The last half of the Mexican Springs topography was turned out on the Stereoplanigraph at the rate of one square mile per each two hours, complete. The necessary control cost was approximately $15.00 a square mile. Add to this the depreciation and amortization on the equipment and the time of an operator and assistant for two hours, and you arrive at a cost per square mile. If this equipment were used by a Government agency and operated at its maximum effectiveness, maps could be made to the existing standards in all but flat or densely timbered country at not to exceed one-half of the present cost. This statement is based on maps at a scale of 1:24,000. As the scale gets smaller, the methods obviously approach each other in efficiency. It is, however, practically certain that within a year or two, 30,000 feet airplanes will be available which fly at high speeds, at which time the photogrammetric method will result in a tremendous economic advantage, even at scale of one inch equals one mile and smaller.

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DISCUSSION OF MR. ELIEL'S PAPER

by

W. N. Brown

I am sure that all of us who have had the opportunity of hearing Mr. Eliel present this paper have had our faith in the efficacy of photogrammetry as means of making topographic maps, strengthened. I hasten to express my appreciation of the service he has rendered. Certainly the map of the Mexican Springs area which he has exhibited for our inspection is most impressive and shows a wonderful amount of topographic detail and expression. I feel also that those of us who have examined the Stereoplanigraph intrument itself must want to pay tribute to the mechanical skill and the profound thought that has brought about its production.

Since I am on the wrong side of sixty years of age, Mr. Eliel's remarks concerning the optical gymnastics required of the eye of a Stereoplanigraph operator intrigued me very much, and I am afraid that I have spent far too much time trying out the ability of my own eyes. The results may be interesting if not instructive. I find that the stereoscopic image begins to separate when the distance between the images on the two photographs is about 3.4 inches apart. The position of the eyes were about 8 inches from the photographs. The distance between my eye centers is approximately 2.4 inches. I figure that the divergence of the axes of my eyes to be 7 degrees at the time of the separation of the stereoscopic image. If I am correct, there may be some hope for men up to sixty years as stereophotogrammetric operators.

Necessarily, it is of vital interest to learn the extent of the application of this method to serve the map needs of the engineer. Mr. Eliel in his paper deals with maps in the abstract. The application of the method in practice will have to deal with each individual type of map. The word map probably conveys a different meaning or conjures up a different picture to the mind of each person. The two maps mentioned by him were both small-scale maps with rather large contour intervals. The Mexican Springs map is on a map scale of

1:24,000 or 2½ inches to the mile with a contour interval of 20 feet. More than 80% of the engineering demand is for maps of a larger scale than 1 inch equals 1000 feet, and much of it is for maps on a scale of 1 inch equals 200 feet or larger. The contour interval demanded is usually from a five foot interval down to 1 foot interval. It would be of great interest to know how well the Stereoplanigraph will meet the demands for maps of this class and what is the upper scale limit of its practical use. Also scale and contour interval alone may not be the determining factors limiting its use. Type of country must seriously affect its use, such as timbered areas and those areas of slight relief lacking in definite shapes or recognizable individual points. Mr. Eliel states "At any give instant we are only interested in one point on the ground--that is, we constantly construct our contour line as a continuous series of points." It must follow that in a monotonous type of country, especially if covered with grass or timber, the contour location must be indefinite due to the lack of definite recognizable points for location along the line of the contour.

In the eastern states, more than half of the area is covered by timber. In the Mississippi Valley and western areas, there are vast grass covered plains and wide river valleys with slight relief where the shapes from a stereoscopic view point are non-existent. Use of the method in these areas I should think would be both difficult and unsatisfactory. It seems probable that 50% of the area of the United States will not be adapted to its use from these causes alone, regardless of the scale and contour interval that may be desirable.

Map scale and contour interval may limit its use in two ways, namely as they affect cost, and the accuracy with which elevations may be determined. In present day ground methods of mapping, costs increase nearly in proportion to the increase of the mapping scale. In photographic mapping, the number of photographs to be handled increase in the ratio of the square of the scale. It seems probable that costs where the Stereoplanigraph is used will increase nearly in this latter proportion. If this is true, then as the map scale is enlarged, the Stereoplanigraph costs will soon outstrip those of the ground methods.

Accuracy of elevation determination is probably a more serious factor than that of cost. Mr. Eliel and others familiar with the operation of the Stereoplanigraph have stated that the accuracy of elevation determination is a function of the elevation above the ground surface at which the photographs are taken and that the probable error of such determination is about 1/1200th of the flying height. If the map scale is to be 1:24,000 or 2000 feet to the inch, then with the camera described, a flying height of 10,600 feet would be required. The probable error of elevation determinations would be 1/1200th of that height of 9 feet. If it is assumed that contours should be correct within 1/2 the interval, it would seem that a twenty foot interval would be about the smallest interval that could be safely used on a 2000 foot to the inch scale, with assurance that the contour would be within the prescribed limit. This does not make allowance for possible horizontal position errors.

On detailed maps for engineering use, spot elevations add much to its usefulness; by spot elevations I meant numbers, showing the elevations correct to the nearest tenth of a foot, of road summits and depressions, road intersections, road and railroad bridges, tops of levees, and to the nearest 1/2 foot of critical topographic points as bottoms of depressions, summits of hills, saddles of ridges, tops of cut banks, water levels of streams, high flood marks, etc. It is well not to forget that unless one uses a very small contour interval of say one or two feet that there are many features that cannot be properly shown by contours alone, but they can be expressed by a wise selection of spot elevations, even though the contour interval be as large as ten feet. These elevations are determined in the process of contour location by ground methods, so can be shown without additional cost.

Concerning proof of the accuracy of location of the contours by the Stereoplanigraph method, I cannot share Mr. Eliel's belief that the production of contours on the adjacent models that match within the specified limits is a more convincing demonstration of the accuracy of their location than would be the test of instrumentally determined positions and elevations over the map. The production of such joining contours means nothing more than a uniformity of product and may have nothing to do with accuracy of position or absolute value. One had just as well say that because a transit chained traverse closes upon itself with a very small closure error that it is proof that the points located by that traverse are of a high degree of precision. Such closures mean merely a consistent or uniform method of procedure in making the measurements and have nothing to do with the accuracy of the traverse; if the methods are wrong, the position will be wrong. One can take a tape which has a length 50% in error and run a traverse that will close perfectly upon itself, yet located positions will be in error by 50% or more.

It seems to me that the Stereoplanigraph can be used to best advantage in open country having rather sharp and definite relief forms and at map scales of 1:24,000 or smaller with contour intervals of not less than 20 feet.

The questions raised by me in this discussion concerning the limitations of the method are not intended as adverse criticism but are intended to provoke discussion that these points may be clearly understood by all of us. If there are limitations, they should be clearly understood and recognized. No one thing could do the Stereoplanigraph and indeed the entire subject of photogrammetry more than [illegible] attempts to use the method on maps beyond its limitations, thereby causing failure and dissatisfaction.

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REPLY TO MR. BROWN'S DISCUSSION

by

Leon T. Eliel

Mr. Brown has raised a number of pertinent points in his

discussion and to do justice to the answer would require another paper at least as long as the original. No attempt will therefore be made to give complete answers to a number of Mr. Brown's suggestions, but some of the more important ones will be touched upon insofar as space permits.

Mr. Brown asks as to the limit of large scale plotting for which the Stereoplanigraph is suitable. The writer is not prepared to answer what the limit is although he has had considerable experience at plotting maps at scales of one inch equals 20 feet and one inch equals 30 feet made to the following specifications.

"In any square measuring 100 feet on a side, the mean ground surface as depicted by the contours, shall not vary from the true ground surface on an average of more than 3/4 of one foot, measured normal thereto."

I am afraid that Mr. Brown has misunderstood my statement relative to representing the ground merely as a point, and the creation of a contour line as a continuous series of points. Those familiar with stereoscopic instruments will at once appreciate that the entire surface of the ground within the field of operations is revealed in beautiful stereoscopic relief. It should be noted that I said that we were only interested in one point on the ground at any given instant.

There are certain flat areas of the United States which are not suitable for stereoscopic plotting. I cannot, however, agree that 50% of the area of the United States is unsuitable for stereoscopic plotting. Slightly rolling and undulated country is ideal for this method. In clarifying this point, it might be said that in any country which is so flat that a map at a scale of 1:24,000 would have to have 5 feet contours to appropriately reveal the surface of the ground which is too flat for stereoscopic plotting by the aerial method.

Mr. Brown is mistaken in quoting me as having said that the probable error in the determination in any elevation will be 1/1200th of the flying height. It has been stated that the probable maximum error of Stereoplanigraph work will be 1/1500th of the height.

Mr. Brown apparently fails to understand that the area plotted from each stereoscopic model, on a machine such as the Stereoplanigraph, is, for all practical purposes, an independent survey, each based on a separate set of ground control points. I am inclined to believe that if Mr. Brown made a boundary survey by instrument of a certain parcel of land, and that if the same boundary lines in this parcel were resurveyed in the course of making a boundary survey of five or six adjacent parcels, and these other surveys all confirmed the length and bearing of Mr. Brown's lines, that he would consider this a pretty fair check.

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REPLY TO MR. ELIEL'S REPLY TO MR. BROWN

by

W. N. Brown

My curiosity is still unsatisfied concerning most of the points upon which it had been aroused by Mr. Eliel's paper on the Stereoplanigraph. I sincerely hope either Mr. Eliel or some other qualified person will give at an early date that other paper which he says would be required to answer the points I have raised. I will give some of the particulars in which Mr. Eliel's reply do not satisfy me, in the hope that someone will be moved to discuss these matters and bring about a clearer understanding rather than just accept the statements made.

My question as to the limit of scale and contour interval to which it was practicable to use the method, referred to the method described, namely its use of four lens aerial photographs. The use of the Stereoplanigraph on scale of one inch equals 20 or 30 feet, mentioned by Mr. Eliel, unquestionably refers to its use of photographs taken with the phototheodolite which, I take it, is another matter altogether.

The specifications mentioned for this 20 foot to the inch contour work do not convey a clear meaning to me. I have tried to apply them to a specific area in which in the space of a hundred feet there are four distinct ridges and ravines, each taking four or five contours. The words "mean ground surface as depicted by the contours" does not seem to mean anything as applied to the accuracy and expression of these contours. The mean may be far from the truth at any particular point. My mind does demand a specification that will require the true representation of the contour at every point. I confess I do not understand the specification. Will someone explain to me just what is meant?

I appreciate the fact that with stereoscopic instruments the entire surface of the ground within the vision of the operator is revealed in stereoscopic relief. The same is true to natural vision when looking at the terrain itself. I feel sure the measurement of the value of this relief in feet and correct position for the contours is another matter. It was in connection with this measurement that I understood the definite points along the contour line had to be determined. I understand that the determination of these values by the stereoplanigraph is by a graphic form of intersection in which accuracy is dependent upon the relation of the photographic base to the altitude and the results are recorded by getting the floating mark in coincidence. If there are no distinct recognizable points for the eye to catch upon, then it seems to me the placing of the floating mark in coincidence with the ground image for any particular contour value must be an indefinite procedure.

I am sorry to have misquoted in connection with the ratio expressing the accuracy of elevation determination. I hope someone will take a specific example of map scale, flying height,

focal length and other factors and discuss the accuracy of elevation determinations with the Stereoplanigraph. The statement of maximum error ratio does not satisfy. What is the probable accuracy of these determinations? For example, one may safely say that elevations may be determined with a wye level with such accuracy that all elevations will be correct within one hundredth of a foot. What is this value for the accuracy of the Stereoplanigraph, either in ratio of flying height or in actual figures?

I still maintain that the matching of contours on adjacent models and the agreement of several surveyed lines common to adjacent parcels is not any check as to absolute accuracy, regardless of the fact that I, like many others, may be prone to accept it as such when it is our own work that is in agreement. The only test of accuracy of position and/or elevation is a definite instrumental determination in which the test line originates from and closes upon definite control points of a known higher degree of accuracy than that of the test lines. Preferably using entirely different methods, I ask for positive tests - not relative relationships based on a uniformity of assumptions and method of procedure.

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*HOW FAR DOES THE PRECISION OF AERIAL PHOTOGRAMMETRY SATISFY THE DEMANDS OF CADASTRAL SURVEY?

by

O. v. Gruber of Jena

The precision of measurement with stereoscopic plotting instruments is largely governed by the flying height, and further by the relative spacing of the exposures. In addition, it is dependent upon the focal length of the camera used. A few characteristic examples will give an idea of the facts without the need of going into too much detail:

	Flying Height	Picture Scale	Map Scale	MP	ML
1. Switzerland (Wild Instruments).....	about 2300m. (7500 ft.)	1:14000	1:10000	±1.56m. (±5.11 ft.)	±1.19m. (±3.90 ft.)
2. Switzerland (Zeiss Instruments).....	2700 to 3500m. (9000 to 11500 ft.)	1:13000 to 1:17000	1:10000	±1.24m. (±4.06 ft.)	±0.91m. (±2.98 ft.)
3. Holland (Zeiss Instruments).....	900m. (3000 ft.)	1:4300	1:1000	±0.19m. (±0.62 ft.)	
4. Berlin.....	340m. (1100 ft.)	1:1650	1:500	±0.24m. (±0.79 ft.)	
5. Berlin.....	350m. (1150 ft.)	1:1700	1:1000	±0.35m. (±1.15 ft.)	

From the foregoing figures, it will be seen that the error in position (mp) increases with the flying height where larger heights are concerned, while, oddly, it does not diminish with lesser heights. The reason is not only that examples (1), (2) and (3) refer exclusively to sharply defined points (marked stones,