CHAPTER 1

Introduction to Maps and Air Photographs

Broadly speaking, we can regard the production of a map for sale to the public as a combination of three main processes—

1. the choice of projection, and design of the map sheets and sheet system,
2. the survey and drawing,
3. the reproduction of the map in large numbers.

Chapter 8 deals briefly with reproduction, and the rest of the book is devoted mainly to one method of carrying out the survey and plotting the map detail. The aim of this second process is the production of a map or plan suitable in every way for the specified purpose, and capable of being reproduced in the numbers required.

Design is outside the scope of the book, but a note on projections seems desirable.

In a mapping operation, a relatively few ground points are first chosen, and their latitude and longitude are very accurately determined. This is the work of the geodetic surveyor. The points are usually known as Trig. points (short for trigonometrical).

The surface of the earth, if we ignore the hills and valleys, forms approximately an oblate spheroid, which is a slightly flattened sphere. As with the sphere, the surface of the earth is not developable (a hollow sphere cannot be flattened without fracture or buckling). Thus although the positions of the Trig. points are very accurately known they cannot be plotted on a plane sheet of paper so that they are correctly positioned relative to one another: this is the problem of map projections.

A map projection is a set of rules specifying the exact pattern which will be made on the map by the lines of latitude (parallels) and lines of longitude (meridians). The pattern is known as the graticule. There is an unlimited variety of projections, each being particularly suitable for some special purpose. For general purposes at medium scales we normally require that bearings remain correct and that the scale error at any point is kept to a minimum.

After the graticule has been drawn the Trig. points are plotted in relation to it. Then the position of each point of detail is determined relative to the Trig. points and plotted accordingly; this is the work of the topographical surveyor. In practice a squared grid would be plotted instead of the graticule and the position of the Trig. points would then be plotted in relation to the grid. Latitude and longitude of each point are converted mathematically into the grid equivalent.

The field work for a topographical survey will be carried out either by ground methods (e.g. a theodolite traverse or a plane table survey) or by a photogrammetric plot. It is with the latter method that this book is concerned, and we shall consider how to plot the map detail relative to the plotted position of Trig. stations, or other ground control.

So far we have ignored height differences and have spoken only of " planimetric " detail. The stereoscope (see Chapter 3) enables us to reconstruct a three-dimensional image from two separate photographs of the same area of ground. Height differences in this " model " can actually be measured. The technique is fairly complicated and the accuracy of the " simple " methods is comparable only with cruder methods of " levelling " in the field; but the method as used in some expensive automatic plotting machines gives much greater accuracy.

Maps at scales larger than about 1 in 10,000 are usually referred to as plans. The essential difference between a plan and a map is that in the former all detail is shown to scale, whereas on maps certain detail is shown by conventional notation; such details as roads, for example, might be shown of exaggerated width so that they stand out better. The surveys for plans are generally known as Engineering or Cadastral surveys according to the required use of the plan. Photogrammetry can be used for this type of work but this is a specialized branch of the subject and nearly always entails the use of the more complicated instruments which are introduced in Chapter 11.

BRIEF HISTORY

Photography began some two hundred years ago and it was soon realized that photographic images were formed according to the laws of perspective and that if two photographs were taken, one from each of two stations, then any point which appears on both photographs could be located in space.

During the nineteenth century little real progress in photogrammetry was made as photographic technique itself was still crude and the preparation of plans was slow and laborious. However, the possibility of air surveys from balloon photographs had been considered and experiments were made.

It was the impact of war which caused the recent developments in photogrammetry. Air photographs were of considerable value in piercing camouflage and even in the First World War it was realized that maps could be made from vertical air photographs which were at first taken with hand cameras.

The technique of making maps from such photographs has progressed steadily, and although the principles involved are quite simple, the machines and the graphical plotting methods are intricate. Before these processes can be understood we must have some basic knowledge of photography which in turn requires an elementary understanding of light.

LIGHT

Light can be thought of as a vibration, the rays travelling in ways similar to those of sound waves. Thus, like ocean waves, a lightwave has length and periodicity. The latter is the frequency with which the pulsations repeat themselves in a given period of time.

$$\therefore \text{velocity} = \text{wavelength} \times \text{frequency}$$

The velocity of light in air is approximately 299,000 km/sec. We may regard this as constant, so that frequency must vary inversely with wavelength. Pulsations giving rise to light have varying wavelengths: visible light consists of waves between about 0·40 microns and 0·70 microns, but similar vibrations having both greater and lesser wavelengths also occur. (A micron is a one-millionth part of a metre.)

Variations in wavelength give rise to the sensation of colour changes. Daylight is often described as white light and comprises light of all the visible wavelengths intimately mixed together.

The three basic laws relating to light are—

1. Light travels in a straight line in a homogeneous medium. That is it travels in a straight line during its journey through the air unless some object other than air lies in its path.

2. When light meets an opaque surface it is reflected back from the surface in such a way that the angle of reflection equals the angle of incidence (see Fig. 1.1). Both reflected and incident rays lie in the same plane. The surface will absorb light of some colours and reflect others. If only the blue light is reflected the object appears blue, and if only red light is reflected the object appears red. If all the light is absorbed the surface will appear black, whereas if it is all reflected the object will look white.

3. When a light ray passes from one medium to another medium of different density (e.g. from air into glass) the ray is deflected.

This is known as refraction, and the incident ray, the normal to the surface, and the refracted ray, all lie in the same plane (see Fig. 1.2). The angle between the incident ray and the normal is known as the angle of incidence, and the angle between the refracted ray and the normal is known as the angle of refraction. The sine of the angle of refraction is proportional to the sine of the angle of incidence—

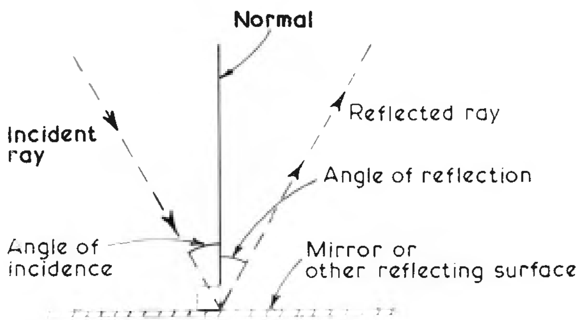

FIG. 1.1. REFLECTION OF LIGHT RAYS

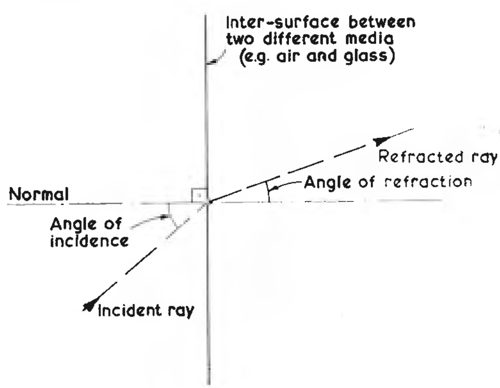

FIG. 1.2. REFRACTION OF LIGHT RAYS

$$\frac{\text{sine of angle of incidence}}{\text{sine of angle of refraction}} = \text{a constant}$$

When the incident ray is in dry air, this constant is called the *refractive index* of the second medium, and is often denoted by *n*.

When light passes through a glass prism it is refracted in such a way that the shorter the wavelength, the greater the amount of refraction.

White light is thereby split up into constituent parts of the colour spectrum, popularly known as red, orange, yellow, green, blue indigo and violet. Such a spectrum occurs naturally in the rainbow. The list of colours given above is in the order of decreasing wavelengths and increasing frequencies but the list is misleading in that there is an infinite number of colour shades in the spectrum. A more practical way of dealing with the problem is by considering the spectrum as split into three almost equal groups of colours: blue-violet, green, and red. In Fig. 9.8 it will be seen that rays of longer wavelength than red are known as *infra-red* because they are of lower frequency than the red rays, and rays of greater frequency than the blue-violet group are known as *ultra-violet*. These rays are not visible, but their effect on things other than the eye is similar to the effect of the rays of the visible part of the spectrum.

THE PIN-HOLE CAMERA OBSCURA

The pin-hole camera was probably known at least as early as the eleventh century. It consists of a closed box from which light is completely excluded except through one small pin-hole. If the

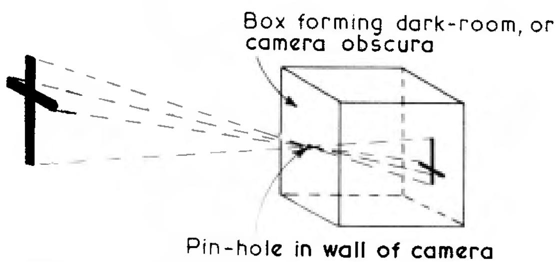

FIG. 1.3. THE PIN-HOLE CAMERA

pin-hole is small enough and is made in very thin metal, an image will occur on the inside of the opposite side of the box. As in Fig. 1.3, this image will be both inverted and reversed.

There are substances which are altered when they are acted upon by light. If the rear wall of a pin-hole camera were coated with one of these substances, a photographic image could be obtained.

In modern cameras a lens is used instead of the pin-hole and the light-sensitive substance is coated in a thin film on a transparent base material. Light falling on the film will cause a change in chemical composition; this is known as a photo-chemical change. Subsequent processing causes a purely chemical change which will remove that part of the film remaining unaffected by light leaving an opaque substance representing the bright areas of the picture; the transparent base is exposed over the remainder of the image. Thus we obtain a picture, or negative copy, on which bright objects are represented by dark and opaque areas, and dark objects by transparent areas. It is the reversal in tone values which makes the image negative.

THE NEGATIVE

There are many chemical substances which change in some way when exposed to light. In modern photography, one group of such chemicals, the silver halides, is used for all negative production. Halides include chlorides, bromides, iodides and fluorides. One of the older processes for producing negatives on glass plates is the wet collodion process which has remained in use because the light-sensitive plate can be made on the photographer's premises and it allows him more latitude in adjusting the exact properties of the plate. Some map-reproduction works still use this process but the improved range of qualities of dry-plates has gradually reduced the use of the wet process.

Collodion

Collodion is a solution of pyroxyline (gun-cotton) in ether or alcohol, forming a gummy liquid which will spread evenly and thinly on to a glass plate. One or more of the following are added to the collodion: the iodide, bromide or chloride salts of ammonia, cadmium, lithium, strontium or calcium. The " iodized " collodion is left to " ripen " until the accumulation of free iodine causes the solution to take on a reddish hue; this may take about a fortnight. The choice of salts will influence the quality of the collodion, e.g. a cadmium salt will increase the hardness and durability of the final image.

When it is ripe, the collodion is spread on to the glass plate by pouring a small amount on to one corner of the plate, and then tilting it so that the bulk of the solution passes gradually round the surface and then the surplus collodion is allowed to drain off. A satisfactory even covering can be obtained in this way provided that the glass itself has been thoroughly cleaned by oxidation, usually by sulphuric acid. Adhesion used to be assisted by first coating the plate with egg-albumen but nowadays a rubber edging is usually fixed to the face of the plate.

The collodion film is left to set and then the plate is sensitized by dipping in a " silver bath " consisting of a solution of silver nitrate. This is the trickiest part of the proceedings since the whole plate must be immersed at the same instant. The silver nitrate reacts with the iodides and bromides to form silver iodide and silver bromide. The plate is again drained, and should then be exposed in the camera.

When the silver salts are exposed to the light they change their physical composition but no change is apparent to the eye, and we say that exposure in the camera gives rise to a *latent image*. The image is developed, or rendered visible, by treating the plate with a reducing agent such as a solution of ferrous sulphate, which causes metallic silver to be precipitated. This silver is deposited only on that part of the film which was affected by the light and the density of silver particles will faithfully record the intensity of light at any point.

The image is then rinsed and surplus silver salts are removed by " fixing ", i.e. washing in a solution of potassium cyanide, which is a solvent of silver iodide. The silver now forms an opaque image on the transparent background of the glass plate.

Collodion plates must be used as soon as they have been sensitized, and developed immediately after exposure.

The Modern Roll Film

The more usual type of negative is manufactured in bulk in the form of pliable film. This may be stored for a time before use and need not be developed immediately after exposure. This is the type of negative used in present day air-cameras, and is similar in most respects to the film used in modern snap-shot and cine cameras.

There are two main components of a film: the base material, and the emulsion in which the sensitizing material is suspended.

The sensitizing material is composed of a mixture of silver nitrate, potassium iodide, potassium bromide, and gelatine. After setting, the mixture is ground into small particles and washed free of unwanted salts. The most important constituent is now silver bromide which appears in granular form as very minute crystals. This mixture, in the form of a milky suspension, is spread on the film base.

Exposure to light again results in the formation of a latent image which is developed chemically. As before, the final image is formed of metallic silver, this time in the form of very minute matt black particles. The amount of silver deposited per unit area governs the opacity, and therefore the " density " of the negative.

The main attributes of a negative are that—

1. It shall record clearly as much detail as possible; this is known as *resolution* or *definition*.

2. The relative position of each point in detail shall be accurately recorded, i.e. *distortion* shall be at a minimum.

The gelatine is more than a suspending medium; it is transparent, hard when dry, and allows penetration of the developer. It also assists the growth of silver halide crystals, prevents the developer from acting on the non-light-affected halide crystals, and increases the sensitivity to light of these halides.

The requirements of a film base, or support, are that it should be thin, transparent, pliable, strong, and unaffected by changes in temperature and humidity. (An air-camera is exposed to great and rapid changes of temperature as the altitude changes.)

The normal base material is cellulose acetate or triacetate which is transparent, thin, pliable, and far less inflammable than its predecessor, cellulose nitrate. The main attribute in which this base is inferior to glass is that of stability. This quality is so important in photogrammetry that a special base material has been developed; cellulose butyrate (a polyester) is so little affected by expansion and contraction that it is known as *topographic base*, a term usually reserved for materials which are sufficiently stable to be used as bases for fair-drawing of topographic maps.

Besides temporary expansion or contraction, the base material is also subject to gradual chemical change which may cause brittleness and, if subjected to strain, it may yield by plastic flow.

THE POSITIVE PRINT

A contact print (see Fig. 1.4) is made by placing a sensitized piece of paper under a negative and passing light through the negative. This operation may be carried out in a machine similar in principle to the vacuum frames shown in Fig. 8.8. Since the sensitized paper is in contact with the negative image, this is known as a contact print. The paper is sensitized with a thin film of silver halides, and its reaction to light and development is similar to that of the negative emulsion. The opaque parts of the negative will, of course, allow less light to pass through than the more transparent parts, and the image will suffer a reversal in tone values. Thus on the positive prints the highlights will be represented by light-toned areas, and shadows will be represented by dark tones; it is therefore a positive image.

Positive prints are sometimes made on glass, when they are transparent and are known as *diapositives*. Paper prints are cheaper and easier to handle; they are therefore preferred for most simple photogrammetric purposes though diapositives are used in most of the larger plotting machines.

Ideally a print is required to reproduce all the information contained on the negative, without loss of resolution, and without

FIG. 1.4. A CONTACT PRINT (shown reduced from 230 mm × 230 mm) (*Fairey Surveys Ltd.*)

further distortion of the image. Perfection in these respects is almost achieved with a diapositive but paper prints are relatively unstable and usually involve a slight loss of resolution especially in the lightest and darkest tones.

The raw material of the photogrammetrist is normally the contact print which is necessarily of the same scale as the negative. It consists essentially of a paper base and a sensitized emulsion. The latter is nearly always sensitized with silver bromide or silver chloride and the processing is very similar to that of negatives.

The Paper Base

In the manufacture of paper, the sheets are made by pressure rolling. If the rolling is only in one direction the fibres tend to arrange themselves so that their longitudinal axes lie parallel with the direction of rolling. Such a paper would be liable to expansion and contraction (caused by changes in humidity and temperature), mainly in the direction of rolling. A photograph on such a paper would thus be liable to a change in shape. This is known as differential expansion and contraction, and is minimized in modern paper manufacture. When expansion and contraction is much the same in all directions it is of relatively little consequence since it only has the effect of a general change of scale.

There are a number of grades of printing paper—

1. *Single-weight paper* is very unstable but it is used for model making where the print needs to be stretched to fit the three-dimensional model. It is sometimes used for uncontrolled mosaics.
2. *Double-weight paper* is more stable and is used for all ordinary purposes, including the making of controlled mosaics.
3. *Waterproof paper* is the most stable of the paper bases, except in and near the tropics.
4. *Aluminium-foil* is more stable than any paper base and is used for special purposes only, usually sandwiched between layers of paper.

The Emulsion

The emulsion may have a matt, semi-matt or glossy finish. The last will give greater reflectivity and consequently a brighter image, but a matt surface is better for writing on. For general work a semi-matt finish will be specified.

The duration of the exposure will depend on the density of the negative and must usually be determined by experience.

THE SIMPLE LENS

We must now consider the general effect of the simple lens on the incident light rays. For the moment we will consider the simple lens to be a flat circular disc of optical glass. If the lens is very thin then it can be considered as lying in one plane, known as the *plane* of the lens. The *axis* of the lens is then that line which is perpendicular to the plane of the lens and passes through the centre of the lens.

If we imagine a point source of light then rays of light will be broadcast along a series of straight lines from this point. This deviating group of rays is known as a pencil of light. In practice there is no such thing as a point of light, and light from a finite source forms a group of pencils known as a beam. In air photography, the light has travelled thousands of feet to the camera, and the rays reaching the camera from a ground object can be thought of as forming a beam of parallel rays. Although we have spoken of " sources " of light, this light is really reflected sunlight.

Focal length

In the theoretically perfect thin lens, the main purpose of the lens is to replace the pin-hole in the pin-hole camera. It captures the

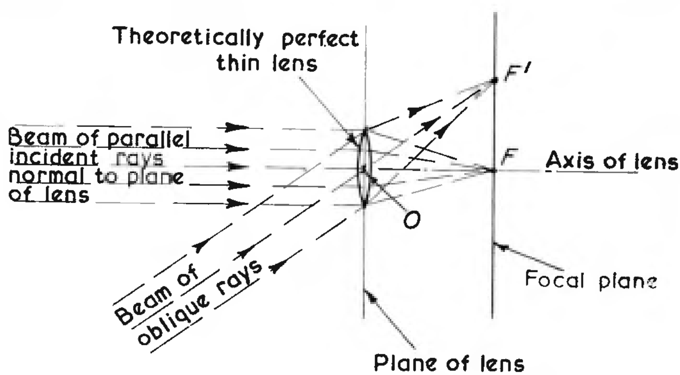

FIG. 1.5. THE FOCAL PLANE IN RELATION TO A THIN LENS
O is optical centre
F is one of principal foci or focal point
OF is focal length
FF' is focal plane

beams of parallel rays and concentrates each beam to re-form the image of the object from which the rays emanated. This action is shown in Fig. 1.5 and is known as focusing. The object lying along the axis of the lens will be brought into focus at the principal focal point *F* in Fig. 1.5. If *O* is the optical centre of the lens, then *OF* is the focal length of the lens. All other points should come into focus in the *focal plane* which is a plane perpendicular to the lens axis and containing the *principal focus F*. In Fig. 1.5, *F'* is a typical image point in the focal plane. Since the image is formed in the focal plane, the film should lie in this plane at the moment of exposure.

The effective area of the focal plane in the camera is usually square, and is known as the format. As this governs the maximum size of the negative and therefore of the print, the dimensions of the image area of the print are usually referred to as the *size of format*.

TYPES OF PHOTOGRAPH USED IN MAP MAKING

Photographs of the ground can be taken with the optical axis of the lens vertical, horizontal or inclined to the vertical at some oblique angle. This gives rise to the classification of photographs as—

1. verticals;
2. obliques;
3. ground (or horizontal or terrestrial).

1. A vertical photograph will record an impression of the ground similar to that shown on a map. If the ground were perfectly flat, and the optical axis truly vertical at the moment of exposure, then the resulting photograph would be a map representation of the ground, although all objects would be shown photographically and not by conventional signs. Photographic maps such as these are sometimes produced by joining parts of a number of vertical photographs; they are then known as mosaics (see Chapter 7). Mosaics suffer from excess of detail and are not sufficiently accurate to be used as maps for all purposes.

Unfortunately for our purpose the ground is rarely flat, and the great difficulty in keeping an aircraft completely steady means that an exposure made when the optical axis is truly vertical is very rare. The term vertical is therefore usually extended to include all photographs taken with the axis so nearly vertical that they may be used in the standard graphical plotting methods. These are the photographs with which this book is mainly concerned.

The term " near vertical " should normally be avoided, as some people use it to indicate the photograph which we have just mentioned, whilst others use it to denote a photograph which is so nearly vertical that it can be used as such, *except* for plotting by simple graphical methods.

2. Obliques are photographs taken with the optical axis of the camera inclined. That is, they are neither verticals nor ground photographs. Maps can be plotted from obliques but the methods are different from those employed with the first class of photographs. We shall consider some of the geometrical properties of obliques in Chapter 2.

(*a*) High obliques are photographs which include the image of the horizon and are sometimes called horizon obliques. They are taken with the optical axis of the lens making a " high " angle with the vertical.

(*b*) Low obliques include all other oblique photographs. They do not possess the easy geometrical relationships of verticals, and they do not cover as large an area as high obliques.

3. Ground photographs are taken from ground stations with the optical axis of the lens horizontal. The views produced are those familiar to our eyes.

THE AIR CAMERA

The basic air camera is similar in principle to the ordinary hand camera, though it is fully automatic in working and is adapted to its specialist role. There are many different makers each of whom

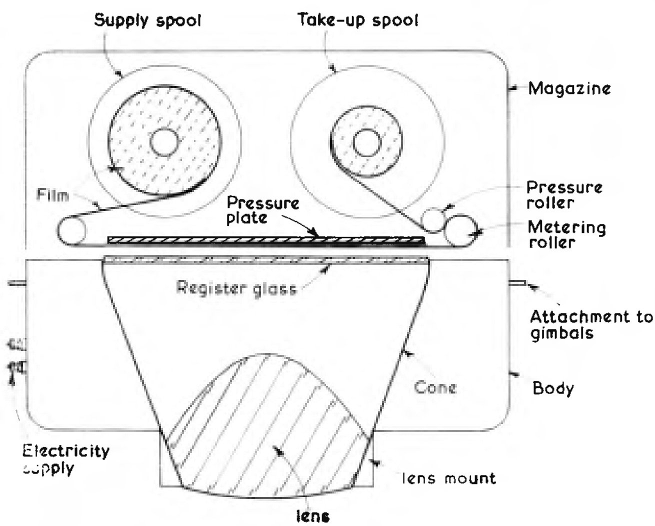

FIG. 1.6. A LONGITUDINAL SECTION THROUGH A BASIC AIR CAMERA
N.B. In a vacuum type the register glass would be omitted and the pressure plate would be relabelled " locating back."

produces a range of different types. Although some of these cameras are designed for some special conditions of operation, and in spite of the recent developments in design, it can still be said that all cameras now in use are basically similar in construction.

Figure 1.6 shows a diagrammatic section through a typical simple air camera. (See also Figs. 1.7 and 1.8). Such a camera comprises—

1. the lens;
2. the lens cone;
3. the body;
4. the magazine;
5. the shutter;
6. the gimbal mounting.

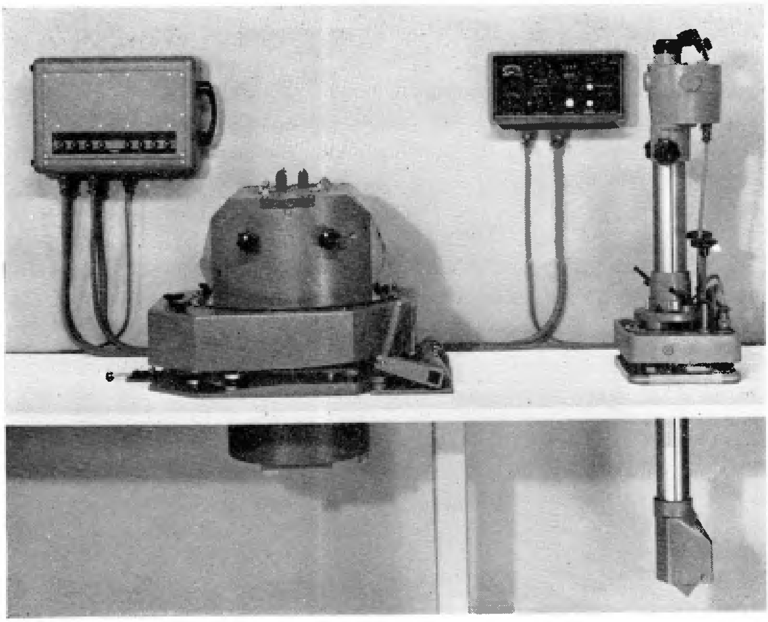

FIG. 1.7. RC10 CAMERA AND ACCESSORIES
(*Wild Heerbrugg Ltd.*)

FIG. 1.8. EAGLE IX 152 mm MK. 2 CAMERA
(*Williamson Manufacturing Co. Ltd.*)

The Lens

In practice, all camera lenses are of a complex nature and can be said to comprise two or more of the individual lenses shown in Fig. 1.9.

Figure 1.10 shows an outline section through such a complex lens with the central ray of each beam entering and leaving the lens.

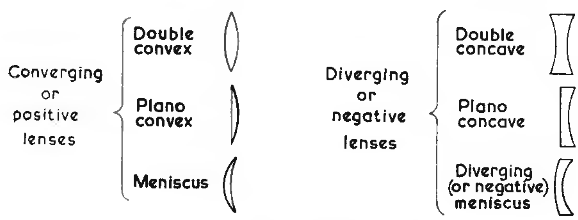

FIG. 1.9. TYPICAL SINGLE LENSES (CROSS-SECTIONS)

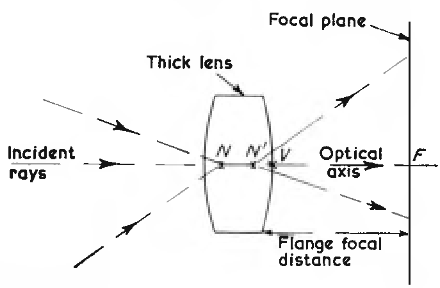

FIG. 1.10. NODAL POINTS IN A COMPLEX LENS
(Outline section only)

N = front node N' = rear node
V = vertex of rear glass F = principal focus
VF = back focal distance

The incident rays are seen to converge to a point N; these all pass along part of the optical axis, and then diverge from the point N'. Each of these emerging rays follows a path parallel to its direction at incidence. N and N' are called nodal points or Gauss points: N is called variously the node of admission, front node, or exterior perspective centre; N' is the node of emergence, back node, rear node or interior perspective centre. It is the rear node which is assumed to be the perspective centre S in the perspective diagrams of Chapter 2.

Equivalent focal length is the focal length of a thin lens which may be said to be equivalent to the complex lens under consideration.

It becomes the perpendicular distance from the rear node on to the focal plane. Note that the *principal distance* is the perpendicular distance from the rear node on to the plane of the negative at the time of exposure, and is therefore an attribute of the camera rather than of the lens.

Calibrated focal length is the focal length determined when calibrating, i.e. testing, the lens experimentally.

When making actual measurements during calibration of a camera, it is not possible to locate the rear node accurately, so that the principal distance and focal length cannot be measured. It becomes necessary to make two other measurements (see Fig. 1.10)—

1. *The back focal distance* (*VF*) which is the perpendicular distance from the vertex of the rear glass of the lens to the focal plane.

2. *The flange focal distance* which is the perpendicular distance from the mounting flange of the rear glass to the focal plane.

Lens Mount and Cone

The special feature of the lens cone is that it excludes all light, other than that entering through the lens, from that part of the camera lying between the lens and the focal plane, whilst at the same time allowing sufficient room for the legitimate rays of light at the time of exposure. It is responsible for maintaining the correct lens to focal plane relationships and is the part of the modern camera which represents the room itself in the original pin-hole camera.

The mount is the frame holding the lens and securing it to the lens cone. A badly designed mount might cause a masking of the lens, with consequent loss of definition at the edges of the negative. This is known as vignetting, a photographers' term denoting that the image shades off gradually into the border of the picture. It is by its reflection of light rays that the mount may effect this gradual reduction in definition towards the edges.

Flare light is any haphazard arrangement of light rays within the lens cone. The effect is to reduce the sharpness of tone changes over all or part of the negative, giving an appearance of fogging. The main cause of flare light is light scatter of incident rays when they are deflected on meeting dust particles on the lens or within the cone of the camera. The " ground " surface of a worn lens might cause the same effect, or it could be caused by the reflection of rays from the sides of a lens cone which was too narrow.

The Camera Body

The body is that part of the instrument which attaches the lens cone and magazine to the gimbal mounting and in modern cameras it may form the inner ring of the gimbal mounting. It contains the main mechanisms and an example is shown in Fig. 1.11.

The altimeter, timepiece and serial number counter are housed in the wall of the body and are photographed through pinhole orifices,

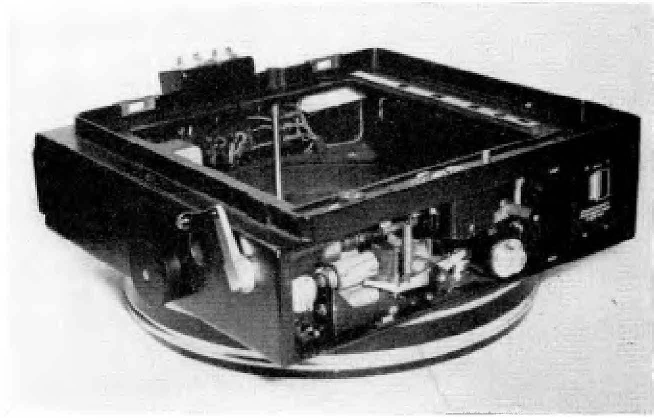

FIG. 1.11. EAGLE IX BODY
(*Williamson Manufacturing Co. Ltd.*)

or small lenses, so that their images appear in the margin of the negative; thus the altitude, time and serial number are automatically recorded at the moment of exposure.

The Film Magazine

The magazine comprises two main parts: the spools for carrying the film, and the pressure plate as shown in Fig. 1.6. There are two spools: the supply spool and the take-up spool (see also Fig. 1.12). A mechanism causes the film to wind on to the take-up spool between exposures but it must be accurately synchronized with the shutter so that there is no film movement during the time of exposure. If the drive were direct to the take-up spool, then as the film wound on to this spool so the effective diameter of the spool would increase and the movement of the film per revolution would also increase. Suppose four revolutions of the unloaded spool are required to move the film through a distance equal to the length of the format. If the mechanism were set so that exactly four revolutions of the spool occurred between exposures, then the leading edge of the second negative would just touch the trailing edge of the first but there would be a narrow strip of unused film between the second and third negatives. The width of this piece of unused film between pairs of consecutive negatives would increase as more film was wound on to the take-up spool and there would be a considerable wastage of film. Some means of reducing the speed of revolution as more film is wound on must be used. This is generally achieved by introducing a metering roller as in Fig. 1.6. The drive may be direct to this roller, in which case the speed of revolution and movement of the film will be constant and a spring-loaded mechanism for rotating the take-up spool to make up

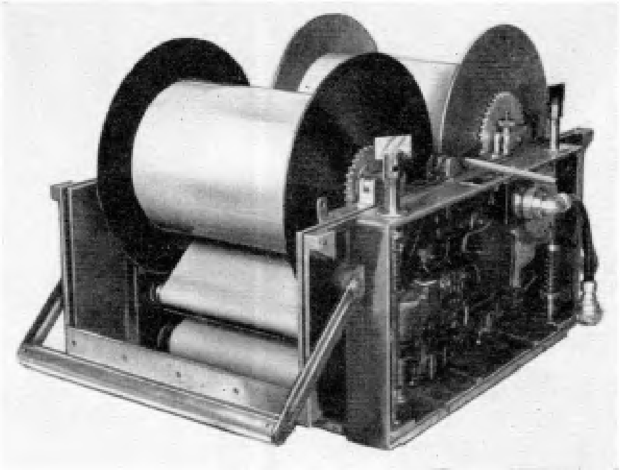

FIG. 1.12. EAGLE IX (F.96) CAMERA MAGAZINE (305 m)
(*Williamson Manufacturing Co. Ltd.*)

the slack in the film is all that will be required. Sometimes the drive will be to the spool, and the metering roller will merely stop the mechanism as soon as it has revolved the correct number of times. In either case the film will normally be kept in close contact with the metering roller by another pressure roller, so that no slipping of film relative to roller will take place.

In order that there is no slack in the film between the two spools, the supply spool must be fitted with an over-run brake whose function is to stop this spool turning immediately there is any lessening in tension in the film.

The capacity of the magazine is related to the length of film which can be loaded at any one time and to the maximum width of film. Magazines are nearly always detachable so that the camera may be reloaded in the air. Besides giving additional capacity, spare magazines are desirable in case of failure because the magazine usually contains the most intricate moving parts in the camera.

One of the most difficult operations in the camera is to ensure that at the moment of exposure the film is absolutely flat and in the focal plane. The difficulty is increased by the fact that between exposures the film must be free to move and in such a way that no scratching results.

Film Flattening Devices

There are four methods of holding the film in the focal plane during exposure—

1. direct tension;
2. mechanical pressure on to a glass plate;
3. air pressure against a locating back;
4. suction by creating a vacuum in the locating back.

1. *Direct tension* is exerted by the pull of the spring-loaded take-up spool against the brake of the supply spool. This is only possible where the length of format does not exceed about 100 mm and is never used in an air camera.

2. *The glass plate* is placed so that its rear surface lies in the focal plane. At the time of exposure the film is pressed against this surface by a pressure pad (see Fig. 1.6) which is released while the film is being wound on. There will be distortion of the image due to the rays passing through the glass plate, but this can be largely offset by adjusting the distance of the focal plane from the lens. The glass must be kept perfectly clean to prevent light scatter, scratching of the film, and to minimize the build-up of static electricity. The last-named is an accumulation of electricity, which eventually discharges causing a phenomenon on the negative similar to intense partly-localized flare-light, or to lightning patterns. The build-up is said to be caused by the rubbing of the film over the glass surface.

The great advantages of the glass plate are the mechanical simplicity of its functioning, and the fact that collimating marks (see Fig. 2.1) and the principal point itself can be engraved on it.

A squared réseau is also sometimes engraved on the plate. This will make apparent any distortions of the negative due to non-flatness in the focal plane, because such distortions will cause bending of the lines. It is especially useful when accurate measurements are made on the face of a print, by a stereocomparator.

3. *An air pressure system* involves pumping air into the camera cone, which must be airtight; the junction between the cone and

the magazine must also be airtight. The air under pressure presses the film flat against the backing plate, or locating back, which here takes the place of the glass plate. The film passes in front of the locating back, which is attached to the cone. This was the system favoured in Europe but the more efficient vacuum is now replacing it. The main disadvantage is that, in spite of an air filter, minute dust particles tend to enter the camera causing scratching of the film and increasing flare-light.

4. *In the vacuum system*, air is pumped out through the backing plate, thus holding the film firmly to the plate by suction. The front of the locating back is engraved with a regular system of straight or curved channels in which, at suitable points, there are small orifices through which the air is pumped. The channel pattern is sometimes rectangular and sometimes radial, but there are many designs actually used and the efficiency of the design determines the efficiency with which the whole of the air is excluded. If any air bubbles remain between film and back at the time of exposure, distortion of the image will occur. Exhaustion of the air is achieved by coupling the system with the aircraft venturi or by a separate vacuum pump.

This appears to be the most popular system at the moment, but it is more complicated than the physical pressure method, and flare patterns from static electricity discharges still occasionally affect the negative. In addition, if the channels are a little too coarse, or the vacuum too great, there is a tendency for the pattern to appear as a background image on the negative.

The Camera Shutters

The function of the shutter is to regulate the light passing through the lens on to the film. During exposure, the shutter opens and admits the image-forming rays. At all other times the shutter remains closed in order to protect the focal plane from light.

Ideally the shutter must expose the whole face of the format to light at exactly the same time, and there must be an accurate method of controlling the time of exposure. In an air camera the duration of the exposure must be so short that the image of a ground point cannot be seen to have moved relative to the focal plane. If an image moves during exposure by as much as 0·25 mm, a visible blur will occur.

There are three main types of shutter—

1. between the lens,
2. focal plane,
3. louvre.

1. *The between the lens shutters* are placed within the lens system at a point where the bundle of rays is narrowest. There are several varieties of this type of shutter. The sector type is in the form of a diaphragm. A number of thin metal leaves are pivoted at their outer edge in such a way that, as the leaves rotate in one direction, a hole appears in the centre. At this stage the shutter will appear similar to the apertures of Fig. 9.11. At exposure the shutter is fully opened, and as it is spring-loaded the leaves immediately return to the closed position. Since the opening begins at the centre and finishes at the centre, the central part of the bundle of rays is admitted for a longer time than the outer parts; the shutter is therefore said to lack efficiency. However, the cross-section of the beam here is so small that the resulting unevenness of illumination is relatively unimportant.

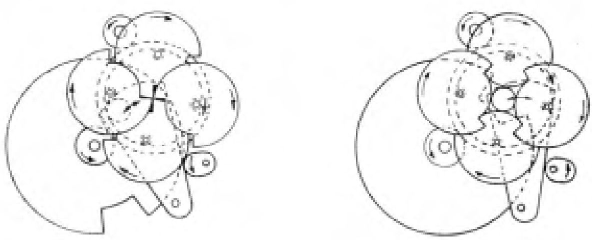

FIG. 1.13. ROTATING DISC SHUTTER
(i) AEROTOP SHUTTER CLOSED
(ii) AEROTOP SHUTTER OPEN
(*Zeiss Aerotopograph, Munich*)

In the rotary variety (see Fig. 1.13), each disc rotates continuously in one direction only. The shape of the leaves causes the shutter to open and shut, and reduces any tendency to uneven illumination so that efficiency is increased. Normally the lever arm will keep the aperture closed; but exposure is achieved when the arm changes position to bring the circular hole into the centre of the aperture.

This is the most popular type of shutter in air cameras, but in a camera having interchangeable lenses each lens would need to incorporate a separate shutter.

2. *The focal plane shutter* (Fig. 1.14), as its name implies, moves in, or at least in contact with, the focal plane. It consists of a blind with a slot cut out. The exposure is made by causing this slot to travel across the face of the film. The speed of exposure can be varied both by altering the speed of shutter movement and by altering

the width of the slot. When we use the term "speed" in its normal sense of governing the time during which any particular part of the film is exposed, then the focal plane shutter is much faster than the other types. However, the whole of the format is not exposed simultaneously, and there may be distortion due to the image movement between the time of exposure at one edge and that at the

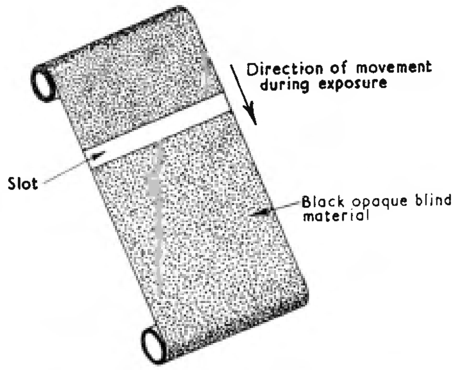

FIG. 1.14. FOCAL PLANE SHUTTER
During " winding-on " between exposures, the movement will be reversed.

other. If, during exposure, the slot always travels in the same direction as the aircraft, the consequent foreshortening tendency may be used to offset the normal blur distortion. This is not as straightforward as might appear, and the possibility of making use of the superior speed of this type of shutter has been the subject of much controversy and experiment.

If the blind is always required to make the exposure while it is moving in the same direction, then the " winding-up " of the shutter between successive exposures must be done with a second blind in front of the shutter itself.

Although the width of the beam of light is at its greatest in the focal plane and the focal plane shutter is therefore bigger than the others, the slot covers the full width of the format. It can be made to travel at a uniform speed so that every part of the negative will receive the same exposure, and the shutter is therefore said to be " efficient." Acceleration at the start of the exposure and deceleration at the end are aided by spring loading.

3. *The louvre shutter* (Fig. 1.15) fits into the cone of the camera and operates like a venetian blind. Its construction and operation are very simple but it is rarely used in an air camera.

The continuous strip air camera does not contain any conventional type of shutter. The film is simply pulled past a slit opening at a rate equal to the apparent motion of the ground relative to the aircraft.

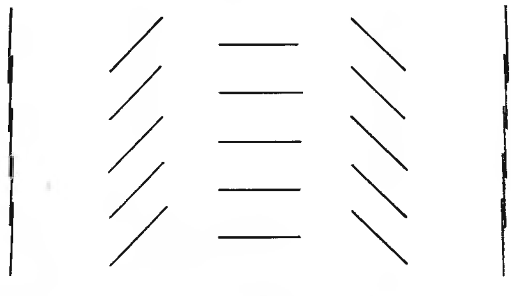

FIG. 1.15. SECTIONS THROUGH A LOUVRE SHUTTER

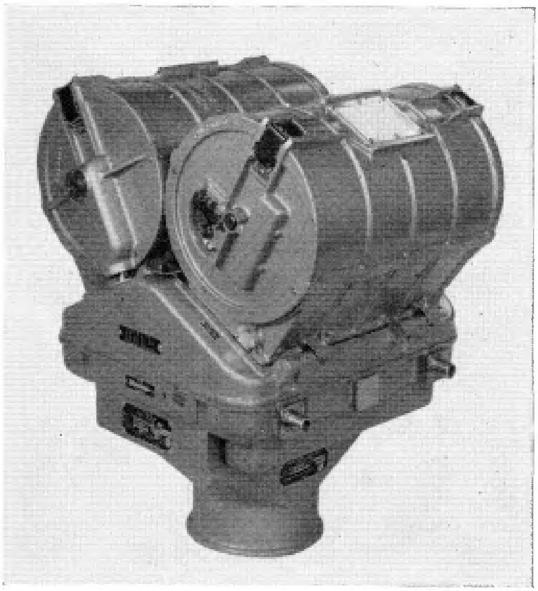

FIG. 1.16. CONTINUOUS STRIP AERIAL CAMERA
(*Chicago Aerial Industries Inc.*)

The KA-18A (see Fig. 1.16) incorporates an electronic computer which automatically adjusts the slit-width and the aperture diameter according to the lighting conditions and the velocity of image movement. A pair of stereoscopic continuous strips can be obtained in one camera but each would only be half the width of the film.

The Gimbal Mounting

This is the mechanism which attaches the camera to the aircraft, and enables changes of orientation of the camera relative to the aircraft. It is dealt with in Chapter 4 and illustrated in Fig. 1.17. It must incorporate some sort of shock absorber (e.g. rubber bushes) to isolate the camera from aircraft vibrations.

FIG. 1.17. EAGLE IX (F.49) CAMERA MOUNTING (R.A.F. TYPE 77 14A/4135) (*Williamson Manufacturing Co. Ltd.*)

FURTHER READING

Although this book has been written with the idea of conveying some knowledge of air surveying to those with a general educational background, it would be foolish to think of actually making maps without the use of land surveying methods. There are many books available on the subject some of which are listed below.

Books on general land surveying for the civil engineer—

1. BANNISTER, A., RAYMOND, S., *Surveying* (Pitman).
2. STEPHENSON, H. W., *Solution of Problems in Surveying and Field Astronomy* (Pitman).

Books on general land surveying for specialists—

1. ALLAN, HOLLWEY and MAYNES, *Practical Field Surveying and Computations* (Heinemann).
2. MIDDLETON, CHADWICK, *A Treatise on Surveying*, Vols. I and II (Spon).
3. CLARK, D., *Plane and Geodetic Surveying*, Vols. I and II (Constable).

The HISTORY of photogrammetry, or more particularly of air survey, is recorded in the following books—

(i) Schwidefsky, Chapter 1; (ii) Hart, pages 7–23; (iii) Lyon, Chapter 8.

(See Bibliography (page 346) for the full titles.)