GERMANY'S USE OF THE SLOTTED TEMPLET SYSTEM

Soil Conservation Service
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UPON their return from a visit to Germany shortly after the end of the war, Colonel FitzGerald and Major Reagan of the Air Forces reported that the Germans had adopted and extensively used the slotted templet system in their war mapping. The Hansa Luftbild published a detailed report upon the German findings with regard to this system, and the German reaction to its possibilities, after detailed investigation. This article deals with that report.

The quotation with which the Hansa Luftbild closes its report sums up very succinctly, I believe, the German reaction. The remarks are taken from Jordan's handbook on the art of surveying, "Slowly acquiring and grasping it at first, then overestimating and blindly trusting it, finally calmly appreciating and successfully executing it."

At the same time as the German reports were being acquired certain of the German equipment was being shipped to this country.

The publication opens with a résumé of the development from the hand templet system to the mechanical method of slotted templets. It is pointed out that advantages of the latter include: first, the possibilities of extensive automatic control; second, that it dispenses with a considerable amount of surveying and field measurements, as well as office calculations; third, that it lends itself to production line methods in that the work may be broken up into various phases.

It explains that in itself this system does not furnish point elevations but only point locations. The report gives credit to this author as being responsible for the first American publication; and mentions that this publication was discussed by Scherpbier. It also gives references to a number of other American writers.

In opening the experimental work a number of questions were proposed which it was considered investigation might answer. (1) Are there definite ratios of maximum value in the relationship of the original photo scale, the templet scale, and the map scale? (2) What influence has the difference between the diameter of the pins and the width of the stenciled slots on the firmness of the joined photos, and on the results of the office assembly? Does it serve any purpose to utilize studs with varying neck diameter? What effect has the rubbing of the slot borders on the stud necks? How can its effects be reduced to a minimum? (3) Are there any rules or laws for the existing systematic error? Is there any relationship to the already known error rules of aerotriangulation? Is there an effective and simple way to rectify systematic errors that may appear in radial slot triangulation? (4) What bearing has the condition of the photo material and the method of assembly on systematic errors? May conclusions be drawn from it as to the technique of assembling slotted photos (templets)? (5) How should one treat the presence of picture tilts, either on a single photograph or on a group of photos? Is it necessary or useful to eliminate those photos with greater tilts, before starting the triangulation? (6) How does the error accumulation depend on the shape of the area to be triangulated? What would be the most desirable amount of parallel photo strips covering long and narrow areas, in respect to the relationship of cost and accuracy? How should control points best be arranged on radial grids of considerable width? What influence has the side overlap of photo strips on the accuracy? (7) How can one explain that in recent experiments big mistakes were found within the immedi-

ate vicinity of control points? (8) Are there any advantages in so-called "distance bridges" (distances between two visible ground points determined through two round holes in a strip of stiff material)? Is it useful to orient such measured field distances by geodetic or astronomical means? In what way are oriented distances in radial slot triangulation most useful? (9) What special relationships exist when using extra wide angle photos? (10) What modifications of the slotted templet method must be contemplated, when it comes to terrain with large altitude differences?

The second chapter of the work takes up the geometrical basis of the method. Since no new formulae were developed I see no reason for reporting this part of

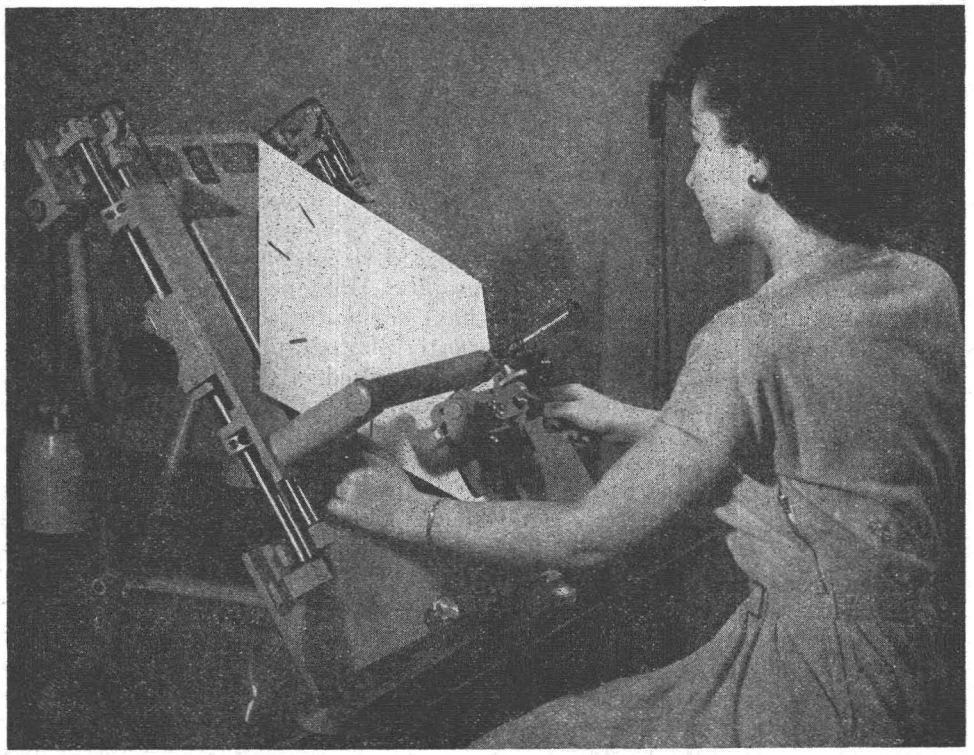

FIG. 1. The German slot cutter in operation.

the work. The conclusions arrived at with regard to the use of the nadir point, or isocenter, rather than the photo center are the same as those arrived at by all American investigators.

The third chapter covers instruments and other aids. Here it was brought out that the mechanical means necessary to slotted templet radial triangulation can be so simple that it is questionable that discussion of the subject is warranted. However, the final slot cutters developed were considerably more elaborate than those in use in this country. The value of enlarged templets was very thoroughly recognized by the Germans. Furthermore the usefulness of the system coupled with extremely wide angle photographs was also recognized. These factors led to the development of a slotter shown in the accompanying photograph. The apparatus can be set to make templets from photographs taken with Pleon lens, as well as with more ordinary equipment. Since this lens has a

coverage of more than 140 degrees the necessary extension of the slots, as the edges of the photograph are approached is easily recognized.

The apparatus is exceptionally well made, fully equipped with ball bearings. It has a telescopic sight of approximately eight power. This sighting system, of course, eliminates all parallax. The diameter of studs are slightly different from those used in this country; not enough, however, to indicate any increased value due to the difference in size.

It may be mentioned at this point that a great deal of the German work was done directly upon the photographs. These were made on correctostat paper and the slots were cut direct in the photographs. Presumably the chief value might lie in the avoidance of having to prick through the photographs to a card beneath, which operation might create a certain amount of error if the transfer was not made with care. I personally believe, however, that the double deck arrangement of a slot cutter such as pictured on page 396 of the American Society of Photogrammetry Manual seems to offer the best solution for templet making, since it avoids all damage to the original photograph, and easily and directly allows for scale change. The addition, however, of a sighting device such as is used on this German cutter would in my opinion be a material advance.

I believe it must be realized that most of the German work was done during the war with comparatively poor photography. Also, speed was a prime requisite and I doubt if the Germans would have concentrated on using the photographs as templets, had more time and better photography been available.

Several ingenious little accessories were received in the German shipment, but in general I do not feel that they were materially ahead of us in any way in the use of this system, that is that they had any equipment which allowed or made possible a better answer than we have been able to obtain.

Chapter four discusses the practical execution of the method and describes the general work methods. The same general procedure was followed in preparing the work as is customary in this country. It might be mentioned that in Germany east-west flights are standard.

Reference was made to the fact that overlap should be from 60 to 70 per cent in line of flight and 30 per cent on the sides. In connection with their work the Germans immediately saw the advantage of holding a straight course in flying; and suggested also that additional tilt eliminating devices would certainly be of advantage. Of course, improvements in flying will benefit any method of map making. Certainly any method of avoiding tilted photographs would materially reduce the work of making correct templets.

In speaking of using the photographs themselves as templets the Germans say, "Photo detail serves to clarify any difficulty that may be encountered in the orientation of the laydown, which on ordinary templets can only be cleared up by the time consuming comparison with photos."

Referring back to the questions propounded, the question of ratio factor was best solved according to their experiments by adopting a scale of $1\frac{1}{2}$ to $2\frac{1}{2}$ to the final map scale. In the German opinion a templet of about $10'' \times 16''$ represents the ideal size. Quite possibly this size represented more nearly the capacity of their so-called desk slotter, than the correct answer to this particular problem, although this size also approximates the mechanical enlargement which we have found feasible here. The standard German film is 30×30 cm. (approximately seven inches square) thus this templet size represents an approximate double diameter enlargement.

In the picking of the points the need for correctly choosing picture points was

stressed. The undesirability of picking such points as road curves, acute road forks, indistinct points in meadows, etc., was pointed out. These are the same as we would point out. There is one difference, however, which should be mentioned. The results of the German experiments indicated to them the advisability of picking points direct on the photograph rather than using a stereoscope to determine these points. I find myself somewhat in agreement (with certain reservations) with this reasoning, based upon the idea that if a point requires stereoscopic identification it should not be used as a radial point, unless no other points are obtainable. I believe that this opinion may cause more discussion, however, than anything else in the German paper. Of course, as is always the case the actual conditions surrounding the experiment materially effect the opinion of the experimenter as to the results. The Germans found it necessary to use a strong, large pin in order to prick through correctostat paper. The fact that this large pin obscured the line of sight in a stereoscope to a certain extent may have influenced their opinion.

The conclusions in this chapter cover the desirable work conditions: (1) Flights as straight as possible, (2) no great amount of tilt, (3) constant end and side lap. (4) Either photo templets or plain templets are satisfactory. (5) Consideration should be given to the scale of the finished map in determining flight heights and templet scale. (6) Consideration should be given to work "split-up" to insure maximum production. (7) A few key men can supervise a considerable amount of the work.

In the fifth chapter a series of experiments were conducted in different areas where the type of terrain varied from swamp land to high mountains. The experiments were largely to determine whether type of terrain made any difference in the efficiency of the system; and the general conclusion was to the effect that with proper handling difference in terrain made no difference in final results.

In the accomplishing of these experiments templets with a different number of slots were used. The conclusion of the Germans was to the effect that 13 slots (including center hole) represented the best average. The additional number was attained by adding two slots in each side overlap area.

Attention was called to the fact that enlarged templets allowed this additional number to be cut without weakening the general structure of the templet itself.

Included in this chapter were the experiments in transferring picture points by direct and by stereoscopic means. The results were listed as follows:

Type of Picture Point	Transfer Error in Millimeters	
	Direct	Stereoscopic
Good	.12	.19
Average	.20	.28
Bad	.46	.74

Quoting the German paper, "stereoscopic transfer is therefore in all three groups almost one-half as accurate as direct transfer," but the author also goes on to state that the reason is partly due to lack of experience of the operators.

Of the experiments in slot accuracy the conclusion was reached that attempt to reduce the tolerance between slot and stud to less than 0.25 mm did not materially improve the final position.

In the original tests which were made in this country it may be recalled that the area selected at Beltsville, Maryland had been covered by the U. S. Geologi-

cal Survey with a dense network of third order triangulation and traverse especially for this test work. In consequence the tests which were made could be graded up in density of control by increasing the number of control points used, maintaining equal spacing throughout the entire area. The Germans did not apparently have this advantage; also they were interested, as stated above, in testing all types of terrain. As a result it is not easy to obtain comparisons between their work and ours. With this in mind I have tried to generalize this report rather than make comparisons, with the hope that the thoughts brought out may furnish a basis for more experimentation here.

The work of the Hansa Luftbild concluded with an analysis of the test work performed here in the U.S.A., reported in the chapter on slotted templets in the Manual. Among the general conclusions arrived at were: (1) End-free triangulation is not feasible. (2) The system of slotted templets is not applicable to single strip assemblies. (3) In places where control is very sparse azimuth bridges, where obtainable, are quite useful. (4) Final results depend upon many factors including the correct selection of templet size, the width of the slot, the number of such slots, etc. (5) Enlarged templets offer a distinct advantage over templets made from photographs of the same size. (6) Enlargement has practical limitations since large templets require larger instruments, are expensive, and are difficult to handle. (7) In the working of the templet the most important point is the amount of care given to point transfer.

Under the final conclusions it was the expressed opinion that where ground control is not dense the accuracy of the system may exceed other methods.

Our opinion that maximum error is about three times the mean error was checked by the German experiments.

The limitation of the system is that it applies strictly to horizontal directions. Also where the ground control is dense the system cannot compare with ground work for the extension of the triangulation system.

With large areas a tremendous time saving was affected.

It offers exceptional opportunity for dividing up the work into various phases to be handled by different groups working on a single area at the same time, and in consequence is exceptionally adaptable to military operations.

The report ends without direct answers to a good many of the questions propounded in the beginning, and with a new list of questions posed for additional experimentation. These questions covered such topics as: (1) The advantage of using pleon photographs. (2) Whether a 60 per cent sidelap would be an improvement. (3) How much the triangulation could be improved by station location in space of the plane at the time of exposure of the photograph. (4) What improvements could be made in stud and templet material. (5) The use of a slotted templet assembly in absolutely uncontrolled areas, and the extension of the system for mosaic work. (6) Is it possible to secure topography in the course of the slotted templet procedure? The Germans stated, "The answer to these questions may not be urgent, moreover the preceding articles cover sufficient ground for present satisfactory application. Additional knowledge will be gained by further practical experience. Considering that radial slot triangulation does not deal with abstract numbers, but with sturdy templets, its highly pleasing results often leave beginners gasping." Then the report ends with the quotation referred to in the beginning of this article.