2. Focke-Wulf FW 58 (Weihe)

v_{max}	=250 km/h (155 mi/h)
cruising speed	=240 km/h (150 mi/h)
flight with throttled down engine	=210 km/h (130 mi/h)
cruising range	=600–700 km. (370–440 miles)
maximum service ceiling	=5,200–5,850 m. (19,000–21,000 feet)

The maximum flying range is eight hours; the useful load (personnel and equipment) for approximate stresses amounts to 350 kg. (770 lbs.) in addition to motor fuels.

Organization and Operation of Photographic Projects

The nearest commercial airports provide the bases of operation for photographic projects while the various sport flying fields are used for intermediate or emergency landings.

Flight maps are generally made on 1:100,000 scale maps.

With regard to weather it must be emphasized that ever since the availability of highly sensitive photographic film, complete cloudlessness is in no wise any longer a condition; rather, sufficiently high cirrus clouds sometime have a beneficial effect upon the quality of the picture by softening the light and reducing the intensity of shadows.

The crew of the aircraft, as a rule, is merely composed of a pilot and a photographer. The activity of the latter relates to the instruction of the pilot as regards the direction of flight, the functioning of the photographic apparatus and the supplementary equipment belonging thereto.

For the preparation and carrying out of the photographic flight in expeditionary regions, the map concerning Northeast-Greenland in the report which has just now appeared in the *Norges Svalbard—og Ishavs—Undersökelser, Oslo,* is very instructive. This report describes photogrammetric studies which were carried out in joint collaboration with the Chair for Photogrammetry TH Berlin, Prof. Lacmann and Hansa Luftbild G.m.b.H. (Hansa Aerial Mapping Non-Stock Corporation) Berlin.

Classification and Recording of Aerial Photography

The developed aerial photographs are examined with regard to quality of the picture and correctness of position (scale, overlap and definition) and are indexed on existing maps.

Great Britain

While Great Britain does not have a National Society of Photogrammetry affiliated with the International Society of Photogrammetry, the Secretary of the Institution of Royal Engineers, and the officials of the Williamson Manufacturing Company, Ltd. have kindly furnished the following material for the International Report on Air Photography.

THE SEVEN LENS AIR SURVEY CAMERA[1]

Preliminary

Photographs of ground which are exposed downwards, their axes being then very approximately vertical, are known as "vertical photographs." When these

[1] This article by Lieutenant E. H. Thompson, R. E. has been reprinted from the October 1937 and January 1938 issues of *The Empire Survey Review,* with the permission of the author and of the Secretary of the Institution of Royal Engineers.

are taken for the purpose of mapping from them, they are utilized in two ways, technically distinct. First, they are used to set up a graphical triangulation which is an extension of the ground control; and, in the second place, they are used with the more obvious intention of filling in the detail. The fixing of a sufficient ground control would involve the survey of four points on each photograph; since this is impracticable under all ordinary conditions, the photographs themselves must be utilized to break down the tertiary triangulation or traverse which generally constitutes the main control. If the photographs overlap by 60 per cent, if their departure from horizontality does not exceed 1° or 2°, if the ground is not too highly featured, and if there appear points on the pictures which are sufficiently well placed and defined, then the establishment of the subsidiary graphical triangulation may be secured to a high degree of accuracy. This net is known as the "minor control plot." When plots are made for each strip of photographs, when the latter are linked together, and finally when they are adjusted to the ground control, then the centre of each photograph is known with considerable assurance of precision, increased or lowered according as large-scale or small-scale mapping is in demand. This procedure constitutes what we know as the Arundel Method.

The minor control plot having thus been finally laid down, the ease with which the detail can be filled in depends on (1) the scale of the map in relation to the photographs, (2) the hilliness of the terrain, and (3) the tilt of the photographs. In the majority of cases the tilt does not seriously affect the plotting, and the distortions due to heights of features can be eliminated, provided that the photographic and plotting scales are reasonably accordant.

The considerations adduced above point to two main desiderata: *ceteris paribus* each photograph should cover as large an area as possible and its scale must approximate to that of the mapping scale. Detail which cannot be shown on the map is not generally of value on the photograph, except when it can be utilized for the establishment of the minor control plot.

The Single Camera

The standard camera in the R.A.F. is the F. 24, giving a picture of 5×5 inches, usually on a focal length of 5 inches. This camera thus covers a square whose sides are equal to the height of the aircraft. If, then, an aircraft flies at 12,000 feet—an economic height suitable for survey work—the scale of the picture will be $5/(12\times12{,}000)=1/28{,}800$. But since the 5×5 inch picture is too small for plotting, the surveyor is supplied with an enlargement to 7×7 inches; so that the scale above is increased to 1/20,600, which is suitable for maps of between 1/20,000 and 1/25,000. For a map at a scale of 1 inch/1 mile it is not suitable.

The photograph at a scale of 1/28,800 could be used for mapping at 1 inch/1 mile if reductions were provided. The resulting print, however, would be no more than about $2\frac{1}{4}$ inches square and would thus certainly not fulfill the requirement of covering as large an area as possible consistent with dimensions between 7×7 and 9×9 inches. With the same 5 inch lens, this disadvantage could be overcome by flying at a height of 37,000 feet, since the scale of the enlargement would then be about 1/63,360, *i.e.*, the "1 inch" scale. Such an effort would, however, be normally thwarted by weather conditions and considerations of economy.

Theoretically another procedure is available. The photographs might be taken at 12,000 feet if a lens of 1.7 inches could be found to cover the 5×5 inch plate. The best lens so far constructed and now in use in many parts of the world is the Ross "Xpres E.M.I."; this lens works at an aperture of f/4, gives a very high standard of definition with no distortion, and offers practically uniform illumination over the whole plate. But its maximum field is limited to 70°; even so, any reader who takes more than a passing interest in photography will realize that the performance of the lens is very remarkable. The angle of 70° is measured across the diagonal of a 5×5 inch plate, 5 inches from the lens; or the diagonal of a 7×7 inch plate under a lens of 7 inch focal length. It is more convenient to consider the angle "across the flats," *i.e.* the width of the plate, in the Ross 5 inch lens this is 53° on a 5 inch width. It is easy to calculate that a lens of 1.7 inch focal length, to cover a 5×5 inch plate, would be required to show a field of about 120° across the flats.

Lenses are improving and it may now be said with assurance that there is every possibility of a new Ross lens—covering 75° across the flats or 95° across the diagonal—being carried beyond the present experimental stage. But an increase from 75° to 120° would imply a tremendous stride, far beyond any development now predictable. The difficulties of design by no means increase only in proportion to the field covered; moreover, mere covering power is not everything: there must of course be very good definition and absence of distortion, but apart from these essentials there must also be good illumination up to the edge of the picture. The wider the field the more important is illumination, coincidently the more difficult to attain. For example, the ray to the corner of a picture of 120° across the flats has to penetrate a space of air equal to 2.8 times the height of the aircraft; the loss of light that accrues therein must not be aggravated by further loss in the lens.

The Composite Camera

A practical way of securing the field of wide angle would be to mount several cameras together in the same aircraft, as was done by Scheimpflug as far back as the days of balloon photography. In a typical arrangement, shown in Fig. 1,

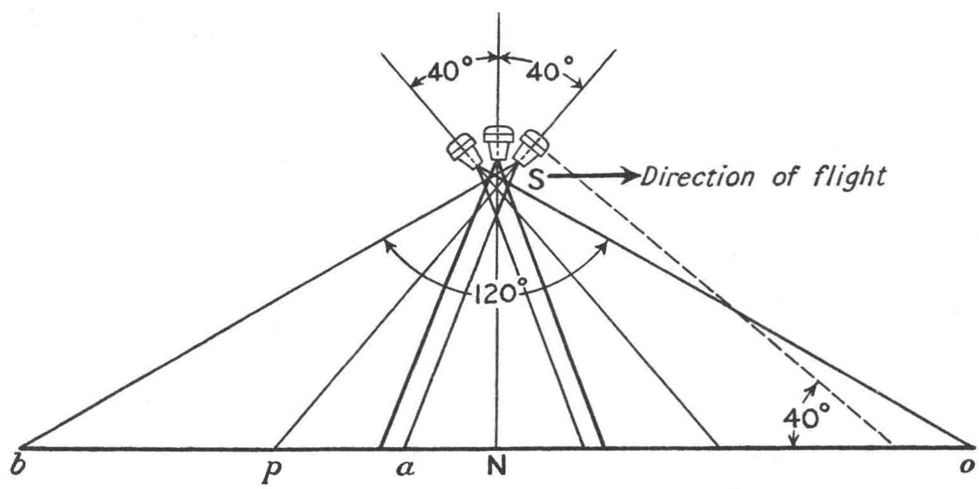

Fig. 1

each camera may be designed to cover 40°, so that by deflecting the outer cameras a field of 120° may be obtained. It is inevitable—and not disadvantageous—that a small area should be common to the inner and outer cameras; this overlap appears large in Fig. 1 because the aircraft height has to be shown out of scale with the picture. The three shutters are released simultaneously and thus, from each position of the aircraft, are obtained one vertical and two oblique negatives. A composite picture of the ground, therefore, is not obtained directly; but by a process of optical transformation, named *Rectification* by Brigadier Winterbotham, the oblique photographs can be converted into "vertical" pictures in the same plane as the central photograph, and thus the composite picture is secured.

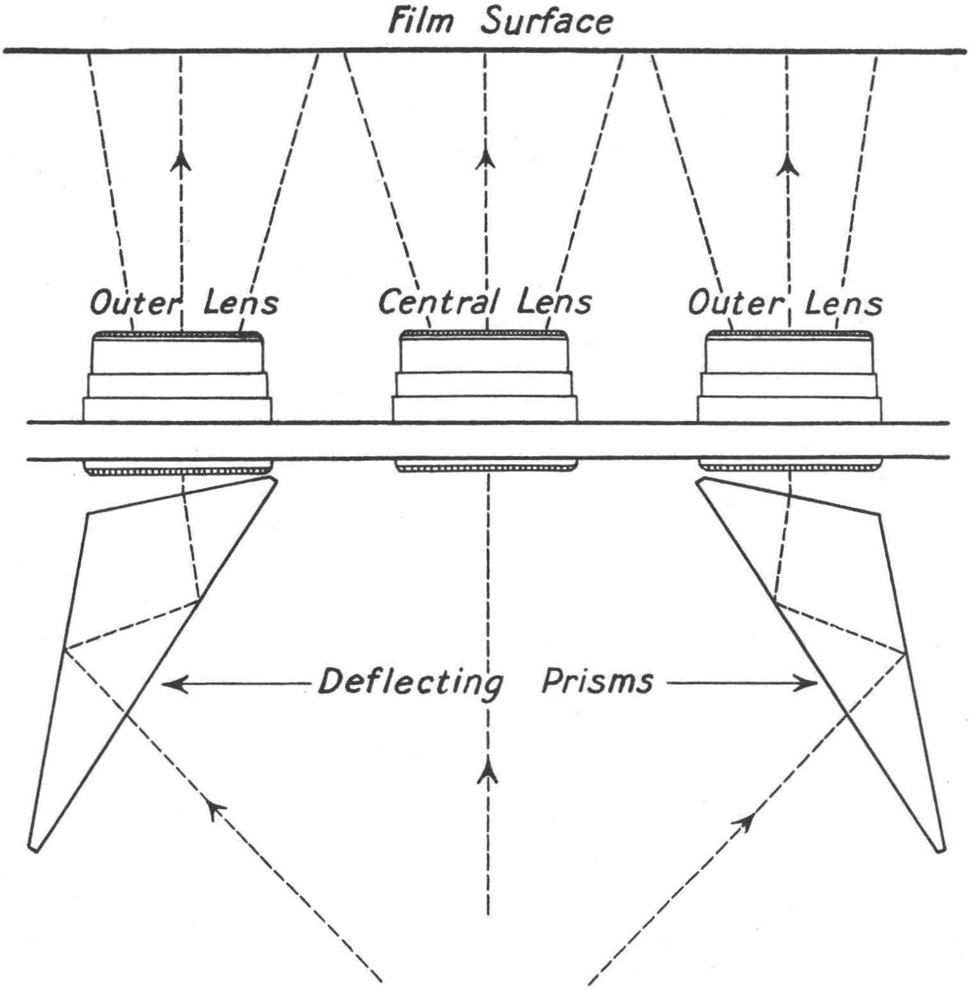

Fig 2

The process of rectification has been dealt with so frequently that it is not proposed to discuss it generally; but there is one matter which demands attention here. Normally it may be supposed that the plane of the oblique will be rectified to the plane of the vertical picture. But this condition is not essential, provided that the focal length of the rectifying lens is modified accordingly; further, the rectified image may be given an enlargement.

In a triple bunch of cameras, in common use in America for example, the rectified picture is an oblong splayed at the ends; the longer axis of the picture is generally athwart the line of flight and thus the area covered by photography in a single flight is considerably augmented. A multiple camera, though it extends the field greatly, is subject to certain disadvantages:

1. It is expensive, heavy, and very bulky, since seven separate cameras would be required to give the square picture theoretically obtainable with a wide angle lens.

2. The maintenance of the seven mechanisms would be difficult.

3. It would necessitate a heavy rigid base to preserve unchanged the relative directions of the component camera axes—a condition of fundamental importance for correct rectification.

It was with the object of avoiding these setbacks that the multiple lens camera was designed.

The Seven Lens Camera

The multiple lens camera aims at replacing the theoretical lens of very wide field with a cluster of lenses in a single camera body. Apparently the first at-

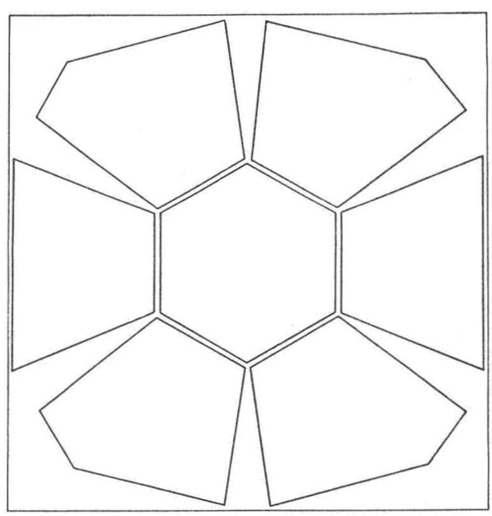

Fig. 2a

tempt at this was made by the Air Survey Committee, which constructed a five lens camera with a single plate. Comparative inefficacy of the metal reflectors which were used for deflecting the images of the outer field upon the sensitive plate led to the premature abandonment of the design; the pictures, however, were not as bad as they were painted, and the completion of a rectifying outfit would have rendered the apparatus utilizable, at least in good conditions of air. The most successful effort was made by Claus Aschenbrenner in Munich, who designed a nine lens camera and rectifier, covering a field of 135°. In the view of British photogrammeters the field was too large, since under ordinary conditions the depths of air traversed by the outer rays are too hazy or murky to yield distinctive features generally plottable, apart altogether from an undue increase of dead ground: in fact in the outer field all the disadvantages of the high oblique photograph were presented—unnecessarily. Necessity became for once the handmaid of convenience and the design adopted and developed by the Air Survey Committee limited the field to 120° and the lenses to seven.

A simplified section through the centre of the lens system of the seven lens camera is shown in Fig. 2. As in the composite camera the central lens points vertically downwards. Six outer lenses, of which two are seen in Fig. 2, are placed with their centres at the corner of a regular hexagon and their axes parallel to that of the central lens. Below each outer lens is a catadioptric (Fresnel, 1827) prism, whereof the outer surface is silvered to give a second reflexion; the result as the diagram shows is virtually to transform inwards the corresponding vertical into an oblique photograph; there are Service reasons

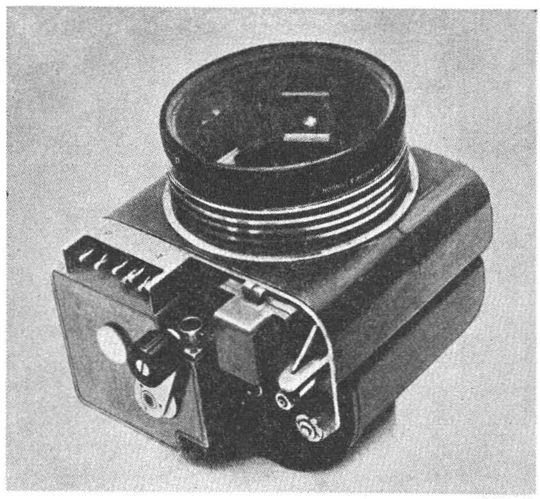

Fig. 3

for preferring an inward rather than an outward deflection. An important advantage of the catadioptric system is the practical immunity from disturbance of the deflecting angle when the prism is not perfectly set. It is thus evident that the several film magazines of the composite camera are replaced by a single magazine, a single film, and a single roller-blind shutter.

Fig. 2a represents an unrectified contact print taken from a negative. The leaves of the photographic rosette are so shaped that, after rectification, the resultant composite "vertical" shall be a perfect square, 9×9 inches, with all the gaps exactly closed.

Fig. 3 is a general view of the camera, with its lenses pointing upwards for illustration. The circular glass cover is a yellow filter, beneath which there can be seen three of the deflecting prisms; reflected in the middle one, an image of a lens is exhibited quite clearly.

The prisms of the cluster turn all the rays through 45° and thus the obliques correspond exactly to pictures inclined at this angle to the central camera. In simple rectification this 45° would be the angle between the photographic and plotting planes; but it has been mentioned that it is unnecessary to adhere to this angle, and for various reasons there are advantages in changing it. The rectifying lens is working under very exacting conditions and there are other conflicting requirements. Hence the best compromise appeared to place the negative and positive planes at right angles.

Fig. 4 is a diagrammatic section of the rectifier and shows the central lens and two of the six outer lenses and prisms. It will be seen that the central lens makes a positive picture from the central negative without rectification but with a small magnification of about $1\frac{1}{4}$. The negative and positive planes

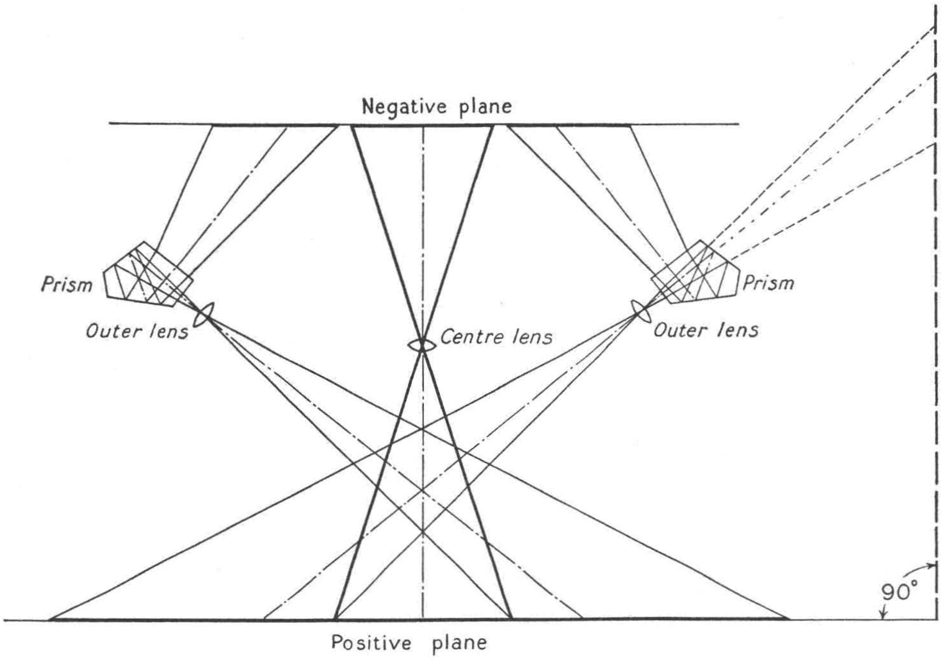

Fig. 4

would be at right angles, but by means of pentagonal prisms they are brought into parallelism, as indicated clearly by the figure. The introduction of the

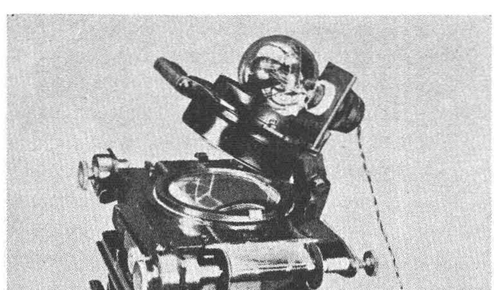

Fig. 5

"pentags" gives a symmetry about the centre which would be impossible in simple rectification but which is of the first importance, since it enables all seven negatives to be printed *simultaneously* as verticals.

A general view of the rectifier is exhibited in Fig. 5. It will be noted that the design is exceedingly compact and skilful. The negatives are not cut up after development and the whole roll is carried on two bobbins which enable each negative in turn to be brought into position on the negative plane; exact positioning is made possible by adjusting screws on the axles of the bobbins. The film is kept flat by a glass plate on which rests the illumination unit, consisting of a lamp, diffusing screen, and water-filter for cooling; but since no glass plate can cover the positive without introducing errors in the perspective, the printing paper is held flat by suction, the vacuum being applied through small holes, as numerous as experiment dictates.

A Test of the Camera and Rectifier

As a first test of the camera and rectifier in the home country, strips of photographs were taken from about 12,000 feet over Salisbury Plain. The rectified prints in the Salisbury test were at a scale of about 1/60,000 and it was decided to map at 1 inch/1 mile, *i.e.*, 1/63,360, the scale of the Ordnance Survey. The strip chosen for plotting was about 12×8 miles, involving five 7-L prints, as against the theoretical minimum of 60 prints from the F. 24 Camera covering the same area.

As control for the plotting two trigonometrical stations *only* were used. It should be noted that the exiguous use of two points solely gives an overall scale and orientation, but that the shape of the strip depends entirely on the accuracy of the photogrammetry itself. There is considerable difficulty in finding the errors of a plotted map by simply laying a tracing from a standard survey over the plot. The only satisfactory method is to choose at random a fair number of points of detail, well distributed over the area, and to compare the coordinates of these points as measured from the plot with the coordinates as measured from a map of much larger scale.

In this case some 50 points were chosen and carefully identified on the 1/25,000 sheets, from which their presumably true coordinates were scaled. In this way the average errors of the photogrammetric plot were found to be 47 metres in northing and 43 metres in easting, on the assumption of course that the 1/25,000 mapping was exact. In view of the very limited control, these figures were encouragingly small.

As a matter of interest the coordinates of these same points were taken from the O. S. 1-inch sheet. The average errors, as compared with the 1/25,000 sheet, were 23 metres in northing and easting. This is somewhat greater than the figure which has been regarded as the possible exactitude of scaling from a 1 inch map, namely 70 feet. Thus, even with the exiguous control, possibly 100 times less than that on which the 1 inch map was framed, the errors of the airphoto plot were no more than about twice as great as those which were in any case inevitable in scaling from the sheet; they were, in fact, worse than the 1 inch by amounts which, on the plot, averaged only 0.3 mm. It must be repeated that the comparison proceeded on the assumption that the 1/25,000 map showed a true picture of the ground. For the benefit of those who have forgotten the methods of the Ordnance Survey, it must be stated that the smaller (topographic) scales were reduced from the larger (cadastral) scales: the mapping is not independent, as elsewhere in general, so that the 1 inch and 1/25,000 are fundamentally copies of the "25-inch" (1/2,500), the errors being introduced, presumably, by the reduction processes and the smaller scale.

Similar tests were made on the other four strips of the survey, with comparable results. The accuracy attained may therefore be regarded as that obtainable under similar conditions with an absolute minimum of control.

The test brought out one curious effect of light. A main road in one place appeared as no more than a track and in other spots disappeared altogether! This, a trick of lighting, had nothing to do with the method except in so far as it implies that small scale photographs will always be subject to increased difficulties of interpretation in certain cases; for topographic mapping at 1 inch/1 mile in undeveloped country, for which the method is largely intended, this will be a small offset against its numerous advantages.

Contouring with the Seven Lens Camera

In order to contour from photographs by the method now standard in the Army, six spot-heights must be fixed in every overlap, *i.e.*, the area of ground common to two successive pictures. If the F. 24 Camera is used from 12,000 feet, this means the "heighting" of one point in less than one square mile, but with the seven lens camera no more than one point is demanded in every five square miles.

With just this amount of height control the whole strip was contoured. The heights of sixteen known points were derived from the photographs, the average error being only 26 feet.

The relief effect is almost wholly dependent on stereoscopic power and this again depends in the main on the length of the air base. With the F. 24 Camera at 12,000 feet, the air base is less than 6,000, *i.e.*, less than half the height; with the seven lens it can be 20,000 feet, *i.e.*, two-and-one-half times the height. This is of the utmost importance, since it more than counteracts the smallness of scale, which is less than half that obtained with the single lens camera. A striking example is the manner in which small rises and falls of railway tracks can be appreciated.

Conclusion

The first tests with the seven lens camera prove that it is a practical instrument, capable of taking photographs for mapping at scales of 1 inch/1 mile or smaller. With a less exiguous control then that employed in these tests the accuracy obtainable in developed countries, even at somewhat larger scales, should be adequate, though care must be taken to avoid faults of interpretation. In undeveloped countries it offers an economical way of producing good maps with a limited control.

In order to obtain at a glance an idea of the great saving in photography and flying, the following table has been drawn up, comparing results from the single lens and seven lens cameras:

Item	*F. 24 Camera*	*Seven Lens Camera*
Size of square picture	2.9 miles	9.8 miles
Area of square picture	8.4 sq. miles	96 sq. miles
No. of photographs per 10,000 sq. miles	4,100	320
Flying per 10,000 sq. miles	4,600 miles	1,400 miles

For the practical realization of this camera the Air Survey Committee is indebted above all to Messrs. Barr & Stroud, Ltd. of Glasgow, who have expended a large amount of time and labour on the constructional problem. The time was not lost and the labour was worthy of accomplishment. The lenses used in the camera were of the latest designs by Messrs. Ross, Ltd.

EAGLE AIR CAMERAS[2]

The Williamson Manufacturing Company has produced a special camera to take the new Ross Survey lens which satisfactorily covers a 7×7 inch picture with a 5 inch focal length.

In addition to the above the latest models of Eagle cameras, the Series III and Series IV camera are of interest. These are single lens film cameras equipped for either hand or automatic operation.

The Series III camera takes a picture size 5×5 inches and has a magazine capacity of 115 exposures. Two sizes of lens cones are available for this camera, a short cone for lenses of 5 to 6 inch focus, and a long cone for lenses up to $10\frac{1}{4}$ inch focus. In addition to the regular vertical mounting a hand mounting can be furnished for taking oblique pictures.

The Series IV camera takes a $6\frac{1}{2}\times9\frac{1}{2}$ inch picture and has a magazine capacity of 200 exposures. Two sizes of lens cones are available for lens up to 30 inch focus.

The cameras are made up of three main units, the camera body, the lens cone, and the film magazine. Camera units are interchangeable and can be attached or removed without tools.

The camera body carries the glass plate through which the exposure is made and the top surfaces of the castings surrounding this glass plate form the plane of the focal register.

The cameras are fitted with Williamson Louvre shutters. These shutters consist of a number of thin steel strips fitting together like a Venetian blind. These strips fit into steel pivots and are directly operated by a circular rack. All the metal strips on one side of the center are made to rotate clockwise and the remainder in a counterclockwise direction until they lie in a plane parallel to the optical axis of the lens. The actual movement of opening and closing the strips or louvres takes place in an infinitely short space of time and the duration of exposure is obtained by arranging for the louvres to remain open for the required interval. The shutter is mounted behind the lens.

The main features of this shutter are summarized by the manufacturers as: (1) all metal construction with a minimum of moving parts, (2) great efficiency and high speed for use with large aperture lenses, (3) even illumination over the entire negative, (4) no distortion of image, (5) unaffected by climatic conditions.

The instrument box on these cameras is a separate, optional, and independent accessory and does not affect the operation of the camera. The instruments are photographed in the margin between the successive exposures.

[2] Manufactured by the Williamson Manufacturing Company, Ltd., London.

Hungary

Redey Istavan, Jr., Doctor of Engineering
Correspondent of Committee No. 2

CAMERAS

In Hungary the Nistri single lens camera of 21 cm. (8 inch) focal length, plate size 13×18 cm. (5×7 inches), with focal plane shutter is used for general purpose photography. This camera is equipped with a Zeiss Tessar lens of 1/4.5 speed. The camera is hand operated, using film with magazine capacity for 50 exposures. The Aeskulin filters are used with this camera.