

SECTION K—Discussion: Values and Problems in High-Speed Photography

Note: A participant's full name and address are given with the 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 K-1: Some Philosophical Aspects of High-Speed Photographic Instrumentation, Morton Sultanoff, Ballistic Research Laboratories, Aberdeen Proving Ground, Maryland.

J. S. McVeagh (Armament Research and Development Establishment, Fort Halstead, Sevenoaks, Kent, England): (1) We have noticed that a shorting screen placed at the position of your barrier is tripped, apparently confirming the high velocity by a different technique, but equally misleadingly. (2) In another case when we had small holes reaching into a cavity in an explosive, light from the shock front lit up the holes ahead of the front, giving the appearance of a spurious pre-shock.

M. Sultanoff: Thank you for these additional observations. There are so many of these in the literature that one could give a ten-hour talk. I'm sure that all of us have run into such effects. The main point here, of course, is that we have to be wary of any results that we get, even if they look normal. And, even more, if the results do not seem normal and will not fall into a physical picture, we should be doubly wary and should make a complete investigation before we publish. Otherwise much time and trouble will have to be spent by others trying to sort out and refute the errors that we have made.

Franz Topfer (Comité Belge d'Optique, 15, Rue Sohét, Liège, Belgium): I fully agree with Mr. Sultanoff's very important and most interesting paper. Nevertheless, I should like to draw your attention to a fact which ought to be taken into consideration when we are interpreting photographic records. Sometimes when we wish to make sure that a thing or phenomenon really exists and is not merely due to a subjective impression, we say, "Let's photograph it. If the photographic record, which is not liable to error, shows what we see by direct observation, we can be sure that the thing or phenomenon really exists." This seems perfectly logical. Is it really?

For the last four years I have been studying the mechanism of vision and the behavior of the human eye. We have to be very cautious when we interpret visual perceptions. There are things we do not see, and also things we are quite sure we see, but which, however, do not exist. I like to say that our eye is a magician who has a curious tendency to complete, transform and assimilate in his own way the aspect of things. Thus, our visual perceptions are sometimes merely idealized reproductions of real things.

Let me give you a typical example. Suppose we rotate a black disc with a concentric white star (Fig. 1(K-1)) at a speed of several hundred rpm. We expect to see (Fig. 2(K-1)) a white circle (I) in the middle of the disc corresponding to the highest white level, and around the star a black annular zone (III) representing the lowest black level. Between the white circle and the annular black zone there must be an annular transitional zone (II) going from white to black. However, we see something more. Around the cen-

tral white circle we see a narrow annular band of a higher white level than the center, and between the gray and black zones, an annular band of a blacker level than the outer black zone. I photographed the rotating disc, using different apertures, exposure times, and kinds of film, always with the same result. The records (Fig. 3(K-1)) show the two bands mentioned above. When the records were measured by means of a microphotometer, it was found that there was not the slightest trace of the two bands: they are merely an optical illusion.

Conclusion: The fact that a thing is seen by direct observation and also on a photographic record — even by numerous observers — is not at all a proof of its existence.

Dr. Hubert Schardin (Institut Franco-Allemand de Recherches, St.-Louis, France; and Ernst-Mach-Institut, Freiburg i. Br., Germany): The thing we see with our eye is not the thing itself. We must be careful in interpretation and take into account the physiological processes in the eye. One hundred years ago, E. Mach mentioned effects similar to those described by Dr. Topfer. The bands have since then been called "Machsche Banden." (See, for example, *Analyse*, E. Mach, 9th Edition.)

M. Sultanoff: I expect that everyone has at some time mounted a series of dark-toned pictures on a white mat cardboard background, say 5 across and 5 down, and then tried to erase the black spots that appeared where the corners come together! However, if you photograph the assembly, and make a slide of it, the same black spots are on your slide — but, of course, they're not on the densitometer records. It is a common type of illusion, and I thank Dr. Topfer for bringing it to the attention of the audience.

Dr. David C. Oakley (University of California, Lawrence Radiation Laboratory, Livermore, California): This phenomenon resembles the reaction of the electronic "dodgers" which often give overshoot. With those machines it is due to the finite scanning spot size and to the limited time response of the instruments. This suggests that the illusions described may be a manifestation of similar scanning and response time mechanisms in the human eye.

Paper K-2: What Is the Sensitivity of a Photographic System? Fred H. Perrin, Research Laboratories, Eastman Kodak Company, Rochester, New York.

Dr. F. L. Curzon (Department of Physics, University of British Columbia, Vancouver, B.C., Canada): You quote that the informational sensitivity, I , available in a picture, is proportional to the inverse product of the granularity, σ , of the film and the spread function, s , in the system. However, if the grain size is zero and the spread function is not, the amount of information is still limited and will be approximately dependent on $1/s$. Similarly, if the spread function is zero and the grain size is not, the available information will be proportional to $1/\sigma$. This behavior is best represented

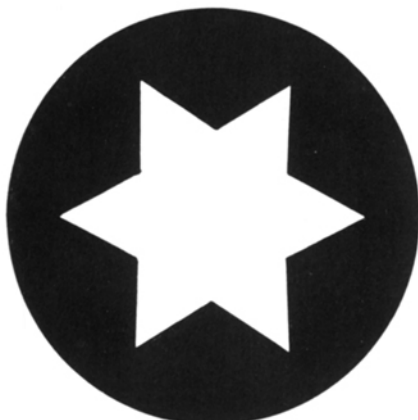


Figure 1(K-1)

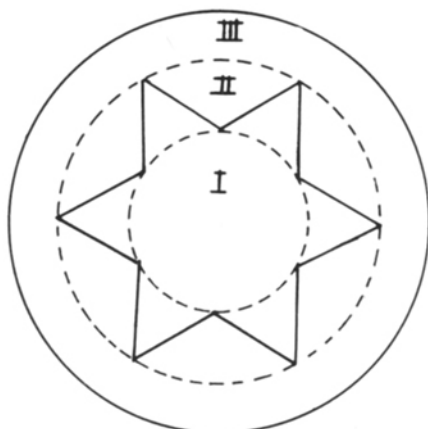


Figure 2(K-1)

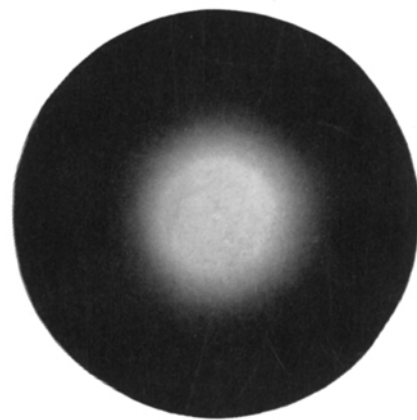


Figure 3(K-1)

by a formula of the type $I \propto 1/[f(s + \sigma)]$. If σ and s are correlated (i.e. σ cannot be made to tend to zero without implying that s tends to a nonzero constant), your formula would only be valid provided the lens system itself causes no spread function. This is not so in emulsions of finite thickness, so I feel your theory could be refined by choosing a better functional dependence for the information factor.

F. H. Perrin: If you have reason to believe that these two quantities should enter into the relations in a functionally different way, you may of course introduce them in that way. The archival paper, however, adduces what seem to be cogent reasons for introducing them as I have. We must remember that often a relation may be perfectly satisfactory over a long intermediate range but may fail when one of the quantities approaches zero. In the present instance, however, we do not have to resort to this qualification. In the first place, when the granularity is high, the spread function is likely to be large also. In the second place, when either the granularity or the spread function becomes very small, the informational sensitivity becomes very high. This can be realized intuitively by noting that, as granularity diminishes, the minimum density increment that can be detected decreases and the informational sensitivity correspondingly increases.

Lincoln L. Endelman (The Martin Company, Cocoa Beach, Florida): If I interpret your bar chart correctly, Emulsion "E" would offer the best solution as a general type of film. The chart indicated that with the shortest-focal-length lens and the shortest exposure it will give results equivalent to or better than the so-called "special purpose films." Am I correct in interpreting your chart?

F. H. Perrin: You have a point there. As a matter of fact, that particular film is a new film which appeared only within the past year, and it has been very successful for certain purposes. For general purposes, there are other considerations. For example, suppose you had been using a 35mm miniature camera, and that

then you wished to change to a subminiature size. You might well find that a slower, finer-grain film would actually be better because it would stand more enlargement for just the reasons that I used in my argument. As a matter of fact, film "E" has been found to be very, very good indeed.

Paper K-5: Study of Resolution Limits in High-Speed Framing Cameras, Thomas E. Holland, Beckman & Whitley, Inc., San Carlos, California.

Berlyn Brixner (Los Alamos Scientific Laboratory, Los Alamos, New Mexico): Consideration should be given to image sweep caused by the off-axis, rotating-mirror surface, which is an important design consideration. Would you comment on that?

T. E. Holland: That is true. We do have a problem as the mirror thicknesses increase. Also, at the edge of the frame, you have effects due to the curvature of field. The analysis shows that diamond-shaped apertures are helpful in reducing the effect of lens field aberrations and the motion (during scanning) of parts of the image near the edge of the mirror.

A. Skinner (Atomic Weapons Research Establishment, Aldermaston, Berkshire, England): The author has compared diamond stops with rectangular stops, on the basis of equal scanning time, to the detriment of rectangular stops. However, if he compares them on the basis of equal area, the exposure time of the rectangular stop will be halved showing it to be superior in stopping power. Probably, however, what is gained in *time* resolution is lost in *space* resolution. Does the author agree that there is really very little overall difference between the two stops?

T. E. Holland: In this respect, the difference between the two stop shapes is not great, nor is it expected to be. The comparison made in the paper is based on equal density on the film. This was assumed to have been accomplished by an appropriate change in the light intensity.