area in the distance. The amount of light received by the selenium, placed, as it is, near the focus of a lens or mirror of definite aperture, diminishes, of course, as the distance is increased. Several factors determine the range of efficient transmission—the intrinsic brilliancy of the light source, the dimensions of the optical parts, the sensitivity of the selenium, and the number of stages of amplification which are used. No very conclusive tests of the maximum range of the photo-telephone have yet been carried out; it may, nevertheless, be asserted with some confidence that, given sunlight and modern amplifying devices, it is probably the earth's curvature which would impose a limit on the range of an instrument of quite reasonably small dimensions.

It is of interest to compare the photo-telephone with the system of wireless telephony now so commonly used in broadcasting. In both, waves in the ether constitute the fundamental basis; the medium is the same and the speed of propagation is the same. In both, speech vibrations modulate the intensity of the energy transmitted, and in both the results are made audible by changes of current in the receiving apparatus. The details are, of course, dissimilar. The radio-frequency waves are produced artificially, and are under control as regards wave-length; the luminous waves are taken as we find them emitted from the source. The detectors—the valve or crystal on one hand, and the selenium cell on the other—are not strictly comparable. But the only really important difference lies in the lengths of the waves. Roughly, the radio-frequency waves commonly employed are one thousand million times as long as those operative in photo-telephony. This difference is of great importance in relation to the mode of propagation. Wireless waves at present in use are so long that they turn readily round corners, so that not only does the earth's curvature impose no serious limitation of range, but broadcasting in all directions is possible and, indeed, inevitable. Light waves, on the other hand, are for practical purposes propagated rectilinearly; consequently photo-telephony can never be expected to attain a very great range. It has, however, the compensating feature that by its directiveness it implies not only secrecy of communication but non-interference by simultaneous transmissions, without the necessity of tuning as in radio-telephony. It is true that selenium is more sensitive to red light than to other colours, and is therefore somewhat selective as regards frequency, but the suppression of the other colours is not called for, and would, in fact, be a disadvantage.

The photophone, as distinct from the photo-telephone, has several other applications. Two may be briefly indicated. The modulated light from the transmitter can be focussed into a narrow line upon a uniformly moving kinematograph film upon which, after development, there appears a band of varying opacity corresponding to the light fluctuations, and, therefore, to the speech or other sounds used for modulating purposes. The same film, on being run at the same speed between a source of light and a selenium cell with a suitable optical arrangement, gives a reasonably good reproduction of the original sounds. With sufficient amplification the results can be heard proceeding from a loud-speaking telephone. The application of this form of gramophone to the problem of synchronised pictures and sounds is obvious, and has been described in an earlier article.[3] Many workers in various countries are now concentrating their attention upon perfecting a system of this kind, and there is no reason to suppose that realisation will be long delayed.

The speech currents controlled by selenium under the action of the modulated light from a photophone transmitter compare favourably in accuracy of form with those obtained by means of a carbon microphone. The photophone as a whole—*i.e.* the transmitter and receiver together regarded as one unit—can thus be used as a substitute for the microphone in cases where stricter accuracy in electrical sound transmission is desired. This necessity has arisen in acute form in connexion with radio-telephony, in which the radio-frequency oscillations have to be modulated in the transmitting valve as nearly as possible in accordance with the sounds it is desired to transmit. A photophone has been used successfully at the Manchester broadcasting station for this purpose, and for some months those who listen to this station have been receiving the results of what can quite fairly be described as a remarkable sequence of occurrences. A singer sings, and the aerial vibrations thus created fall upon a diaphragm. This is forced also into vibration and imparts its motion to a small mirror, which in turn deflects a beam of light so that more or less of it reaches a selenium cell. By its photo-electric property the cell controls an electric current so feeble that it has to be amplified by thermionic valves in several successive stages before it is intense enough to modulate efficiently the radio-frequency oscillations in the transmitting valve. Thence the modulated wave travels through the ether to the receiving aerial; here, perhaps, it undergoes one or more high-frequency magnifications, and then the modulations are detected by a crystal or valve. Then there may be several low-frequency amplifications before, eventually, the fluctuating current actuates a telephone diaphragm causing it to re-create those aerial vibrations which we hear. When we bear all this in mind our attitude is not that of criticism of the defects of reproduction, but rather that of amazement that it so closely resembles the original.

[3] NATURE, vol. 108, p. 276 (1921).

Recent Experiments in Aerial Surveying by Vertical Photographs.[1]

By Prof. B. MELVILL JONES and Major J. C. GRIFFITHS.

II.

COMPILATION OF THE MOSAICS.

THE compilation of the mosaics presents considerable difficulties unless approached in a systematic manner, for, although individual prints fit well together, there are always some slight errors which tend to accumulate, unless special precautions are taken to prevent this occurring.

We begin the compilation by laying out each strip of photographic prints separately, paying special attention to the joins between successive prints. Slight

[1] Continued from p. 709.

changes of height, either in the aeroplane or the ground, will cause slight changes in scale between successive strips, and slight persistent tilts, either in the camera or the ground, will cause the strips, as fitted in the first place, to show fictitious curvatures due to differences being represented to a larger scale on one side of the strip than on the other.

To make a good fit between successive strips, these fictitious curvatures and differences of scale must, so far as possible, be eliminated by distributing errors between all the joins of the individual prints. We do this by securing to the back of the strips lengths of stretched elastic, fixed to each print in one spot by dabs of seccotine, and, when all the strips have been so treated, we lay them side by side upon a table and stretch and bend them systematically, until we have got the best general fit that can be obtained, without detail handling of the separate prints.

Provided that the strips were originally taken in fairly straight lines, this process of systematic adjustment appears to eliminate the fictitious curvature almost entirely and to adjust the relative positions, even of points that are far apart, with remarkable accuracy. A final adjustment is then made, in which attention is given to each print separately, but no print is moved far from the position that it has taken up in the systematic adjustment. Fig. 1 shows a mosaic laid out in this way. Notice the straightness of the strips due to the gyroscopic control, which was used in this case.

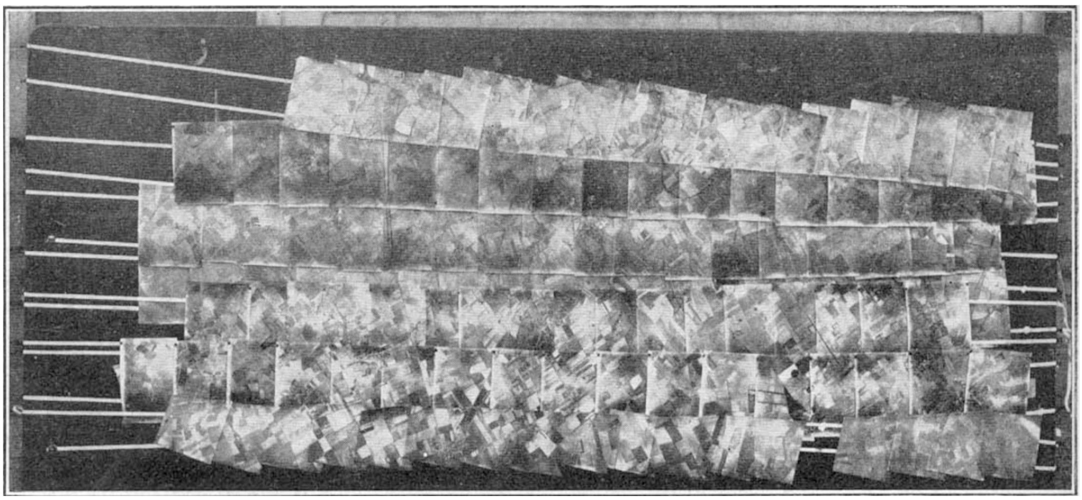

FIG. 1.—Photographic map of $7\frac{1}{2}$ by 15 miles, showing the elastic bands used in the compilation. In the finished map the prints would be properly trimmed and the elastic bands removed.

ACCURACY OF THE MAPS.

Two mosaics of $7\frac{1}{2}$ by 15 miles have been compiled in this way, without any reference whatever to existing maps. Some 40 points were selected on each of these, and their positions on the mosaic plotted on transparent paper. A plotting of these same points was then taken from the Ordnance map and enlarged until the best possible fit could be obtained with the points from the mosaic. The two plottings were then slid over each other until the best fit was obtained, and thus the remaining discrepancies give a measure of the distortion of the mosaics, without regard to scale.

The first of these mosaics was made without the gyro control on the rudder; it contains an area of 10 miles by 5 in which no point is displaced by more than 100 yards, but outside this area, towards the ends, there are points displaced by as much as 250 yards.

In the second mosaic, which is the one illustrated in Fig. 1, the gyro rudder control was used, and in this mosaic there is no distortion greater than 100 yards in any part. The increased accuracy is due, mainly, to the greater straightness of the runs, and to the pilot having been able to give more attention to maintaining height and speed constant.

The average scale of both mosaics came out to 1/19,800 as against 1/20,000 intended. The difference of 1 per cent. may be due either to the aeroplane having been about 100 feet too low, or to errors introduced during the systematic adjustment.

COMPILING TO CONTROL POINTS.

Our next experiment was to start again with new prints and to compile these two days' work together into a single 15-mile square. But this time, instead of fastening the ends of the elastics down to the table, we fastened them to laths on the edges of the table. (See Fig. 2.) The object of this was to enable us to apply systematic strains to the mosaic as a whole, after the first systematic adjustment, to cause it to fit control points.

We chose four control points, forming a rough 10-mile square, and, assuming their positions to be independently known (in this case from the Ordnance map), constructed a template to fit them, upon a scale that would most nearly fit the corresponding points upon the mosaic, after its first adjustment. We then applied this template to the mosaic and found that, owing to the distortion of the latter, displacements of about 150 yards were necessary at each control point to obtain an exact fit. These displacements were given to the mosaic by moving the laths as a whole, so that the adjustments were distributed over all the joins. The mosaic was then given a final adjustment in detail and the prints stuck down in place after removing all the elastics. When this work had been completed, some 40 points, distributed over the surface of the mosaic, were measured up and compared with the Ordnance map, and it was found that there were no errors of more than 60 yards, except on the extreme northern edge of the part of the mosaic that was made without gyro control on the rudder. In this region errors up to 130 yards were recorded.

The scale to which the template had to be constructed came out at 1/19,930. The difference between this scale and that of the separate mosaics compiled from the same photos was possibly introduced during the systematic adjustments.

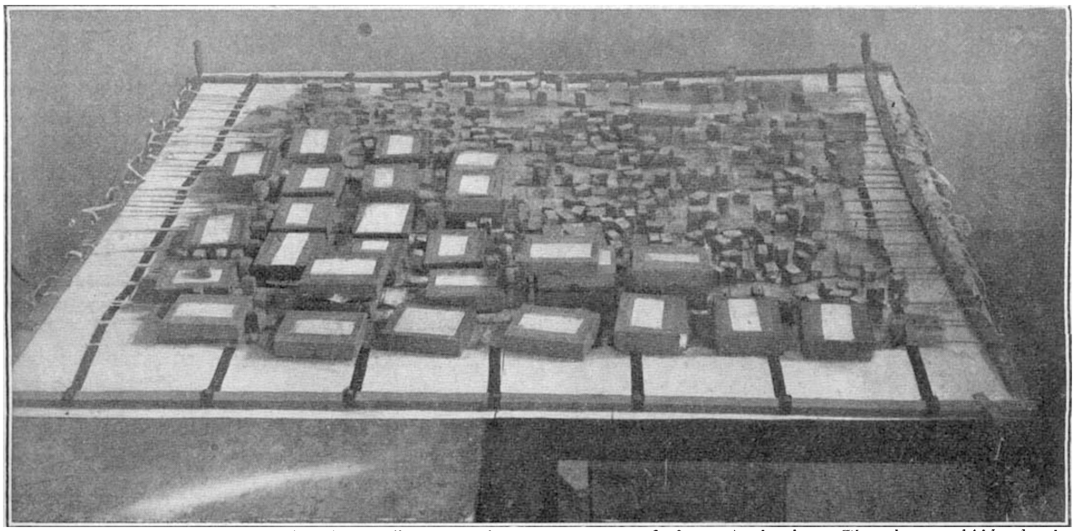

FIG. 2.—Showing method of compiling the 15-mile square photographic map to fit four control points. The prints are hidden by the weights used to hold them in place after their final adjustment, but the white elastic bands to which the prints are fastened are clearly shown. The black elastic bands were added to facilitate systematic straining at right angles to the direction of the strips.

VARIATIONS OF HEIGHT.

The country of which this map was made contains local differences of level up to 300 feet in several places and on the extreme southern edge rises to 500 feet above the lowest part.

NAVIGATIONAL CONTROL.

In some types of country, control points even of 10-mile spacing may not be economically obtainable. The complete absence of control points would not, as we have seen, seriously affect the accuracy of the individual mosaics as regards distortion, but it may leave their average scale in some doubt. There may, therefore, be some difficulty, in these circumstances, in fitting the mosaics together and in controlling their relative positions. It will be remembered, however, that it was necessary, for the identification of the starting points of the mosaic strips, to begin a survey by laying down identification strips spaced 10 miles apart. The most economical way to do this, when mapping over large areas, would be to commence by laying down a series of long parallel strips 10 miles apart having a convenient length of, say, fifty miles. If care is taken to fly these indication strips very straight and at a constant speed, it may be possible to use them to give quite a good measure of control between very widely spaced ground-surveyed points. If, for example, the photos in these flights be taken at exactly equal time intervals and the positions of the ends of the strips be known, the centre of each intermediate photo could be determined with considerable accuracy.

We have in hand experiments upon a scheme for using these indication strips, together with a few long strips at right angles, to control the positions of the 10-mile square units. We estimate, on good but not yet conclusive evidence, that, representing these preliminary strips by elastic bands and stretching the frame so formed to fit control points, we could so distribute the errors that the 100 square mile units mosaics could be located in position within $\frac{1}{4}$ to $\frac{1}{2}$ a mile, even when the control points are spaced as much as 50 miles apart. It will be noted that this method of locating position is unaffected by the presence of hills.

We do not recommend using control points so widely spaced as this, but we are concerned to show that the mosaics could be located with moderate accuracy even when the control points are so far apart.

The methods upon which experiments are in progress would not be limited to use with control points forming any particular pattern; they could be used with any form of triangulation. If, however, triangulation is impracticable, as it may be in flat wooded country, we are informed that astronomical methods, carried out on the ground, with the help of wireless time signals, can be used to locate position within 100 to 200 yards. If this method could be employed, therefore, in conjunction with aerial methods, it would be possible to push accurate mapping into unsurveyed country in which the ordinary ground-surveying methods, based on triangulation, are impracticable.

TRAINING AND EQUIPMENT.

The methods that we have described require considerable skill and special training on the part of the pilot and observer. If they are not adequately trained the probabilities are that the strips of photographs that they produce will be badly curved and leave gaps between them, while the individual photos will be tilted up to about 6 degrees and taken from varying heights. In such circumstances accurate compilation is almost impossible unless a map already exists, and, even then, re-section and re-projection of individual photos will be necessary if anything but the roughest results are to be obtained. The gaps that have been left between strips will, moreover, have to be filled up; and, as this is not an easy operation, several additional flights may be necessary for a satisfactory completion of the mosaic.

We are, for these reasons, definitely of the opinion that to employ crews that are not specially practised in the work is to court certain failure; at least in the earlier stages, before experience has been gained.

Special equipment, such as gyro rudder controls, etc., is, in our opinion, necessary for continuous successful work at the rate we have indicated, namely 100 square miles a day. Should the gyros break down in the field, it would be possible to carry on for a time in the absence of any gyroscopical aid, but the strain on the pilot would be so greatly increased that his work would deteriorate seriously unless he confined himself to considerably less work than we have indicated for a single flight.

It is also important to use a stable aeroplane, having adequate accommodation for the observer and his camera and for the pilot's special instruments. We have ourselves used a tractor (D.H. 9a), but we consider that a pusher would be far more satisfactory on account of the better view downwards, sideways, and forwards.

Summary.

We have shown that it is possible to carry out aerial surveying by vertical photographs at the rate of 100 sq. miles to the day's flying. When working in moderately flat country the results so obtained can be worked up into 100 square mile mosaics which, when reduced to a suitable scale, will fit a true map within 100 yards at all points. If so desired these maps can be adjusted to fit any number of control points with very little extra labour. If these control points are spaced about 10 miles apart, the absolute error of any point on the mosaic should be less than 100 yards, but, if more closely spaced control points are available, the errors can be reduced, reaching a limit of something less than 20 yards, when the spacing is reduced to one mile.

If the available control points are spaced more widely than 10 miles apart, a measure of control can be provided from the air by navigational methods. We estimate that, even when the control points are spaced so far apart as 50 miles, we could in this way control the position of the 100 square mile units within ¼ to ½ mile. We are working on this problem at present.

The maps can be made throughout from contact prints off original negatives, no re-projection of individual photos being necessary.

Triangulated points, forming any convenient pattern, can be used as control points; *e.g.* previously existing primary, or secondary, triangulations could be used.

The methods are dependent on there being sufficient detail visible on the photos to allow them to be joined correctly; they would not be practicable on absolutely featureless deserts or prairies.

Specially trained, picked crews using suitable aeroplanes, specially equipped, are necessary for success.

Obituary.

Col. G. F. Pearson.

On April 25, Col. George Falconer Pearson died at Kington, Herefordshire, aged ninety-six years. He was one of the last, if not the very last, of devoted servants of the Crown who joined the Indian service some time before the Mutiny, and became a distinguished pioneer of systematic conservancy of the Indian forests.

Pearson commenced his service in the 33rd Regiment of the Madras Light Infantry in 1846, in which he became adjutant, and he also acted for some time as A.D.C. to Sir Herbert Maddock. He happened to be on leave at home when the Mutiny broke out, but returned at once to India and joined his regiment in the Central Provinces, where he was employed in the chase of Tipoo Sahib and other rebels. After the Mutiny he raised a force of military police, 600 strong, with which he put down general lawlessness in the province.

Having thus become well acquainted with the extensive forests and the various tribes living in and around them, Mr. Temple, the Chief Commissioner, appointed Pearson the first Conservator of Forests of the Central Provinces in 1860. Pearson, being endowed with an iron constitution and great energy, devoted the next eight years to the organisation and administration of the 20,000 square miles of Government forests in the province, selecting and demarcating reserves, introducing a system of regulated utilisation, starting a successful method of protecting the forests against the annually recurring forest fires, and regulating shifting cultivation; in other words, substituting a regular system of management for the method of reckless devastation of the past. His success brought him the special thanks of the Government of India for his valuable services.

In 1868 Pearson was transferred to the charge of the forests in the North-west Provinces, where he reorganised the department, estimated the yield capacity of the forests, and opened out the hill forests by the construction of roads, bridges, and timber slides, by which large quantities of timber were brought down to the plains for railway construction. In 1871 he was appointed to act for Dr. Brandis as Inspector-General of Forests, and in 1872 he left India to take up the appointment of director of studies to the British forest probationers at Nancy, a post which he held until 1884. On his final retirement he settled at Kington, where he lived for thirty-nine years, being a J.P. and the friend of all classes of the inhabitants.

Pearson, though not specially educated as a forester, energetically absorbed and utilised the leading principles of rational forest conservancy, and took a great part