*Precision Lenses and Shutters**

HERBERT TRAGER, *Photogrammetric Engineer*
Zeiss-Aerotopograph,
Munich, West Germany

ABSTRACT: *The step-by-step development of the f/4 Topar and f/5.6 Pleogon high-performance lenses is demonstrated by an example. The Hypergon computed as early as 1900 was used as a basic lens. It is shown how Dr. Richter developed the first wide-angle lens for aerial survey cameras by splitting up the two meniscus lenses and bending them to the required radius. The result is the Topogon f/6.3. Then, the Topogon V and, in the course of time, the Topar and Pleogon Lenses were developed from the Topogon. Mention is also made of other lenses derived from the Topogon or Topogon V.*

Discussed also is another family of lenses which is topped by the Russian Liar and Russar Lenses. This part of the paper is substantiated by a description of the optical data of these lenses as defined in a French patent, as well as by the projection of their pupil sizes.

The new Aerotop Shutters I and II, developed by Zeiss-Aerotopograph, are discussed with special consideration to the big advantages resulting from the extremely short exposure times these shutters are capable of producing, as well as of their high degree of light efficiency. The total lack of image movement in an aerial photograph taken from very low altitude and a relatively fast flying plane is used to demonstrate the high performance of this new shutter.

THE request of Mr. Harman was that I present a paper and participate in the Panel discussion, giving a few facts concerning steps taken to improve the efficiency of aerial lenses and also describing the new 130 degree wide-angle lens of the Russians. I was somewhat surprised by his request, as in school I had specialized principally in photogrammetry and had not spent much time in studying the mathematical aspects of geometric optics. Consequently, I have taken the liberty of slightly modifying the subject and presenting a few facts on precision lenses and shutters, with special consideration to those manufactured by Zeiss-Aerotopograph, with which I am most familiar. I have chosen an example to demonstrate the step-by-step perfection of an aerial lens into a modern high-performance lens.

HERBERT TRAGER

I will first present the ancestor of a family which even today is applied in photogrammetry, although it was born almost sixty years ago. This is the well-known Hypergon lens which was computed by E. von Höegh. On account of its strong spherical and chromatic aberration, it was first used with an aperture of f/22 only. Since its curvature of field and

* Presented at the 22nd Annual Meeting, Shoreham Hotel, Washington, D. C., March 23, 1956. This paper was a part of the Panel on Aerial Photography.

its distortion characteristics are very good, and since this lens has an angular field of 140 degrees, it maintains its position as a plotting lens even to this very day.

The desired improvement of the spherical aberration of the Hypergon, could be achieved in part only, even though its angular field was reduced to 90 degrees at an aperture of f/6.3. This was the main reason why Dr. Richter in 1932 decided to create a high-performance wide-angle lens for photo-taking purposes, starting with the Hypergon as the basic design. In his experiment, Dr. Richter began by splitting up the two meniscus lenses forming the Hypergon. The thin lenses thus separated were curved until full correction of the longitudinal spherical aberration had been reached. The chromatic aberration of the Hypergon could be reduced to such a degree as to obtain a sharp picture on aerial film. With this separation achieved, the Topogon f/6.3 came into existence in 1934. Very soon the Topogon had acquired a predominant position, since for a long time it was the only wide-angle mapping lens in existence. The appearance of the Topogon lens also had an important influence on the design of cameras, since the multiple-lens cameras that were being constructed elsewhere were soon entirely replaced by the Topogon wide-angle camera.

The creator of the Topogon lens was Dr. Richter who, unfortunately, passed away on February 12. He did not have to place much emphasis on the elimination of distortion, since the plotting instruments then most widely employed, i.e., the Stereoplanigraph and the Multiplex, were operated on the Porro-Koppe principle.

With the passage of the years, the Topogon gave birth to five pretty children, of which the Metrogon, the Ross, and Aquilor, and the Rigel lenses evidence the greatest resemblance to their mother. For the first two mentioned, the Metrogon and the Ross lenses an indication of a further improvement of spherical and chromatic aberrations is demonstrated by the splitting up of one more meniscus lens in each. The diagramatic assembly of the Rigel and Aquilor lenses is not shown in Figure 1, but these are very much like the Topogon.

The most important descendant of the Topogon, however, is the Topogon V lens, which was also computed by Dr. Richter. The original Topogon lens was computed for photographing infinite objects. However, because lenses with a larger angular field were also required for rectifiers, a completely new lens was created by simply adding one thick glass plate each in front and in the rear of the basic lens. The image errors of this new lens were independent of the scale of reproduction. In addition, the new lens evidenced the astounding quality that all the errors of distortion had almost completely disappeared. Together with the projector-type Topogon V lens, the mapping version of the Topogon V was developed. This evidenced a residual distortion of approximately 6–7 microns and was considered distortion-free at the time of its introduction.

There are now three descendants of the Topogon V lens, i.e., the Planigon, the Cartogon and the direct improvement, the Topar f/4, which was also converted from the Topogon V lens by Dr. Richter. The somewhat modified basic design of the Topogon continues to be a central element of the Topar lens f/4. The two outside meniscus lenses of the Topogon were split up and one more optical element added in the diaphragm plane. (Figure 2) At this juncture, your attention is called to the fact that the projector-type Topogon V lens now used in the Seg V Rectifier was also further improved and furnished with an additional optical element in the diaphragm plane, so that it is not identical with the one shown in the diagram.

The Topar now takes its place among the so-called normal-angle lenses. It evidences all the characteristics a high-performance lens should have. (Figures 3 and 4) Its distortion can be kept to less than ± 3 microns. Its resolving power is quite excellent, as will later be shown by a few sample photographs. And finally, the Topar is color-corrected to such a high degree that it can without hesitation be employed for color photography without using a yellow filter.

In the case of the projector-type Topogon V lens, the outer optical elements were plane-parallel plates, and the front and rear elements of the Pleogon f/5.6 which were converted from the Topar and the Topogon V lens, have been reshaped into meniscus lenses so as to achieve a reduction of the angle of incidence of the bundles of rays in the interior of the lens and to contribute to a considerable improvement of

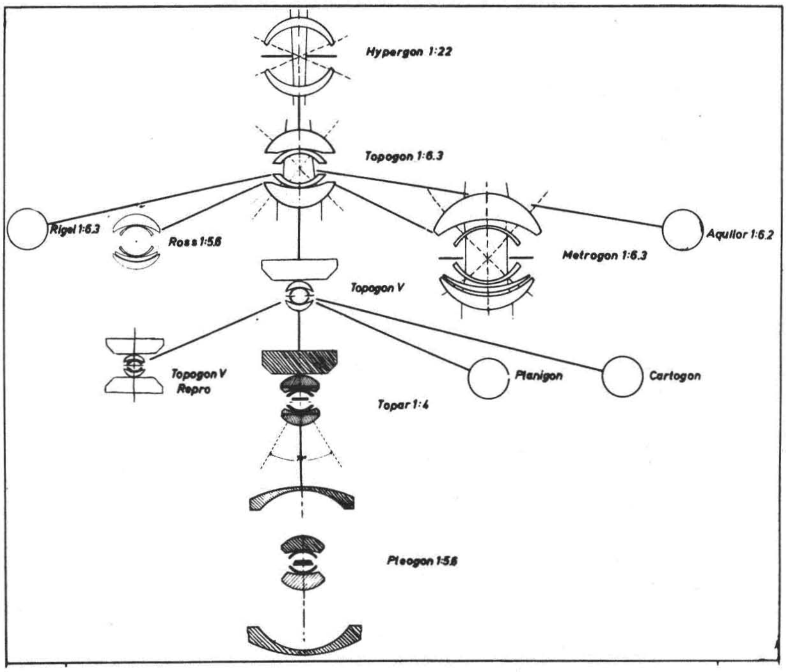

FIG. 1. The Topogon family.

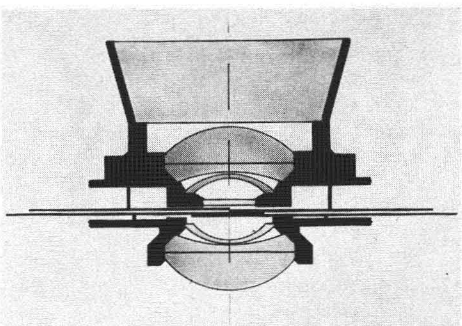

FIG. 2. The Topar 1:4f = 210 mm.

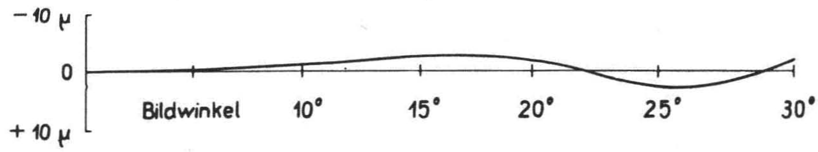

FIG. 3. Computed distortion curve of the Topar 1:4.

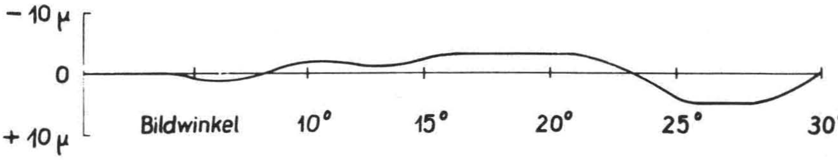

FIG. 4. Measured distortion curve of the Topar 1:4.

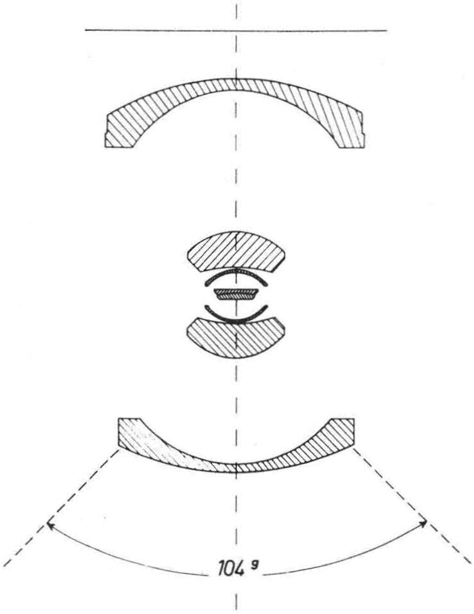

FIG. 5. Zeiss Pleogon 1:5.6 f=153 mm =6″.

illumination in the corners of the negative. (Figure 5) The optical element formerly introduced in the diaphragm plane has now been split up, while the splitting-up of the original meniscus lenses, as effected in the Topogon, has been abandoned. The perfection achieved in improving the illumination in the corners of the negative is demonstrated in Figure 6 which shows the pupil size of the Pleogon when photographed at different angles with reference to the principal axis. The image brightness in the extreme corners of a 9×9″ negative size is 100 per cent better than that obtainable with the Topogon or Topogon V lens. In addition to a cross-section of the Pleogon lens, Figure No. 7 shows the curves of its spherical aberration, its curvature of field, and its distortion. At an angle of 94 degrees, the Pleogon evidences a maximum distortion of ±4 microns. Also in the case of this lens, color-correction can be carried to such a perfection that the Pleogon can very well be used for color photography.

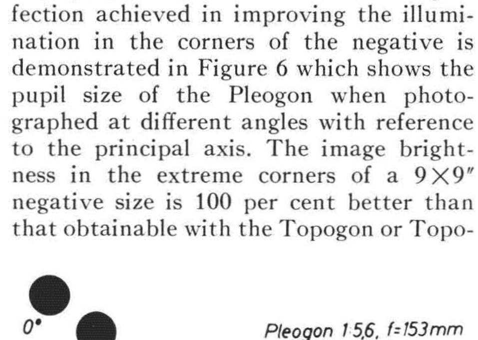

FIG. 6

It is hoped that these brief outlines have provided an idea of the special characteristics of both the Topar lens f/4 and the Pleogon lens f/5.6, which must be considered as top-quality high-performance lenses.

A short study of another group of lenses was made and will now be described. These are shown in Figure 9. At the end of the group will be noted another high-performance lens, i.e., the Aviogon, as computed by Mr. Bertele. At the beginning, there is the Russian Liar lens computed by the Russians Kossyrev and Roussinov in 1933. Around 1936 Roussinov also computed the Russar lens which has now become known through technical publications that are available outside the boundaries of the Soviet Union. For this purpose, he used the basic design of the Liar lens. The Russar is a super wide-angle lens with an angular field of 133 degrees. In accordance with the French Patent No. 935 617, the loss of light toward the edges does not follow the law of $\cos^4\beta$ but that of $\cos^3\beta$.

The pupil sizes of the Russar lens at an angle of 30 degrees–55 degrees, as indicated in the aforementioned patent, are shown in Figure 9. For comparative purposes, the pupil sizes of the Hypergon f/30 are reproduced in the upper line of the same Figure. The same patent was consulted for information on the spherical aberration (Figure a), the curvature of field (Figure b), and the distortion (Figure c) of the Russar lens. The aperture of this lens is stated as f/8.

It is regretted that it is not now possible to furnish any additional information since the Russar lens is not available in the Western Hemisphere.

This would be an incomplete report about high-performance lenses if—under present conditions—high-efficiency shutters were not also mentioned. It is a recognized fact that the effectiveness of a photographic lens of an aerial camera is in-

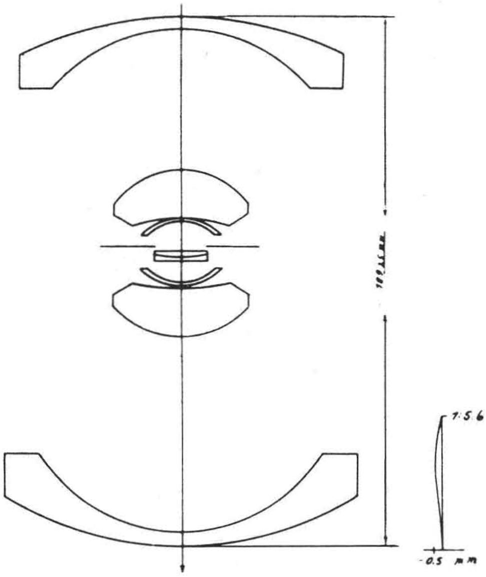

FIG. 7

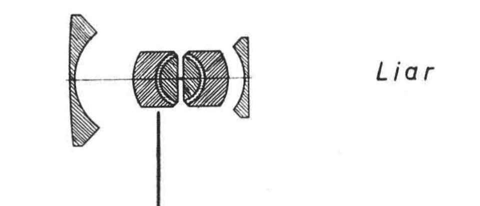

FIG. 8

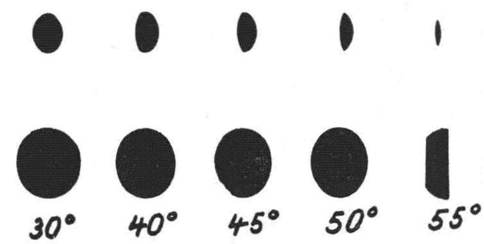

FIG. 9

creased by the use of a high-performance shutter. The reason is quite obvious: aerial pictures are not taken from a stationary balloon but, on the contrary, from relatively fast-flying aircraft, so that the relative image movement, caused by the advance moment and the angular movement of the aircraft at the moment of exposure, would result in blurred images. For exactly the same reason, resolution figures of a photographic lens established by laboratory tests are a very relative quality classification only. If the shutter is too slow or keeps back too much light, the performance of the lens will be greatly impaired, despite the excellent results obtained in laboratory tests. Auxiliary instruments and devices are contrived to counter-act the apparent movement of this ground. These, however, are very suscep-

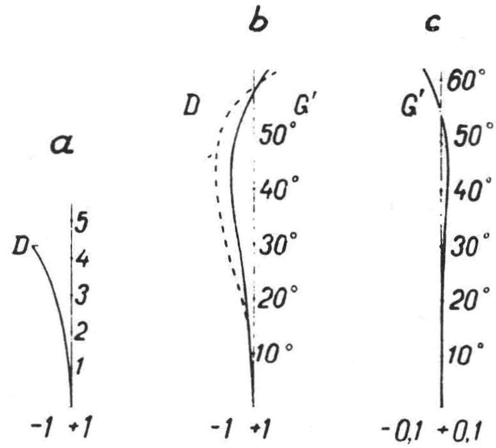

FIG. 10

tible to failure and—on top of that—cost a lot of money.

With their new aerial cameras, that is, the RMK 21/18 with Topar f/4 and the RMK 15/23 (i.e., 6″ focal length and 9″×9″ negative size) with Pleogon f/5.6 Zeiss-Aerotopograph has marketed a new high-efficiency shutter which is completely new in this field. Figure 11 shows a diagram of a motor-driven shutter. In this shutter, the motor drives a central master gear which, in turn, gives a continuously rotating movement to four disks provided with segments. The speed of rotation of these disks can be variably set up to 9,000 revolutions per minute. This continuous

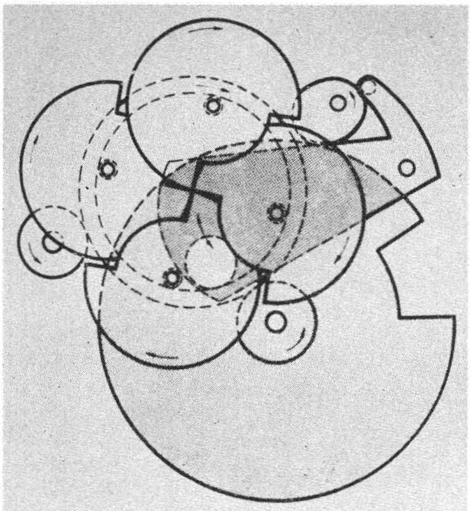

FIG. 11. Zeiss-Aerotop shutter diagram.

rotation allows 120 exposures per second at a speed of 7,200 revolutions per minute. Since such a large number of exposures is never required, another disk with a considerably slower speed of rotation selects approximately 10 per cent of these "open-time" positions. A sixth disk in turn selects the one desired actual exposure from the 10 per cent left over by the aforementioned disk. This last-mentioned disk (the sixth) is controlled by electrical impulses emanating from the intervalometer. Thus, there are no springs employed in order to drive these disks. It is not necessary to quickly accelerate resting parts to a fast rotating movement, nor is it necessary to rapidly stop this movement. Consequently, each exposure is made with a "flying start," so to speak.

This shutter is available in two different models, one of which, the Aerotop Shutter I, allows the shutter speeds to be variably set from 1/5Cth to 1/500th second, while the other model, the Aerotop Shutter II, permits the variable setting of exposure times from 1/100th to 1/1,000th of a second. At full aperture, the light efficiency of the first model is 92 per cent, that of the second one somewhat lower. If a diaphragm is used, however, the degree of light efficiency will be increased in both cases.

Installed in a Topar camera, this new shutter which gives excellent service at any imaginable working temperature, was rigidly tested in many countries and also in the United States. (Figures 12 to 14) Figure 12 is a reproduction of an aerial photograph taken of a portion of Southampton, England. Figure 13 is an enlargement of a portion of the same photograph as Figure 12. The minute lines of the corrugated roofs to be seen in the factory area of Figure 13, which are partly at right angles to each other, make an ideal natural test target. It is impossible to detect the slightest image movement in this picture and thus determine the direction of flight.

Figure 14 pictures the camera (an RMK 21/18) with which these photographs were taken.

DISCUSSION OF DR. TRAGER'S PAPER

MR. HARMAN: I have a question for Dr. Trager. Are those lenses used at maximum aperture, at f/6.3 or at f/5.6; were the pictures taken with either of these?

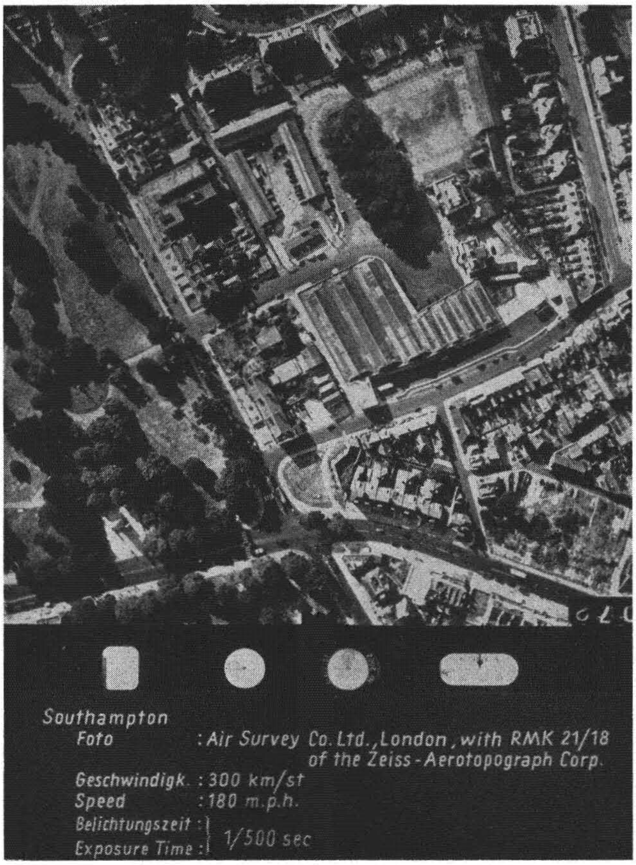

FIG. 12

MR. TRAGER: With the present design of the camera, both lenses are always used with a full aperture. We haven't even built in a diaphragm. At some future time we intend to do this in order to take off some light. Test flights performed in California areas, with 1/500 second exposure, Kodak super-XX film, and a yellow filter B in front of the lens, have shown that we have over-exposed film due to the 92% light efficiency of the shutter. We can reduce this quantity of light by building in a diaphragm in both cameras. The critical aperture will be about 1 over 11, of both lenses.

MR. VICTOR ELLIS (commercial camera designer, Montclair, N.J.): In 1952 at Columbia College, Doctor K. Lienstiener from the Army Signal Corps Photo Lab gave five lectures on optics. He astonished us by this assertion: "Categorically there are no good lenses made, manufactured, for photographic purposes." A dramatic pause; But then he added, "As compared with microscopic and telescopic lenses." Doctor Trager, how do you consider this assertion?

DR. TRAGER: It is possible to design a camera lens as good as we already have in microscopes and telescopes. The biggest problem is manufacture. I agree with Mr. Sewell in an article published in PHOTOGRAMMETRIC ENGINEERING, Dec. 1955 and entitled the Planigon Story. His conclusion is that it is just a manufacturing problem—not a question of design.

MR. MORRIS THOMPSON, (U.S.G.S.): Doctor Trager, can you inform us on the development of super-wide-angle lenses in Western Europe and when they may be commercially available?

DR. TRAGER: I cannot tell you much and I don't know whether other companies in Europe in the near future will be in the market with a super-wide-angle lens. The

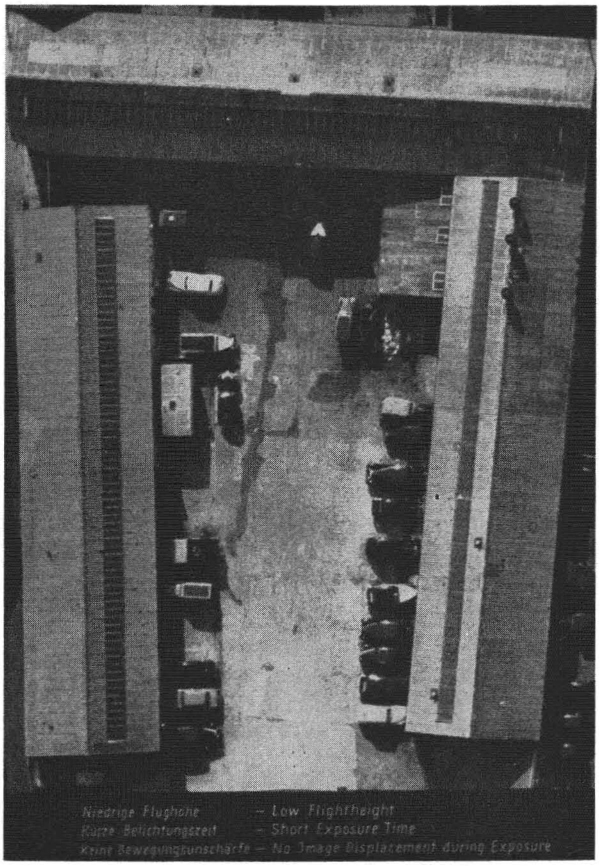

FIG. 13

talk is that they will be. The Zeiss Company has notified me that we will have a 120-degree super-wide-angle lens, but when I cannot now say.

MR. PAUL BLAKE (U.S.G.S.): One problem faced in camera operations is servicing the shutter. From the sketches this new shutter seems very good. But is it required that the lens be dismounted and disassembled in order to service the shutter?

DR. TRAGER: That's right; it is necessary;

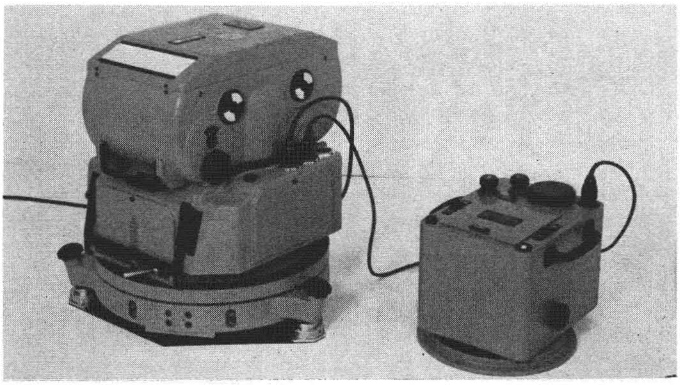

FIG. 14

it is not a shutter which you can exchange easily. But on the other hand, the merits of the shutter are proved in that we have already destroyed three electric computing systems to get a shutter worn out. The first shutter built has now made 1,200,000 exposures without being worn out. That is because no springs are involved. We cannot build, and we cannot guarantee, such high precision lens, when it is so built that you can shift something between the lenses. We also tried to make the mount of the lens as stable as possible.

MR. BURKE (Signal Corps Engineering Laboratories): How much advance notice is necessary before the shutter will open up? What's the time interval between when the pulse comes into the shutter and the time that your final capping blade opens up?

DR. TRAGER: It may be up to one-fifteenth of a second at the lowest shutter speed.

MR. SANDERS (Aeroflex Corp.): I'm quite flabbergasted at the efficiency that you speak of. Am I correct in understanding it to be 92% at 1/1,000 of a second?

DR. TRAGER: No. 92% for 1/50 to 1/500. It is actually about 84% for the setting 1/100 to 1/1,000 of a second. But we are coming up also with this shutter type to 90% when we have installed a diaphragm to an aperture f/0.8.

MR. HARMAN: Doctor Trager, do you desire to comment on what plotting instruments have been devised for the use of this super-wide-angle lens?

DR. TRAGER: I do not have much information here because the instruments my company manufacture are for nearly all types, but especially our own types of cameras and lenses. I don't think that we will ever be able to handle Russian pictures with a German instrument in this way.

MR. PECKINPAUGH (Photogrammetry, Inc.): Why do you stop down with a diaphragm rather than go to a faster shutter speed?

DR. TRAGER: It is a question of mechanics. Working with 9,000 rounds a minute requires quite a mechanical design and I think there should be shutter limits with 1/1,000 of a second. Actually when tested in the factory the shutter shows that the highest shutter speed is already 1/1,250 of a second. But we are not claiming this speed practically. Our shutter speed should be limited right now to 1/1,000 of a second.

Mass Production of High Quality Contact Prints

EARL M. KNIBIEHLY,
Army Map Service,
Washington, D.C.

ABSTRACT: *The mass production of highest quality contact prints from aerial negatives has been realized by the introduction of electronic printing devices and mass or continuous processing equipment. The processing equipment preceded the controlled exposure instruments and was virtually useless in regard to high quality prints without the electronic equipment to provide the scanning, dodging, and exposure.*

IN SOME circles automation is an ugly word, but it has made possible the mass production of high-quality contact prints from aerial negatives. At Army Map Service mass production means 50,000 to 75,000 contact prints from 9″ by 9″ or smaller aerial negatives per month. High quality means that all of the detail in the negative from high light to shadow has been reproduced on the paper prints with-