USE OF STEREOSCOPIC METHODS IN PREPARING TOPOGRAPHIC MAPS FROM AERIAL PHOTOGRAPHS

By M. J. Harden, *Topographic Engineer*
U. S. Geological Survey

SYNOPSIS

This paper describes the preparation of topographic maps by the multiplex instrument. The process involves the use of aerial photographs to form true scale stereoscopic models of the terrain in which the necessary measurements for position and elevation can be made much more rapidly than similar determinations can be made by survey parties operating in the field. The method is particularly advantageous due to the relatively large scales at which the drawings are made, the accuracy at which horizontal positions are represented and the faithfulness of the contour lines to the true ground forms. The preparation of maps can proceed continuously on a two-shift-per-day basis without the usual delays by inclement weather or other retarding factors usually experienced by field survey parties.

The process has many other advantages not shared by the customary way of making maps in the field, and lends itself well to the mapping of areas through which it is proposed to locate new highways, particularly those routed through mountainous regions.

The effort to secure a better and more complete representation of the surface of the earth has been the moving force responsible for the fine maps that are being prepared at the present time. Some of the older topographic maps of the United States seem quite incomplete and unsatisfactory when compared with those being made today because they are badly out of date and inaccurate as to detail in many instances. Yet, we must remember that they were the finest map products of their time and the improvements that have been secured are the results of minor changes in methods and practices that have been made from year to year. It is the purpose of this paper to describe one of the recent improvements that has made it possible to produce maps that will fully satisfy the needs of those engineers and scientists who look to them as the best source of information regarding the topography of any area of interest to them It is the intent to give a brief description of the multiplex instrument as it has been found particularly effective in the preparation of maps that are of maximum usefulness in highway location and design problems

The multiplex method was first employed experimentally by the U S. Geological Survey in 1935 and from that small beginning its use has expanded rapidly until the method is now in great demand While the instrument itself is mechanically simple, yet it fulfills all the requirements that are needed in reproducing a plastic model of the terrain on which the operator of the instrument can make in the laboratory all measurements necessary to the proper delineation of the cultural, drainage and hypsometric features usually represented on topographic maps. The method yields results that are particularly exact both in scale and in the accuracy with which the contour lines are drawn. The original scale of the map drawings are much larger than usual, thus making the method especially attractive to those who have need for large scale maps.

The multiplex instrument consists of a horizontal bar supported on a finely constructed table having one plane surface which represents the datum plane from which all measurements of elevation are made. Supported on this bar are a number of miniature projectors which serve to cast onto the table top positive images of the aerial negatives of the terrain that have been secured by the photographic crew. Each projector is equipped with six independent motions in order that the projector can be moved in space as desired and the diapositive plate inclined or orientated as may be necessary in order to restore it to a position corresponding to that occupied by the negative at the moment of exposure of the aerial mapping camera. These motions permit the operators to recover the relative position and inclination of the photographs with an excellent degree of accuracy. Proper orientation of the projectors will enable them to perceive on a viewing platen a three-dimensional model of that part of the terrain which is common to any two consecutive overlapping aerial photographs The multiplex instrument must be employed in a darkened room as the anaglyphic principle is employed to separate the two overlapping images thus permitting the stereoscopic model to be perceived. This separation of images is accomplished by coloring one of the projected images with a red filter and the other with a blue-green filter and then viewing them through spectacles of corresponding colors. When this is done the operator obtains a highly accurate and satisfactory stereoscopic impression of the area, and providing the projectors have been actually returned to positions comparable to those of the aerial camera, an exact model will be available for mapping purposes. This model can be utilized in the laboratory in making all measurements needed in preparing a topographic map and in this way eliminate all necessity for making costly and difficult field surveys which frequently are retarded by the difficulties of the terrain and by the loss of time due to inclement weather

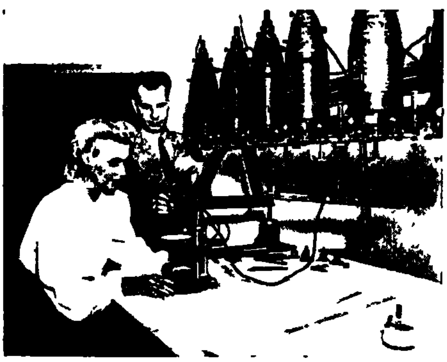

Figure 1. Geological Survey Multiplex Instrument

The multiplex instrument is provided with a small movable device known as a tracing table which carries the viewing platen and the pencil which draws onto the drawing paper the features that are to appear on the map. The tracing table is provided with a luminous mark in the center of the platen which is utilized in making all measurements on the model required in delineating the cultural and drainage features of the terrain as well as contour lines. Those details which ordinarily appear on a planimetric map can be shown on the drawing paper by causing the floating mark to trace all meanderings of cultural and drainage features regardless of the relief of the country while the drawing pencil is in contact with the map paper. Contour lines can be drawn by setting the platen to the elevation of any selected contour line and then moving the tracing table until the floating mark is in apparent contact with the ground surface. When this has been done one point on the contour line will have been determined. The contour itself can be drawn from this point onward by causing the floating mark to move in such a way that it will always remain in contact with the apparent surface of the stereoscopic model Thus it will follow along the sides of a canyon and around the points of ridges and spurs and eventually close on itself providing that its meanderings have not taken it beyond the limits of the model that is being drawn. Other contour lines can be drawn in a similar manner by setting the viewing platen to the proper elevation

The diapositive plates which are reductions of the original negatives must be made with great care if the stereoscopic model is to have the same scale vertically as it does horizontally. This requires very careful calibration of the instrument and complete knowledge of the constants of the aerial camera. The horizontal scale of the stereoscopic model can be caused to match the scale of the map projection on which the map is drawn without difficulty. This adjustment of the scale of the stereoscopic model assures that the drawing that will be made therefrom will be accurate both horizontally and vertically

Small lantern slide plates used in the multiplex projectors are known as diapositive plates and are made from the original aerial negatives with an accurately calibrated reduction printer. This instrument is an essential part of the equipment used in the production of topographic maps from aerial photographs and when properly calibrated will reduce the aerial negatives to a size that will permit differences of elevation to be accurately measured As the range of adjustments of the printer is limited it is necessary to provide individual printers whenever cameras of different focal lengths are employed by the aerial photographer. In order to assure proper control of the measurements of elevations the printer has been provided with lenses so designed as to compensate for the distortion of the aerial camera lens. If this is not done the distortion errors will have a serious effect on the accuracy with which elevations can be measured.

The aerial photographs intended for use with stereoscopic mapping instruments must be made with an accurately calibrated camera if true to nature models are to be attained. It is most essential that every effort be made to obtain models of this kind, otherwise accuracy of the resulting map product will not be satisfactory. Moreover, efforts to use existing negatives several years of age or to employ a camera that has not met the specifications for mapping work are certain to retard the progress of the multiplex operator and result in a map which does not accurately represent the areas that are photographed. Aerial photographs must provide a true and undistorted record of the cone of light rays that formed the original photographic image If such a true perspective record is to be obtained it is essential that the camera lens be as free of distortion as the present state of optical lens design will permit. The residual distortion should then be compensated for by the design of the lens of the multiplex reduction camera

The aerial camera must be constructed with great care and looked upon as a mapping instrument rather than a piece of photographic equipment It must be given the same care and calibration as the finest theodolite if the best results are to be obtained As a consequence of this requirement, it is rarely possible to use existing negatives if accurate contour lines are to be drawn unless a complete record exists of the constants of the camera that was used in making the negatives. Under certain conditions it is possible to utilize old negatives if the type of map to be prepared with the multiplex instruments does not require the drawing of contour lines. The aerial camera should preferably have a wide field of view for any multiplex mapping project as the area encompassed by a wide angle photograph is much greater than that covered with usual types of cameras. Consequently, there will be fewer photographs to process, a lesser number of flight lines to be flown, and the amount of ground control required to properly orientate the models will be greatly diminished, all of which will have a major effect in reducing the cost of the map Inasmuch as the air base is also increased, a greater accuracy of vertical measurement will result.

The multiplex method of mapping has many advantages over those customarily employed and is well worth the attention of engineers interested in highway location and relocation problems. It yields maps particularly advantageous for such studies because they can be made rapidly and at a relatively large scale.