LARGE-SCALE SMALL-CONTOUR INTERVAL TOPOGRAPHIC MAPPING

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JUST a little over two years ago, the Connecticut Highway Department issued invitations to bid for producing topographic maps at a scale of 1″ = 40′ showing one foot contours of an area approximately ¼ mile wide, approximately 4 miles long, in conjunction with some 5′ contour mapping at a scale of 1″ = 200′. Commercial photogrammetric organizations have been producing topographic maps showing 5′ contours at a scale of 1″ = 200′ to standard accuracy for several years. However to most if not all of us, one foot contours at a scale of 40 feet to the inch was something new. We did a lot of figuring, and such long haired research as was possible in the short ten days available. In theory we could find no reason why one foot contour maps at a scale of 1″ = 40′ could not be produced with our multiplex equipment, provided satisfactory aerial negatives could be obtained. To determine this we flew a strip of pictures with one of our cameras having a 5.2″ focal length at a flight height of approximately 900′, and found that we could obtain the required type of negatives. With this information we made our best guess-estimate and submitted a bid accordingly.

Bids were opened about a month before the Annual Meeting of this organization two years ago. It was found that our bid was low and we were awarded a contract. I will never forget the ride given me at that Meeting by friendly competitors and government employees. I am sure that at least some suspicioned that the job could be done by photogrammetric methods; however a few made a project of trying to prove to me why it could not be done by photogrammetry, and that the job would eventually have to be done by plane table methods. This coupled with at least one other problem I had at that Annual Meeting caused me to leave town in a quandary. I took the train home in order to have some uninterrupted time to completely re-do all of my two-by-four arithmetic. Much to my relief, about the time I arrived in Saint Louis, I came up with confirmation of our original results. Generally, the job worked out about as we had anticipated, and I wish to say that the entire job was done by photogrammetric methods. To us, this was the first of large-scale small-contour interval jobs. I classify such a job to be one with a horizontal scale of 1″ = 100′ or larger, and a contour interval of 2′ or smaller.

In our opinion it is necessary to have complete theoretical data together with complete practical working knowledge of the equipment to be used, including the aerial camera, diapositive printer, and multiplex projectors. Without very well theoretically matched optics in all related units, there may easily be considerable accumulated error. In addition to theoretically matched optics, further data must be obtained by practical on-the-job experience. It is also extremely important to know the ability of the multiplex operators. An operator with six months to a year's experience, on top of the training program generally given, cannot be expected to produce results comparable with those of a topographic engineer with five to ten year's experience in multiplex operation.

Starting with the aerial camera, the characteristics of its lens must be known, and its distortion must be compensated for to the maximum extent possible by the diapositive printer. Any residual distortion between these two lenses must be known and accounted for by special diapositives or other means. The aerial camera must cycle very fast and be capable of making very short exposures. Since this first job we have experimented with several different flight heights, and are still undecided as to what flight height is best when everything is considered. It appears that the safe "C" factor will vary considerably from one type of terrain to another. Assuming the flight height of 900 feet with a camera having a focal length of 5.2″, an exposure must be made about every 600 feet along the flight line. With the plane traveling at 120 mph this means an exposure about every $3\frac{1}{2}$ seconds. Except for recent military developments there are not too many cameras that will make an exposure and completely cycle during this time. If the aerial camera will not cycle this fast, then each exposure must be made as a spot shot. Even with an exposure interval of 1/300 second, the camera travels about .6 of a foot during exposure which we believe is about the maximum permissible. With a negative scale of about 1″=170′, this amounts to movement in the image on the photographic negative, of about 3/1000 inch. Considering the fixed ratio of enlargement between the aerial negative scale and the multiplex plotting scale, this amounts to almost 9/1000 of an inch. From this it will be seen that for one foot contours, a very slow airplane and a very fast camera are essential.

One should never expect uniform scale negatives from this type of flying. We have found by experience several jobs with different planes, cameras and crews that, when most of the negatives are within 5% of the specified scale, the tilt seldom exceeds about 5°, and that you have usable overlap and sidelap; there is no need to try for further improvement in the flying. A light plane throttled back at an altitude in the vicinity of 900′ is similar to a cork in heavy surf. To be on the flight line and take exposures meeting overlap requirements is quite a problem to say the least.

One major difference in this type of mapping is in field control. I think that most commercial and federal mapping organizations use a type of level line for vertical picture points called 3rd order B, 4th order A, or a similar name for a line that will close within the requirements for the contour interval specified for the map. For one foot contour maps with 90% of the points tested required to be correct within $\frac{1}{2}$ contour interval, the minimum requirement for vertical picture points is just plain 3rd order, as defined by the U.S.C. & G.S., and we strongly recommend that whenever possible, such lines originate and terminate on 1st or 2nd order U.S.C. & G.S. control. There are all kinds of "so-called" 3rd order lines and frequently an attempt to tie between them is very sad.

Finding suitable horizontal picture points is a major problem in addition to a minimum requirement of 3rd order traverse or triangulation. This is true to a certain extent in vertical control. However since most jobs of this type do not contain a great amount of relief, it is generally possible to select vertical points in relatively flat areas, and by obtaining slope change data in all four directions from the selected points, this becomes relatively simple. Coming back to horizontal picture points, they really are a problem. It is absolutely necessary to have positive identities of small features, as most specifications require that the distance between 90% of any two well defined cultural features, scaled from the grids on the map, shall check with the distance between these points when measured on the ground, within *two feet*. In no instance can the difference be greater than *four feet*. On one job this part of the specifications was reduced 50%, allowing a horizontal error of only *one foot* for 90% of the distances and a maximum of *two feet*.

The following are descriptions of horizontal control points as selected by our field engineers, and found to be satisfactory in the office:

1. Fence line intersections
2. Corner of sidewalk intersections
3. Intersection of white line indicating center line of street with line of crosswalk

4. White line corner of tennis court
5. White center line of highway and one rail of railroad

Bringing the job into the office, and putting it in the Multiplex Department, we find that a great many more features must be delineated on this type of map, than on smaller-scale larger-contour interval maps. For example, sidewalks, curbs, driveways, individual trees, individual rails of railroads, and street car lines, fire hydrants, telephone and telegraph poles, the actual size and shape of buildings, and many other features are required to be shown. Contours are found to cross features such as roads, curbs, etc. in a very detailed fashion, as compared to bringing them across the roads at right angles, on smaller scale maps.

As we have been able to correctly plot so many small features to a rather high degree of accuracy, I am somewhat inclined to be in disagreement with those who have presented papers before this Society and who have called the Multiplex a "dull sighted instrument" and have classified it as being somewhat inferior to other types of photogrammetric instruments. I am sure that we can technically and theoretically discuss and argue the merits of various types of plotting equipment all day and never reach an agreement. I do not believe that there is as much difference between the various types of instruments as there is in the people operating the equipment. If there is a difference, I believe that cost is the only way of obtaining conclusive information regarding the advantages of the various types of equipment. By this I mean the over-all total cost including everything from the original planning through the final drafting. This total cost would necessarily include the initial installation cost of the equipment charged off over the correct number of years, maintenance, repair, and other items sometimes overlooked.

From a business volume standpoint, I think I am safe in saying that most companies, engaged in commercial photogrammetry during the past two or three years, have been rather anxious to get most, if not all of the jobs on which invitations have been issued. At least most companies have bid on all invitations. The prices we have bid are public information. Since companies using Multiplex equipment have submitted the low bid in competition with the more elaborate foreign equipment, and have been awarded contracts for at least their fair share of all competitive work advertised, I am inclined to believe that the Multiplex compares favorably with the more elaborate and expensive foreign photogrammetric equipment.

As mentioned above, it is essential to know your photogrammetric equipment and personnel from a practical working standpoint in addition to having the best possible theoretical data. Multiplex projectors, manufactured by Bausch and Lomb Optical Company, are sold in sets of three and are supposed to be matched. On the basis of theory and the closest possible measurements, we do not question but that they are perfectly matched. However, from a practical working standpoint, we have found that some projectors work better together than others. Out of the group of projectors we have certain ones which work better together for horizontal and vertical bridging, and this group in the sequence selected are always used for this function. In addition we have paired off the projectors that work best together for manuscript plotting. It was a long and tedious task to determine which projectors and groups of projectors work best together; however we feel that after determining this we are able to exploit our equipment to a greater extent.

We feel that we have a great deal to learn in large-scale small-contour interval mapping. I believe that C factors normally used for 10′ and 20′ contour intervals are not at all applicable for one and two foot jobs. Although we have not established a maximum flight height for this type of work at this time, I feel that the C factor for such work will be found to be much larger than those currently used for smaller contour intervals. I certainly would not state that the Multiplex equipment is perfect and entirely satisfactory for this type of work; nor do I know of any equipment which I consider to be entirely satisfactory. However, the Multiplex is doing an acceptable job of producing this type of map which after thorough testing has been found to meet the requirements of the specifications.

Large-scale small-contour interval mapping today in my opinion is in about the position that the 20′ contour map at a scale of 1″=1 mile was some fifteen to twenty years ago. When this type of map was made some fifteen years ago it was considered to be a good map, while by today's standards it is considered "lousy" and the area needs to be completely remapped.

We now have a request to produce a map at a scale of 1″=20′ showing 6″ contours. At the moment I am of the opinion that the easiest way to do this job is to load it on a wagon and haul it into the customer's office.

We feel that the camera and instrument manufacturers have a big job ahead of them. To do the job required for map users at a cost they can justify, we operators need more efficient equipment than any manufactured at this time.

Moderator Sharp: Mr. Quinn will now read his paper.

REPORT FROM AERO SERVICE CORPORATION

A. O. Quinn, Aero Service Corporation

AERO SERVICE CORPORATION has used and is now using a stereoscopic mapping method which has been referred to as both primitive and archaic by critics who have failed to recognize the basis for this very successful mapping method. The Brock process which utilizes a series of highly precise instruments was designed to answer the following mapping fundamentals:

1. In making topographic maps from aerial photographs, some operations can be performed without the use of a machine and those operations performed on machines do not require the same amount of time. Therefore, a single machine performing all operations would not be economically successful, as its output would be limited by the operation requiring the most time.
2. Because of possibility of relatively large errors introduced by angular displacement of optics, due to lost motion and deflection of supporting members, non-movable optical systems should be used where possible.
3. That until film free of non-uniform shrinkage or expansion is available, aerial photographs should be made on glass plates, for accurate determination of contours.

I am not going to take the time to describe in detail each of the component parts of the Brock equipment. These instruments have been very well described in the "MANUAL OF PHOTOGRAMMETRY" and various articles which have appeared in "PHOTOGRAMMETRIC ENGINEERING." Also, many of you have visited our offices in Philadelphia. The equipment consists of an aerial camera, which is on exhibit for this meeting, a measuring stereoscope, a correction printer which is used in the solution of the tilt problem and also to produce rectified photographs, a scale equalizer and a precise projection camera.

Basically the Brock process requires: the exposure of a glass plate negative, the determination of tilt of each exposure, the horizontalization of each photo-