will be made, when testing a camera, and the plate will be measured on a two-axis comparator. It is believed that not only will accurate calibration of aerial cameras be possible, but it will be fairly convenient to secure distortion data for not only one half a diagonal but for the whole field. This distortion data for the whole field is expected to shed considerable light on the matter of unsymmetrical

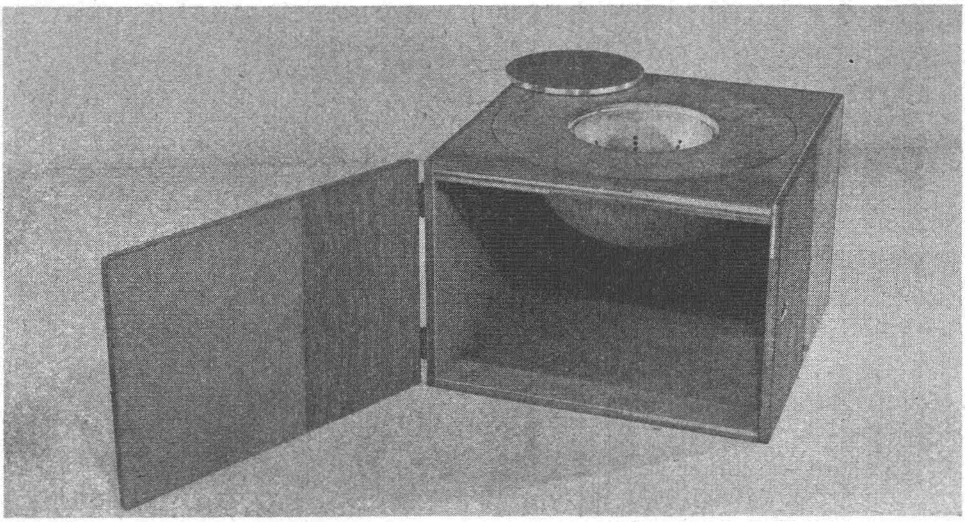

FIG. 12. Wood scale model of proposed "Hemispherical Collimators." The outside hemisphere will probably be about 9 feet in diameter. The inside hemisphere will probably be about 5 feet in diameter. Approximately 185 two-foot focal length collimators 2 inches in diameter will point upward at a camera mounted at the center of the hemisphere.

distortion and the so-called, but little understood, "tangential distortion." This tangential distortion is apparent when it is observed that a line in the image through the principal point is bent. It is also hoped that this device will provide a method of selecting only top quality lenses for mapping cameras.

There is still much interesting work to be done; and when this set of collimators is finished, it is expected that it will be made available to the aerial survey industry for the calibration of cameras.

DEVELOPMENT IN THE FIELD OF AERIAL PHOTOGRAPHY

Aelred A. Koepfer

Aerial Photography Branch, Photographic Laboratory

A DEFINITE two-fold developmental objective is being pursued by the Photographic Laboratory. On one hand, we are progressively improving our present type aerial cameras to fulfill present and near-future requirements. At the same time, we are sighting well into the supersonic era and are planning that phase of our research accordingly.

The results of this long range program for the future may find aerial photography practiced in a completely altered form, with equipment and techniques almost unrecognizable in terms of present-day standard equipment. Aerial photography will adapt to its use the latest developments in the fields of electronics, radar, and allied endeavors. We're quite enthusiastic about the prospects, and we definitely intend to have aircraft cameras ready in their future role for both military and commercial applications.

Before discussing future trends, however, it would be opportune at this time to touch on a few of the aerial cameras and techniques employed during the war so as to secure a basis of comparison.

The reconnaissance type cameras used largely throughout the war were the K-17, K-18, K-19, K-22, K-24, and K-25. Each of these cameras as shown in Figures 1 to 6 inclusive vary in respect to functional characteristics and are therefore basically different in design, construction, operating characteristics, etc.

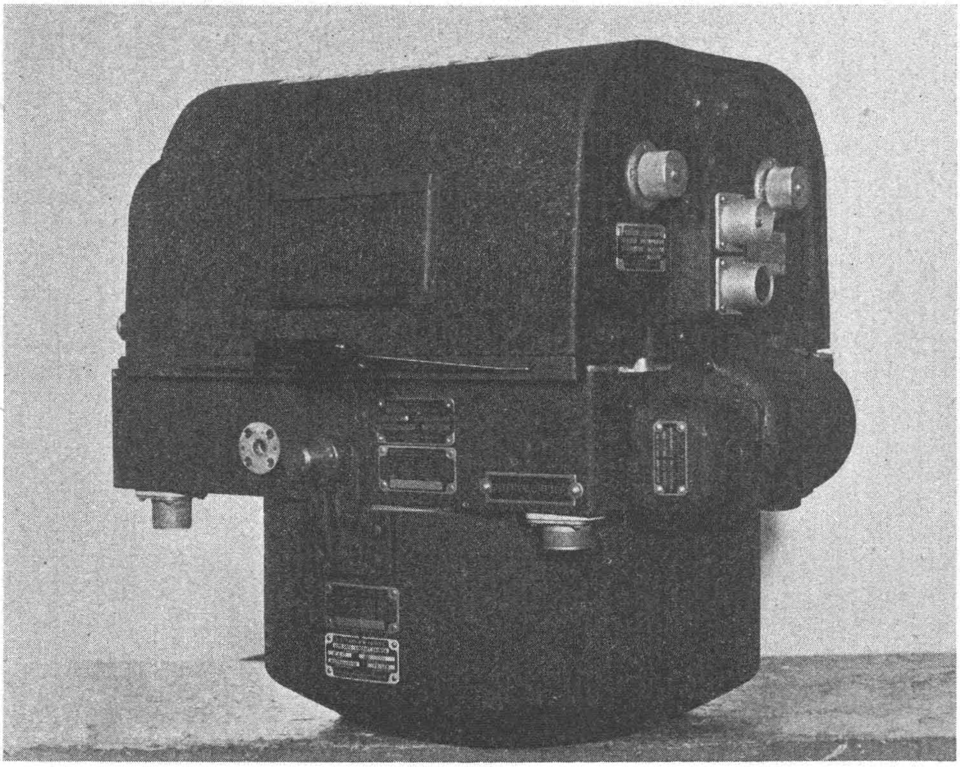

FIG. 1. AAF Type K-17 day reconnaissance camera; manual or electrical operation; 24-V; 6-inch f/6.3, 12-inch f/5, 24-inch f/6; interchangeable cones; AAF Type A-5A magazine; $9\frac{1}{2}'' \times 150'$ film load size; 190 exposures. Weight of A-5A magazine and 6" cone and body 51.2 pounds.

The types of lenses and shutters employed, and the picture size of each is generally dependent upon the use for which the particular camera is intended. The AAF's standard mapping camera is the Type T-5 shown in Figure 7. This camera was employed throughout the war on several precise mapping projects.

It can be stated that one of the outstanding developments in aerial photography during the war period was the continuous strip camera, shown in Figure 8. This camera uses no conventional shutter, but instead employs a narrow slit, adjustable to the thousandth of an inch, past which the film is moved at the same rate as the image of objects on the ground move across the camera's focal plane. The principle of exposure is practically the reverse of focal plane shutter photography, wherein the film is stationary and a fixed slit moves across the film.

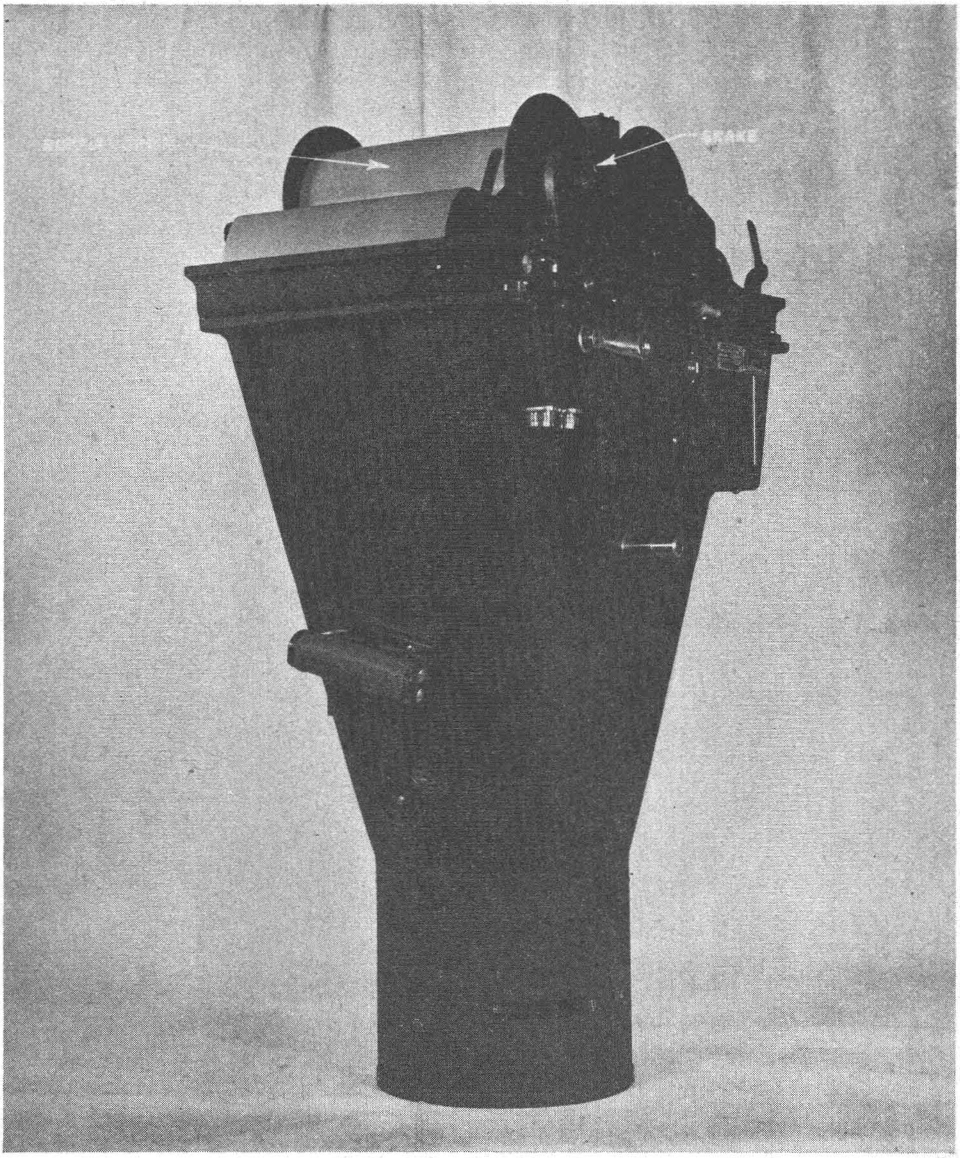

FIG. 2. AAF Type K-18 day reconnaissance camera; manual or electrical operation; 24-V; 24-inch f/6 between-the-lens shutter. Uses AAF Type A-8 magazine, 9×18″; film load size 9½″ ×150′; 95 exposures; weight of camera and magazine 70 pounds.

Not only will the continuous strip camera operate with razor-sharp precision at today's fastest aircraft speeds, but it can already do as well at tomorrow's supersonic speeds of 1,000 miles an hour. A flip of a switch on the instrument panel permits the pilot of a plane to operate it by remote control, an electronic and optical device automatically compensating the rate of film speed for any changes in altitude or speed of the aircraft.

Using color film and its stereoscopic lenses in combat, this camera produced third dimensional photos from which the height of cliffs, walls, and other obstacles confronting our invading forces were computed to an accuracy within a fraction of a foot. As an example, the height of Orange Seawall on Okinawa was computed from the study of stereoscopic continuous strip photography to be 6′7″. After the troops landed and secured the beach-head, the wall was measured and found to be 6′5″.

The wartime strip camera employed interchangeable lens cones. Single 6-inch lenses were provided for non-stereo photography and dual 88 mm, 100 mm, and 5-inch lenses for stereo photography. Under development at present are stereoscopic cones accommodating two 12-inch f/5 lenses and two 20-inch f/5.6 lenses for medium altitude photography.

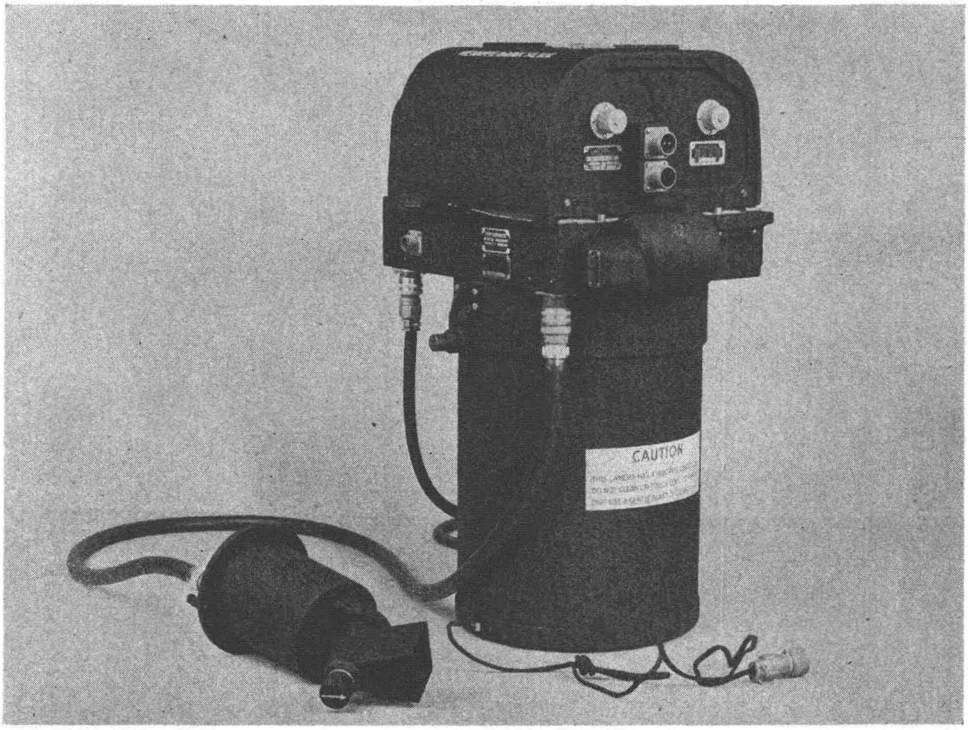

FIG. 3. AAF Type K-19B night reconnaissance camera; electrical operation, 24-V; 12-inch f/2.5 between-the-lens shutter; AAF Type B-1 and A-5 film magazine; negative sizes 8×10 and 9×9 inches; $9\frac{1}{2}''\times150'$ film load size; 190 exposures; weight of camera with B-1 magazine 65.4 pounds.

To specifically improve the overall operating performance of the continuous strip camera and strip photography in general, an improved model is presently under development. It will have a non-banding precision film drive mechanism, a stabilized mount, larger film capacity and several other features.

While the first continuous strip cameras were designed for extremely low altitude high speed photo reconnaissance, a new type of stereoscopic strip camera now being developed is intended to meet the requirement for high altitude strip photography. It is equipped with a single 40-inch f/5 telephoto lens and will utilize two exposure slits positioned fore and aft with respect to the lens axis, in contrast to the present type which utilizes two lenses and one exposure slit. The camera will accommodate two 400-foot rolls of $9\frac{1}{2}$ inch film, each

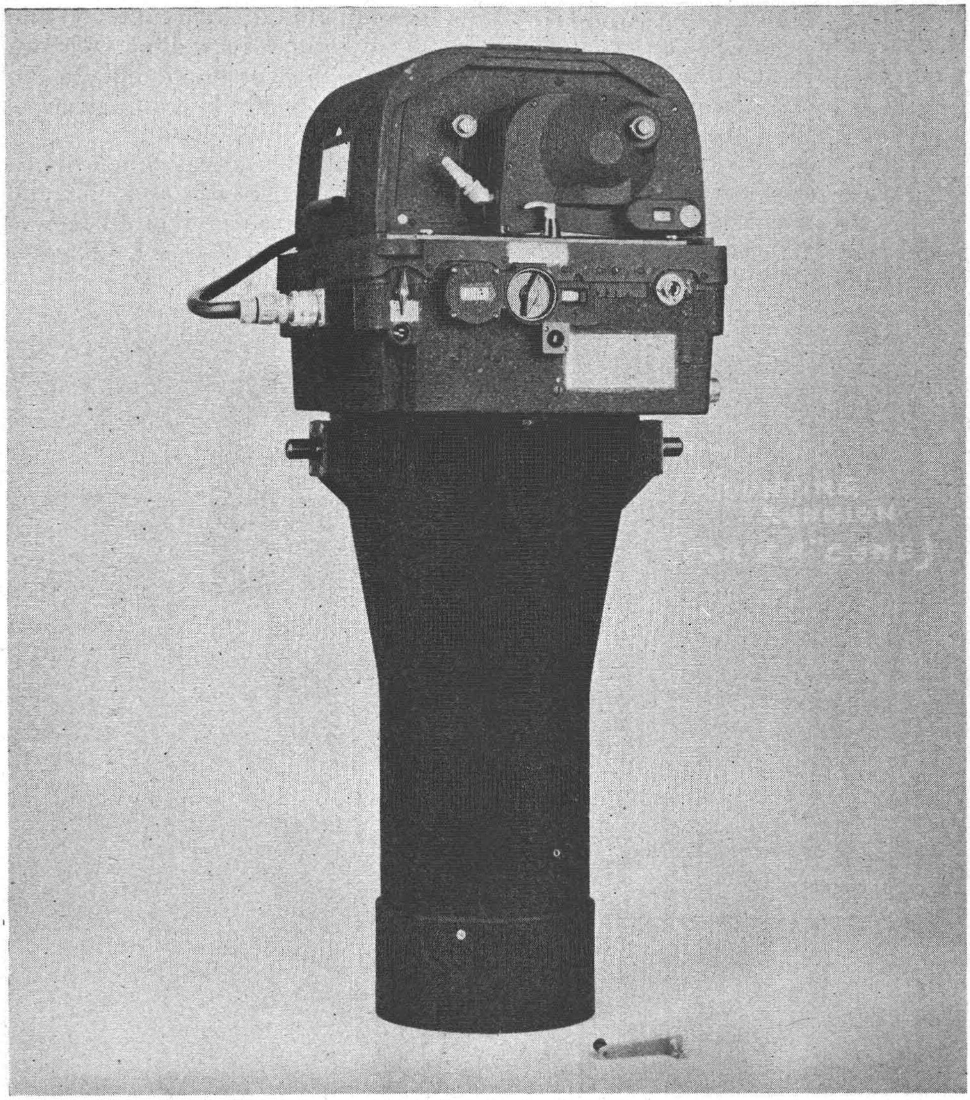

FIG. 4. AAF Type K-22 day reconnaissance camera; electrical operation, 24-V; interchangeable cones with 6-inch f/6.3, 12-inch f/5, 24″ f/6, 40″ f/8, 40″ f/5, 40″ f/5.6 focal plane shutters; Film magazines used AAF Types A-5, A-1B and B-1. Negative sizes 9×9, 7×9, 8×10 inches; film load size $9\frac{1}{2}$″×150′, $9\frac{1}{2}$″×75′, 8″×10″. No. of exposures per load 190, 110 and one. Weight of camera with A-5 magazine, 6″ 60 pounds; 12″ 56 pounds; 24″ 80 pounds; and 40″ 85 pounds.

of which will be pulled past its respective slit simultaneously and at the same rate of speed as the image moves across the camera's focal plane. Should non-stereo pictures be desired, the design will provide for the two rolls to be exposed separately, thus providing 800 feet of continuous print. This camera, in conjunction with a stabilized mount and jet aircraft, is expected to lift the ceiling for stereo strip photography to as high as 40,000 feet and still obtain the photographic scale desired.

Our experience during World War II indicated that sufficient detail was lacking in the majority of photographic prints. The most pronounced lack of detail was probably due to image motion in the direction of flight, resulting from the forward movement of the aircraft during exposure. For that reason, it was necessary to compensate for this image motion by moving the film in synchronization with the movement of the image across the camera's focal plane. By so doing, an ideal photographic situation is created in which there is no relative movement between image and film, thus yielding photographs of amazingly

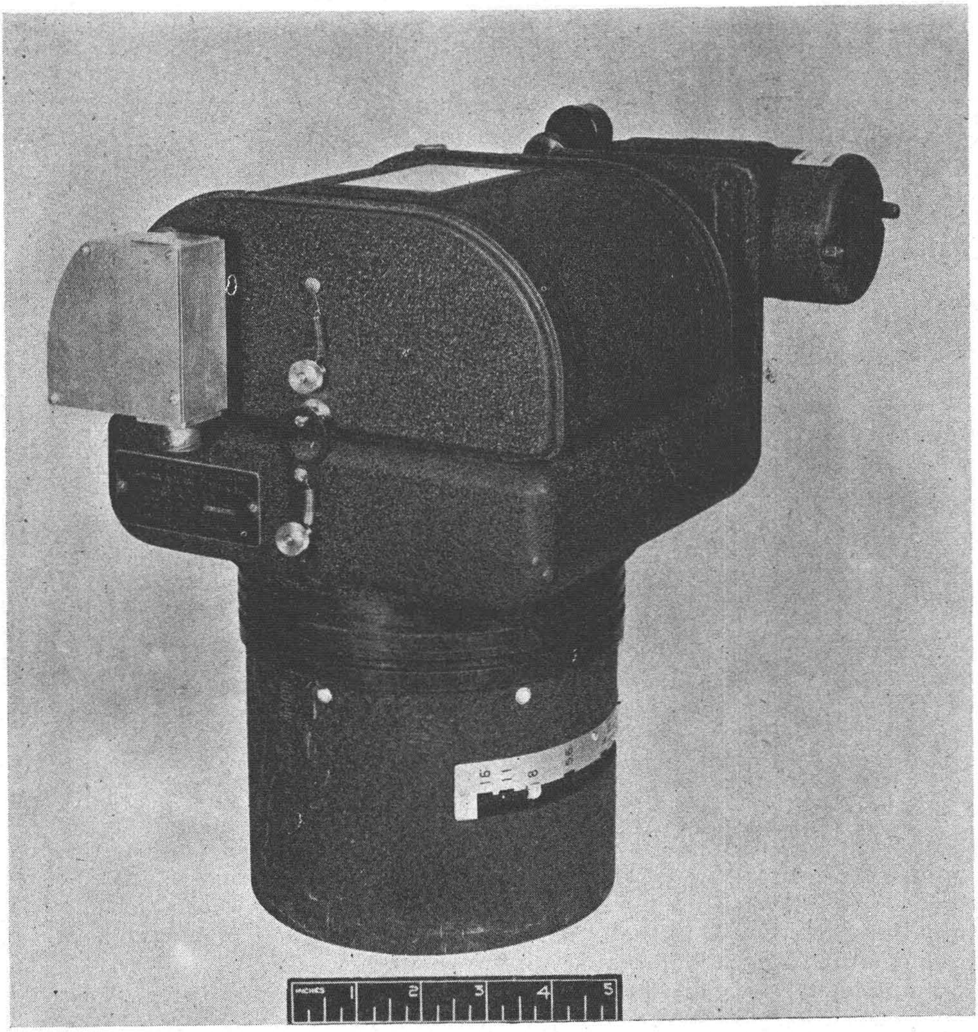

FIG. 5. AAF Type K-24 orientation day and night camera; electrical and manual operation; 24-V; interchangeable cones; $6\frac{3}{8}''$ f/4.5, 7″ f/2.5, 12″ f/5, 20″ f/5.6 focal plane shutters. Negative size 5×5; film load sizes $5\frac{1}{2}''\times6'$, $5\frac{1}{2}''\times26'$, $5\frac{1}{2}''\times56'$. Weight of camera with longest roll of film 26.4 pounds.

sharp detail. During the war, the moving film system was incorporated into the Type A-9A magazine and excellent results were obtained. Figure 9 shows the magazine and Figures 10 and 10A show photographic results obtained with this magazine as compared to conventional types.

In our continuous efforts to secure the most suitable and efficient means of compensating for image motion, we also experimented with a swinging mount device, rotating prisms, and other means, in addition to moving the film. Compensation by the rotating prisms, shown in Figure 11, is accomplished by rotating two prisms in opposite directions and making the exposure at the instant the base of each prism is exactly opposite the vertex of the other prism. The prisms rotate at a uniform rate, the speed of rotation being a function of the overlap interval. While, at present, the moving film principle appears to be the most

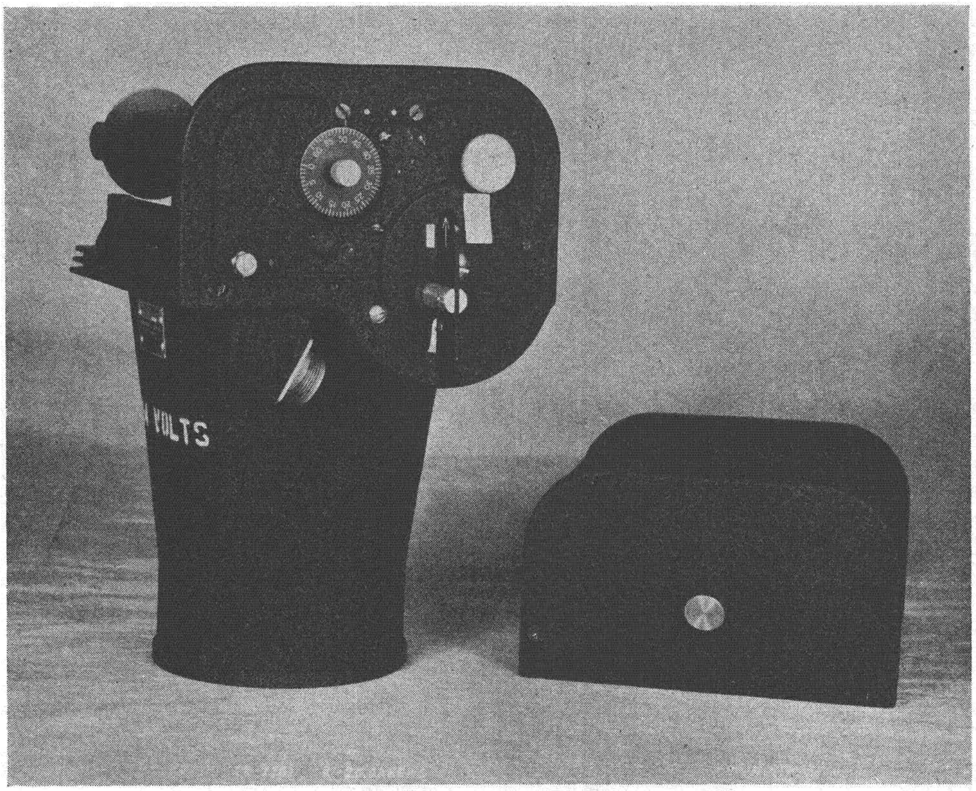

FIG. 6. AAF Type K-25 day reconnaissance camera; electrical operation, 24-V; $6\frac{3}{8}''$ f/4.5; shutter speeds 1/125th, 1/250th, 1/500th between-the-lens shutter; 4×5 negative size; film load size $5\frac{1}{4}''\times20'$; No. of exposures per load 50; weight of camera 11.2 pounds.

promising, it is possible that the rotating prism method may become more prominent in cases of high cycling rates.

Completely new experimental reconnaissance cameras are being developed today which will have as an integral part the moving film principle of image motion compensation. One type will provide 9×9-inch pictures with an exposure capacity of 500, while another will take 9×18-inch photographs with an exposure capacity of 250. The cameras will utilize between-the-lens type shutters with speeds ranging from 1/5 to 1/300th of a second. Complete electrical remote control facilities will be provided for their operation. These cameras are being designed to automatically provide 60% overlap without any computation of cycling rate necessary on the part of the photographer. The overlap becomes an automatic function of the compensating film speed. Further, a positive integral mechanical pulsing device will trip the camera when the film and image speeds are synchronized, thus eliminating the need for an intervalometer. Also, an integral speed changing device will automatically synchronize the film speed for any angle of obliquity of the camera.

Another outstanding and important development during the war years was the adaptation of Doctor Edgerton's electric flash lamp, Figure 12, to night photographic uses. Based on the long-known principle that electrical energy stored at high voltage in a condenser and rapidly released through a gas-filled tube will produce a short but brilliant flash, the flash lamp meant one thing to

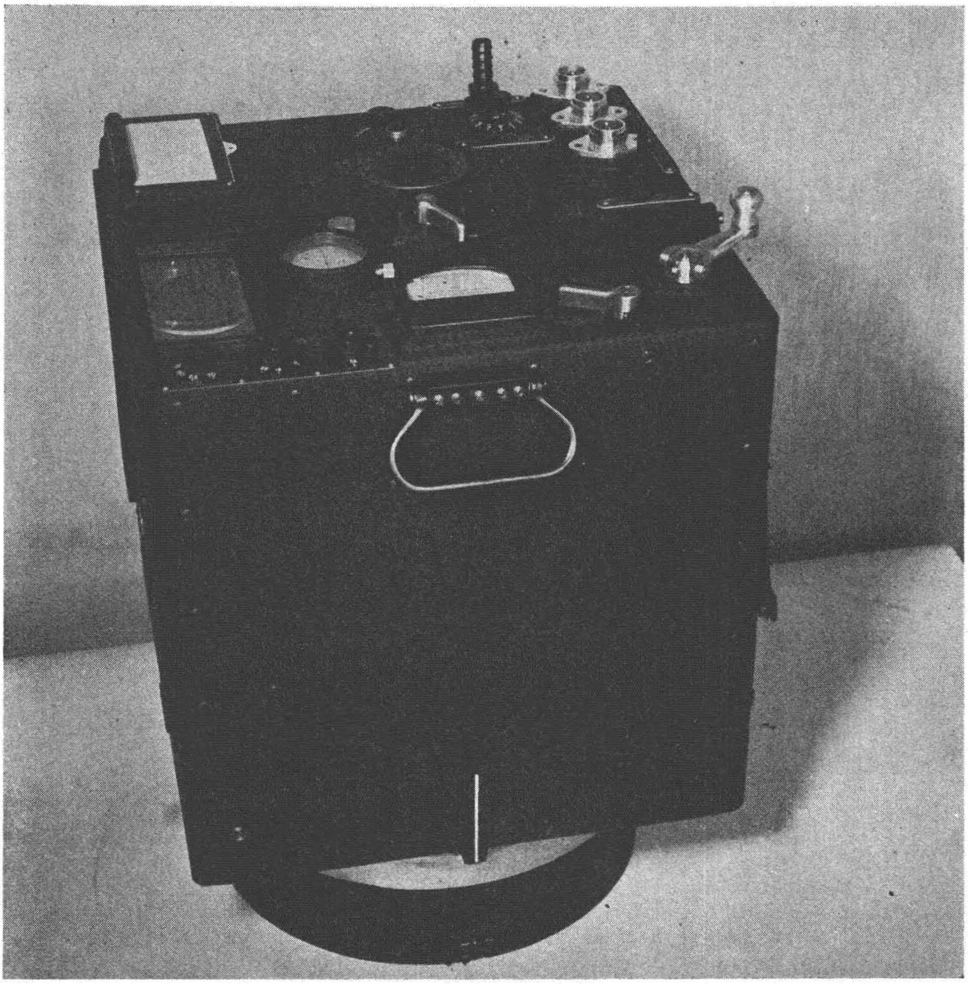

FIG. 7. AAF Type T-5 topographic camera; manual or electrical operation, 24-V; 6″ f/6.3; shutter speeds 1/50th, 1/100th, 1/200th, 1/300th, between-the-lens shutter; negative size $9\frac{1}{2}''\times150'$; No. of exposures 190; weight of camera loaded, no filters or cables, 84.5 pounds. This camera has a built-in viewfinder, intervalometer and exposure meter; automatic recording of altitude, time, and data card made during each exposure.

the Photographic Laboratory. If a unit utilizing this principle could be installed in a photographic plane, it would mean that the number of night photos that could be taken on any mission would be limited only by the amount of film and not by the quantity of flash bombs that could be carried.

Producing approximately 80,000,000 peak candle power in short, brilliant electric flashes every few seconds, this man-made sun, when adapted to night aerial photography, proved to be a boon for our photo reconnaissance men by turning midnight into high noon over the battle fields of Burma and Europe. The importance of night aerial photography during military operations cannot be overemphasized when you consider that night photography is the only means we have of recording enemy activities during the hours of darkness.

The electric flash assembly, however, was utilized only with our standard

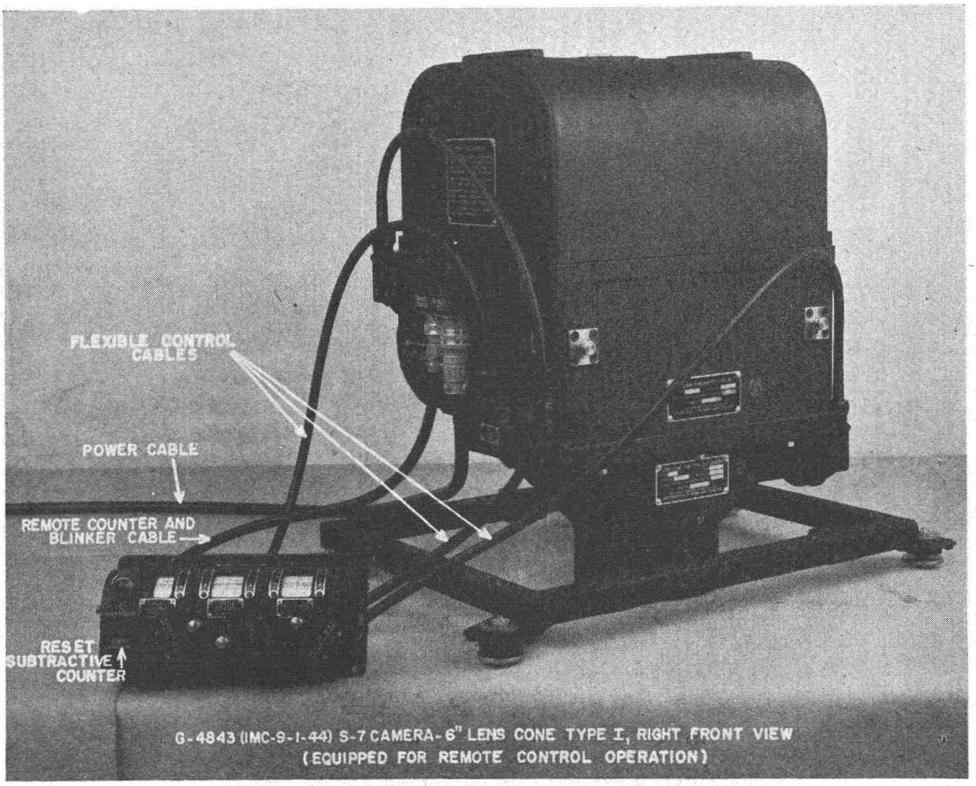

FIG. 8. AAF Type S-7 continuous strip camera; designed for making sharp vertical photographs at very low altitudes and high speeds. This is a continuous strip, shutterless, aircraft camera using $9\frac{1}{2}''$ film in lengths up to 200 feet. The Type S-7 aircraft camera consists of the following component parts: camera body; remote control assembly; camera mount; flexible remote control cables; electrical connecting cables; two idling gear assemblies of different sizes—one for use with 6″ lens cone and the other for use with the 88 mm stereoscopic lens cone; three knob assemblies—one for speed control, one for slit width control, and one for diaphragm control. Film speed and exposure computer; 6″ single lens cone assembly type 1; 88 mm stereoscopic (double lens) cone assembly Type 11; Camera carrying case; carrying case for 6″ lens cone and film spool. The synchronization of image motion with film speed produces a motion stopping effect. Exposure is governed by the speed of travel of the film, the width of the slit and diaphragm opening. A camera mount which fits AAF standard camera mount pads is furnished with the camera.

night camera. What was also needed was a continuous electric light source that could be used with the continuous strip camera described previously. Our postwar developmental period has produced such a unit, and is presently undergoing tests. Initially, the project was undertaken with the expectation of using only visible light for continuous strip night photography. However, as a result of the high efficiency of the newly developed projector and the high sensitivity of infrared films recently produced, it was possible to cover the projector with a Wratten

#88 filter which reduces the visible light intensity several thousand times. In fact, this reduction in intensity is so effective that the photographic aircraft can pass over and photograph an observer on the ground without his being aware that any light was projected on him unless he happens to look straight up at the fraction of a second the infrared beam sweeps across him. Even then, only a faint deep red flash is visible.

In this new developmental program, a specific aid to mapping and charting will be the new Type T-9 mapping camera, which is expected to be far more re-

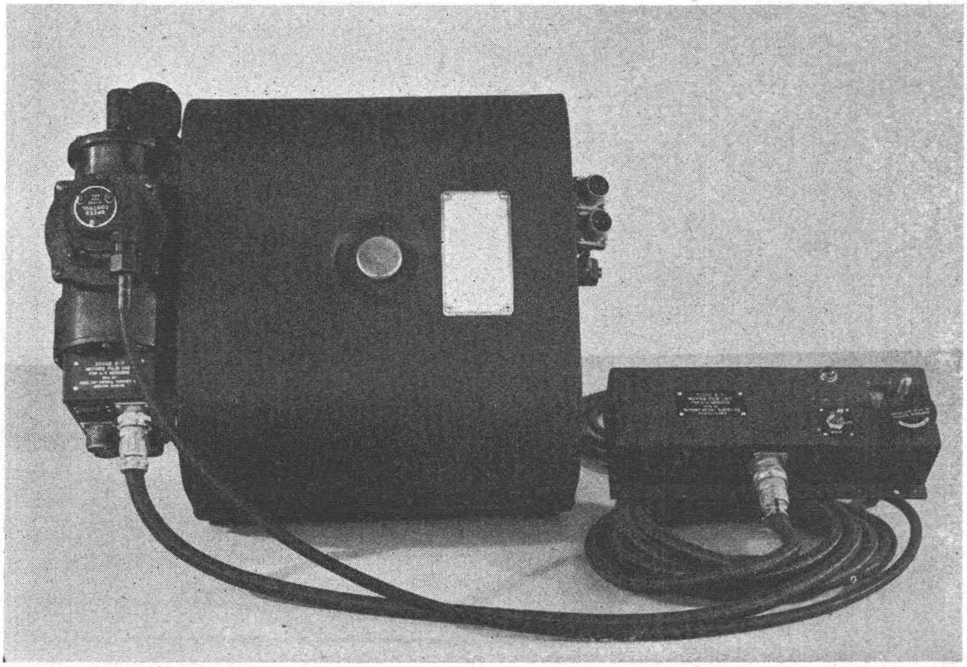

FIG. 9. AAF Type A-9A magazine with remote control, moving film, image motion compensating unit.

liable and accurate than types previously used. Equipped with a 6-inch Metrogon lens, the prototype model of this camera will have provisions for recording Shoran in order to accurately locate the picture geographically. Its data recording facilities also will include the recording of the serial number of the camera, the serial number of exposure, the time of day, date, altitude of flight, and other pertinent data. Shutter speeds up to 1/500th of a second, and an efficiency of at least 75% at the top speed will be available. These features and still others indicate the fulfillment of a vital need in future mapping cameras.

It is apparent that with the introduction of faster and longer range aircraft, where size and weight are of prime importance, aerial cameras may reflect the small weight and size requirements. In fact, it is highly possible that the present trend toward larger and heavier aerial cameras will be completely reversed.

Various cameras have been designed to record radar scope images. Radar itself may be further developed to such a stage that the mere photographic recording of the radar scope image will be entirely suitable for photo interpretation purposes. Aerial photography in the future may be accomplished in part by the recording of televised images transmitted from remotely controlled airplanes back to ground or aerial stations.

Cameras of extremely long focal lengths will be required because of the extremely high altitudes at which future photography will be accomplished. Already, a 100-inch f/10 lens and camera shown in Figure 13 has been completed, and is undergoing test. This camera, weighing over 600 pounds, utilizes two mirrors to direct the image to the focal plane, thus providing compactness.

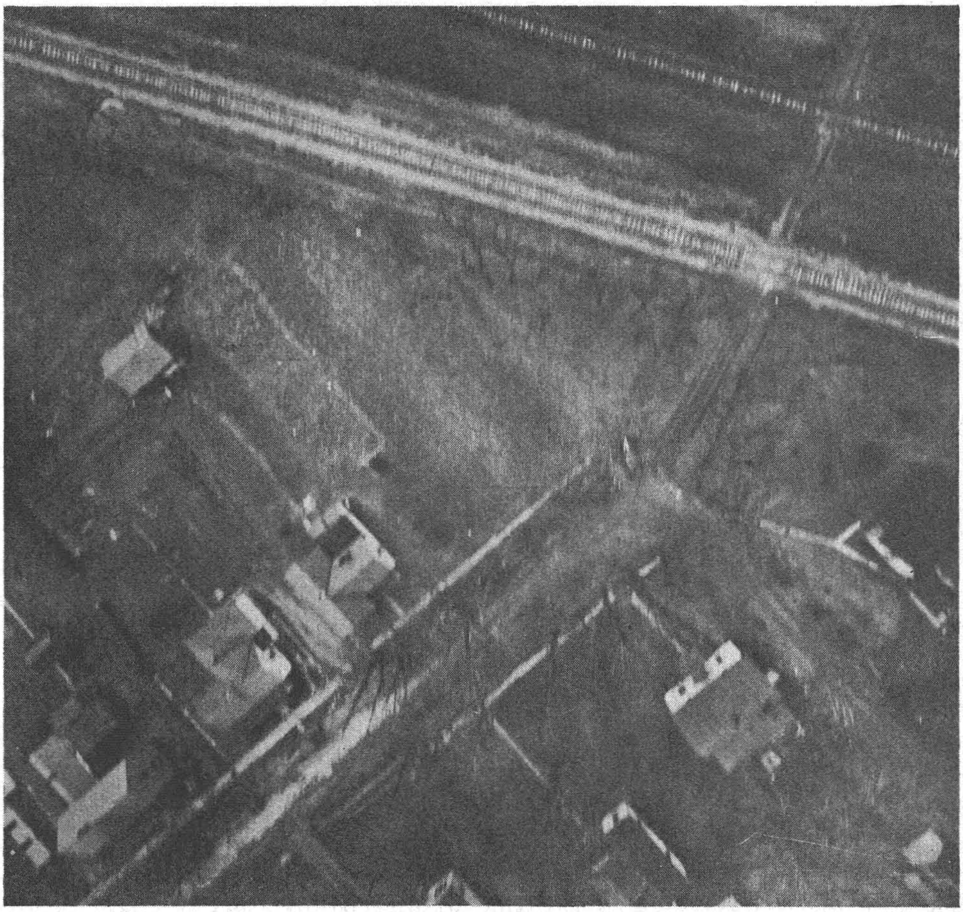

FIG. 10. K-17 6″ photograph made from 150 feet altitude using conventional magazine.

Present plans call for the development of a lens of 240-inch focal length and 40 inches in diameter. The camera and lens will likely be a fixed part of the airplane and would be in a horizontal position along the fuselage, with mirrors used to direct the field of view of the camera at the object to be photographed. Negatives up to 40 inches square would be produced.

Our experience during World War II indicated that long focus cameras, in focal lengths longer than 24 inches, produced unsatisfactory results because of the effects of low temperatures and low air densities at the high altitudes at which these cameras were used.[1] Steps taken during the war to correct these difficulties were the inclusion of thermostatically controlled heating elements

[1] E. B. Woodford and R. N. Nierenberg, "Effects of temperature and pressure on the focus of Aerial Cameras," Journal of the Optical Society of America, October 1945.

and automatic air-density compensating elements within the camera. More recent experiments and ideas along this line indicate that the future solution to this problem may be represented in the idea of hermetically sealed cameras where the complete camera is inclosed in an air-tight compartment, having a window in one end, insulated, and containing suitable automatic temperature controlled heating elements. Such a camera, containing a 60-inch f/6 telephoto lens to cover a 9×18 negative is now in the process of development.

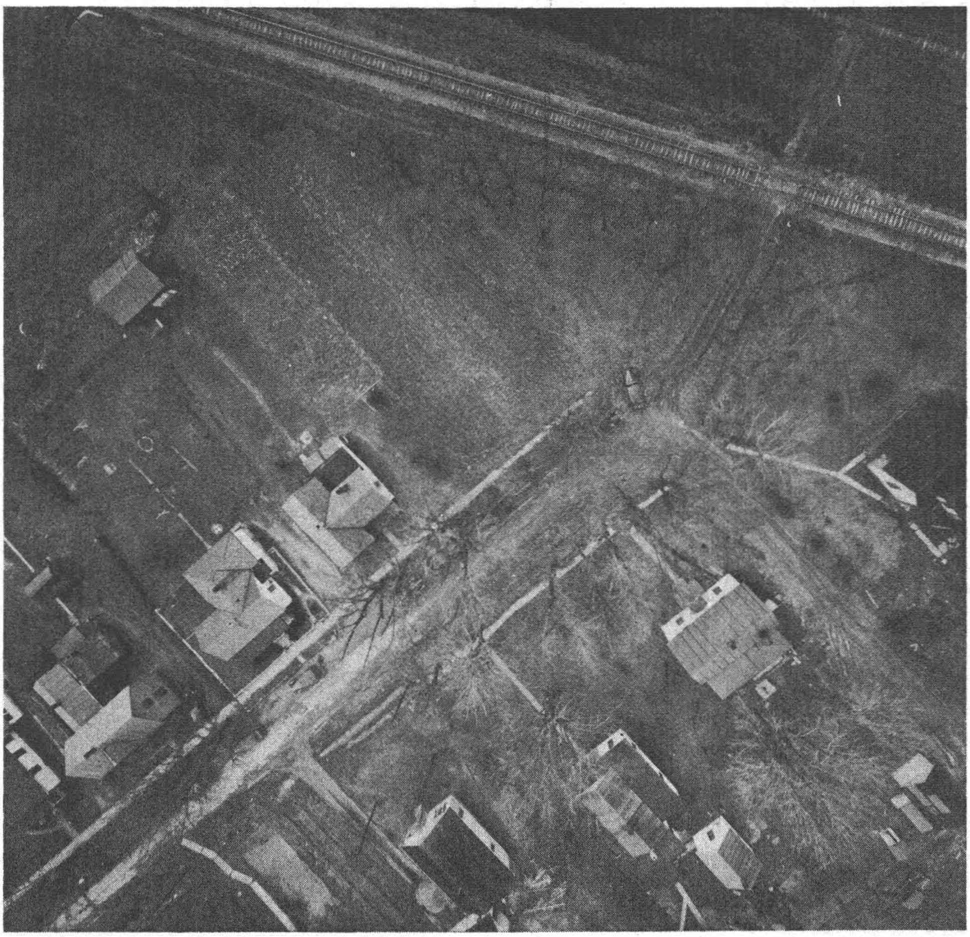

FIG. 10a. K-17 6″ photograph made from 150 feet altitude using moving film magazine. Photographs illustrated in 10 and 10a were made simultaneously from the airplane in flight at low altitude.

An interesting solution to the temperature problem is represented in the new 24-inch lens cones now being developed. This cone is made on the principle of the compensating pendulum. Magnesium alloy and Invar are the metals used. Changes in temperature have no effect on the length of the cone.

A unique solution to the air pressure problem is embodied in the 40-inch f/5 lens cone, Figure 14, developed by Dr. James Baker of Harvard. In this case, the rear lens element floats on small bellows. These expand at higher altitudes and change the focus of the camera to compensate for the changes due to air pressure.

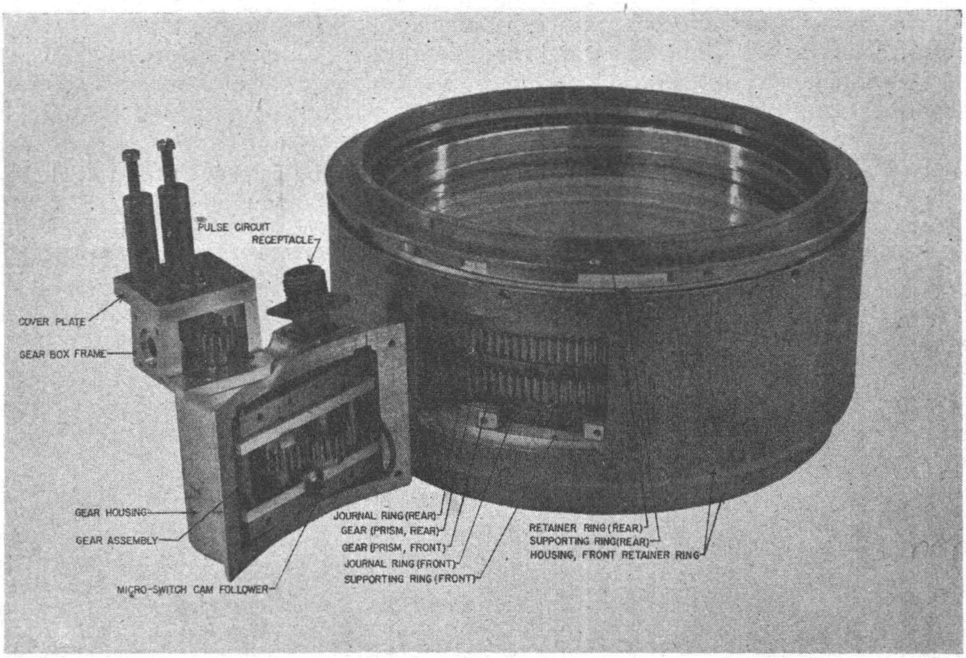

FIG. 11. Prism compensator for image motion.

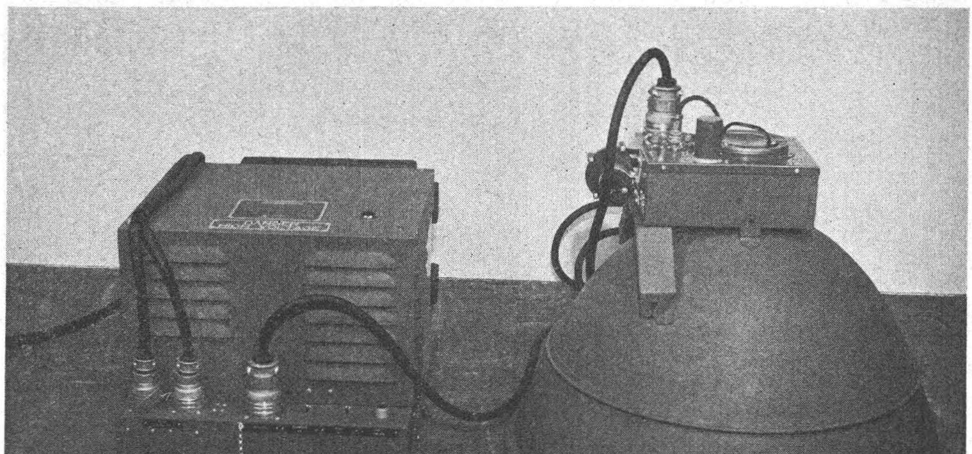

FIG. 12. AAF Type D-4 Electric Flash Lamp Assembly.

An especially interesting development being carried out is the 6-inch f/3.5 sphere lens covering 120° angular field. This lens is a segment of a sphere, the center of this sphere being the center of the lens. It produces a uniformly sharp and unvignetted image on a 9-inch hemispherical plate. The exposure is made

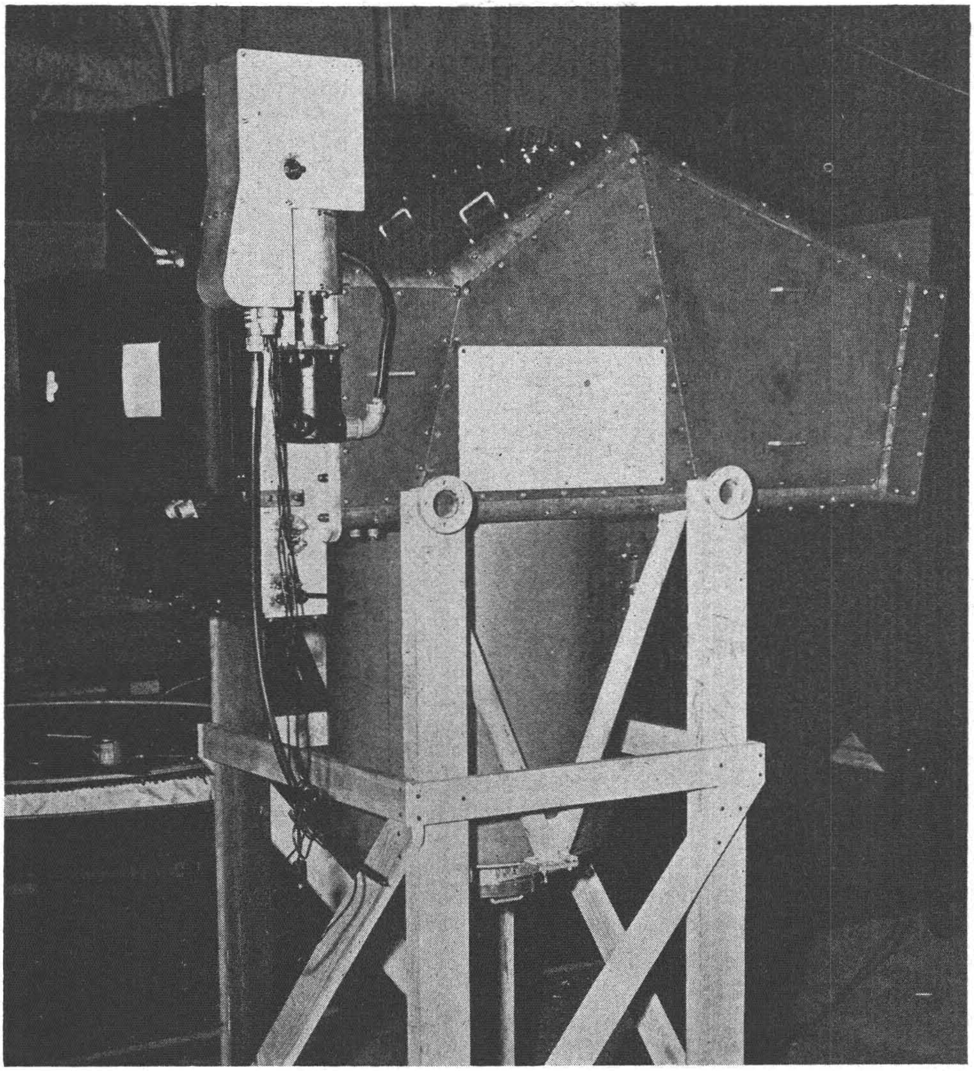

FIG. 13. AAF experimental type K-30 day reconnaissance camera, 100″ f/10, 9×18 inch with A-8 magazine focal plane shutter. Weight 600 pounds.

by rotating the whole lens about an axis through its center. This lens has great possibilities for use in wide angle mapping. A single photograph made with it at 40,000 feet will cover a circular area 26 miles in diameter. Prints can be made from this sphere negative in a projector giving a 40×40-inch print, and the negatives, or the positives from these negatives may be viewed in a special viewer.

Also available is a 6-inch f/1 lens. Plans are now being formulated for the design of a night camera utilizing this lens in conjunction with the electric flash lamp assembly. This lens requires a focal plane pressure plate in the form of a sphere with an approximate radius of 4 inches. Carbon Dioxide gas will likely be used to hold the film flat during exposure.

This necessarily limited treatise of present developments and future photo-

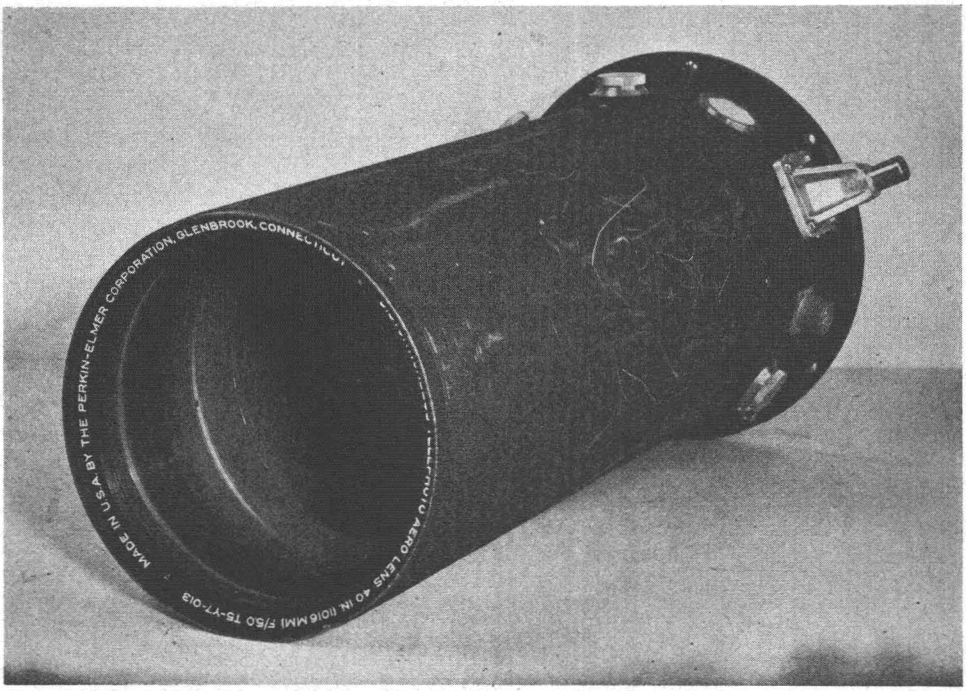

FIG. 14. 40″ f/5 lens cone for AAF Type K-22 day reconnaissance camera.

graphic trends is intended to give an indication of the work that has been accomplished and the job that remains to be done.

The aforementioned developments are but a few of the hundreds of accomplishments of the Photographic Laboratory, commercial, and educational agencies during the war and post-war period.

The future depends upon our efforts.

GROUND PHOTOGRAPHIC EQUIPMENT DESIGN IN THE AAF

C. P. Owen

Ass't Chief, Ground Photo Branch, Photographic Laboratory

THE stereo projector, the metal surface screen, and the techniques used in the preparation of stereo slides were developed by the Ground Photographic Branch. There is a tendency to emphasize one or the other phases of photography, but no part of the photographic chain can be allowed to weaken if good photographs for mapping and intelligence purposes are to be produced.

Ground photography is an important link in the photo production chain and