THURSDAY AFTERNOON SESSION

January 22, 1948

The meeting reconvened at one-forty o'clock, President Sanders presiding.

President Sanders: For those who are interested, the registration at eleven o'clock this morning numbered 850. That is a tremendous number, and probably before the meeting is over the total registration will be in the neighborhood of nine hundred, the highest we have ever had. That is a tribute to the Program Committee.

The luncheon was very well attended this noon, with about one hundred twelve present. That is encouraging. There will be another luncheon tomorrow. We urge you to get your tickets today, if possible, so that we can obtain a larger room.

I will announce once again that there is an addition to the program. This afternoon a film prepared on one use of the helicopter by the Engineering Research and Development Laboratories at Fort Belvoir will be shown following the last speaker. I understand that it is an outstanding film and well worth seeing.

I will now officially open the program for this afternoon. We have long had a custom whereby the Canadian Institute of Surveying and the American Society of Photogrammetry interchange official delegates at their respective annual meetings, and the chief delegate in each case has always been invited to prepare a paper.

I was fortunate enough to be the delegate last year to the Canadian Institute, and I had a marvelous time up there and found it very well worth while. It is fine to have this pleasant relationship with a similar society in another country, and I think both societies grow in stature by virtue of the interchange of ideas and viewpoints.

This year we are continuing that custom, and we have once again an outstanding delegate to speak to us. Before I introduce him, however, I would like to mention the annual meeting of the Canadian Institute of Surveying. That meeting will take place February 4th in Ottawa, Canada. The meeting is well worth attending, and while I have no written authorization to extend an invitation, I at least can do so on my own, because I am a member of the organization. I know that every member up there would be glad to have us attend. It is a most hospitable group, and I hope many of us can attend their meeting.

The man who comes to us from that organization is well experienced in photogrammetry. He is Major J. I. Thompson, from the Army Geographical Service, as I know it, but I think they have changed the name. He is going to give the address on behalf of his organization, and I am glad to have him here with us to speak on the "Application of Terrestrial Photogrammetry to Multiplex Heighting in Canada." Major Thompson.

Major J. I. Thompson: Mr. President, Ladies and Gentlemen: My first task this afternoon is a very pleasant one. I wish to convey to you greetings from the members of the Canadian Institute of Surveying. Those among our members who have been fortunate enough to attend other annual meetings of this Society in the past have always returned with glowing reports. I know already from my own experience that this year will be no exception.

Those of us from across the border have appreciated the kind invitations which you have given to us from year to year, but even more so we value the genuine friendship which you have offered to us.

Mr. President, I trust you will accept these greetings and with them our very best wishes for the success of your meeting and for your Society in this future year. I would like to add in this introduction that I feel, first of all, rather honored to be able to represent our organization, and I feel very humble in the fact that there are members here, particularly one of them, Mr. R. B. McKay, to whom we have looked for advice and help in our work at home, especially those among us who have not had the previous extensive experience that Bob himself has had, I hope that you will bear with me. If there are any extra noises that you hear, that is just my knees behind this desk.

The title of a recent travel book on Canada was rather aptly given as "The Unknown Country"—she is one of the "unmapped" countries of the world. Approximately 40% is covered by 4 miles to one inch topographic maps, and less than 5% by 1 mile maps. In the bulk of the unmapped areas, the only lines of communication are those that nature offers; the Rocky Mountain region provides areas of extreme relief while the pre-Cambrian shield, which has only low relief, is very difficult to traverse. Thus mapping in Canada has always been a "tough " problem. The progress made is a tribute to the small group of men who have persevered against the trials of nature.

It can readily be seen that the photogrammetric techniques which will have the most to offer for Canadian problems are those which substantially reduce the amount of field work required. The use of slotted templets has made possible reducing the horizontal control formerly required by a third, as well as producing a better result. Vertical control, however, still offers a difficult problem, particularly in the mountainous areas. It is the purpose of this paper to discuss two methods by which this problem has been attacked in Canada, by terrestrial photogrammetry and by multiplex.

Multiplex was first introduced to Canada in 1937. The operation of the Zeiss narrow-angle projectors with low altitude photography did not prove economical and little work was done after 1940. Overseas the Canadian air survey company made extensive use of narrow-angle equipment originally made for the U. S. Engineer Corps. Early in 1946 our first experimental work on bridging vertical control using the overseas equipment with Canadian $8\frac{1}{4}''$ photography gave promising results. These results were verified and improved when Bausch and Lomb wide-angle equipment became available for the first time in Canada in 1947.

The methods used in bridging are not original. They were first observed at B Co 660 Bn US Engineers in Paris where Capt. Bauer and Chief Warrant Officer Wolverton employed them in operational work; modifications in calculations were made by Dr. L. G. Trorey in 1945 and no fundamental changes have been made since then. More recently I have been informed that similar calculations were used in prewar Europe in the operation of the Wild A5 and the Zeiss stereoplanigraph.

The fundamental assumption is that the tip curve which inevitably appears in multiplex extensions follows a regular pattern and may be calculated using the general curve $y=ax^n$, where y is the height correction due to tip, x the distance from origin along the line of flight, and a and n are constants. Lateral tilt is assumed to be linear. Sufficient control to set up the initial and final overlaps only is required.

In practice the procedure is as follows:

Operation

1. The initial overlap is carefully set up to control.
2. The second overlap is brought into correspondence with the first, great

care being taken to eliminate all want of correspondence in the model and also to see that the pass points common to the two models read exactly the same in both.
3. This procedure is repeated for each succeeding overlap until the extension is complete.
4. The horizontal position and model reading of all intermediate control points required is noted on a trace fastened in position on the plotting table.
5. The extension is now broken up and the final model set up to control; model readings are taken on the same points noted in the extension. This completes the operator's task.

Calculation

1. A comparison of readings on points in the final model as provided by results from the extension and true setup gives a correction which may be used to calculate the values of the variables in the tip curve $y=ax^n$. The tilt may also be evaluated from these corrections.
2. With this information and distances from the initial overlap as given by the trace, error in height due to tip of each intermediate control point may be determined.
3. The same trace gives the distance each intermediate control point is from the line of flight; with this information and with the distance from the initial overlap the tilt correction may be determined.
4. These two corrections are added algebraically to the model readings to give the final adjusted value.

This very briefly is the procedure followed for determining the height and position of a number of intermediate control points on a single extension. A large mapping project requires a slightly different procedure although the fundamentals are the same.

Several extensions in areas of low relief using from ten to fifteen projectors were run this past summer for experimental purposes. The average error of heights of intermediate points in these extensions was about 10 feet, approximately 0.35 mm in model scale. This is about the same error as was found in narrow-angle investigations, but the maximum number of overlap bridged then was ten. In the long extension the effect of the earth's curvature was taken into account. Further work to prove the value of this method is required before putting it into full operational use, but it has proved of assistance in the few times there has been occasion to use it.

Approximately 62 years ago the late Dr. Deville, then Surveyor General of Dominion Lands, sent out the first field party to carry out terrestrial survey photography in Canada. Since then practically all mapping in the Canadian Rockies has utilized this method. The techniques that were employed by Dr. Deville's men have changed with the passing of time; improvements in the manufacture of instruments, small lens cameras and photographic plates, along with the advent of vertical air survey photography have been responsible for the principal changes.

The mountainous regions in Canada present a very difficult mapping problem. The only practical means of establishing main horizontal and vertical control is triangulation. The task of supplying the necessary intermediate control in a seemingly inaccessible country is further complicated by a short field season. Terrestrial or horizontal photography offers one of the most economical means of establishing this control. When each triangulation point is occupied a

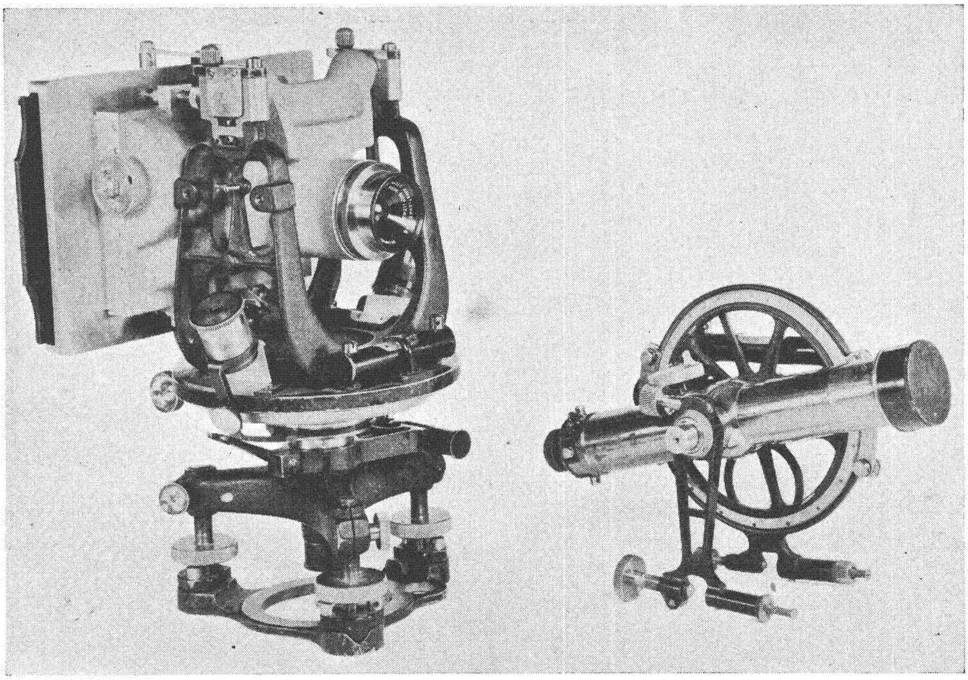

FIG. 1. Photo of camera.

round of horizontal photographs is also taken and the direction of each photograph noted. Often auxiliary camera stations are needed to give the desired coverage; their positions are determined instrumentally in the field and the horizontal photos taken in the normal manner. Thus the mountains are carried back to the office in the form of photographic plates for plotting at the end of the field season. The instrument used is designed for precision as well as compactness. A small camera taking a $3\frac{1}{4} \times 4\frac{1}{4}$ plate and a telescope are interchangeable in the transit standards (Fig. 1). This feature enables the operator to determine the exact direction of each photograph taken. Although in this paper we are more concerned with office procedure, I feel we should not leave this résumé without discussing the importance of the part the field man must play. His choice of stations, his operation of camera and theodolite can make or break the entire project; in addition he has many a cross to bear, such as the management of pack trains and camp in areas miles from the nearest habitation, the climbs of several thousand feet to stations, the handling of instruments in face of thirty mile an hour winds at freezing temperatures, the heart-breaking disappointment of a long climb when fog and rain suddenly descend and necessitate a return trip, and many others. Surveying in Canada has never been a pastime but working in mountainous areas calls for a degree of skill, initiative and sheer tenacity that few types of field work demand.

The preliminary office work consists of computing the position and elevation of all the camera stations and plotting them on the manuscript. Enlargements, approximately 3 times are prepared from the $3\frac{1}{4} \times 4\frac{1}{4}$ plates and their equivalent focal length computed. The compiler is now ready for the initial part of his task; with the horizontal photographs, he must supplement the framework of triangulation with enough auxiliary planimetric positions and heights to control the verticals.

The first step is to determine the approximate positions in which supplemental control is desired. This done, the next problem is to choose points in these areas which may be identified on both the vertical and terrestrial photos. This is probably the most difficult task and requires considerable experience. The success and accuracy of the entire job depends on accurate identification more than any other single factor. When the points have been selected their planimetric positions and elevations are determined from the terrestrial photographs. Position is determined by intersection; for example a point A appears in photographs taken from stations 1, 2 and 3. The direction of the principal vertical of each of these photos is plotted on the manuscript from field information. The horizontal angle to A then may be determined and plotted. These three directions to A if correctly determined will intersect at one point, thus giving its true horizontal position. The horizontal distance to A from station 1 may now be scaled from the manuscript; this combined with the angle of depression will give the difference in elevation between A and station 1. Similarly the differences

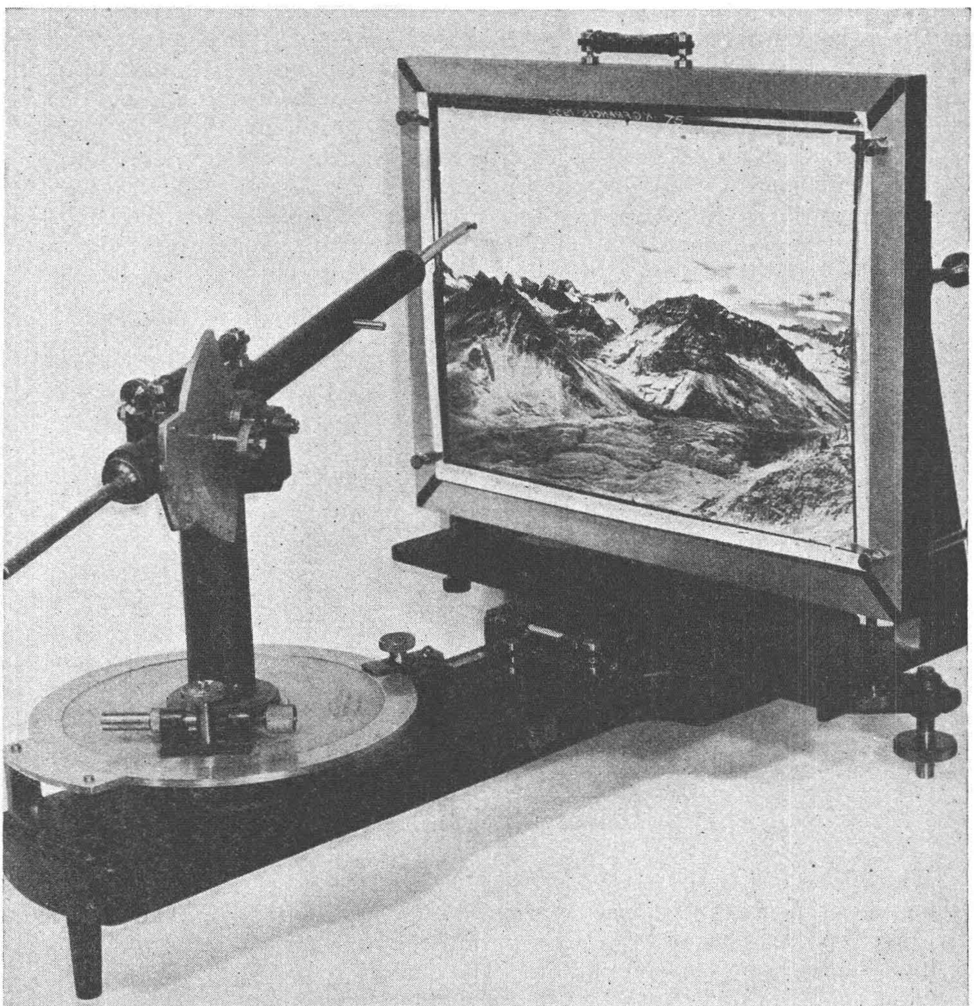

FIG. 2. Photo of angle measuring device for horizontal photos.

in elevation between A and stations 2 and 3 are determined and an average value for A's elevation arrived at.

The horizontal and vertical angles referred to may be determined graphically or instrumentally quite simply. An instrument used for this purpose is shown in figure 2 and the simple geometrical relations governing the determination of these angles are illustrated in its operation.

When sufficient elevations and planimetric positions have been determined, the normal methods of compiling a topographic map from vertical photographs in areas of extreme relief are followed.

Field work in the past season was carried out on the basis that the normal methods of compilation using horizontal survey photographs would be used. The acquisition of new wide-angle multiplex equipment opened new avenues of approach to this problem and in the past few months a method in which the multiplex is used in conjunction with horizontal photographs has been evolved.

Previous experience in bridging has indicated that the tip curve in multiplex extensions is quite small near the origin; in most cases it was less than half of one millimetre of model scale at the third overlap. Thus in a set of six projectors, in which the centre two are properly levelled off, the "bow" in the model due to the presence of the tip curve would not be greater than one half millimetre. If the multiplex bar position is altered so that points at the centre and one end of the extension read correctly, the bow between them is reduced to one quarter of the original, and the detail and topography in this portion may be taken off with very little error caused by the tip curve; the detail and topography at the other end of the extension may be taken off when the position of the bar is altered to create a similar condition. It is doubtful if this procedure would cause an error of more than 10 feet, which with a 100 foot contour interval is not a serious discrepancy.

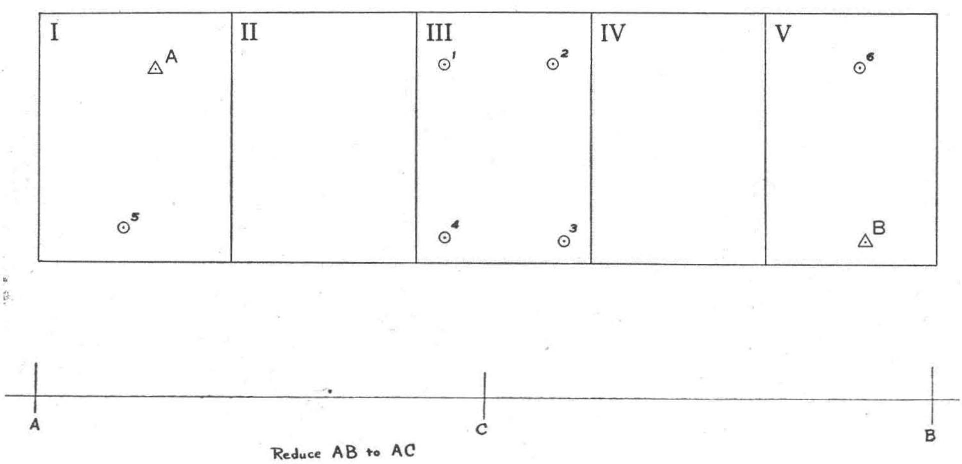

FIG. 3. Diagram showing numbered overlaps.

The initial part of the office procedure is the same as before. The positions of triangulation points and camera stations which appear in approximately every fifth overlap of the vertical photograph are computed and plotted on a manuscript. The selection of points follows. The density is considerably less than before but their position relative to the triangulation points is important. Let us take for example a series of five overlaps, with triangulation points A and B appearing on the initial and final overlaps (Fig. 3). First, auxiliary control points 1, 2, 3, 4 must be chosen in overlap III so that the overlap may be properly scaled and horizontalized. In addition, points 5 and 6 are required in overlap I and V to ensure that lateral tilt may be controlled.

Multiplex operation may now commence. Overlap III is set up to the control given and, overlaps II and I, and IV and V added as in extension work. Points A and B are used as the basis for final scale adjustments and their elevations combined with those of the auxiliary points to control tilt. When these adjustments are complete the position of the entire bar is altered so that the model readings of points 1, 2, 3, 4, 5 and A are correct; the contours and detail of overlaps I and II may now be taken off. When this is complete the bar is again adjusted so that the model readings of 1, 2, 3, 4, 6 and B check; the topography of overlaps IV and V is now taken off.

In this example the control points were very favourably sited. Often triangulation points do not appear or the terrestrial photos do not cover the areas as desired. These instances can usually be foreseen in the initial planning stages and auxiliary points established in adjoining flights to overcome the difficulties. At the time of writing, little difficulty has been encountered in the running of individual strips or in assembling the work from the different adjoining strips.

The value of two-ray, or narrow three-ray intersections in photogrammetric methods has always been questionable. Terrestrial photogrammetry is no exception to this rule. The difficulties of precise identification and transfer are responsible for the slight inaccuracies that occur in horizontal positions. For this reason in the procedure outlined it was stated that although the initial setup is controlled by auxiliary points, the final scale is determined by triangulation points.

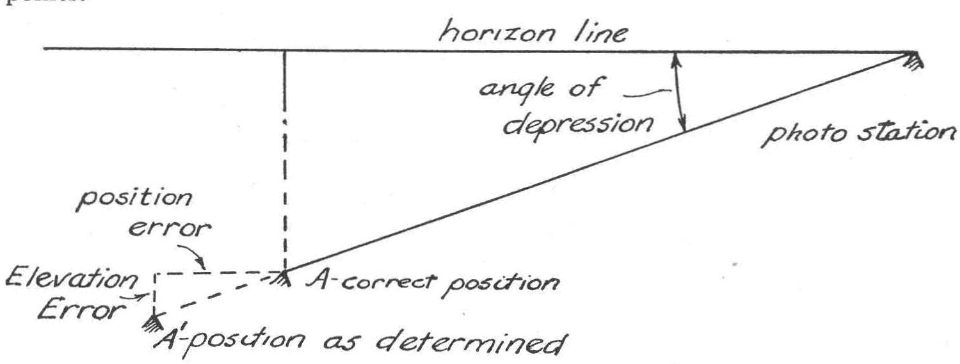

FIG. 4. Diagram showing error in elevation due to error in position.

The values of elevations as determined from these points is of a higher order than their position. This may easily be seen by a study of the basic theory (Fig. 4). The difference in elevation between the camera station and auxiliary point is the product of the tangent of the angle of depression from the horizon to the point and the horizontal distance between them; the error in elevation due to incorrect position is then the error in position times the tangent.

The field of the lens allows a maximum angle of depression along the principal vertical of about 22°. The maximum angle of depression normally used is around 15° and has a tangent of 0.27; hence the error in elevation would be about one quarter of the error in position.

This is the first year in Canada in which the multiplex has been used in conjunction with horizontal photographs and it is probable that the next few years will see many changes made in the procedure just outlined. It is felt that it is a definite step forward in mapping mountainous regions.

In this paper no reference has been made to the various government agencies which have carried out this work in Canada. The original mapping with horizontal photographs was under Dr. Deville's direction in the Department of the Interior. In conjunction with the International Boundary Commission, the Geological Survey of the Department of Mines, and the Topographical Division of the Department of Lands and Forests of British Columbia, they mapped approximately 50,000 sq. miles in the years prior to 1925. The Topographical Division of the Department of Lands and Forests of British Columbia pioneered in the use of horizontal photos with verticals. Later the Topographical Survey of the Dominion Government followed suit, adapting trimetrogon photography for four mile to 1 inch in mapping as well. The experiments in bridging vertical control with multiplex and the operational use of horizontal photographs in conjunction with multiplex are being carried out at the Army Survey Establishment.

PRESIDENT SANDERS: Thank you, Major Thompson. We trust that you will take back with you our sincere appreciation to the Canadian Institute of Surveyors, for which you are the delegate.

We have just heard from our good neighbor to the north. We have another neighbor, not close in the sense of miles, but which is very close to us in the sense of language and cultural background. We have been trying to have this gentleman with us for a long time, and it is fortunate that we succeeded at the time of our annual meeting in having with us Mr. F. L. Wills, the founder and director of the first air photographic company in England. He is now Managing Director of the Hunting Aerosurveys, Ltd., of London.

Mr. Wills, Member of the British Empire, is a Fellow of the Royal Photographic Society. He is a member of the Royal Society of Arts, and is also a member of the British Institute of Photographers. But most important of all, to us at least, he is a member of the American Society of Photogrammetry.

I have great pleasure indeed in presenting Mr. Wills who will speak on the subject of "Equipment and Methods Employed by the Hunting Group of Air Surveys Companies."

MR. F. L. WILLS, M.B.E.: Mr. Sanders, Members of the Society, Friends and Distinguished Guests: I am very glad that your President mentioned that I was a member of the Society, because I wear a red badge, which is a guest badge. This I think is due to the hospitality of the committee because of the fact that I was permitted to come here by the goodness of the British Treasury who hand out their dollars in sufferance.

I appreciate the honour of submitting a brief paper to this Society which has done so much towards the advancement of Photogrammetry throughout America and the rest of the World. I must first explain that I am not a technician but a business administrator and therefore I am not able to give you a learned exposition on the Science of Photogrammetry. Perhaps the brief outline of the activities of my Associated Companies within the British Empire will provide you a little diversion, at this stage of the Conference.

The Hunting Air Survey group consists of a number of associated companies established in Africa, Canada, Australia, New Zealand, South America and the United Kingdom. The Group takes its name from the Chairman of my London Company, Mr. P. L. Hunting, who co-ordinates the various interests of the companies. He comes of an old Scottish family, which from 1860 was associated with ships of the sea and to-day is, in addition, associated with ships of the air.

Varying types of available civil aircraft, modified for air survey are used within our Group of Companies. There is the "Bristol Freighter," with 1350