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AERIAL PHOTOGRAPHY

Prepared under direction of the
Chief of the Air Corps

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CHAPTER 1

GENERAL

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1. General.—All photography accomplished from an aircraft is termed "aerial photography," regardless of the type of camera used. Aerial photographs may be taken singly with any length interval of time between, in which case they are known as stills, or the individual pictures may be taken rapidly in succession so as to record movement in the scene, in which case they are known as motion pic-

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tures. Motion-picture photography is sometimes referred to as "cinematography."

2. Aerial photographs.—The design of this manual is to teach the taking of all the types of aerial photographs used for military purposes. Aerial stills or still photographs are classified as vertical, oblique, and mosaic or composite photographs.

a. A vertical photograph is the picture of an area or objective made with the camera axis perpendicular to the earth.

b. An oblique photograph is any photograph made with the axis of the camera tilted sharply from the vertical.

c. A composite photograph is the finished product of a multi-lens camera. It is composed of a contact print of the vertical chamber and the prints of the oblique chambers after they have been projected in the proper rectifying printer designed for the camera.

3. Aerial cinematography.—Aerial cinematography may be either sound or silent, vertical or oblique.

4. Military aerial photography.—Military aerial photography is divided by its tactical employment and equipment into two general classes:

Mapping photography.
Intelligence photography.

Whereas maps may be compiled from either vertical, composite, or oblique photographs, only the vertical or composite photograph will be considered as a map-making aid. Inasmuch as the technique of the cameraman is much the same when using either a vertical or multi-lens camera, the technique of mapping photography will be treated from the standpoint of vertical camera operation.

5. Instructions for use of equipment.—A complete list of the standard cameras and accessories used by the Air Corps may be found in Air Corps Technical Order 00–1. Air Corps Technical Orders, series 10–10, describe in detail the installation, operation, and maintenance of the various types of cameras. The pertinent technical order will be consulted before operating equipment with which the cameraman is unfamiliar. In addition to cameras, Air Corps Technical Orders include necessary operation instructions for all types of photographic equipment or accessories and therefore detailed instructions concerning such auxiliary equipment will likewise be omitted from this manual.

CHAPTER 2

MAPPING PHOTOGRAPHY

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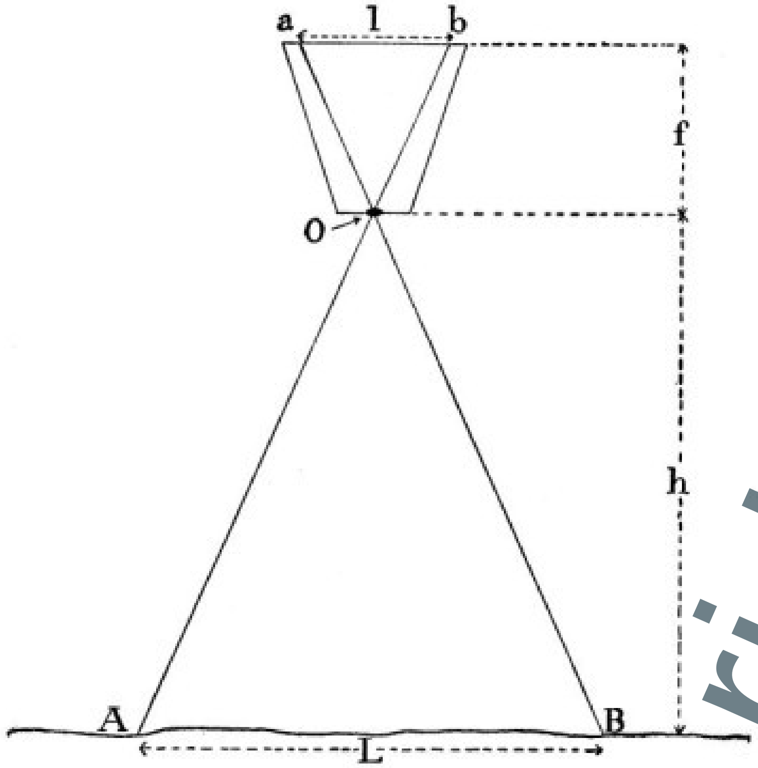
6. General requirements.—Mapping photography will be performed with the best and latest equipment available as it is a very precise operation and must be accomplished with the utmost skill and precision.

7. Preflight preparation.—*a.* The scale of a map or the scale of a photograph is the ratio existing between any distance on the ground and the representation of that distance in either the map or in the photograph. It must be computed with like units of measurement. The two factors for determining scale are focal length of the camera and altitude above the terrain. For example: It is impossible to obtain initially a vertical photograph at a scale of 1/40,000 with a camera of 24-inch focal length. To do so would involve flying at 80,000 feet. However, it is a simple matter to obtain it with a camera of 6-inch focal length, which requires flying at 20,000 feet above the terrain.

(1) *Methods of expressing scale.*—(*a*) The scale of any vertical photograph is the relation between any distance on the print to the corresponding distance on the ground. There are different methods of expressing the scale of aerial photographs and the methods used are the same as employed on line maps.

(*b*) The "representative fraction" (R. F.) of a map is one whose numerator shows the units of distance on the map and whose denominator shows the corresponding units of distance on the ground. Thus, scale 1/12,000 means that one unit on the map represents 12,000 of the same units on the ground, be it inches, feet, yards, or any other unit of measurement. In manuscript, the R. F. is usually written 1: 12,000.

(*c*) Another method of stating the scale is in words and figures, as 6 inches equal 1 mile, which means that 6 inches on the map represent 1 mile on the ground; 1 inch equals 800 feet, meaning that 1 inch on the map equals 800 feet on the ground. A scale of this kind can very easily be changed to a "natural" scale (the R. F. also is called "natural" scale), as for example, if 6 inches equal 1 mile, or 6 inches equal 63,360 inches, then 1 inch equals 10,560 inches, which of course gives the R. F. of 1:10,560, since both the numerator and the denominator are of the same units.



l. Focal plane.
f. Focal length.
O. Lens.
h. Altitude.
L. Ground coverage.

FIGURE 1.—Similar triangles.

(*d*) A graphic scale is a line or double line drawn on the map, divided into equal parts, each division being marked with the distance it represents on the ground.

(*e*) The scale of aerial photographs depends on the focal length of the lens and the altitude at which the photographs were taken. It will be seen that lines drawn from the sides of the sensitized material to the lens and from the lens to the sides of the area covered on the ground form two similar triangles (fig. 1).

(2) *Methods of finding scale.*—(*a*) Since the sides and altitude of the triangles are proportional, the scale of the photograph is the ratio between the altitude of the small triangle (the focal length of the lens *F*) and the altitude of the large triangle (the distance from the lens to the ground *A*), or the ratio between the base of the small triangle (distance on the film *d*) and the base of the large triangle (ground distance *D*).

Example: The focal length is 6 inches, the altitude 25,000 feet; $\frac{f}{a}$ equals R. F., which is $\frac{6}{25{,}000\times 12}$, which equals $\frac{6}{300{,}000}$ or 1: 50,000.

Both the numerator and the denominator must be of the same unit, so altitude is multiplied by 12, changing feet to inches. Or, the distance between two points on the ground is 3,000 feet, the corresponding distance on the film, 5 inches:

$$\frac{d}{D}=\text{R. F. } \frac{5}{3{,}000\times 12} \text{ or } 1:7{,}200.$$

NOTE.—When a 12-inch focal length lens is used, the denominator of the scale corresponds to the altitude required. If the desired scale is 1:12,500 the altitude is 12,500 feet.

(*b*) The first method of finding the scale is, of course, accurate only providing the altimeter is accurate, the airplane was flown at exactly the same altitude for each exposure, and the elevation of the ground did not change. However, such ideal conditions seldom exist. Consequently, the scale is only approximate, but accurate enough for ordinary calculations which do not involve projections.

b. Ground area included in vertical photographs and number of exposures required to cover certain areas.—(1) It was stated in *a* above that the ground distance and its image on the sensitized material are the bases of two similar triangles. Therefore, the sides and altitudes of one are proportional to similar sides and altitudes of the other. This gives the following equation for calculating the ground distance covered by one exposure, say 7- by 9-inch film, using a 12-inch focal length lens at an altitude of 11,000 feet.

For the 7-inch side:

$$\frac{F}{A}::\frac{d}{D} \text{ or } \frac{12}{11{,}000}::\frac{7}{X}$$

$$X=\frac{77{,}000}{12}=6{,}416 \text{ feet.}$$

For the 9-inch side:

$$\frac{12}{11{,}000}::\frac{9}{X}$$

$$X=\frac{99{,}000}{12}=8{,}250 \text{ feet.}$$

NOTE.—Since in both ratios the denominators are in feet, it is not necessary to reduce feet to inches.

(2) The number of exposures required to cover a certain area depends on the scale and the amount of overlap desired. It is customary to have an overlap of 60 percent between exposures in the direction of flight and 50 percent between strips. That means that we use only 40 percent of the negative on the 7-inch side and 60 percent on the 9-inch side. Suppose the area to be mapped is 10 by 15

miles (the direction of flight being the long way). The area covered by one exposure on a 7- by 9-inch film is 6.416 feet times 8,250 feet. Forty percent of 6,416 feet (6,416×40÷100) equals 2,566.4 feet. Sixty percent of 8,250 feet (8,250×60÷100) equals 4,950 feet. Dividing the length of the area by the distance used on the 7-inch side of the photograph gives the number of exposures for one strip, and dividing the width of the area by the distance used on the 9-inch

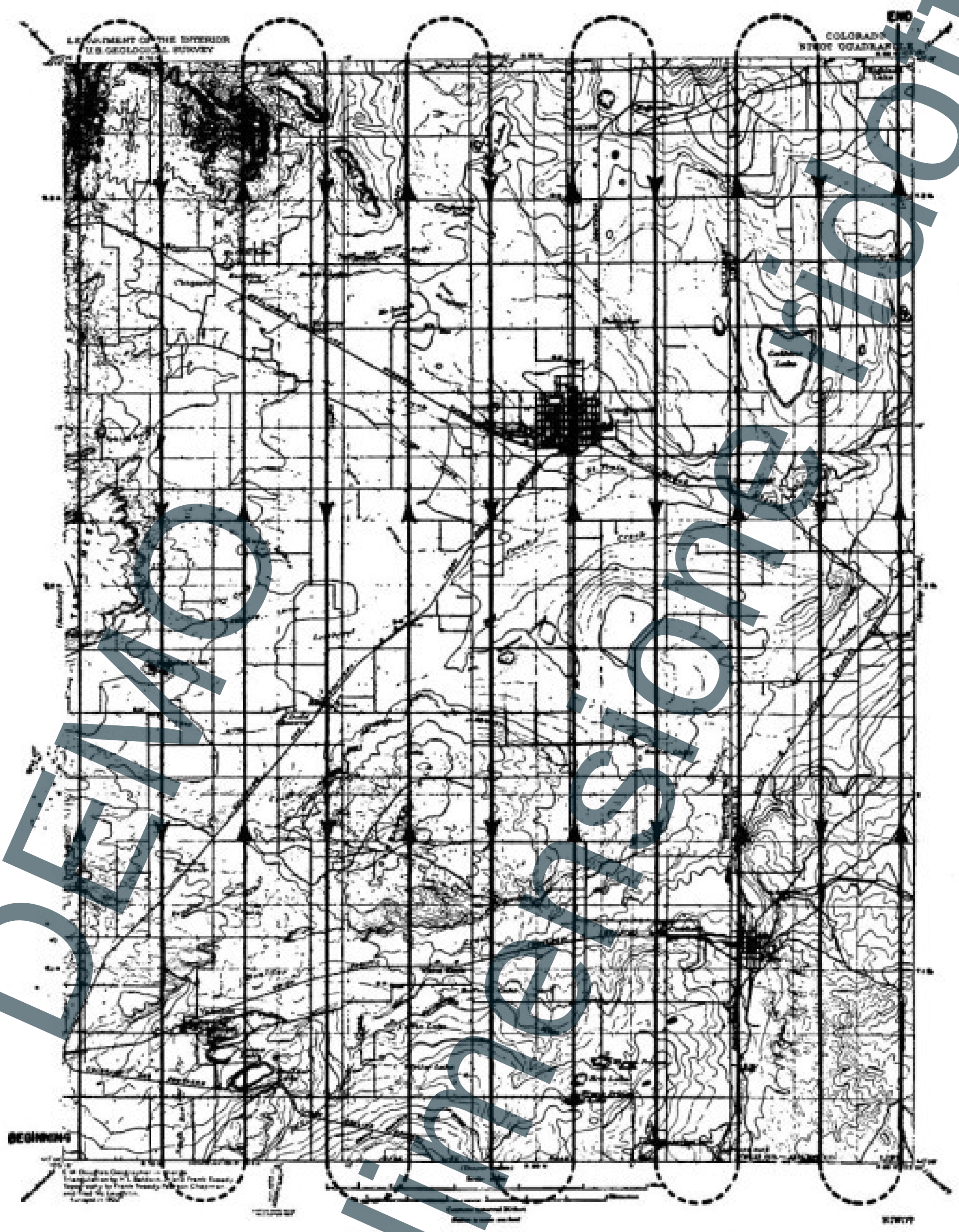


FIGURE 2.—Flight map. (Original scale 1 : 62,500—plotted for focal length lens 24 inches, focal plane 7 inches by 9 inches.)

side of the photograph gives the number of strips. Thus 15 miles, or 79,200 feet divided by 2,566 equals 30.8 exposures; and 10 miles, or 52,800 feet divided by 4,950 equals 10.6 plus strips. It would be necessary to make 31 exposures per strip and fly 11 strips, making a total of 341 exposures.

c. Flight map (fig. 2).—(1) The flight map is a map or sketch of the territory to be photographed. On this map or sketch, the flight lines are plotted to scale, indicating the number of flights to be made and the distance between the lines of flight. The flight lines are so spaced on the map that the strips of photographs overlap each other the desired amount. The flight map is a valuable guide to the pilot in selecting the lines of flight and indicates the beginning and end of each strip. The following examples will illustrate two methods of calculating the distance between the flight lines on the map having a scale of 1:62,500, allowing an overlap of 50 percent between strips. At an altitude of 30,000 feet, using a 24-inch focal length lens, a ground distance of 11,250 feet is covered by the 9-inch side of the film. Of this distance 60 percent is used (6,750 feet), which is reduced to a scale of 1:62,500.

$$\frac{6{,}750\times 12}{62{,}500}=\frac{81{,}000}{62{,}500}=1.30 \text{ inches},$$

or the length of the 9-inch film used is 5.4 inches (60 percent) and the scale of a negative at 30,000 feet altitude, using a 24-inch lens, is 1:15,000, which gives us the following equation:

$$\frac{\frac{1}{12{,}000}}{\frac{1}{62{,}500}}=\frac{5.4}{X} \text{ or } \frac{62{,}500}{15{,}000}=\frac{5.4}{X}, X=\frac{81{,}000}{62{,}500} \text{ or } 1.30$$

inches, which is the distance between the flight lines.

(2) The problems illustrated in the preceding paragraphs may be more briefly shown in the form of formulas. In each case let S equal the scale, expressed as representative fraction (R. F.), h equal height or altitude; f equal focal length, W equal width of ground area covered by photograph, w equal width of film, L equal length of ground area covered by photograph, and l equal length of film; then:

$$S=\frac{f}{h}$$

$$W=\frac{h}{f}\times w$$

$$L=\frac{h}{f}\times l$$

$$h=\frac{f}{s}$$

d. Installation of equipment.—(1) It is the cameraman's responsibility to install in the airplane all the photographic equipment required for an aerial mission, and to see that it is in operating condition. This equipment will include an aerial camera complete, of specified focal length, filter unit, sufficient film to accomplish the contemplated mission (whenever this exceeds one loading, additional film will be carried either in interchangeable magazines or in film spools available for daylight loading), mount, view finder or sight, electrical cables for automatic or semiautomatic operation, vacuum hose from camera to source of supply, intervalometer, data pad or flight record, exposure meter, safety wire, lens tissue, adhesive tape, pencil, altitude temperature computer, and adequate protective clothing.

(2) In the selection of a filter for the mission the following information will be found helpful. The filters supplied the Air Corps for aerial photography range in color from a light yellow to red and eliminate haze in proportion to the depth of color. Formerly, with the use of slower and less color-sensitive emulsions, the choice of a filter was a matter requiring considerable practical experience in aerial photography. Now, with very color-sensitive film the choice of a filter is not such a critical matter. Haze conditions in relation to aerial photography may be characterized under three classes, namely, approximate absence, light haze, and heavy haze. For vertical photography at altitudes below 2,000 feet, no filter is required; at altitudes from 2,000 to 5,000 feet no filter is required for the first class, a light filter for the second, and a deep yellow filter for the last; at altitudes from 5,000 to 10,000 feet, a light yellow filter is desirable for the first class, a deep yellow for the second, and a red filter may be desirable for heavy haze conditions; at altitudes above 10,000 feet there will probably be no change in filter use from the last indicated. Oblique photographs made at angles from 30° to 60° from the vertical require the use of the same filters designated for vertical photography at the same altitude. Oblique photographs made from angles of 60° to the vertical to and including the horizon require, in the approximate absence of haze, a light yellow filter; under light haze conditions, a deep yellow filter; and for heavy haze, a red filter. The choice of the filter for oblique photography depends more upon the angle at which the photograph is to be made than upon the altitude. For aerial photography ranging from vertical to 60° of vertical, it is desirable to use a filter which avoids excessive contrast and sufficiently excludes haze. The filter must be a compromise. For oblique photographs taken at angles ranging from greater than 60° of vertical

to and including horizon objects and sky, it will be necessary to use a filter of deeper color that may overcorrect in the foreground and produce undesirable contrast in the nearer portions of the photograph. The photographer must estimate his needs somewhere between these two, bearing in mind that any of the three filters may produce undesirable contrasts in the foreground, and base his choice on these conditions and upon experience. The average yellow filters require increased exposures, usually not more than two times normal. Use of the red filters requires approximately four times normal exposure.

(3) During installation the following precautions will be observed: Check to make certain sufficient oxygen is in the aircraft to complete the mission; cleanliness of camera compartment; cleanliness of inside and outside of fuselage near camera opening, especially for oil or fluids; test camera hatch or hatches for proper operation (this hatch should be kept closed during take-off and landing; when camera is mounted in bomb-bay, the bomb-bay doors are kept closed during take-off and landing); check a complete cycle of automatic operation after completing installation. The photographic crew must be prepared to execute the mission at any one of several altitudes whenever weather reports are inadequate or in the event that hostile territory is defended against aircraft.

8. Camera operation.—*a. Method.*—Aerial cameras may be operated by any one of the following methods: fully automatic, semiautomatic, manually, or remote control.

(1) Fully automatic operation involves the rewinding of the film and shutter mechanism by an electric motor, the use of an intervalometer for tripping the shutter, and signal lights to warn both the cameraman and the pilot when the next exposure is to be made.

(2) Semiautomatic operation requires the use of an electric motor to rewind the film and shutter mechanism. The shutter is tripped manually.

(3) The camera is said to be manually operated when the leveling of the camera, the shutter rewinding and shutter tripping are all manually performed.

(4) Aerial cameras may be operated by remote control by any one of several means. The camera may be mounted in some inaccessible part of the airplane, such as the bomb-bay, the leading edge of the wing, the tail of the airplane, or in the nose compartment. Remote control may be through mechanical gearing or by electrically controlled servo units. Cameras will be operated by remote control in all pressure-cabin type airplanes, and in other aircraft where it is desirable to locate the camera in a position inaccessible to an operator.

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b. Determining crab and interval.—When the airplane has attained the altitude at which the mission is to be flown and reached the objective to be photographed, the airplane should be alined with the first flight line several miles prior to the boundary of the objective. The pilot or navigator signals the cameraman who determines the crab and interval by the use of the vertical view finder; the dark slide is then removed and about 10 seconds before reaching the objective the pilot or navigator again signals the cameraman to start his exposures.

c. Exposing first strip.—It is now the pilot's function to adhere as closely as possible to the track of the flight line and maintain the airplane laterally level and within the required altitude, plus or minus 50 feet. The cameraman must use the utmost precautions to secure photographs that are truly vertical, being positive the camera is level at the instant of exposure. He must check the view finder for crab after each exposure. When the flight line is finished the pilot or navigator notifies the cameraman to discontinue exposing.

d. Second strip.—The pilot continues on the course for 2 or 3 minutes before making the turn for the approach of the second flight line. After the turn has been made and the airplane alined on the approach of the second flight line, the pilot or navigator signals this fact to the cameraman, who checks the crab and interval, which usually must be changed with the change of direction. The second strip is then flown in the same manner as the first. This procedure is continued until the area to be mapped has been completely photographed.

e. Maintenance of record.—The cameraman must note the exposure meter reading at the beginning and ending of each flight line, the time of beginning and ending of camera operation on any particular mission, direction of flight on the various flight lines, and the order in which they are flown. When the area to be photographed is larger than that which can be covered in one loading, an additional magazine is installed if the camera permits interchangeability of magazines. The data obtained by the cameraman should be attached to each magazine in order to be with the roll of film while being processed.

f. General information.—(1) Two prime factors must be remembered at all times: leveling of camera and overlap. The cameraman must have the camera level at the instant of exposure and secure the proper overlap in line of flight, and the pilot or navigator must be positive that side overlap is sufficiently covered as reflights over hostile territory to rephotograph "holes" would be impracticable.

(2) On long missions the filter, shutter, and general mechanism

of the camera should be periodically checked to be certain of proper mechanical functioning. In the event of camera failure the airplane commander will be notified immediately, the cameraman stating whether repairs can or cannot be made during flight, and if so, the length of time before camera operation can be resumed.

9. Completion of camera mission.—*a.* On the return flight after the completion of the photographic mission the cameraman should check the data cards for completeness, ascertaining that all data are recorded that will be necessary for the processing and identification of the film by laboratory technicians, maintenance of W. D., A. C. Form No. 45, any special data pertinent to the mission, and the legibility of all data.

b. Upon landing, it is the cameraman's responsibility that all film, with data cards, is delivered to the laboratory for processing. The camera and accessories should then be dismounted and thoroughly checked, and any repairs or alterations necessary should be made. All empty film magazines should be reloaded and installed on cameras, and all equipment prepared for another photographic mission.

CHAPTER 3

INTELLIGENCE PHOTOGRAPHY

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SECTION I

VERTICAL PHOTOGRAPHY

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10. General.—Intelligence photography gains information for a commander through the medium of stereoscopic pairs (vertical or oblique), reconnaissance strips, small mosaics, and some oblique photography.

11. Employment.—The cameraman's duties in securing vertical photographs for this class of aerial photography are essentially the same as in performing a mapping mission, the principal difference being that less time is afforded the cameraman before operation. While there will be no attempt to describe the different tactical situations under which intelligence photography is performed, it must be constantly borne in mind by the cameraman that intelligence photography frequently calls for securing photographs of fleeting objectives. This term is used here to denote not only moving objectives, but also objectives such as hostile aircraft on camouflaged airdromes that are not definitely located prior to the departure of the mission. The determination of whether an objective is photographed vertically or obliquely will depend upon the judgment of the cameraman as to the manner in which he can best secure the necessary coverage under the conditions existing at the time. It is obvious that cameramen employed on this duty must be readily responsive to the signals of the airplane commander.

12. Cameraman's duties.—It is of vital importance that the cameraman clearly indicate the time of exposure, the nature of the objective, its location, the altitude, and if possible, the direction of north. Upon returning to the base, it is the cameraman's duty to see that the exposed film is turned over to the photographic laboratory for processing, together with all essential data. Reports should also be rendered upon the functioning of all photographic equipment.

13. Mosaics.—Mosaics for the purpose of intelligence photography will be quite limited. They might consist of a mission calling for verticals of an objective whereby weather conditions will not permit the full coverage by a reconnaissance strip, thereby making it necessary for two or more short strips to be flown at a comparatively low altitude. In such cases, computations for flight lines and line-of-flight overlap should be computed as explained in paragraph 7*b*. The resultant photographs will then be susceptible of subsequent stereoscopic study.

14. Reconnaissance strips.—A reconnaissance strip is a series of overlapping vertical photographs made from an airplane flying a selected course.

15. Pinpointing.—When two or more aerial photographs are taken of a small area or point the result is called a "pinpoint." Such photographs are useful in intelligence work and therefore at least two overlapping pictures are taken of the objective so that the resultant photographs may be studied through a stereoscope. The pictures made in pinpointing are classed as vertical views and are essentially the same as those obtained in making reconnaissance strips or mosaics. The term pinpointing refers more to a type of photographic mission than to a kind of aerial photograph. As pinpoints must be taken so as to permit of subsequent stereoscopic study, certain precautions must be observed in the photographing. It should be remembered that the vertical view finder does not fully cover the area that will appear in the resultant photograph, and therefore care must be taken to see that—

a. The camera and finder are level at the moment of exposure.

b. The view finder shows as much margin as possible around the objective.

c. At the time of making the second exposure this objective still appears in the view finder and has traveled across it sufficiently from its position at the moment of the first exposure to afford the overlap required for stereoscopic viewing.

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graphs of buildings or structures should show at least two sides and will normally include the sunny side of the building. Similarly a photograph of a bridge will not be made from a viewpoint at right angles to the bridge but from some angle between 30° and 60° in order to reveal the construction of piers or supports. Photographs of terrain made for the purpose of yielding information to advancing troops should be made from as low an altitude as practicable and show the terrain to the horizon. Photographs of docks and wharves should be made at a fairly steep angle to show as much of the underwater structure as possible. Similarly photographs of obstructions placed under water at beaches should be made from a steep angle. In the latter type of photography the direction of the sun must always be considered, as reflection will completely obscure all underwater detail.

19. Technique.—Oblique photography requires greater effort on the part of the cameraman than does vertical photography. It also requires that the cameraman have a clear understanding of the nature of the objective and an ability to recognize it because under combat conditions it may be expected that acceleration forces will be present at the time of exposure, whereas the cameraman should expect this and not endeavor to aim the camera until just before making the exposure. It is essential that exposures made at different altitudes and times of day be made so as to secure negatives of about the same density, which will greatly facilitate processing in the laboratory. The simplest method of making oblique photographs, if the cameraman has a choice of positions, is to point the camera to the rear or in front of the airplane. If the photographs can be made directly ahead of the airplane more time is afforded the cameraman to compose the objective and secure the desired perspective. Active cooperation of the pilot is essential in all oblique photography as he must have a clear understanding of the coverage which may be expected at different altitudes and viewpoints; he must also realize the problems of the cameraman and avoid acceleration except when essential from a tactical viewpoint. The highest shutter speed that will yield a satisfactory exposure should always be used in oblique photography. This is especially important in low altitude photography where the relative motion is great, if the photograph is being made at right angles to the direction of flight. A common error is the alinement of the camera with some opening or part of the airplane which frequently produces photographs not square with the vertical. The camera should not at any time during exposure rest upon a metallic portion of the airplane as vibration of a ship will spoil photographs except when extremely high shutter speeds are used. The condition of the lens and the filter unit should be frequently inspected as should the vacuum supply, shutter mechanism, and film rewinding. Accurate and complete data regarding the nature, location of the objective, time, and altitude must be maintained.

20. Aircraft processing.—At this point it is considered opportune to enjoin the caution that whenever photographs are very rapidly processed in an aircraft while in flight, according to the method known as "quick work photography," in which a portable processing outfit is carried, care must be taken to prevent the spilling of chemicals and chemical solutions.

21. Cameraman's duties.—An important duty of the cameraman is to assist in the identification of the ground areas or objectives represented in the aerial photographs taken by him. His other duties and responsibilities are stated in paragraphs 18, 19, and 20.

22. Additional information.—Additional information on aerial photography concerning tactical employment, particularly with reference to the duties of members of the combat crew other than the cameraman, is contained in FM 1-35.

CHAPTER 4

AERIAL CINEMATOGRAPHY

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23. General.—*a.* The Air Corps is charged with all cinematographic work from aircraft which may be either silent or sound, vertical or oblique.

b. Cinematography is based on an optical illusion. It has been found that if a series of pictures are presented to the eye in rapid succession, spaced by intervals of darkness, the eye retains momentarily the impression received from each picture until it is replaced by a new impression from the next picture. If the pictures vary one from the next only slightly, the impression of smooth gradual change is received and the illusion of motion is created.

c. The successive pictures must be presented to the eye at the rate of at least 16 pictures a second to fulfill the conditions outlined above. To meet this requirement a large number of pictures are needed. It has been found best to make these pictures, individually small in size, on long strips of film. Since the advent of sound recording on motion-picture film, the use of 24 frames a second has become standard.

d. A camera basically similar to the ordinary type cameras is required which will accommodate large rolls of film and a mechanism which will intermittently advance the film a frame at a time behind a closed shutter, and then hold the film stationary in the focal plane while the shutter opens and the exposure is made.

24. Motion-picture camera.—Figure 4 illustrates clearly the essential parts of a common type of motion-picture camera. These parts are a lens, a shutter, a film gate which is back of the lens, a mechanism for feeding the film and intermittently stopping and pulling it through the gate, a finder, a reel containing the roll of unexposed film, a take-up reel, and a mechanism for drawing the film through the camera, which actuates sprockets and rollers that keep the film at proper tension. The camera is driven by one or more of three methods, namely, hand drive, spring drive, or electric motor drive.

25. Technique.—*a. Camera check-up.*—As film is so easily and so rapidly exposed in a motion picture camera an especially careful check should be made before each mission not only to see that the camera is complete with all accessories possibly needed, but that there is a very ample supply of film.

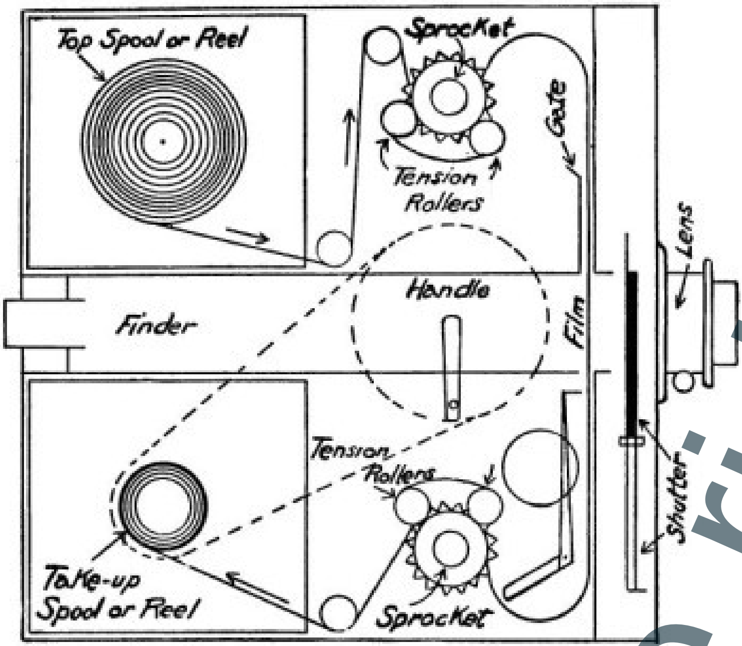

FIGURE 4.—General mechanism, motion-picture camera.

b. Importance of skill and training.—Because of the small field of view of the lens of the motion-picture camera, and the fact that the camera must be kept on the subject for long periods, the taking of motion pictures from aircraft requires considerable skill and practice. The work of the motion-picture cameraman when photographing from aircraft is analogous to that of the aerial machine gunner because each must be able to point the machine he is operating at the target and keep it there for a considerable time. In order to accomplish the purpose each must depend upon the pilot to put him in proper position to "shoot" and to keep him there regardless of the uncertain movements of the target. Panoraming and tilting of the camera in the airplane should be kept at a minimum.

c. Camera mount for aerial work.—In aerial cinematography any one of several mounts may be used. These include a special attachment designed for the machine gun tourelle, a floor mount for "shooting" out of an open door or window, and a floor mount for "shooting" out of the hole in the bottom of the ship (verticals). The two latter types may be constructed at the discretion of the aerial cinematographer, although some cameramen use the standard tripod by securing it in the airplane in such a manner that the vibration will not loosen it.

d. Position of camera in aircraft.—If the motion pictures can be taken from the nose or tail of aircraft the work of the photographer is considerably lessened, for his camera can be trained easily in almost any direction and the pilot can readily aid him in keeping the airplane in proper position. If the photographs are taken from the center station of an airplane, the field of view is limited to the sides and over the tail. In any case the relative motion between the camera and the ground objective should be kept as small as possible. This is enhanced by photographing toward the nose and tail of the airplane rather than at right angles to the direction of travel of the airplane.

e. Composition of picture.—The composition of the picture in the view finder of motion-picture cameras is similar to that exercised in making aerial obliques and verticals with "still" cameras.

f. Adjusting shutter for aerial work.—For aerial work use the largest shutter opening with which it is possible to stop the motion. The belief that the narrow shutter opening should be used in order to neutralize the effect of vibration is incorrect. If vibrations are severe enough to spoil single pictures they will spoil the strip. While each individual picture may be sharp when a narrow shutter opening is used, a succession of sharp pictures, separated by a large interval, will flicker on the screen. In order that the eye may be able to see a series of still pictures as a moving picture, the interval of motion between successive pictures must be small. It is better that the entire series be made with a larger shutter opening and small stop. To illustrate, it is assumed that the film is being exposed at the rate of 24 frames a second. We may choose either a 90-degree (small) shutter opening or 180-degree (large) shutter opening. In the case of the small shutter opening each frame receives $\frac{90}{360} \times \frac{1}{24} = \frac{1}{96}$ second exposure. This leaves $\frac{270}{360} \times \frac{1}{24} = \frac{3}{96}$ second for the shutter to be closed, the shutter open one-fourth the time and closed three-fourths of the time. In the case of the large shutter opening each frame receives $\frac{180}{360} \times \frac{1}{24} = \frac{1}{48}$ second exposure. This leaves $\frac{180}{360} \times \frac{1}{24} = \frac{1}{48}$ second for the shutter to be closed. The shutter is open one-half of the time and closed one-half of the time. It is obvious that in the second case the amount of time the shutter is closed is less, giving less time for the object to move between frames, thus reducing the flicker. True, there is more blur in each frame due to longer exposure, but this is not as noticeable in a series of pictures as the longer interval.

g. Camera speed for aerial work.—Aerial motion pictures should generally be filmed at a higher rate of speed than normal because of the speed of the airplane. This reduces the interval of motion between frames. (See *d* and *f* above.) Thirty to forty-eight frames a second are generally used at higher altitudes. As the altitude increases the camera can be run at slower speeds without causing flicker. In the case of a sound picture taken from the air, the deviation from 24 frames a second (sound camera speed), is not serious as the sound and picture are seldom synchronized. However, if life motion and exact sound synchronization are required, a camera speed of 24 frames a second must be used.

h. Lenses.—Long focal length lenses are not ordinarily used because of the effect of the movement of the airplane while using such lenses. However, medium focal length lenses may be used when photographing one or more airplanes from another. The focus of the lens is set at infinity except when the objective is less than infinity.

i. Filters.—Filters should not ordinarily be used at low altitudes or on clear days. Definite rules cannot be laid down regarding their use. However, the rules as applied to "still" aerial photography and photography in general apply as well to motion-picture photography.

j. Photographing airplanes in air.—When the subject is one or more airplanes flying in the same direction as the one in which the camera is mounted, a small shutter opening may be used provided the earth is not used as a background or if the altitude is at least 4,000 feet.

26. Exposure of negative.—*a.* The absolute exposure received by each single frame of a motion-picture negative depends upon several factors, namely, shutter opening in degrees, linear film speed, lens diaphragm stop, amount of incident light falling upon the subject, the reflection properties of the subject, the filter factor of the filter (if used), and speed (or light sensitivity) of film to be used.

b. For any one combination of the factors listed in *a* above, a definite shutter speed is determined and expressed as a fraction of a second. An exposure meter or exposure table will indicate the relative amount of light reflected from the subject. Knowing the emulsion speed and filter factor (if any), it is only necessary to adjust the diaphragm stop accordingly.

c. Although experience combined with exposure tables relative to lighting and illumination has been used, a reliable exposure meter is strongly advised. The error of personal judgment is thus greatly reduced. Exposure meters set for the emulsion speed rating, filter factor, and shutter speed will give the correct diaphragm stop when set at the indicated light reading.

d. The use of neutral density filter is recommended to compensate for a faster emulsion speed (when a fast film is being used and the illumination is suddenly increased), or when the minimum *f* value of the lens is not sufficiently small to give the correct exposure. An alternative of the latter is to reduce the shutter opening in degrees, which would automatically increase the shutter speed. It must be remembered, however, that reducing the shutter opening also increases the interval of motion between frames.

e. In shutter speed calculations, the actual time of exposure of each frame of a motion picture negative is determined by the speed at which the film passes through the gate and the shutter opening of the camera. A simple formula for determining such is as follows:

$$\frac{\text{Shutter opening in degrees}}{360} \times \frac{1}{\text{exposures per second}}$$

Example: Shutter opening 180°; exposures per second, 24. Find the shutter speed.

$$\frac{\text{S.O.}}{360} \times \frac{1}{24} = \frac{180}{360} \times \frac{1}{24} = \frac{1}{2} \times \frac{1}{24} = \frac{1}{48} \text{ second}$$

This fraction of a second is the one used in making exposure meter calculations for the indicated shutter opening and film travel. Some motion-picture cameras have a table of shutter speeds relative to these two factors printed or attached directly to the camera body for reference.

27. Maintenance of records.—It is essential that detailed and accurate data cards pertaining to the subject, weather conditions, altitude, time of day, location, and any other pertinent information, accompany each reel of film upon being delivered to the laboratory for processing. The cameraman should also include all data necessary for the maintenance of W. D., A. C. Forms Nos. 10 and 45.

CHAPTER 5

AERIAL PHOTOGRAPHIC MOSAICS AND MAPPING

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SECTION I

GENERAL

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28. General.—*a. Mosaics, how made.*—The greater the altitude at which a photograph is taken the greater the size of the ground area that will be included in the picture. However, there is a limit to the altitude that can be reached by an airplane and therefore it is often impossible to include in a single exposure the total ground area that may be desired. Resort is then had to the taking of a number of vertical photographs in such way that they can be joined to form a single picture. As the combining of the individual photographs resembles the art of joining pieces of colored glass, stones, tiles, etc., in the form of decorations or pictures called mosaics, the term "aerial photographic mosaic" has been applied to a group of overlapping vertical aerial photographs assembled to form a single composite picture. To be able to fit the photographs together, it is necessary that they all be of the same scale. The scale of an aerial photograph depends upon two factors, namely, the focal length of the lens used, and the altitude of the airplane at the moment the exposure was made. Therefore, in preparing to take photographs for the making of a mosaic, selection must be made of the aerial camera with reference to the focal length of the lens thereon, and decision reached as to the altitude at which the airplane will be flown. The flying problem involved consists of maintaining the airplane at a uniform distance from the earth's surface so that all the photographs can be taken from the same altitude. As there are a variety of available focal length lenses and the only limitation as to altitude is performance ability of the aircraft, it is possible, practically speaking to make a mosaic at almost any desired scale.

b. Importance.—Mosaic photographs are valuable for a variety of military purposes, especially when topographical maps are not available or are obsolete. They can be produced roughly under war conditions in a surprisingly short time with a degree of accuracy proportional to the time available and the accuracy of the photographs, and because of the fact that they represent current conditions and that every object on the ground is reproduced in the photograph in its proportional plan view size, they compare very favorably for military purposes with hasty topographic maps. In addition to this, proper study of an aerial mosaic indicates the details beyond the ability of topographic mapping symbols, that is, scattered or dense woods and approximate heights and kinds of trees.

c. Reconnaissance strip.—A reconnaissance strip is a single strip of overlapping photographs taken especially for reconnaissance purposes following a central line of interest.

29. Scale.—The scale, methods of finding, ground area included in vertical photographs and the number of exposures required to cover certain areas, the flight map, general information, routine of a photographic mission, ground preparation, season and time of the day, and photographic missions have been thoroughly covered in paragraph 7.

30. Index map (fig. 5).—*a. Uses.*—After the negatives of a vertical mission have been lettered and numbered consecutively as prescribed in Air Corps Circular 95-3, an index map should be made indicating the area covered by each individual negative. A map of average scale such as a 1:62,500 or 1:48,000 topographic map is usually selected. A map of this scale has detail in such quantity and sufficiently large to be used in the identification of the area covered by each negative. In the case of T-type photographs, a map of smaller scale might be used to advantage, since the area covered by each photograph will be much greater from a given altitude. The index map is useful for the following reasons:

(1) Indicates total area covered by a given flight or assignment.

(2) A suitable negative covering any particular point may be selected.

(3) The index map is used to determine the center of the mosaic so that in the case of a controlled mosaic, meridians and parallels of the polyconic projection may be properly located with respect to the center of the mount.

(4) Suitable stations may be selected from the computation of "average scale" of mosaic by triangulation for ground distances between said stations.

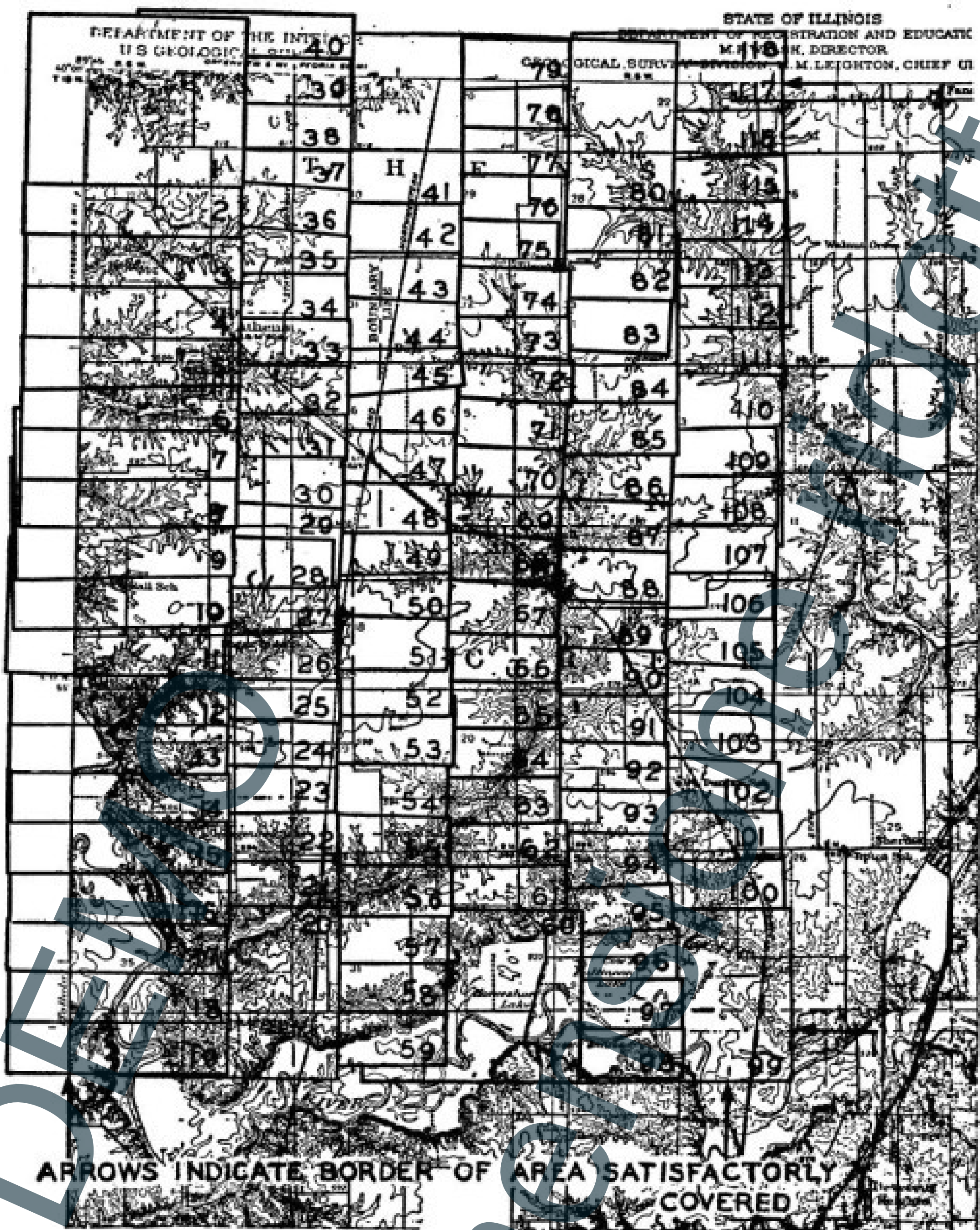

FIGURE 5.—Index map plotted with template.

b. Template.—In order to locate correctly the area covered by each negative on a map, two templates are constructed. A first template is made by cutting out a 7- by 9-inch area in a slightly larger piece of cardboard. The standard mounting board for photographs is well adapted to this use. The edges of this cut-out rectangle are grad-

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