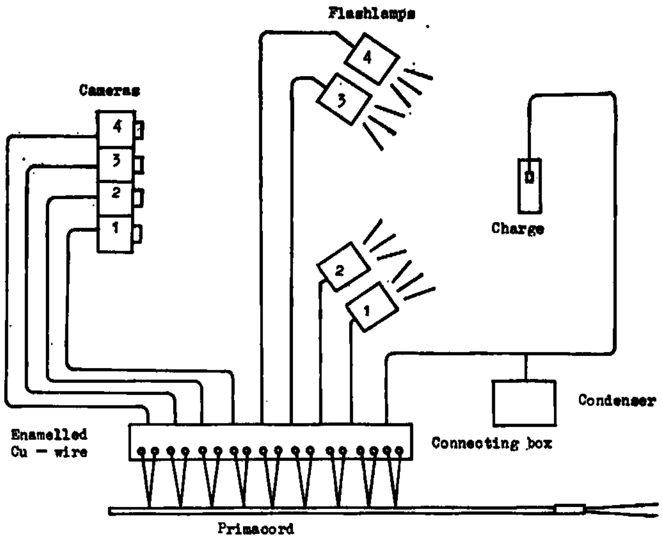

Fig. 6. Primacord synchronizing circuit used in connection with the camera illustrated in Fig. 5.

celeration better than the neck. Positioning of diagonal belts was found to be extremely critical—with the possibility that small passengers may slip out of the belt with fatal results.

L. S. Thickett, United Kingdom, demonstrated applications of high-speed photography in the study of bar-mill shears and vacuum casting in the steel industry using conventional techniques with rotating-prism-type cameras (86).

Accelerating growth patterns of the high-speed photographic field in the USA were traced by W. G. Hyzer, USA (84). Hyzer emphasized the importance of (a) technological advances, (b) economic considerations and, finally, (c) educational opportunities if the field is to continue to grow at its current pace. He warned that instrument designers often lose sight of user requirements and that 5 to 10% accuracy in a measurement today may be a much more important contribution than ½ to 1% accuracy several years from now.

A multiple Kerr-cell camera developed for detonation research at the Swedish Detonics Research Foundation was described by Algot Persson, Stockholm (17). The Kerr-cell system is built up of four identical Kerr-cell units, each complete with a high voltage supply and pulse generator. The optical axes of the Kerr cell form the corners of a square with a side of 60 mm. The exposure time of the shutter can be varied in four steps of 0.1, 0.3, 1, and 3 μs. Picture repetition rates up to 5×10^6 frames/s are possible. The camera, having four standard lenses, is placed behind the Kerr cells to record four pictures $5\frac{1}{2} \times 6$ cm in size on a $12 \times 16\frac{1}{2}$ cm film, Fig. 5. Four electronic flashtubes (Phillips 103730) are used for illumination in close-up photography of objects that would be damaged by argon bombs. Satisfactory exposure at 0.1 μs is obtained on 160 ASA film using a 10-μF condenser charged to 4 kV as a power package for each lamp. Synchronization of event, shutters and lamps is achieved by means of a "primacord clock," Fig. 6. Enameled cotton wire is used for the ionization contacts in the primacord to initiate the nine channels in sequence as shown.