organization financially. As a general rule, it does not have much money to spend in order to develop new types of photography, and so on, with which it should be experimenting. We more or less have had to borrow experience from other air places and try to put it to use. We are getting over that stage now, and I think that in the near future, we are going to see some changes. We are going to see some demands for new types of photography. You heard Mr. Spurr mention a few of them; and I believe there are going to be a lot more.

Let me elaborate just a minute, on what I am driving at. At the present time, we are using photographs of approximately 1 to 20,000 scale. A forester has to use those to interpret forest conditions, that is, our foresters do, because that seems to be the general practice. In some cases, we have used scales as high as 1 to 48,000—they definitely are not the best scale. We can do better if we had scales of around 1 to 8,000. As a result of that type of photo, I am sure we could reduce our ground work. There isn't any question in my mind. Where the balance is going to be, I don't know. We can't afford a complete coverage at that scale. It costs too much money. But certainly, we can use some kind of a sampling scheme, which is not now thought out, I will grant you, but I believe it exists. We will have to request photogrammetrists to help us work out a sampling scheme. Most photogrammetrists engaged in mapping are unfamiliar with terms of sampling. They map the country on a large area—one hundred per cent. In our particular field, we can't go out and measure every tree. We must use averages. And that is where photogrammetry can come into the picture, to help us design some method whereby you can help us reduce our field work through the use of aerial photography.

THE BROCK METHOD*

Robert Singleton, Aero Service Corporation, Philadelphia, Pa.

THIS talk will be as short, informal and non-technical as possible, since my purpose is to introduce the Brock Process to those who don't know anything about it rather than to try to tell anything new to most of you who do know something about it.

First, I should like to give a very short history. As I began to gather data for this talk, I felt more and more presumptuous about making it, because the start in thinking about the Brock Process was before I was born. The first piece of equipment, a film camera, was built in 1914, about the time I started to learn how to walk. That was done by Arthur Brock, Jr. The development of the equipment continued from 1914 through the First World War and a few years afterward. It reached its first culmination in 1921 when the map on the program was made.

Brock and Weymouth, Inc., continued the development and in the Twenties built a second set of bigger and better equipment. You will see this tomorrow.

At the turn of the decade when everything was closed down, Brock and Weymouth also closed down, and the equipment remained idle until Aero Service acquired it in 1938. Since that time, we have operated the original, larger set of equipment essentially without changes, but with maintenance, of course. We have developed a few of our own techniques, but essentially the same Brock and Weymouth Process is still being used.

Figure 1 illustrates the operations. This chart starts at the left and runs to the right.

* A paper given before American Society of Photogrammetry at the Semi-Annual Meeting in Philadelphia, Pa., October 7, 1948.

The photography is taken on glass plates in the plate camera, and the first thing done to these glass plates is to enlarge them two times onto 14 by 17 inch glass; from then on, the work in the Brock Process is carried on at the 14 by 17 inch size.

The process is divided into two parts. The determination of horizontal positions, which is carried on separately, is shown by the bottom line of Figure 1.

About eight points per pair of photographs, which amounts to three or four points per photograph, are used as pass points or intermediary control points, and their horizontal positions are determined by intersection using the standard radial control method from a few known horizontal points. From a 14 by 17 inch print, cardboard templates are made and laid on a control board. The positions of these pass points are assembled on a manuscript sheet so as to be ready for the contours when they get through the contouring process.

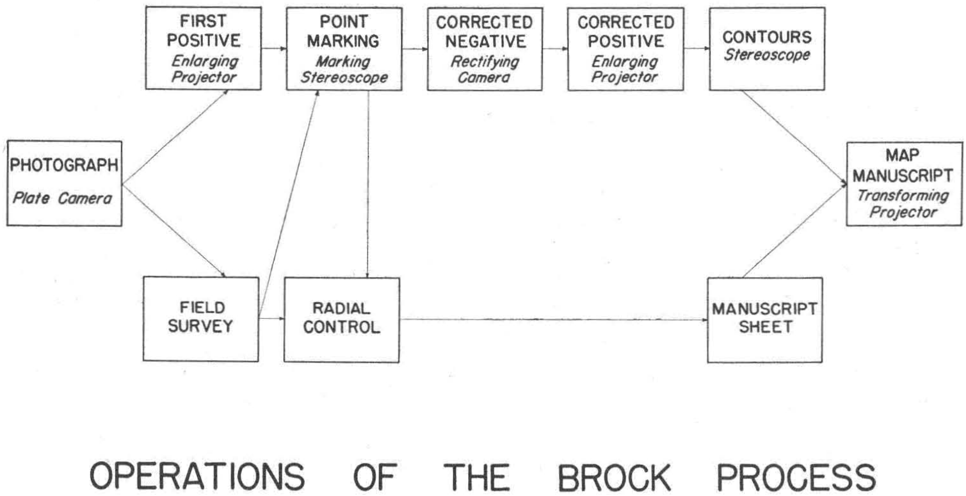

FIG. 1

As indicated in the upper line of Figure 1, this first positive, or two times enlarged projection on 14 by 17 inch glass, is placed in a stereoscope and the selected pass points are marked on the first positives. These plates are then taken to the rectifying cameras in order to be corrected.

The Brock Process is a rectification process—until very recently the only process using rectification in the United States. Rectification means that the tilt is removed from the aerial photographs. When an aerial photograph is taken, the camera is not leveled and the axis does not point vertically downward. However, the resulting photograph can be re-projected into a plane just as if the camera had been vertical at the time of exposure. This adds essential simplification to the later process of contouring, and is done in the rectifying cameras.

The rectifying cameras are cameras in which the object and image planes may be tilted. The amount of tilt is determined by a successive approximation method. A photograph is placed in the rectifying camera, and is projected so that the projected image can be measured. Using these measurements and the known elevations of pass points, the amount of tilt can be determined, in each of two photographs of a pair. This tilt is then set into the rectifying cameras and the projected image is re-measured. If there is a small residual tilt, an additional correction is necessary. This is put in also, until finally the readings of

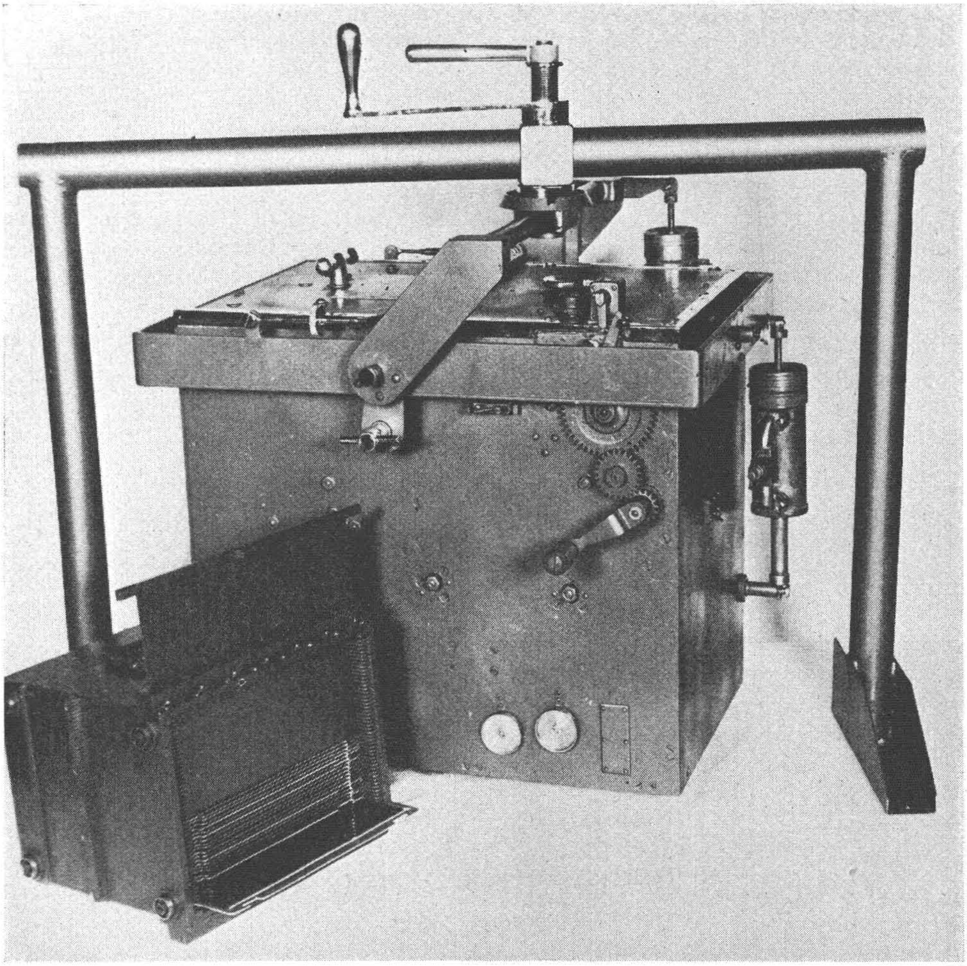

FIG. 2. The Brock camera.

the projected images show that the two photographs as projected are now vertical photographs. In other words, a photograph is made of the projected image.

This is now a 14 by 17 negative photograph on sensitized plates. It is taken back to the enlarging projector and made a rectified positive. At this stage, it is usually necessary to make a slight change of scale in one photograph since the two photographs in a pair will not be exactly the same scale.

We now have two rectified photographs with an overlap that can be seen stereoscopically by direct view, without a complicated viewing device. These two photographs are taken back to the stereoscopes and the photographs are contoured.

The contours are drawn on a sheet of vellum, which is indirect contact with the right-hand plate of a pair. This means that the contours, since drawn in contact with a photograph, are in the perspective of the photograph rather than the orthographic projection of a map. By explanation, in an aerial photo, the area at the higher elevations, since closer to the camera, is portrayed on a larger scale than that at lower elevations. The one remaining action is to get all contours on the same scale. This is done in a tracing instrument. We have from the stereoscopes a template—a sheet of vellum—on which the contours are drawn. This may be placed in the tracing instrument and projected. The scale of that projection is continuously variable and the contours are simply retraced with the scale of the projection changed between the tracing of successive contours so as to bring them all to the same scale.

During this tracing, planimetry which is located close to any contour being traced, is also taken off, and thus the planimetry also is brought into the orthogonal projection of a map.

This retracing is done on the map manuscript sheet which is ready for use with the control points marked in horizontal position. The result is an assembly of the individual contours from each pair of photographs into a continuous map manuscript at the correct desired scale.

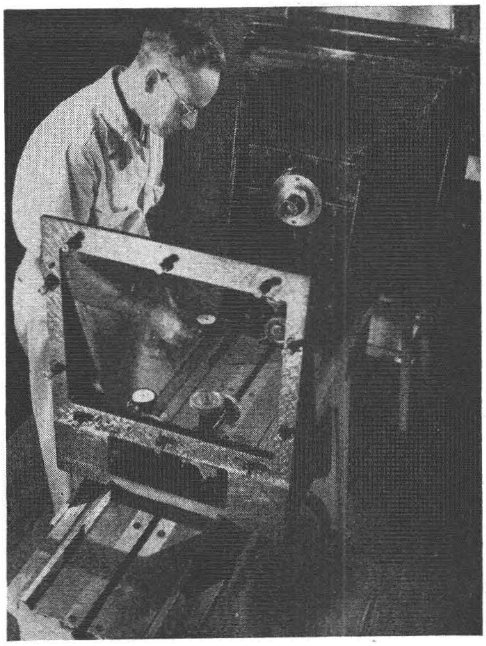

FIG. 3. The enlarging projector.

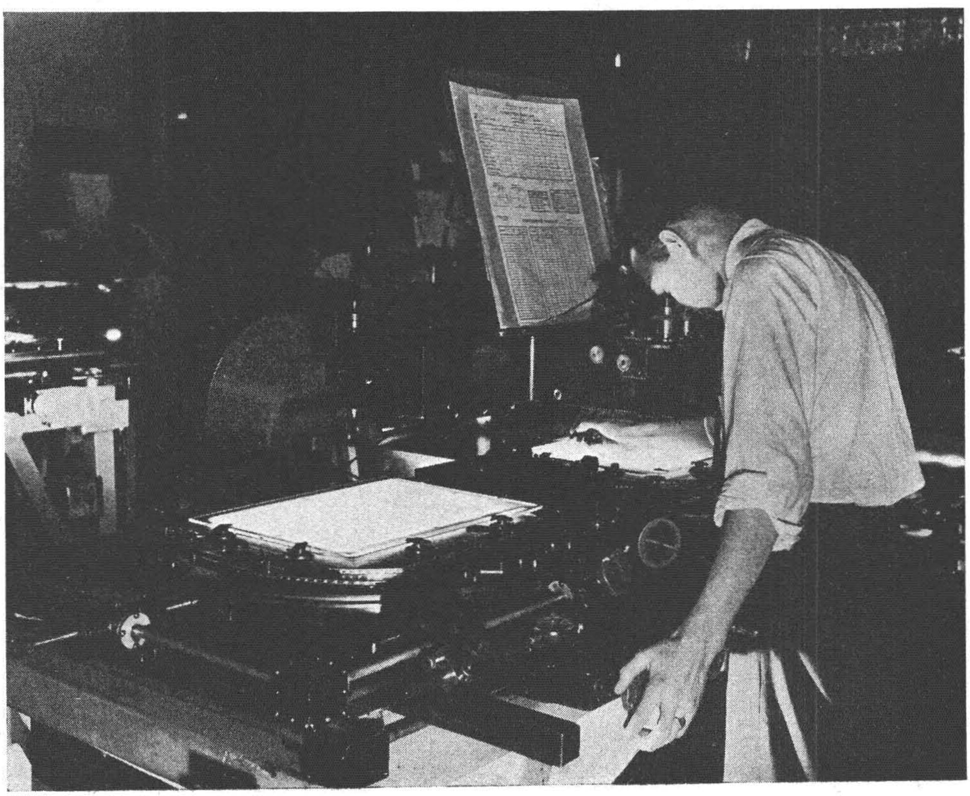

FIG. 4. Stereometer.

FIG. 5. Stereometer plateholder (close-up).

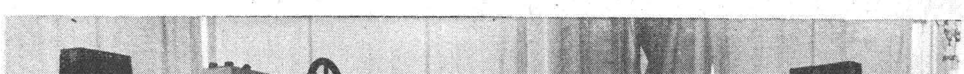

FIG. 6. Rectifying cameras.

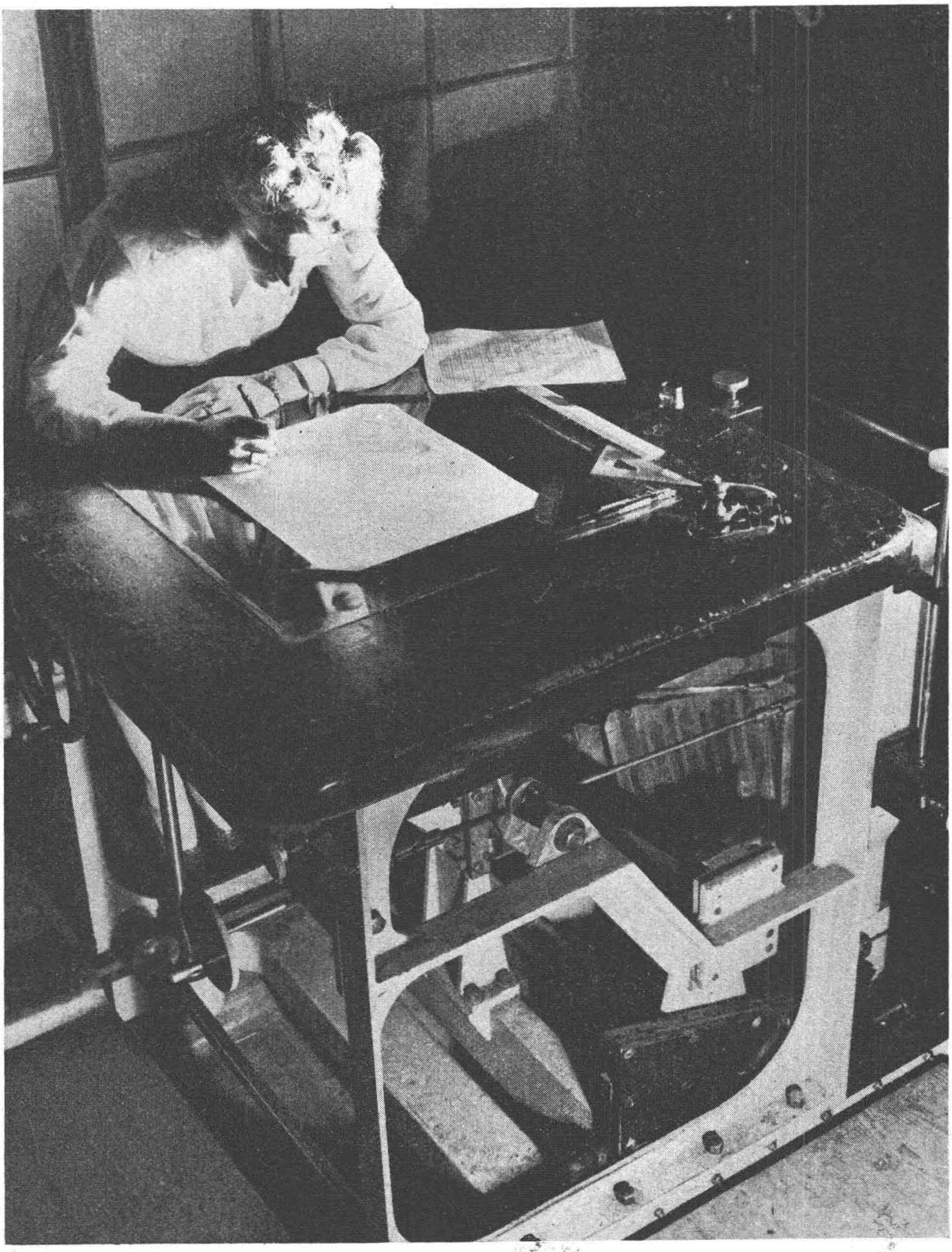

FIG. 7. The tracing instrument.

The Brock camera is shown in Figure 2. The camera is the big square box with gears and handles. It is suspended in a gimbel mount and has dash pots between the camera and the mount to dampen some of the vibration. The plates are carried in a magazine such as that in the lower left, which holds 48 glass plates, $6\frac{1}{2}$ by $8\frac{1}{2}$ inches. The image size is 6 by 8 inches. Various cones may be put in the camera. We have cones carrying 7 inch lenses, 5.2 inch and 4 inch lenses; and others can be made as needed. There are three such cameras. The camera is completely hand-operated. The magazines may be readily removed and a new magazine put in during flight so that the flight is not limited to 48 plates.

Figure 3 shows an enlarging projector—the projector which in the first instance goes from a 6 by 8 image to the 14 by 17 glass plate, and in the second instance, gives the final rectified positive. It is a projection camera; it is highly

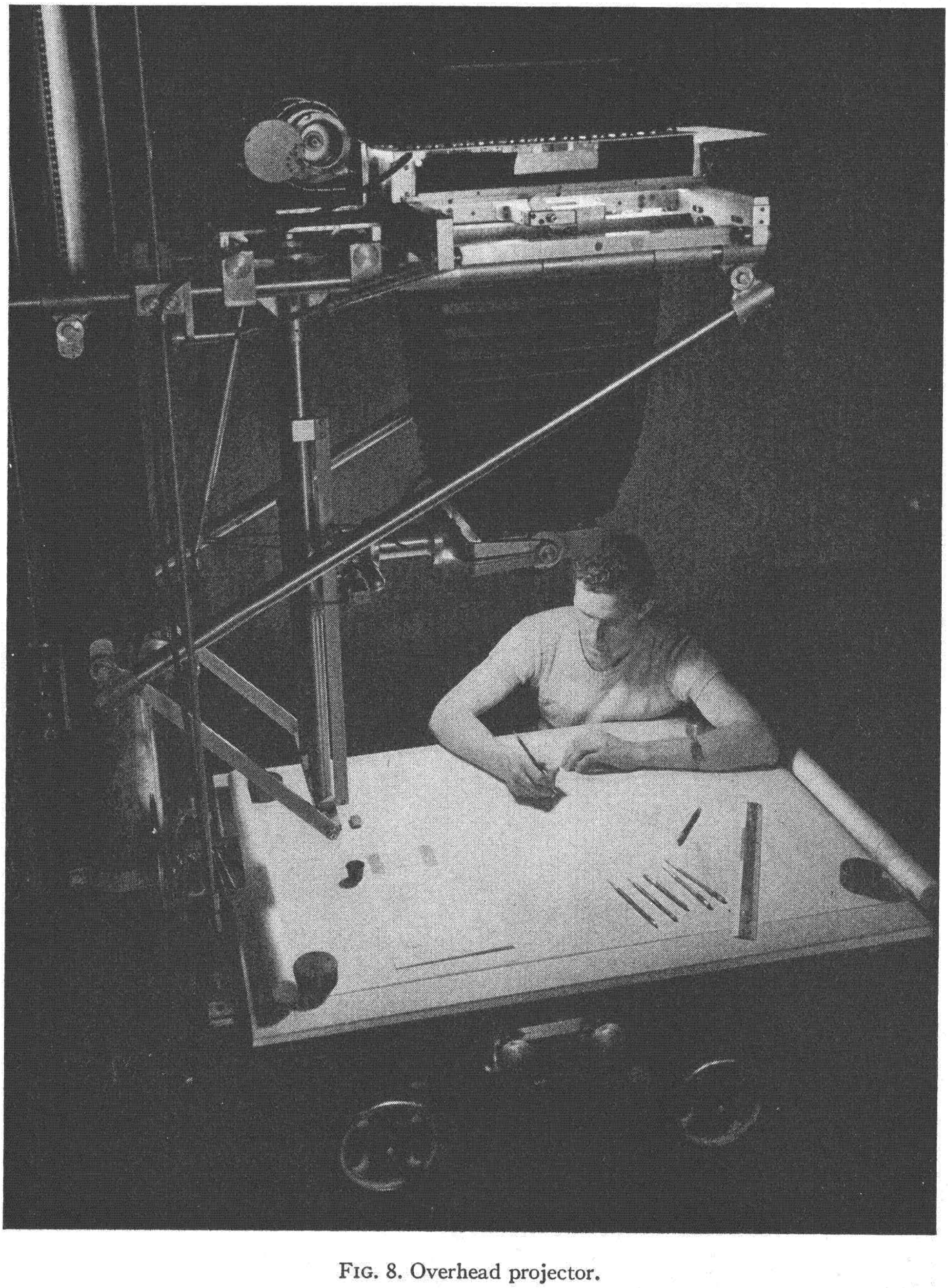

FIG. 8. Overhead projector.

precise; its accuracy is better than two parts in ten thousand of the enlargement ratio. There are two such cameras.

Figure 4 shows the stereometer, of which there are eight. Figure 5 is a closer view. Two plates are held horizontally on the left and on the right. There are X and Y motions and a rotary motion from each plate holder to center and line up the plates. The plates as a pair may be moved in X and in Y directions so as to traverse the entire plate, and the left-hand plate may be moved closer to and farther from the right-hand plate, in order to pass from one contour to the next contour. The viewing system is a telescopic system of about four power.

There are the four rectifying cameras or correction projectors. Two are shown in Figure 6. The view you see from one side is the plane which receives the projected image. The plate is put in in back of the machine. It has a half-inch grid used in measuring coordinates. The grid may be taken out and a sensitized plate put in to receive the rectified image.

Contouring a pair is illustrated in Figure 5. The operator is behind the right-hand plate of the pair. A sheet of acetate has been placed over it. The operator's pencil is at about the center of the viewing circle. He sees a small model of the ground, cut by a plane, determined by the cross hairs of the telescope, so he knows where the contour goes and he can draw it on the photograph.

The contour sheet is taken to this tracing instrument that is shown in Figure 7. This is somewhat like an overhead projector except that it is underneath. The image is projected upward onto the glass plate on top. The girl operator has a sheet of vinylite on top of the glass. She is retracing the contours. This instrument is an automatic focusing device, so all she has to do is turn a wheel to change the scale; it automatically keeps itself in focus. There are two of these instruments.

Figure 8 shows an overhead projector for doing the same thing. There is one like this; it is a new machine we had built last year. The standard ratio of the other tracing instrument was about a one to one projection, varying from .75 to 1.25. This new instrument will give a projection up to better than three times. We normally use it at about two and a half times projection in order to get a larger scale in the map manuscript.

As a summary, this system is excellently designed for contours because of the very great visual scale at which the contours are drawn. The visual scale is four times over the 14 by 17 inch plate, which makes a visual scale over the aerial negative of anywhere from eight to eleven times magnification. Because of that, because of the use of glass and various other things, it is an excellent contouring method. It is less well adapted to planimetry. It finds its best application in large-scale maps with close contour intervals.