SECTION G — Discussion: Streak Cameras

Note: A participant's full name and address are given with his first contribution to the Discussion. Authors' full names and addresses are given with the title of each paper. For subsequent entries the addresses are omitted.

Paper G-1: An $f/1$ Streak Camera for Spark Studies in Both Ultraviolet and Visible, *J. Dyson, R. F. Hemmings and R. T. Waters*, Associated Electrical Industries Ltd., Aldermaston, Berkshire, England.

Berlyn Brixner (Los Alamos Scientific Laboratory, Los Alamos, New Mexico): What is the name of the 60,000 rpm electric motor used for driving the mirror?

Kenneth R. Coleman (Atomic Weapons Research Establishment, Aldermaston, Berkshire, England): The motor was specially developed by Associated Electrical Industries (Rugby), England, and to the speaker's knowledge is not yet available commercially. Motors of this type have been described by a number of people, particularly A. E. Huston (*Proc. 4th International Congress on High-Speed Photography*, Verlag Dr. Othmar Helwich, Hoffmannstr. 59, Darmstadt, Germany, 1959, p. 163).

Paper G-2: Streak Camera Development at The National Research Council, *E. H. Dudgeon*, Gas Dynamics Section, National Research Council, Ottawa, Canada.

A. Skinner (Atomic Weapons Research Establishment, Aldermaston, Berkshire, England): In the streak camera just described, how was the polishing of the mirror surfaces achieved? I note that the mirror surfaces are not the most prominent surfaces of the component concerned.

E. H. Dudgeon: The diameter of the thrust bearing at the mirror end is smaller than the mirror thickness, so polishing of the mirrors is restricted on only the bearing side. The mirror surfaces are flat up to approximately $\frac{1}{4}$ in. from the bearing shoulder. This section was not included in the mirror dimensions given in the paper.

Willard E. Buck (Consultant, P.O. Box 930, Boulder, Colorado): There are many doing research in high-speed phenomena who would like to build their own streak cameras and who will find this article extremely interesting. Although the air bearings incorporated in these designs have desirable features, I believe that the asserted low cost of construction is quite misleading. In particular, it is very costly to get a satisfactory optical surface on a mirror machined on a shaft as described in the article. The article also states that in the rotating mirror camera the static film resolution on Kodak Tri-X Film is 20 lines/mm. This is probably true only over a very limited arc, as there is apparently no correction made to keep the image in the plane of the film. This image does not follow a circular arc, as the mirror surface is not on the center of rotation. This camera is approximately twice as big and uses four times as much film as required, as only a 90° arc is useful per exposure.

The air-bearing drum camera is more complex than one that was commercially available, shown in Fig. 1(G-2). This latter camera has more than twice the writing speed with the same aperture, and also a daylight loading feature.

The above criticism is not made to detract from the novelty of the article, but to prevent readers from attempting similar designs which may not be the best available for their purposes.

E. H. Dudgeon: We realize the performance of our cameras is somewhat inferior to the best commercial models available but they have proven themselves quite satisfactory for the majority of the high-speed shock wave studies in our laboratories. With regard to cost, although the models described were made in our shop, outside quotations for their manufacture were obtained, and for both models the prices (including the cost of mirror finishing) were substantially below those of equivalent commercial cameras.

Paper G-4: A High-Speed Rotating Mirror With Greater Dynamic Resolution, *Willard E. Buck*, Buck Instrument Co., and Consultant on Instrumentation, P. O. Box 930, Boulder, Colorado.

Sigmund J. Jacobs (U.S. Naval Ordnance Laboratory, White Oak, Silver Spring, Maryland): How did you arrive at the relative distortion of a beryllium mirror as compared with a steel mirror?

W. E. Buck: These values were calculated from the theoretical formula of (Poisson's Ratio X Density)/Youngs Modulus, using the published values for steel and beryllium. We have checked these values experimentally, but because of the smallness of the distortion we were unable to make an accurate check. However, the distortion was small enough to be negligible for most applications.

A. E. Huston (Atomic Weapons Research Establishment, Aldermaston, Berkshire, England): Has any special technique been developed for polishing the beryllium mirrors mentioned in the paper?

W. E. Buck: The beryllium polishes very much like stainless steel. It is more difficult to get a scratch-free surface as beryllium is much softer. Careful work will, however, produce satisfactory surfaces without any new techniques if one is used to polishing metal surfaces. One word of caution should be added: beryllium is toxic and must be handled with care. The Brush Beryllium Company has published information on proper procedures.

Anonymous: What are your gears made of?

W. E. Buck: We are still experimenting with that. It seems as though a plastic gear mating with a very highly hardened steel gear does the best job, but I'm afraid that we've still got problems.

Anonymous: Do you care to say what plastic you used?

W. E. Buck: It is a laminated phenol-plastic. We tried Nylon, but that seems to get too hot.

Papers G-5 and G-6: Model 200 Reflecting-Optics Sweep Camera, *Thure Anderson*, University of California, Lawrence Radiation Laboratory, Livermore, California; Smear Camera Techniques, *Thomas P. Liddiard, Jr., and B. E. Drimmer*, U.S. Naval Ordnance Laboratory, White Oak, Silver Spring, Maryland.

Dr. Hubert Schardin (Institut Franco-Allemand de Recherches, St. Louis, France; and Ernst-Mach-Institut, Freiburg i. Br, Germany): I want to make two comments:

1. The quality or merit of a rotating mirror is given not only by the rotational speed but also by the mirror width. The best way to state the relative merit is to give the peripheral speed of the mirror. (See "The Relationship between Maximum Frame Frequency and Resolution in Rotating Mirror Framing Cameras," H. Schardin, *Proc. 3d International Congress on High-Speed Photography*, Butterworths Scientific Pub., Ltd., 88 Kingsway, London W.C.

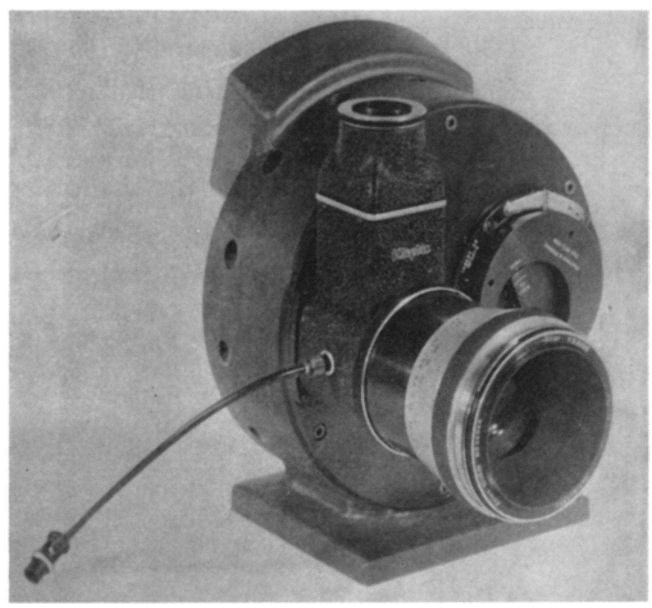

Fig. 1 (G-2). Drum Camera Model No. 307 which used to be available from Beckman & Whitley, Inc.; maximum aperture, f/3.5; maximum writing speed, 1,000 ft/sec; air-turbine drive.

2; in U.S. by Academic Press Inc., 111 Fifth Ave., New York 3, 1956, p. 316; *see also* the discussion following that paper, *Idem.*, pp. 333–336.)

2. It is not the writing speed of a streak camera that is important, but the real time resolution. A higher writing speed does not always give a better time resolution. The time resolution is the parameter that one should use to identify the quality of a streak camera.

E. W. Walker (*Atomic Weapons Research Establishment, Aldermaston, Berkshire, England*): In designing a streak camera to write at the highest speeds, one is invariably short of light. One decides to use the fastest possible emulsions, and then chooses the optics so that the inherent associated diffraction limit does not appreciably deteriorate the image formed by these emulsions. The relative aperture comes to $f/64$ or thereabouts in the writing direction. If, now, one lengthens the mirror in the other direction and can succeed in spinning this long thin mirror, as Thure Anderson has done, then one can get more light into the system; and this is a real, worth-while advance.

Edgar A. McLean (*U.S. Naval Research Laboratory, Washington, D.C.*): Would the speaker comment on the use of the terms "streak" and "smear" cameras? Do either of these names refer to particular qualities of these cameras?

T. P. Liddiard: As far as I know, the terms "smear," "streak" and "sweeping image" are used interchangeably. Historically, I believe, "rotating-mirror camera" or "rotating-drum camera" were the names first employed. Introduction of rotating-mirror framing cameras forced the introduction of the new names. Perhaps it would be useful if we all agreed to use only one of the three synonyms. In our laboratory we prefer to use the term "smear" to emphasize the fact that the resulting photo contains a series of light smears, as against the "portrait" type of photo obtained with a framing camera.

J. S. McVeagh (*Armament Research and Development Establishment, Fort Halstead, Sevenoaks, Kent, England*): When I show uninitiated people around our laboratories, I usually refer to the "streak" or "smear" camera as a graph-drawing machine. I find they understand it better.