PAPER K—4

Value Received — The Use of High-Speed Photographic Techniques in Research and Industry

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The economics of high-speed photography as a basic tool in research and industry is discussed. A spot-check survey of nonmilitary users of high-speed cameras and how the cameras are used is presented to show the tremendous increase in use of high-speed techniques in the last ten years and the potential use of high-speed photography as a basic industrial and research tool. Examples of the wide variety of uses of high-speed photography in research and industry are cited. A discussion of the types of cameras generally used in industry and the general trend to development of higher-speed cameras, simpler, more effective light sources and analytical equipment lead to the conclusion that high-speed photography is becoming more and more important as a basic economical tool in research and industry.

In the eight years since the First International Congress, high-speed photography has grown greatly. Today it has won a place in industry, research and science.

The unique ability of high-speed photography to record and magnify discrete intervals of time and space for future study and analysis has made it a basic research tool throughout industry.

The original intent of this paper was to evaluate the nonmilitary use and growth of high-speed photographic techniques and equipment. When we get into this subject, however, we find that the military and space agencies' demands for faster and more sophisticated recording systems have given the engineer and researcher better cameras and analytical equipment much sooner than they might otherwise have been developed.

A good example of this accelerated development is the Beckman & Whitley type 189 framing camera which was originally built for military use. Three of these cameras were built and the company expected that these would more than supply the demand for ultra-high-speed cameras of this nature. Today there are about 50 in use throughout the world, and the firm is still building more. Although only about 10% of these cameras are being used on purely industrial problems, many more of them are being used at least part of the time to solve industrial problems, particularly in research institutes such as Stanford Research Institute and Armour Research Foundation.

In 1950, the commercially available high-speed cameras were manufactured and sold by about three concerns; and in most cases, only one or two models were available with top practical speeds ranging from 3,000 to 8,000 frames/sec. Comparatively slow black-and-white films and hypersensitization were the order of the day, and high-speed color films were only a dream. Lighting was accomplished primarily with high-intensity arcs, tungsten lamps, multiple-flash units, or sunlight when it was practical. Very few industrial plants owned high-speed cameras, and high-speed photography was used only as a last resort by skeptical engineers and management.

A quick look at the use of high-speed photography in 1960 will verify its acceptance as a practical working tool in industry. Today there are at least six manufacturers of high-speed equipment in the United States. One such manufacturer, the Wollensak Optical Co., produces 24 models of their Fastax Cameras which are available in 8mm, 16mm and 35mm formats covering speed ranges from 150 frames/sec to 16,000 frames/sec. Another producer, Beckman & Whitley, Inc., carries a line of high-speed cameras covering the complete speed range from 200 frames/sec to 4,300,000 frames/sec in their Magnifax, Dynafax and Model 189 framing cameras, plus a line of drum and streak cameras with writing speeds of up to 9 mm/μsec. At least two new high-speed cameras have entered the field during the last year: the Waddell high-speed camera with framing rates up to 10,000 frames/sec and the Benson Lehner Ultra High Speed Camera with framing rates up to 1,600,000 frames/sec.

High-speed black-and-white emulsions which can be pushed to A.S.A. 4,000 are commonplace and high-speed pictures are frequently taken in color. Color films now available can be pushed to better than 400 A.S.A. An outstanding example of the advancement in equipment and films is the series of color pictures on the cover of the brochure announcing the Fifth International Congress. These pictures by Morton Sultanoff are selected frames from a sequence of detonation studies taken with the Beckman & Whitley Type 189 framing camera at 1,200,000 frames/sec using Super Anscochrome film.

Advancements in lighting technology have kept pace with other developments in the field. Small high-intensity tungsten lamps, such as the General Electric 750-R, the Westinghouse R-30, the pulsed xenon arc lamp, square-wave pulsed speed lamps, long peak flash lamps and repetitive speed lights which will flash several thousand times a second, have all played an important part in making high-speed photography a practical, indispensable research tool.

High-speed "still" pictures have reached a new level of excellence due to the development and improvement of

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sub-microsecond speedlight and spark systems. The magnetooptic shutter built by Edgerton, Germeshausen & Grier, new and improved commercial versions of the Kerr cell shutter and fast developing systems such as used in the Land Polaroid camera are important steps in the development and application of high-speed photography.

At best, high-speed photography is only as good as its interpretation. Here again, many improvements in analyzing equipment have been introduced in the last few years. Several projectors, designed for quantitative analysis of high-speed photographic records, are now on the market. Quantitative analysis may be obtained by scaling off image displacement from frame to frame on the projected image. For more accurate measurements an optical comparator, a measuring microscope, or analyzers which have been specifically designed for quantitative analysis of film are available. One such instrument is the Vanguard Film Motion Analyzer which features manual or automatic film transport, transparent viewing screen, rotating projection head for accurate linear and angular measurement, Vernier-driven cross hair accurate to 0.0001 in. in relation to the film, micrometer readout and positive frame counter. It may also be equipped to give digital printout on either punch card or tape for electronic data reduction.

It is impossible to get any exact figures on either the number of high-speed cameras in use or the volume of nonmilitary high-speed photography work being done in the United States because most camera manufacturers and industrial concerns are reluctant to divulge any exact figures.

One exception is Bob Shoberg*, manager of camera products at Beckman & Whitley, Inc. He reports that about 50 of their Type 189 framing cameras, 20 of their Type 192 continuous-writing framing cameras, 30 special drum cameras and 50 Dynafax cameras have been delivered in the last few years. He also estimates that there must be in use between 3,000 and 4,000 of the old Eastman high-speed cameras (now made and sold by Beckman & Whitley as the Magnifax). Approximately 50% of the Dynafax and Magnifax cameras and 10% of the ultra-speed cameras are now being used on purely industrial problems.

Mr. Shoberg has said, "I believe that the users of high-speed photography have increased tremendously during the last ten years, with the last five being accelerated. It is pretty hard to give actual figures. I would guess there are approximately $30,000,000 worth of true high-speed cameras in use in the United States today. My best guess is that 30% to 40% of these are in industry. I would say that half of them have been delivered in the last five years."

Fred M. Emens of The Wollensak Optical Co. estimates that the volume of high-speed photography has increased 10 times in the last 10 years and that 20% to 25% of the Fastax cameras now in use are being used in industry on nonmilitary jobs.

William G. Hyzer, consulting engineer and a well-known authority, estimates the industrial use of high-speed photography as follows: "A typical American industrial concern which has used high-speed photography within the past five years owns one high-speed camera, usually a 100-ft capacity model. The most commonly used high-speed cameras in industry today are undoubtedly the Fastax WF-3, the Fairchild HS-100 and the Beckman & Whitley Magnifax (formerly Kodak High-Speed Camera, type III). All of these are 100-ft 16mm cameras. Four-hundred-foot 16mm Fastax and Fairchild cameras are coming into wider use but, in overall application, these cameras are in the minority.

"The number of high-speed cameras owned by a typical American industrial concern varies from zero (for those who rent or borrow equipment or use outside services) to 20 to 25 cameras for large corporations with many widespread divisions or large aircraft or missile contractors who utilize high-speed photography extensively. As a rough breakdown I estimate that perhaps 25% of industrial users rent, borrow or utilize an outside consulting service; 50% own one camera; while the remaining 25% own more than one camera. Amount of film consumed per user varies considerably. I would estimate that a typical value is about thirty 100-ft rolls per year."

Mr. Hyzer is now making an extensive survey of the industrial use of high-speed photography which, when finished, will give precise answers to many of these questions.

Value received is a nebulous and touchy subject. I have yet to find one concern (even the one where I am employed) which can or will put a price tag on what high-speed photography has saved it in time or money. In many cases I am sure that they neither know nor have any means of arriving at such a figure.

Who could possibly put a monetary value on the human life and suffering saved by the safety device programs carried out in the last few years by both automobile and aircraft companies? In every case you will find that high-speed photography has been used extensively to evaluate every new safety device before it received final approval.

Who can put a price tag on the saving to each of us in our everyday lives where high-speed photography has been used by research or industry to develop a better product — the machinery which spins and sews our clothing, the automobiles we drive, the food we eat? One could go on and on as there is scarcely an industry you can name where these techniques have not been used successfully.

In many research programs such as explosives, flow studies, ballistics, etc., high-speed photography is the only method of obtaining data. In one research project at Dow a $100,000 test setup employing a time-of-flight mass spectrometer would be useless if we could not record the data using a high-speed drum camera. This data is presented to the camera as an oscillograph trace. Sweep time of the scope is 1 μsec on a P16 phosphor with a decay time of 1 μsec and a time delay of 50 μsec between sweeps.

High-speed photography could well be called industry's "private eye." The titles of many of the cases it has been called on to solve read like paperback thrillers. For instance:

"The Case of the Bouncing Checks" — Willard Hicks of Burrough's Adding Machine Co. tells how high-speed photographs showed how checks bounced in a sorting

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system and jammed the exit slot; and how other pictures pointed the way to correct this problem.

"The Case of the Missing Blade" — In the plastics department at Dow we had a propellor-type pellet cutter which was cutting pellets that were too long. One run with a high-speed camera solved the problem. Vibration due to the shock of the first cutting blade threw the second blade out of line to such an extent that no cut was made.

"The Case of the Unlocked Door" — a lock manufacturer found that when a door was slammed shut, the latch would not catch consistently. High-speed photographers spotted the malfunction and pointed the way to correcting it.

As to the future of high-speed photography in industry and research, I am sure we all agree that it is here to stay and if I may quote Bob Shoberg again: "My estimate of the future of high-speed photography is that I have to repeat the old saying, 'We haven't scratched the surface yet.' I believe that in ten years high-speed photography will be taught in all engineering schools and will become as universally used as an oscilloscope is now. I believe that the big emphasis must be placed on engineering applications where actual numbers come out rather than purely qualitative analysis."

Every day there are improvements in techniques and equipment. Every day new uses and new users of high-speed photographs are being discovered. Two years from now as many of us as are able will meet in another country at the Sixth International Congress on High-Speed Photography to renew acquaintances and exchange information. And at that time we are sure to find that high-speed photography has forged ahead as a better and more useful recording tool for the investigation of high-speed events.