So, adaptability of stereoplotting instruments depends upon the skill of the photogrammetrist. The wise photogrammetrist will not rank stereoplotters in their order of accuracy and adaptability, without weighing all factors including capital outlay, ease of operation, quality of the photographic materials, operator skill, map accuracy standards, and work schedules. The Topographic Division of the Geological Survey cannot overlook these factors, for to do so would be to ignore the realities of map production which is its chief responsibility.

Moderator Sharp: I am sure there is a lot of meat in Mr. Altenhofen's paper.

Our next speaker is Professor Schermerhorn. I believe his biography has been presented twice before at this meeting, so I will only say, that we felt that, with his outstanding background, Professor Schermerhorn seemed the ideal person to summarize, discuss and possibly suggest avenues of approach for the improvement of our ideas on the very important subject which we are discussing.

DISCUSSION AND SUMMARIZATION

Professor Ir. W. Schermerhorn

I HOPE that you will take my remarks for what they are worth as expressions of impressions I have gotten from this discussion and my former partly prewar experience.

I feel a little bit as I did many times in the years between 1936 and the outbreak of World War II, when we in Delft were one of the few places on earth where we had the different plotting machines, especially the stereoplanigraph and A-5. How many times did it happen that colleagues and technicians asked me my idea of the kind of instrument I would prefer for our future work? I remember answering that I felt that the major problem was not in the plotting machine, but in both ends of the instrument; on the one end, the film, and on the other end, the operator and perhaps the staff behind the operator. I have given that answer many times and I give it again today. They were the major problems before World War II; they are still the major problems.

Comparisons of instruments based on the data available now is a very dangerous thing. Listening to the figures given in the excellent paper of Mr. Altenhofen, I am inclined to ask what is the mean square error of his figures.

I have another impression. I know by experience that each one of these plotting instruments has its own qualities and lack of qualities. In Delft we had two stereoplanigraphs and two A-5's. These instruments were both of the same type, but they were not equal and have never been equal. The explanation of these small differences of the order of 1 in 5000 to 1 in 6000 is very difficult to make.

That makes me a little afraid to give too clear-cut statements about the capacity of special instruments. Naturally, there is apparatus that fall into the first, second and third order. I have a certain impression, also based on experience, about the results of comparing the multiplex against the stereoplanigraph and that kind of instrument. It is very difficult to give figures that have 100-per-cent reliability. Not only are there differences in the behavior of each of the instruments, but there are also differences in circumstances. In many cases, instruments I should not like to use are useful for certain purposes and under special circumstances.

The fact stated by the representative of Aero Service Corporation about the

famous Brock and Weymouth system proves that there is something in this possible variety of usefulness of instruments, but you must analyze the causes of its quality. I have the impression, for instance, that 90 per cent of the success of the Brook and Weymouth system is not due to the system as such, but only due to the use of a camera which uses glass-plates and eliminates one big difficulty that causes limitations in the accuracy of photogrammetry, at least up to now.

I have never forgotten the discussion I had in 1938 in Rome at the Italian Congress. At that time, we used, for the first time between 1936 and 1938, the Zeiss B-10 on a large scale. We started aerial triangulation. We got into all kinds of trouble. Santoni long before that had built an automatic plate camera. He was at the conference advocating a film camera. I was asking for a glass-plate camera because of the fact that we both experienced the weak points of the two systems.

The situation is still the same here in the United States with large areas to be photographed. You still stick, in the majority of cases, to the film camera.

In Europe where high precision work is developed, one automatic-plate camera after the other has been built; you can see the latest product, the RC-7, in the exhibit room.

There are three different methods by which to try to compare the instruments. We have heard the advocation of the comparison in different stages—the total cost of the result, the accuracy of the map and the analytical method for grading. The problem is how far these different methods will give results which are in accordance with each other. How far does there exist a certain correlation between the measured mechanical and optical accuracy of the instrument and the results obtained by practical work?

In Delft we have a very nice example that there is a certain correlation in a special field. Many of you know the difficulties of the systematic errors in aerial triangulation caused by the instruments, by the stereoplanigraph and also to a certain extent by the A-5. This was the problem I discussed and brought before the Rome Congress.

During the war, we had no opportunity in Delft to do much practical work. One of my most capable young friends, Mr. *Van der Weel*, made a thorough research of the stereoplanigraph, computed from each of the difficult mechanical and optical causes. He determined then what we called in Europe the C factor. That is a term used by my friend Von Gruber. It is the determination of the systematic error in an aerial triangulation. It is the factor of lineal proportion. He determined for both instruments a factor which was $+2.8$ times 10^{-6} for one, and -1.3 times 10^{-6} for the other.

Then we could compare these values with the results from a great number of strips triangulated for practical purposes from not a few, but from a thousand negatives, as earlier mentioned by our Brazilian friend.

The instrumental research for planigraph No. 1 showed 2.8, the practical 2.6. The other showed -1.3 and the practical -1.5. That means that it seems that the method of a theoretical analysis of these kinds of instruments, if executed with the necessary skill and knowledge of the instrument, can give a deep insight in what happens in practical work. That is the great importance in this kind of work.

Yesterday I said with respect to the calibration of cameras and testing lenses, that it is up to the designer and the manufacturer to improve these instruments. If they are not good, send them back. But in this case the staff working with the operator should know the instrument well enough so that they are capable of

doing this kind of work, of analyzing the instrument and not merely comparing the result of the map with the real values of the control points in the field.

That, in my mind, is more or less an easy method that you can apply with closed eyes. If you never do anything more, then you never will understand where the real causes for the limitations of the accuracy of your instrument and your method are located. That is the importance of this comparison of the mechanical and optical accuracy of your instruments with these grid plates. From the early beginning we have had our instruments under control, using grid plates, measuring coordinates that are monocular and turning in the base lengths in the instrument and reading all the altitudes on the grids.

It is true that the value you will obtain is not the same; the accuracy and the precision mean square area is not the same as you will get in a real photograph. If you want to compare precision of instruments, if you want to analyze the causes of errors in your instruments, then it is absolutely necessary to do this kind of work. The role a plotting machine plays in practical service is quite different from that of the camera. It has always been my impression that the relation of the scientific staff service to the manufacturer, in the case of a plotting machine, is one of close collaboration in which the scientific staff gives valuable indications to the factory. This was the basis of my close collaboration, at the period before the war, with my friend *Von Gruber*.

The camera is another problem. It is more or less an instrument that we check and it is up to the factory to improve it. It is true that if you go into these other methods of comparison, if you compare practical results, as has been indicated here by Mr. Altenhofen, there is an enormous number of influences—influences determined by the qualities of the instruments themselves.

You have to involve them in your comparison; I am sorry there are quite a lot of things that are common to all data, all comparison work that you are doing. They are more or less causing difficulties in such a way that only large statistical numbers and statistical data will give you more or less reliable impressions.

If you go further into the cost, then it is still worse. I know that many people say they are only interested in the cost of a product that fulfills the requirements and no more. That is sound and true. Here again, if you want to compare two types of instruments, on this basis you still have more varying circumstances that are causing differences which have nothing to do with the quality of the instruments. If you indicate that quite a lot of work has been done by the lowest bidder with the multiplex or with another instrument, and that other people with more expensive instruments did not succeed in getting the job, that means nothing to me. It may be that if you exchange the instruments in both organizations, and each works for a certain period with the other's equipment, the result will be still more to the advantage of the lowest bidder.

There are more factors which make it difficult for me to compare instruments at this moment in Europe and here in the United States.

May I take another example from what I heard this afternoon? My neighbor on the left mentioned the kind of work they do on a very large scale. He mentioned the determination achieved by flying very low. Nowadays, for this kind of work, there are quite other solutions, as has also been indicated by Mr. Altenhofen in giving his proportion of flying altitude to metric scale. If you take that scale of 1 in 500 and you use the glass-plate camera and a nice plotting machine, then you are easily able, without making dangerous errors in accuracy, to apply a scale that is six times the scale of the map to your photographs. That means 1 in 4000, which reduces, to a large extent, all the trouble of flying, as has been shown by several examples. Look at the publication from the

British side in PHOTOGRAMMETRIC ENGINEERING about the railway survey that has been made.*

I have a few remaining remarks about the application of the theory of errors. I am grateful that two days ago my friend here did his best, in a better way than Saralegui, to teach me the deep roots in the significance of the American C factor, or the United States map error.

My colleague, Dr. Hallert, has distributed in the United States a publication which now is written in English.

I come now to the quite different approach to photogrammetry in Europe and in the United States, and this difference has perhaps a much bigger influence than I described in my address on the first day. In Europe, photogrammetry in the early days after the First World War, was perhaps a business in which pilots promised the whole world to surveying and map-making people.

I always have remembered one day in 1919 that two German people came to my boss and said they could give him a solution for the whole mapping problem of the Netherlands East Indies. They said, "You no longer need any survey. The whole story has changed." The result was that they were thrown out of the door and they did not succeed in getting a job. Two years later an experiment was made in the same way. These people did a wonderful job, but the fact that they promised more than they could deliver meant that until 1929 no Netherlands authority would listen to the words "aerial survey,"

In Europe, in general, the real scientific and geodetic people did not accept anything. Gradually photogrammetry has been developed in Europe by geodesists. In the beginning by men like *von Gruber* who was a geodesist. There are many others in Europe. These people have certain knowledge about the theory of errors, and this is one of the important items in the United States aerial photographic field, in cartography, in civil engineering. Without a real education in this special mathematical branch, these people have been the ones who attacked aerial survey, have had a big success and have rendered a wonderful service to their country. But now you want to compare results. You also want to compare instruments. You want to make an analysis of what happens in a plotting machine. Then it is necessary that you know exactly what each relation in each plotting machine means. Then you have a method of comparing the errors in the law of propagation in the whole system of manipulation. Then it is necessary to know the correlation between the various factors influencing the result. If we are triangulating two strips, one east and west and the other west and east, we take the average of the coordinates of common points, without talking about the difference in the coordinates of these points, which may be much worse even in the same negative, in the same pair of photographs, as has been mentioned by Mr. Altenhofen and by Mr. Hallert before him. Others have indicated the difference in width, the difference in precision. That means the difference in mean square error.

If we are to have a real possibility to judge our instruments, to judge our results, only on the basis of cost per square mile, then it will be necessary to have a deep insight in what happens in this highly complicated procedure of a plotting machine. I am not thinking only of a stereoplanigraph, an A-5 or instruments like that. Even the multiplex is a complicated instrument in that regard.

What do you know exactly about the precision, the mean square error of measuring the height in the different parts of an image? What do you know about the propagation of errors from one image to the other and of the method

* Dawe, H. G., "Large Scale High Precision Mapping by Photogrammetric Methods," PHOTOGRAMMETRIC ENGINEERING, Vol. XVI, No. 1, p. 142.

of adjustment? These are all tasks in the development of photogrammetry, both in Europe and in the United States. What is necessary for both of us is that we start using a common language, and I ask you to drop these definitions, such as United States map error. You as Americans can sell quite a lot in the world, but you create quite a lot of confusion with this kind of thing.

For contour lines, it may be that in this situation, in your aerial triangulation, you can do nothing with this kind of indication of precision. We now are all using the one single expression that gives the complete indication of the Gauss square errors.

Mr. Altenhofen has said that if you know the mean square error, then you multiply it by five and you have the possible contour line. That is easy enough. Use this expression. And we will understand each other in this simple matter. It is difficult enough to understand each other in the more complicated matters where the spirit of a people enter, so let us not make it more difficult than it is by making confusion where this is not necessary. Let us use those words which are clean from a mathematical point of view. That is what I ask of you.

Moderator Sharp: Professor Schermerhorn, that was a very interesting discussion. Do any members of the panel have any brief statements to make with regard to what has taken place at the table here?

GENERAL DISCUSSION

Mr. Eliel: In all of this discussion, very little consideration has been given to the exact relationship and total cost of the results gained by the plotting machine, with other costs which go into making up the total for a job. Actually, there are some jobs, with which I am familiar, where the stereoscopic plotting costs run only 5 per cent of the total cost of producing the map. Most of them run between 5 and 10 per cent. Therefore, if we get a stereoscopic plotting machine which is 25-per cent faster than another, it actually means a difference of perhaps 1 per cent in the total cost of the job. The effect of the amount of field control, which runs with the kind of quality machine you use, is a very important factor.

Mr. Altenhofen stated that my Kelsh truck actually had more than 1 gear. I would like to call his attention to the fact that, while some of the Kelsh planigraphs have two gears, it works in the wrong direction. My one-gear truck runs 3 miles an hour and his runs $1\frac{1}{2}$ miles an hour, because actually he is reducing the scale of the drawing.

Some mention has been made of the effect of very high altitude flying on the ability to draw complete planimetry. A balance has to be struck in this matter. We have had a good deal of experience with pictures at 1 to 50,000 and 1 to 60,000. Let us suppose you can only get 98 per cent of the planimetry correctly drawn, but the cost of drawing such a map is only 50 per cent. Someone has to decide whether it is worth while to draw that map losing a couple of per cent of planimetry, in favor of the much lower cost. Someone also has to make a decision as to whether it is not cheaper to apply higher planimetry and make up the matter of increased cost in field completion.

Mr. Bertil Hallert: My paper "Contribution to the Theory of Errors for Double Point Intersection in Space" has been mentioned by some of the participants in this discussion and has perhaps caused some difficulties. Let me, therefore, briefly describe its principles and the reason why it was written.

In geodesy, as in photogrammetry, no decisive measurement may be regarded as finished before the result can be checked. This generally means that supernumerary observations are necessary. We use these primarily to make sure that no large errors are present. But since no measurement or operation can be made without errors, systematic or accidental, we usually find that there are smaller or larger discrepancies discovered by the supernumerary observations for instance in control points. A theoretically and often practically important problem is to treat these discrepancies in a correct man-