CORRESPONDENCE

The Editor, JOURNAL OF THE ROYAL AERONAUTICAL SOCIETY.

Dear Sir,—I have read Lieutenant Salt's lecture with a great deal of interest. He has covered the broad fundamentals of the subject thoroughly and at the same time concisely. I admire his ability as a writer, because I know from experience how difficult it is to explain and describe photographic surveying methods. I do not concur in all of his conclusions and recommendations and believe several eminent photogrammetric engineers have quite different views. The wide differences of opinion among students of this subject are to be expected, in view of the great differences in the basic map problems of different countries and territories.

Taking his lecture by paragraphs :—

1. *The Social Function of Air Survey*

I am confident nearly every experienced surveyor or map technician, who has studied the functions of maps, will agree whole-heartedly with Lieutenant Salt. From an article recently published in the *National Geographic Magazine* on the history of mapping, I concluded maps were appreciated more a hundred years ago than they are to-day. It appears to be a fact that executives in charge of big construction projects will shop the whole world over to save a few cents per ton for steel and at the same time hesitate to approve expenditures for mapping, which might influence the basic designs sufficiently to save many tons of the steel itself. In the case of steel, of course, the comparative prices indicate the amount saved; unfortunately the possible savings from map information are harder to determine, because so often no map is ever made; therefore, no comparison becomes possible. Furthermore, a conscientious engineer will hesitate to estimate in advance what saving any particular map will enable him to make.

I believe the difficulty in definitely determining the money value of maps, both present and future, is one of the major obstacles to be overcome before people can be brought to recognise their necessity. If Lieutenant Salt has data on more cases similar to the Gold Coast Railway, I hope he will publish it.

2. *Photography as an Aid to Survey, and*

3. *General Theory of Stereoscopic Pairs*

Lieutenant Salt's method of explanation is splendid.

4. *Plotting Machines*

Lieutenant Salt has been very clear in his description of internal orientation, external orientation and setting of scale and orientation of relief model. Other lecturers and photogrammetric technicians often divide these various operations (there are six separate steps) into simply two general operations: Internal and external orientation. Various authors use somewhat different terminology. Unless a student knows the writers' peculiarities in this regard, he may become confused.

I fear such eminent engineers as Henry Wild, inventor of the Wild autograph plotter; Dr. Hugershoff, who developed the aerocartograph; Dr. von Gruber of Zeiss-Aerotopograph, G.m.b.H., who designed the stereoplanigraph; and others, may question Lieutenant Salt's statement that the Fourcade stereogoniometer is the only instrument constructed on fundamentally correct design. Theoretically, Lieutenant Salt is probably correct. It is a fact, however, that splendid maps are being produced economically with these other instruments and the recent application of the new Zeiss aerotopograph multi-lens camera to the stereoplanigraph promises not only to reduce costs materially, but to increase accuracy at the same time.

Lieutenant Salt points out the disadvantage of the high cost of these instruments. The cost is indeed high, especially in countries exacting import duties and often in addition royalties are assessed. One stereoplanigraph, together with the Zeiss four-couple camera, imported, set up and placed in operation in the United States, involves approximately $50,000. However, experience has proved instruments of this type have a long life, in fact they will probably be made obsolete due to some future invention long before they wear out. The carrying charges and necessary reserves for obsolescence are heavy, but by working the apparatus in shifts so as to keep it continuously in operation, my computations indicate the cost per unit of map produced will compare most favourably with the best of all other methods, in producing maps of a high order of accuracy or at the larger scales.

5. *Simplifications in Case of Vertical Photography*

I do not entirely concur with Lieutenant Salt's conclusions. Much depends upon the scale and accuracy of the map required. For the reconnaissance or semi-reconnaissance type of map, made at the smaller scales with considerable tolerances permitted, his method has many of the advantages claimed for it. However, as mapping specifications become more rigid and greater accuracy is required, I believe the automatic plotting stereoscope will unquestionably prove more efficient.

Let us review the advantages Lieutenant Salt enumerates. He claims:—

(1) *Simpler and cheaper equipment may be used.*

This is true and in turn permits quick and easy transportation, which should interest military men.

(2) *Film negatives and paper prints are normal, with correspondingly simpler air photographic problems.*

I cannot agree. The modern plotting machines use film successfully. Paper prints are not even essential, although they are desirable for many collateral purposes. The greatest difficulty in aerial photography I have experienced is to get photographs without tilt; the camera bubble is not a dependable indication and the only reliable test is laborious comparisons and computations from the ground control. Unless tilted pictures are detected and corrected, the portions of the map corresponding thereto will be in error. On the other hand, tilted pictures do not affect the accuracy or speed of automatic plotting. My experience indicates that aerial photographic problems with automatic plotting methods are slightly simpler than with Lieutenant Salt's method.

(3) *Less ground control is required, and no hard and fast layout is necessary. Whatever control there is may be used to the best advantage.*

It is extremely difficult to draw fair comparisons between relative costs of the ground control required with different methods because again so much depends upon the scale and accuracy of the final maps.

For example, if the "aerocartograph" plotting stereoscope were selected for the production of a map of civilised territory to a scale of 1 : 50,000, we would ordinarily require two control points for each 2.65

square miles. That is at the rate of .75 control points per square mile or 75 points for an area of 100 square miles.

The accuracy of the control is a function of the accuracy required in the map. The control points must be three times as accurate as the map. That is if a tolerance of nine feet is allowed in the elevations as represented by the contours of the finished map, the control points must be determined within three feet of their true elevation.

According to Lieutenant Salt's lecture, four points per square mile are required in his method, which means 400 points for a 100 square mile area. This is five times as much control as required with the plotting machine for a 1 : 50,000 map, but the comparison may not be entirely fair because Lieutenant Salt may intend to control a different scale of map. However, I am surprised that he can get along with so few points even for the smallest scales. It would be interesting to know how accurate control must be for his method.

In this connection, one very interesting point is the fact that most plotting machines will absolutely not accept a control point which is in error, either in elevation or plan, and startling errors are regularly detected in the most carefully checked ground work. Such errors might pass unnoticed by Lieutenant Salt's method.

(4) *The work of plotting may be sub-divided among a large number of draughtsmen, thereby increasing the speed of map production.*

I believe plotting by machine is more accurate and uniform. It tends to eliminate the human error and quality is only slightly affected by the relative skill of the machine operators. Operators vary greatly as to speed, but only slightly as to quality. I have often had two operators draw a contour on transparent paper and, when superimposed, only one contour could be seen. On the other hand, the skill of draughtsmen often shows in the quality of their work as well as speed.

The speed of production will depend on the number of units working, whether they be teams of draughtsmen or " machines and operators."

6. *The Air Photographic Problem*

With the exception of tilted photographs and the necessity of multi-motored airplanes, my experience checks Lieutenant Salt's conclusions.

I believe it is extremely difficult, if not impossible, to secure any appreciable number of aerial photographs without a small percentage having tilt well in excess of two degrees. It is true that the majority may be satisfactory, but the few bad ones may be as dangerous as the weak links in a chain.

Multi-engine airplanes are desirable in bad country, but also expensive. Photographic flying is the safest of all aircraft operations. Flights are undertaken only when the weather is perfect. The altitudes are high and the tendency is toward greater heights. Therefore, in case of forced landings the pilot has a large area to pick from and good visibility. As a result, for photography single-engine ships are satisfactory over much worse territory than for transport services. The pilot assigned to a large air survey over a portion of the Andes Mountains, a rough, inaccessible, sparsely inhabited region, recently advised me he felt quite confident in his single-engine ship, because at his altitude, even in such country, he usually had an emergency field within gliding range.

Many photographic pilots like a glass bottom in the fuselage of the ship directly under the control stick, in order that they may have clear vision directly beneath them.

7. *Air Survey Procedure*

It is hazardous to prophesy further developments in the art of air survey, but the trends are surely towards multi-lens cameras. The economies which might be made possible through the application of the multi-lens principle were recognised by Scheimpflug thirty years ago, at which time he worked out a design for a nine-lens camera. Something over six years ago, Mr. Leon T. Eliel, of the Fairchild Aerial Surveys, Inc., designed and patented a nine-lens camera which in air tests gives promise of being a splendid instrument. Photogrammetry, G.m.b.H., of München, Germany, has designed a nine-lens camera unit which resembles Mr. Eliel's camera very closely. The economic application of the nine-lens unit is subject to much controversy and the ultimate success is problematical.

U.S. Army three-lens, four-lens and five-lens cameras have all been proved satisfactory under regular service use. The latest of these is the five-lens, which has proved to be so efficient that it is somewhat doubtful if efforts will be made to increase the number of lenses in the near future.

Zeiss-Aerotopograph, G.m.b.H. (a company affiliated with Carl Zeiss, Jena, Germany), has adopted four lenses for its multi-lens camera unit.

Rather than cameras having a greater number of lenses, I wonder if the next big step towards more efficient mapping will not be in connection with high altitude airplanes. Possibly ceilings of 30,000 feet can be reached for photographic work. These higher altitudes would permit much greater areas to be covered on each photographic flight and achieve most of the economies which camera designers are now striving for with their multi-lens developments.

Yours very truly,
Fairchild Aerial Surveys, Inc.,
E. R. POLLEY, *Vice-President.*

REPLY BY LIEUT. J. S. A. SALT

It is very gratifying to have the opinion of an expert that my paper fulfilled in some small measure its object of presenting in a compact form some cardinal aspects of air survey. The points of disagreement are, I think, due partly to the inevitable omissions of such compression, and partly to the necessity in such a broad subject, of limiting the boundaries of one's objective. The objective in this case was survey from the point of view of developing the British Empire, the immediate crying need of which is for good maps on medium topographic scales, say from 1 : 50,000 to 1 : 500,000. The method described has been arrived at as a result of examining all the factors involved; photographic, topographic and cartographic, from the point of view of technique and personnel, modified by the existing organisation of the Empire itself. It makes no claim to be necessarily the most suitable for a private company operating by contract—the factors involved are usually very different.

These considerations will explain the regretted omission of a discussion of the merits and applications of such plotting machines as those of Wild, Hugershoff, Zeiss, Nistri, Poivilliers, Gallus, etc., all of which have done excellent work, but almost entirely on the larger scales from 1 : 1,000 to 1 : 20,000. With regard to the design of the Fourcade stereogoniometer my somewhat laconic statement was based on the following facts:—

(1) Most of the continental plotting machines, and in particular those of Wild, Hugershoff and Zeiss, were designed originally for terrestrial photogrammetry, where each goniometer in the plotter can be set to a known orientation, and their equivalent separation to a known scale.

(2) In air photogrammetry these latter quantities are not known. They were originally determined by the resection in space of each photograph from four

https://doi.org/10.1017/S0368393100109551 Published online by Cambridge University Press

known points, and the design of plotting machines (*e.g.*, the function of the x, y and z axes) was flavoured with this outlook.

(3) The principles of mutual orientation of two photographs by means of correspondence in five basal planes were expounded first by Dr. Fourcade in 1925 and his stereogoniometer was constructed to carry out this operation in the most efficient manner. The straight line joining the rear nodal points of the goniometer lenses consequently became the air base and the five setting movements were related to this.

(4) Users of other plotting machines also discovered the necessity of the *method*, but the machines they used were not constructed to carry out those *principles*. Consequently various additional movements were incorporated without consideration of the fundamental principles involved.

(5) A result of this is that in such machines the setting for scale and orientation of the relief model cannot be carried out without upsetting the mutual orientation, and the two processes can only be finally achieved by successive approximation or by the use of correction tables or nomograms. In the case of the Zeiss stereoplanigraph, it has led to a curious anomaly. One corner of the famous "Zeiss parallelogram" is moved during setting out of the plane containing the other three, thereby destroying the function of the properties of the parallelogram on which the mechanism is based.

As a result of this neglect of fundamental principles certain of these machines thus introduce definite errors, which, however, under normal conditions are reasonably small. I do not suggest that they do not offer highly efficient and practical solutions to many survey problems, but, to qualify my original statement, I do believe that these faults would be avoided if the designers tackled the problem afresh and from the point of view of air photography first, and that the result would be a plotting machine far simpler in design and of even greater application.

The question of ground control is somewhat thorny, and all generalisations are dangerous. Comparisons can seldom be fairly made unless a particular problem is chosen and all the various factors discussed. In this case, however, Mr. Polley has, I think, slightly misunderstood my statements. Using the method described, the ground control required for a map on a scale of 1 : 25,000, in quality equal to that obtained by good ground methods, is as follows:—

(i) For planimetry: A second order triangulation, say one point per 10-15 square miles.

(ii) For contouring: Four spot heights per square mile. The *positions* of these need not be fixed, and they are obtained by means of aneroid barometers and marking on the photographs.

The particular point urged was the flexibility of the demands on control. In a particular case, for instance, maps on a scale of 1 : 50,000 were produced of an area of nearly 2,000 square miles in Transjordan, where the control consisted of half a dozen astronomical points and a couple of barometer traverses. The results are, of course, by no means perfect, but bearing in mind the nature of the country and the purpose of the map, fulfil the original object in a practical manner.

The question of multi-lens cameras is of great importance for the future. The factors here seem to me to be as follows:—

(i) If the greater angular field available is to be used to reduce the costs of flying, while maintaining a favourable ratio of air base to height, then the area of ground covered at each exposure should, for efficiency, be roughly square in shape.

(ii) If we take an angular field of about 120° across the flats of this square picture as representing the maximum obliquity which can conveniently be used, then in order to make use of the wide angle properties of the modern survey lens, a seven-lens camera is the most efficient.

The American five-lens camera which produces a photograph in the shape of a Maltese cross appears to be of no more value than a three-lens camera. It may be though that I have not the latest information on this point.

I feel sure that Mr. Polley's remarks and my own actually fit without discord into the same framework, and that such differences of opinion as have emerged arise from the widely different points of view from which we approach the problem. A third opinion might be focussed on yet another facet of the central theme. The most important fact, however, is that the great body of data on this subject has now reached a stage where it can offer a suitable technique for the solution of almost any survey problem. It remains to educate the administrator.

REVIEW

Thermodynamics Applied to Heat Engines

By E. H. Lewitt, B.Sc., A.M.I.Mech.E. Sir Isaac Pitman and Sons, Ltd. 12s. 6d. net.

This text book has been written to cover the syllabuses of the B.Sc.(Eng.) and A.M.I.Mech.E. examinations on this subject. It deals with the laws of gases, unicycles, entropy, air compressors, refrigerators and fuels. In addition, seven chapters are devoted to steam engines and turbines, and two only to the internal combustion engine. Considering the extensive modern use of the internal combustion engine as a prime mover in all industrial applications, it would seem that more space might have been devoted to the latter, but it is presumed that this is due to the syllabuses referred to.

The book is clearly written, adequately supplied with diagrams, and can be thoroughly recommended as an excellent text book on the subjects with which it deals.

https://doi.org/10.1017/S0368393100109551 Published online by Cambridge University Press