Chapter 6

Measuring and Plotting Instruments

37. Comparator and Stereocomparator. After the photographs have been rectified they are ready to use in some one of the various instruments for measurements. These photographs are usually on glass plates (called plate positives) instead of paper. Fewer errors due to shrinkage, etc., are experienced in the use of plates. The instruments are provided with a means of illumination so that every detail is visible.

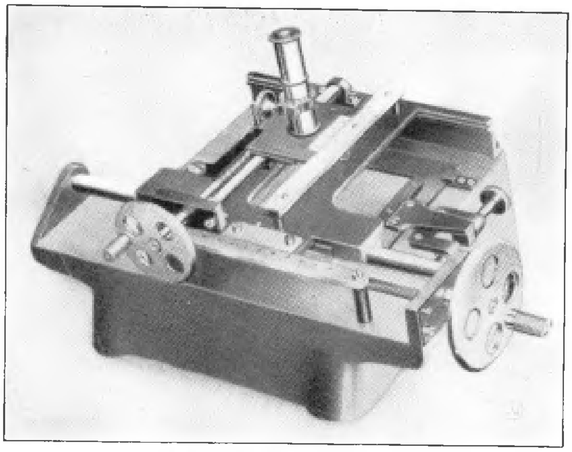


FIG. 52. Comparator.

Comparator (Fig. 52). This instrument consists of two perpendicular motions for measuring rectangular coordinates with a high degree of precision. Readings on the scales are to 0.01 mm. and the measurements are usually reliable to 0.02 mm. Only one photograph is used at one time in this instrument.

Stereocomparator (Figs. 53*a*, 53*b*). If x, y, and p coordinates are to be found, a stereocomparator is used. The principle of this instrument was explained by Figs. 35*a* and 35*b*, pages 29–30. Although the instruments illustrated may look a little complicated, they measure very accurately the x and y coordinates and the parallactic displacement from a pair of adjacent overlapped photographs. The scales read to 0.01 mm. as on the comparator.

Mirror Stereoscope and Magnifying Stereoscope. Various forms of simple stereoscopes are on the market, and every office working with stereophotographs is usually equipped with one type or another.

Two adjacent overlapped photographs are viewed in one of these instruments and the relief stands out so that all hills and valleys are apparent.

In the *mirror stereoscope* the lines of vision are directed to the photographs by means of a series of mirrors. The photographs are placed on a table under the outside mirrors and shifted by hand until stereoscopic fusion is accomplished.

The *magnifying stereoscope* is much the same except that magnifying eyepieces are used to increase the stereoscopic perception. (See Figs. 54, 54*a*.)

These last two instruments are valuable in studying photographs for detail and selecting ground control points.

38. Plotting Instruments. Four types of plotting instruments are in use: aerocartograph, stereoplanigraph, multiplex, and stereocomparagraph.

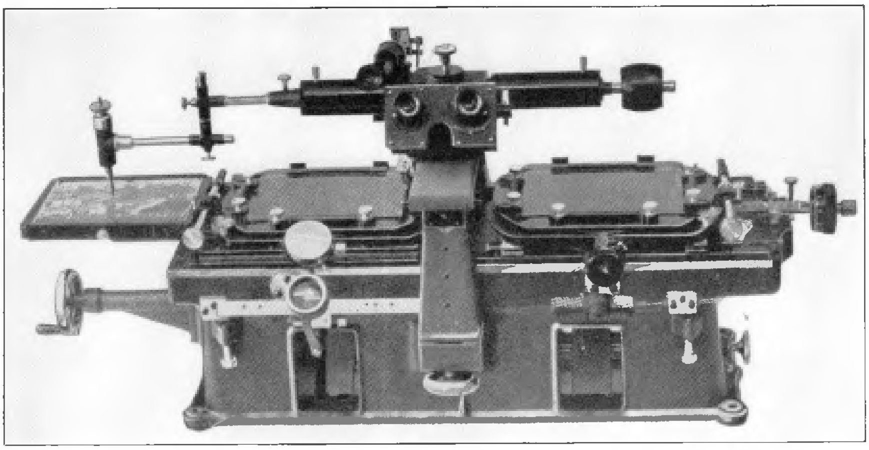


FIG. 53a. Stereocomparator.

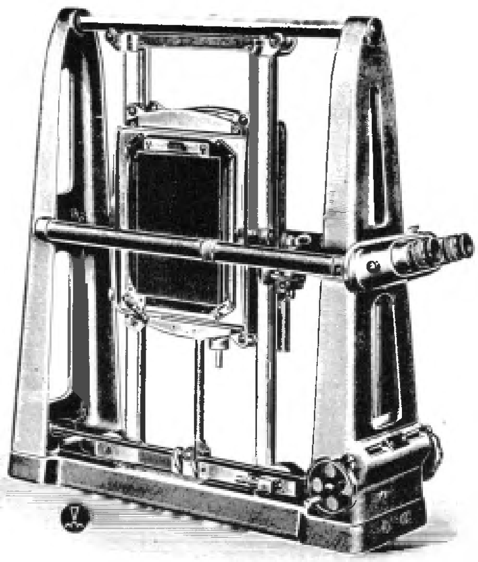


FIG. 53b. Stereocomparator.

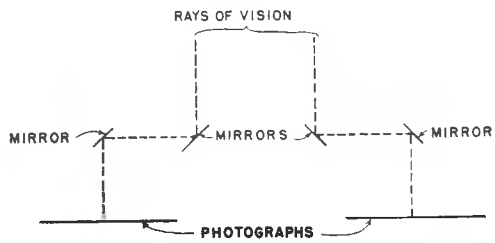


FIG. 54.

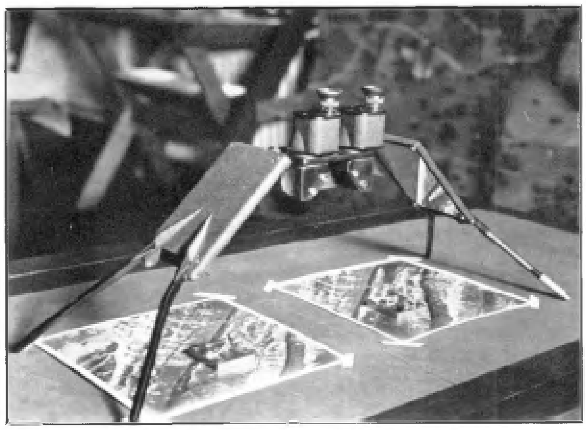


FIG. 54a. Magnifying Stereoscope.

THE AEROCARTOGRAPH

The aerocartograph (universal stereoscopic plotter), Figs. 29 and 30, is a combination viewing, measuring, and drawing instrument. By means of a series of prisms and lenses, two overlapped photographs are viewed stereoscopically. A floating mark is carried in each plate holder and these are fused together as in the stereocomparator. This floating mark can be moved over the picture viewed in an x and y direction by the two hand wheels shown. The parallactic displacement, which is really a measure of the altitude, is controlled by a footplate. By operating these three controls, the floating mark can be made to trace over the portion to be mapped. While this is being done the drawing pencil S is drawing the map.

The aerocartograph is a universal topographic mapping machine. It provides a means for drawing a complete topographic map from a stereoscopic pair of photographs and further, owing to its special optical switch, permits, by aerial triangulation, the extension of ground control throughout a flight of stereoscopic photographs.

Figure 29 shows the aerocartograph in use at Wright Field. It has been partially rebuilt and adapted to use the Army Air Corps T-3A (five-lens) camera pictures. The pictures are exposed with the usual 60 per cent overlap along the flight and 10 to 30 per cent side lap between adjacent flight strips. Contact positives on plate glass are made of each picture. The plates for the first stereoscopic pair are mounted on the plate holders in such relation to their respective lenses that the cones of light rays formed by passing light from the plates through the lenses is identical with those which originally come from the ground through the camera's lens to make the exposures. These cones of rays are transmitted by the optical train of prisms and lenses to the eyepieces at a convenient position for viewing by the operator. Now, guided by the parallaxes, seen at various specific points throughout the overlapping portions of the two plates, one plate is shifted along and parallel to the three rectangular axes of the aerocartograph and rotated about these three axes until its cone of rays perfectly merges with that of the other. The emulsions on the two plates now occupy the same relative spacial relation with each other in the mechanical system of the aerocartograph as existed in the air between the two films at the moments of the two exposures. The operator sees before him a stereoscopic optical model of the earth's surface in true horizontal and vertical proportions. He also sees an optical pointer in the form of a *V* which appears to float in the space of his optical model. The turning of the hand wheels moves the optical pointer about the entire field of the model. The rotation of the foot plate raises and lowers the optical pointer in this space. An automatic counter records the elevation of the pointer and a pencil on the drawing board of the coordinatorgraph moves always in the horizontal projection of the pointer, both in the horizon of the machine.

If two or more points in this area are known in horizontal position, the entire model can be expanded, contracted, tipped, or tilted until it is brought to the desired map scale, and its datum plane (usually sea level) made parallel and coincident with that of the machine. Wherever the pointer is placed in contact with the ground in this optical model as seen by the operator, the counter reads the true elevation of the ground at that point and the pencil gives its true horizontal position. Furthermore, the emulsion of each plate now occupies the same relative position with respect to the axes and horizon that the film in the camera did with respect to the ground and sea level at the time of the exposure. This is the fundamental assumption back of all triangulation work. For, if this is true, not only is that position of the second plate within this model in its true spatial position but all the plate is as well. If the third plate is now brought into perfect stereoscopic coincidence with the other half of the second plate, we have recovered the true spatial position of the third plate. All points in this second model can be measured and their true positions and elevations determined. This process is then continued throughout the strip.

The optical switch in the aerocartograph is the device which permits the above operation to be carried out successfully. By throwing a small lever, the left eye sees the right plate and the right eye sees the left plate. Thus, in effect, the whole right side of the machine is transported (optically) to the left and the left side to the right. Plate 1 is removed and 3 put into its place and adjusted stereoscopically to fit 2 without in any way disturbing the relation of 2 to the axes or horizon of the aerocartograph.

In each model, new control points are selected in the overlap area with the next model, one always being as near as practicable to the center of that plate which is common to both. The pencil is left on this point while the next model is being adjusted. The new model is brought to the proper scale stereoscopically by expanding or contracting it until this central point has the same elevation as in the preceding model. The pencil is then connected, other old points checked, with slight further adjustments when necessary, and again new points selected along the overlap with the next model. This is continued throughout the strip.

When enough ground control is available so that a good start can be obtained in each strip and there are new points to check upon in each new model, or at least every two or three models, no extended triangulation is necessary. As soon as a model has been adjusted and certain tie points chosen and measured for connection to the next model, all its detail can be drawn. But when there are wide gaps between control it is necessary first to resort to triangulation.

In plotting contours with this instrument the floating mark is brought in contact with some point of known elevation on the photograph and the foot plate locked. Then by operating the two hand wheels the floating mark is kept in contact with the ground. If one or both hand wheels are turned too much, the floating mark will appear to float in space or under the ground. By keeping the floating mark in contact with the ground, a contour of the known elevation is traced on the map.

The Stereoplanigraph

The stereoplanigraph is a stereoscopic plotting instrument used in much the same manner as the aerocartograph (Fig. 55). The main difference lies in the fact that the plate positives are viewed in the aerocartograph, and in the stereoplanigraph the projections of the two overlapped photographs are viewed.

The Multiplex Aeroprojector

The multiplex aeroprojector is a stereoscopic plotting instrument for producing maps by way of the simultaneous spatial project of several aerial pictures of a series.

The multiplex is a double-projection apparatus developed from the original ideas of Scheimpflug and Gasser. A relief model of the ground is generated by reversal of the photographic process and projection with rays of two complementary colors. Corresponding rays are caused to intersect in space by suitable adjustment of the projectors. This spatial model is stereoscopically viewed through filters of complementary colors in the form of spectacles, and is gone over and measured with the aid of a spatially adjustable measuring mark. A pen-

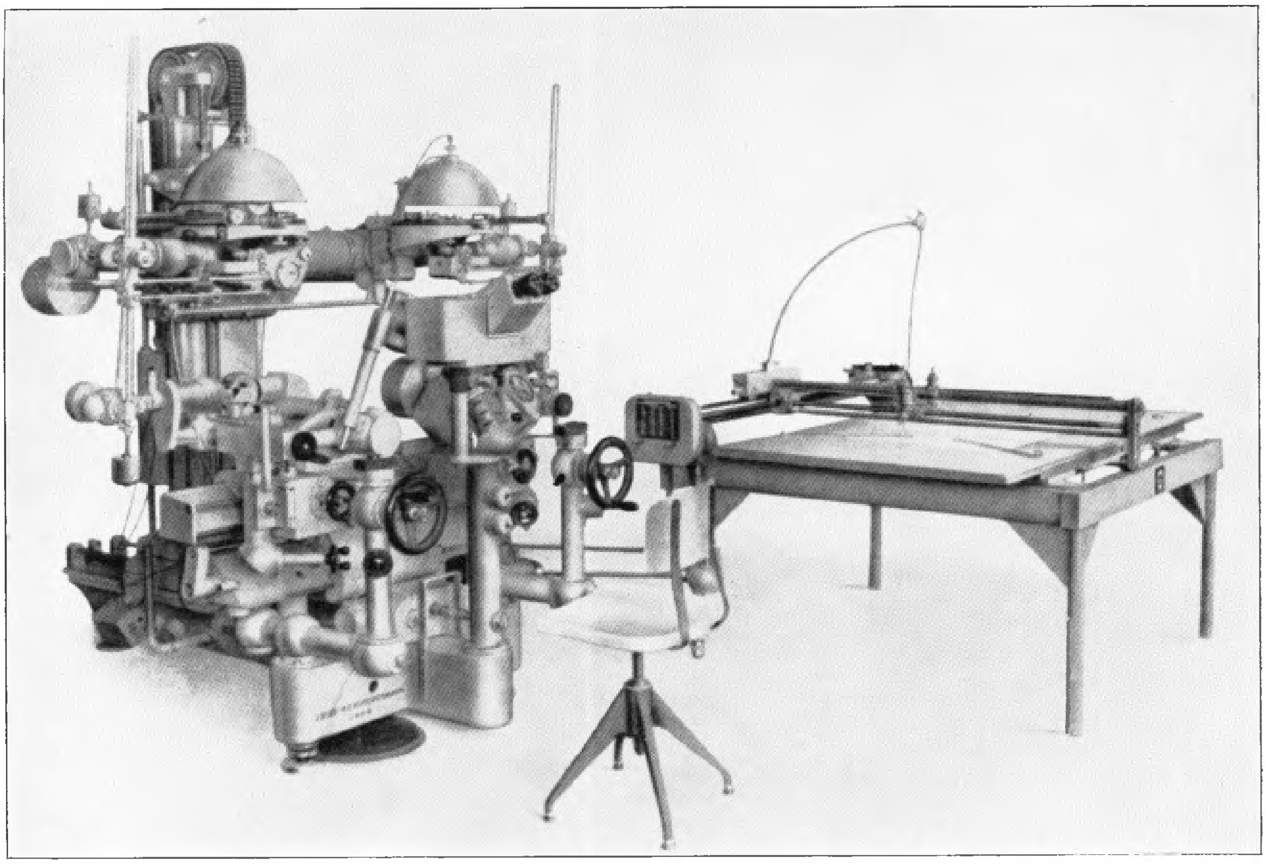


Fig. 55. Stereoplanigraph.

cil connected to the measuring-mark carrier permits of the direct generation of a map by the continuous tracing of topography and contour lines. As compared with most stereoscopic plotting instruments, the multiplex is simple, easily transported, and relatively low in price. Its efficient optical equipment and clear arrangement make for ease and convenience in use and permit of adapting the working speed to varying requirements. Handy size and suitable mapping ratio are obtained by the employment of 4 × 4 cm. (about 1½ × 1½ inches) reductions from the original negatives. This reduction in size enables the use of as many as nine projectors on a common carrier, while still enabling the entire instrument to be mounted on a table of ordinary size.

The multiplex is equally well suited to the mapping of plane and of mountainous country. Its field of use is a matter of the desired operating economy and of the working precision and scale ratio attainable by the process. The scale ratio, again, will be determined by the scale of the original pictures and the dimensions of the instrument.

To obtain maximum economy in plotting, the best mode of procedure is to trace the maps at anywhere from double to five times the intended final scale, the ratio used depending upon the precision demanded of the completed map. By proceeding in this manner, the drawing tolerances in the ultimate reduced map will be restricted to below the admissible limits of error.

Because of the small size of the projectors, vertical photographs taken with the commonly used aerial cameras of 8- or 5¼-inch focus, at an overlap of about 60 per cent, may be directly plotted to a scale of 1 : 5000 for flying heights between 4300 and 8500 feet, to a scale of 1 : 10,000 for flying heights between 8500 and 17,000 feet, and to a scale of 1 : 20,000 to 1 : 25,000 with flying heights over 17,000 feet. As an example, scales of 1 : 10,000 to 20,000 would generally be used in tracing with the multiplex to obtain a map of a scale of 1 : 50,000, or a scale between 1 : 20,000 to 1 : 25,000 for an ultimate ratio of 1 : 100,000, the tracing scale actually used depending upon the scale of the original photographs and the demands as to accuracy. The original maps so obtained are then reduced to the prescribed scale or, in the case of the examples mentioned, 1 : 50,000 or 1 : 100,000.

The several projectors used in the multiplex have provision for separately orienting them in space in a manner to reproduce the successive positions of the photographic camera at the moment of exposure. The carrier bar common to the projector is vertically adjustable. With this design, it becomes possible to orient, first, several pictures relative to each other, and then to orient all the pictures together. A stretch of some length can thus be bridged by as many as nine consecutive photographs without the need of ground control in the intervening space.

Figure 56 shows the multiplex aeroprojector equipped with nine vertical projectors. The supporting columns at a and a_1 form a base which in turn support the columns b and b_1. Supports a and a_1 can be used for horizontalizing the entire projection of the nine projectors.

Columns b and b_1 are equipped with hand wheels at c and c_1, which make it possible to raise or lower all the projectors and therefore change the scale of the projection.

At d (Fig. 56) is a bar arranged so as to prevent the projectors from being bumped by the operator's head, and may be adjusted to be either at the back or at the front of the projectors.

At e (Fig. 56) are shown four control stands used in scaling and horizontalizing the model. These stands are adjustable in height and have a small table which carries a small "floating mark." Otherwise the table is perfectly white. Vertically under this floating mark is a needle point which acts as an index mark when placing the stand over a plotted control point on the map sheet.

The differences in heights of these control stands are so set as to agree with the elevations of control points and to the scale of the map. If we now change the scale of the projection by raising or lowering the projectors and tip or tilt it so as to make the control points in the projection coincide with the floating points on the stands, we have oriented out projection and are now ready to draw on the map sheet.

The control stands are now removed and replaced with a tracing table T. This is somewhat similar to the control stands except that the table is larger and the needle index point is replaced with a pencil. The stand is provided with small rollers which allow for ease in movement over the draw-

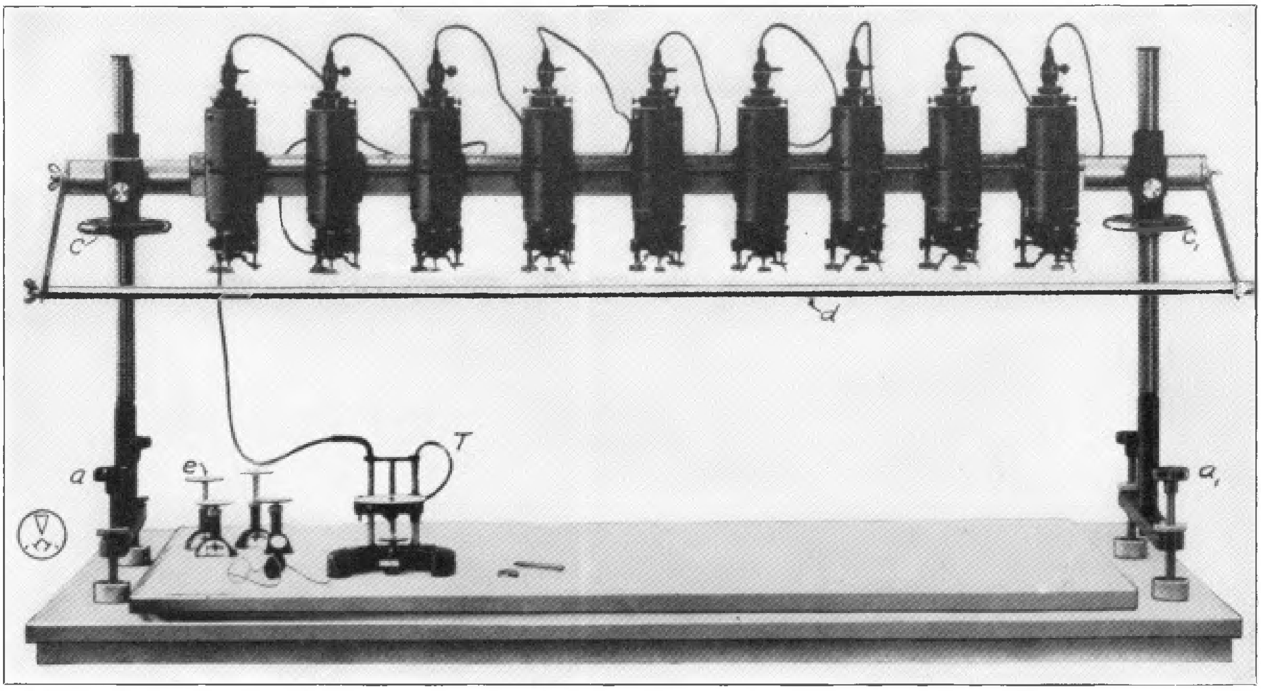


FIG. 56. Multiplex Aeroprojector.

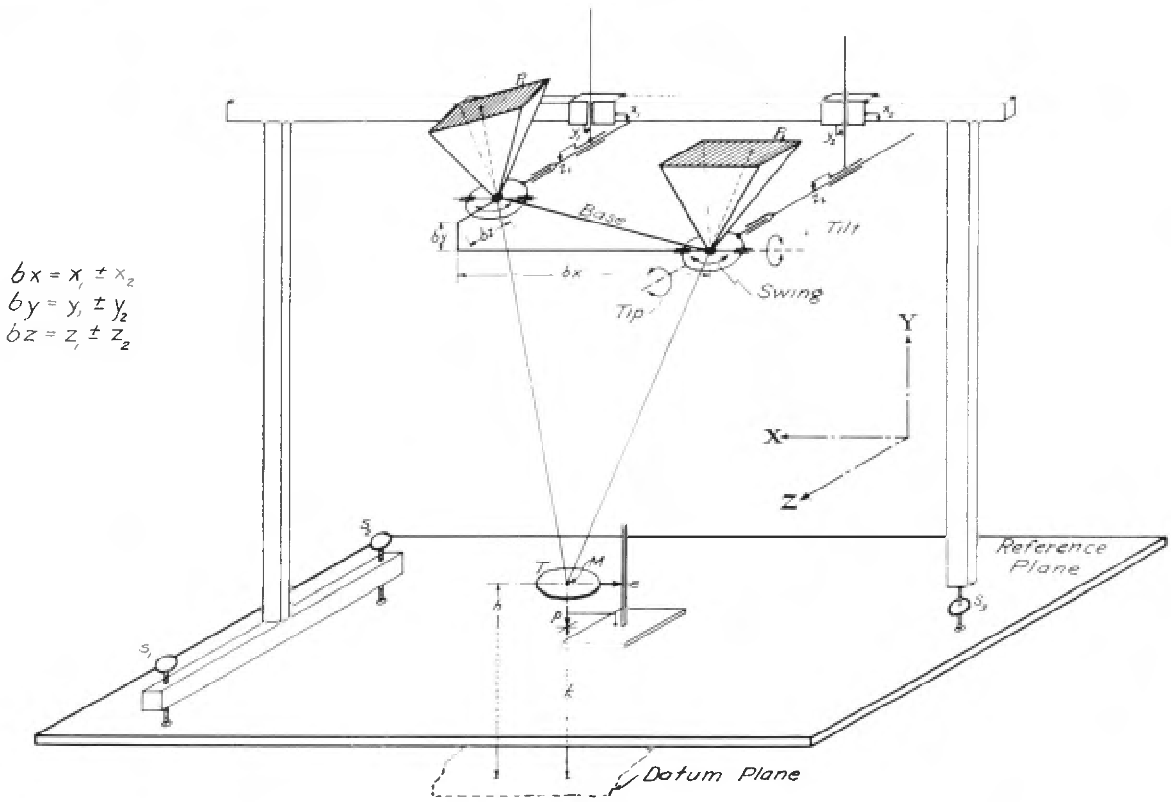


FIG. 56a.

ing table. The tracing table can be changed in height as in the case of the control stands and is white except for a small floating mark.

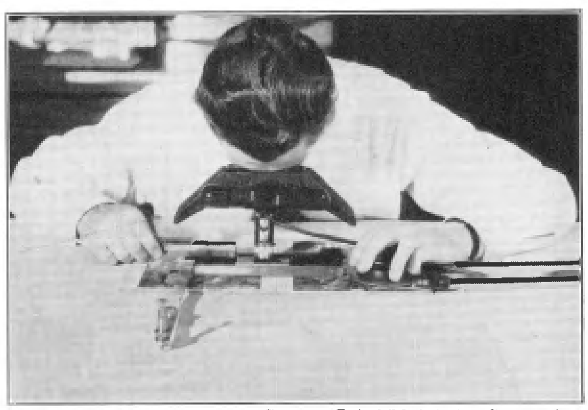
Figure 56*a* shows a schematic diagram of the theory and operation of the multiplex.

Diapositives are made on glass plates and reduced to the equivalent focal length of 46 mm. in a special reducing camera. Arranged above each other in a metal housing in the reducing camera are centered projection filament lamp, a multiple-lens condenser designed for obtaining uniform illumination of the image field, the film holder, the projection objective, and a frame for the diapositive plates.

The film is threaded through between two glass plates as it is unrolled from the spool without cutting, and is rewound on the receiving spool. Of the two glass plates which hold the film during the reduction process the lower bears marks for centering the picture, while the upper one serves as a pressure plate for flattening the film. This plate can be raised by a foot lever in order to free the film for advancing and adjusting it. The position of the pictures relative to the adjusting marks is observed through a window closed by a magnifying glass transmitting red light only, so that there is no disturbance to other darkroom operations from the use of the reducing camera. The plate-holder frame is rigid and is ground to the exact focal length. It carries stops for registering the plate in the correct position, and can be closed light-tight by means of a cover, thereby permitting the room illumination to be turned on whenever required after the plate is in place. The objective is so related to the optical equipment of the projectors as to prevent inadmissible deformation of the light beams and distortion of the image. Slidable in the neck of the housing below the objective is a compensator for neutralizing the natural marginal decrease in illumination caused by the objectives of the aerial cameras. Exposure is made by turning on the projection lamp by means of a lever switch on the side of the housing.

The diapositives resulting from the above process are now placed in projectors of the multiplex and in the order as photographed in the field with the usual 60 per cent overlap. The first projector has a bluish-green filter in it, number two a red filter, number three bluish-green, and so on through the series of projectors. The lights are turned out in the room and the lamps in the projectors are turned on. There is immediately visible a projection on the mapping table.* The operator, wearing a pair of spectacles with one bluish-green lens and one red lens, views this projection and immediately is impressed with a marvelous stereoscopic model which shows all the hills, valleys, and any change in elevation.

To draw a contour of known elevation the tracing table is moved so that the floating mark is in contact with a point of the required elevation. This is accomplished by raising or lowering the table and by moving the tracing table. After this adjustment has been accomplished, the tracing table is held at constant altitude and then moved so that the floating mark remains in contact with the ground. In doing this the pencil attached to the tracing table draws a contour of the elevation designated. After this contour has been drawn the altitude of the table is changed and the next contour drawn; the process is repeated for succeeding contours.



Courtesy Fairchild Aviation Corporation.

FIG. 57. Stereocomparagraph.

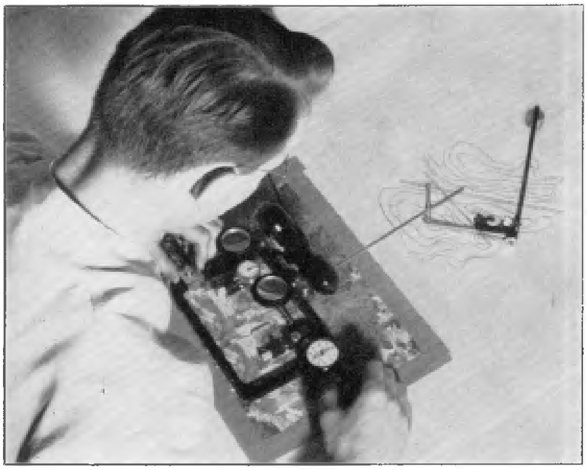
STEREOCOMPARAGRAPH

This instrument is a simple plotting instrument which uses the stereoscopic principle of parallax for plotting military and other small-scale contoured maps. It is one of the few stereoscopic plotting instruments manufactured in this country. It is manufactured by the Fairchild Aviation Corporation and is designed to be attached to a standard-

* See the anaglyph (two-color) plate with spectacles at the back of this book.

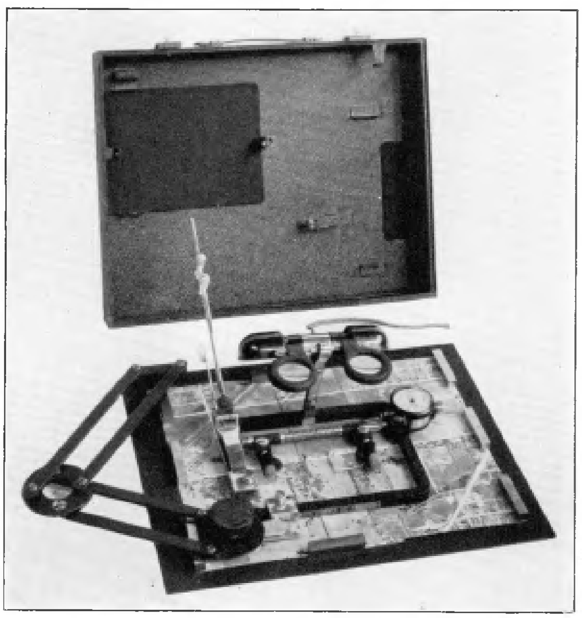
type drafting machine. Figure 57 shows this type of instrument.

The following derivation gives a more convenient equation to use with the stereocomparagraph.



Courtesy Abrams Instrument Company.

FIG. 57*a*. Abrams Contour Finder.

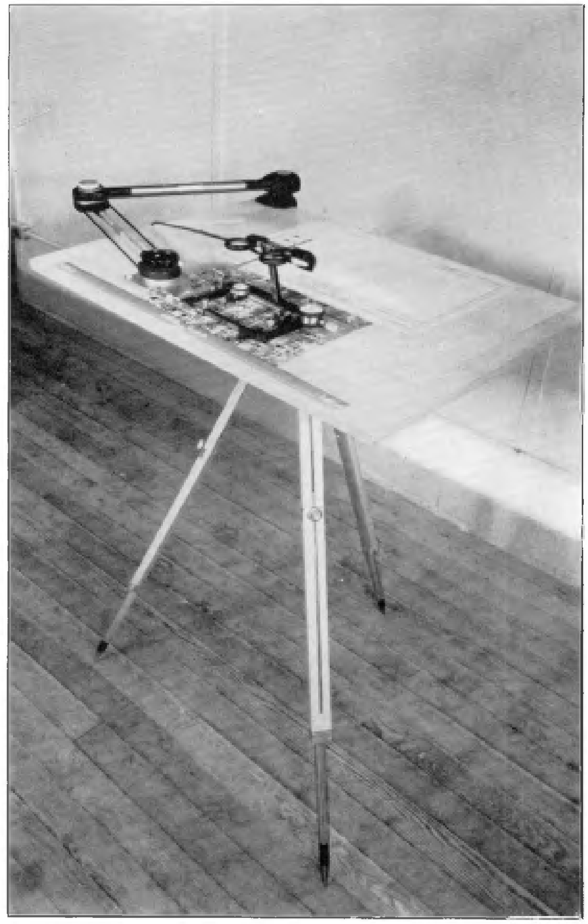


Courtesy Abrams Instrument Company.

FIG. 57*b*. Field Equipment for Using Abrams Contour Finder.

In Fig. 58 let C and A represent two points whose difference of elevation is Δh. The value of Δh is to be determined and, since the elevation of one point in practice must be known, like A, we need Δh to determine the elevation of C.

d = total displacement of the images of A.
d' = total displacement of the images of C.



Courtesy Abrams Instrument Company.

FIG. 57*c*. Plane Table Equipped with Abrams Contour Finder.

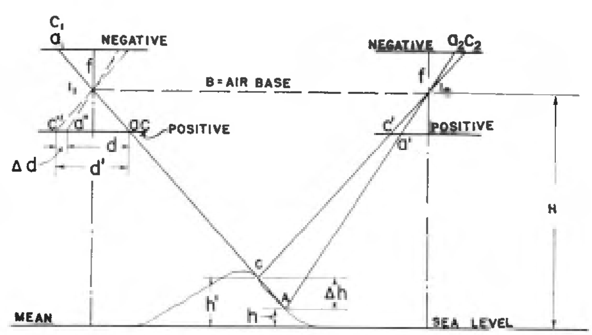


FIG. 58.

The difference in displacement due to the difference in elevation is $\Delta d = d' - d$.

H = the elevation of the camera lens above sea level.
B = the air base or distance between exposure.
f = the equivalent focal length of the camera lens.
h = the elevation of A above sea level.
h' = the elevation of C above sea level.
Δh = the difference in elevation of A and C = $h' - h$.

By similar triangles $I_1a''a$ and I_1I_2A.

$$\frac{d}{f} = \frac{B}{(H-h)} \quad \text{or} \quad d = \frac{fB}{(H-h)}$$

By similar triangles $I_1C''a$ and I_1I_2C.

$$\frac{d'}{f} = \frac{B}{(H-h')} \quad \text{or} \quad d' = \frac{fB}{(H-h')}$$

$$\text{Then } \Delta d = d' - d = \frac{fB}{(H-h')} - \frac{fB}{(H-h)}$$

$$= \frac{fBH - fhB - fBH + fh'B}{(H-h')\,(H-h)}$$

or

$$\Delta d = \frac{fB\,(h'-h)}{(H-h')\,(H-h)} \qquad [1]$$

This equation may be expressed in terms of B_m. The air base on the photograph is expressed in millimeters; f_m, the equivalent focal length of the camera lens, is expressed in millimeters; and H and h in feet.

The value of Δd is usually in millimeters as read from the micrometer on the stereocomparagraph. Then

$$B = \frac{B_m\,(H-h')}{f_m}$$

Substituting this value of B in equation 1, we have

$$\Delta d = \frac{f\,(h'-h)}{(H-h')\,(H-h)} \times \frac{B_m\,(H-h')}{f_m}$$

$$\Delta d = \frac{B_m\,(h'-h)}{H-h}$$

Let $(h'-h) = \Delta h$. Then

$$\Delta h = \frac{\Delta d\,(H-h)}{B_m} \qquad [2]$$

The stereocomparagraph shown in Fig. 57 consists of a stereoscope, a measuring system, a drawing attachment, and an alignment mechanism. It is also equipped with two lights for illuminating the photograph.

The stereoscope is of the reflecting type, with a pair of matched lenses for magnification of the detail of the photographs. The mirrors are provided with an interpupillary adjustment to allow easy fusion of the images of the photographs and floating marks. This is accomplished by changing the angle of the mirrors by turning a knurled screw located beneath the hood.

The measuring system consists of two floating marks, one in the center of each lens. The lenses rest on the photographs, and the space between the lenses may be varied by means of a micrometer attachment located to the right of the operator. Only one lens moves, and the amount of its movement is measured on the micrometer head. The micrometer is graduated from 0 to 25 mm., reading directly to hundredths of a millimeter, and is provided with a lock to clamp it at any setting. The micrometer head travels ½ mm. for each complete revolution. It is graduated with 50 divisions, making each division 1/100 of a millimeter. The short marks above the line on the barrel indicate ½ mm., and the long marks below the line indicate whole millimeters.

The micrometer records the movement of the right-hand lens and is operated when the floating mark (caused by the fusion of the two) is made to rest upon a point in the fused image of the stereoscopic model.

The left-hand mark may be moved a distance of 25 mm., in steps of 5 mm., by removing the pin in the lock and then inserting it in another hole after the lens has been moved. This movement will affect the parallax readings and there it is better not to change the left mark after a set of photographs have once been set up. If a change is necessary, the extent of the movement should be added to or subtracted from the micrometer readings taken after the movement.

The right-hand mark may be moved in or out a distance of ¼ inch on either side of its zero position by the small knurled nut directly in front of the lens. The purpose of this motion is to compensate for small amounts of tilt.

The drawing attachment consists of a special pencil mounted at the end of a drawing arm attached to the base of the instrument. The pencil chuck at the end of this arm holds a drawing lead and, when in contact with the drawing paper, records any movement of the instrument. This drawing attachment is used when contours are to be drawn directly by the floating-point method.

The alignment mechanism consists of any standard drafting machine.

Operation of the Stereocomparagraph. Assume that the stereocomparagraph has been assembled and attached to the drafting machine. Then:

1. Place a clear white paper under the floating marks.
2. Set and pin the left floating mark in its middle position along the base.
3. Set the (by) motion of the right floating mark in its middle position.

Note: The (by) motion is the motion which moves the right floating mark in a direction at right angle to the base of the instrument and is the adjustment for compensation of tilt.

4. Adjust the interpupillary setting of the stereoscope and micrometer until the index marks fuse into a single floating dot without eye strain with the micrometer near its midpoint on the scale.
5. When the adjustment for interpupillary distance has been made, any images brought under the index marks will automatically fuse and may be observed stereoscopically.

Preparation of the Photographs.

1. From the fiducial marks on the photograph spot the center of each photograph and mark by a pin prick.
2. Since the photographs were taken in a flight strip with at least 60 per cent overlap, the center of the second photograph in a flight strip may be spotted on the first photograph and the center of the first photograph spotted on the second photograph. (See Fig. 59.)

The line (a–b) may then be drawn on each photograph and is the air base (B_m) when measured in millimeters on the photograph.

3. Place the photographs under the stereocomparagraph so that the distance from a (photograph 1) to a' (photograph 2), Fig. 60, is the same as the distance from the left floating dot to the right floating dot on the lenses. The distance b' to b should be the same, provided the scale of the two photographs is the same.

In addition turn the photographs so that the straight edge of the stereocomparagraph falls along the lines a–b' and a'–b.

Fasten the photographs to a stable background, and the set-up is complete and ready for operation.

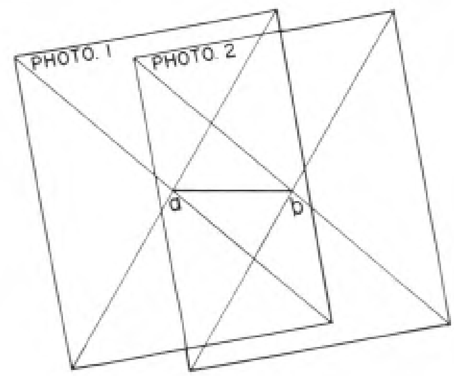


Fig. 59.

In the operation of the stereocomparagraph, differences in elevation are represented by difference in parallax. Contour lines may be drawn by the use of the fused floating mark in the following manner. At least two (preferably four) or more control points should appear in each photograph.

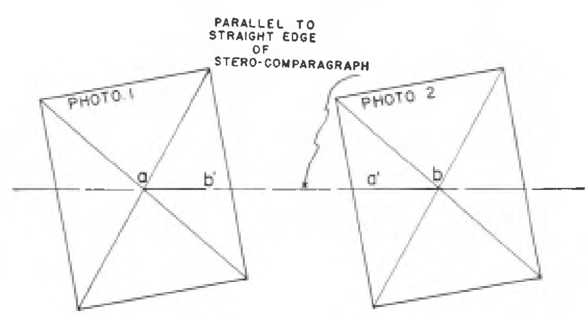
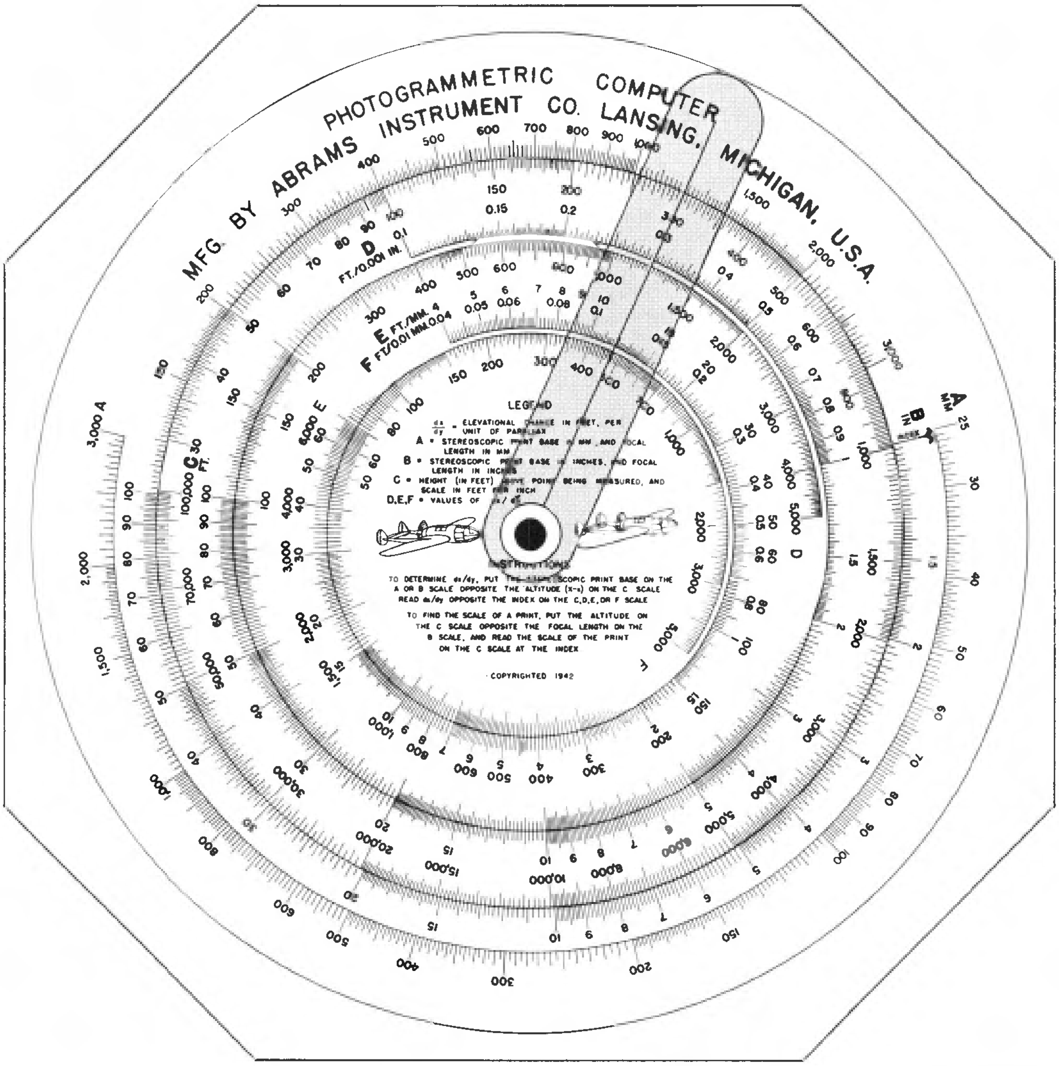


Fig. 60.

1. Bring the floating mark in contact with a control point by adjusting the micrometer. The fused image of the floating mark will appear to rise or fall as the spacing of the marks is changed. When the fused floating mark appears to rest on the control point in the stereoscopic model, read the micrometer.
2. Move the instrument to a second control point and proceed in the same manner. Read the micrometer.



Courtesy Abrams Instrument Company.

FIG. 61. Abrams Photogrammetric Computer.

3. The difference between the two micrometer readings (in millimeters) will be the change caused by the difference in elevation of the control points. Since the difference in elevation of the control points is known from the control data, compute the movement of the micrometer for the contour interval desired.

4. Settings may then be computed for desired contours.

5. Now move the instrument until the fused floating mark appears to be in contact with the ground in the stereoscopic model.

6. Lock the micrometer and release the pencil on the tracing arm.

7. Move the instrument over the photographs, keeping the fused floating mark in contact with the ground, and a contour of the desired elevation will be drawn by the pencil.

8. Compute a micrometer reading for the next contour level, set the micrometer, and proceed in a similar manner.

The contours should be drawn on a separate sheet of paper and later transferred to the planimetric map.

In the foregoing description it was assumed that the tilt was negligible. If tilt exists in the photographs, some method of correction should be used. A graphical method and the use of stereoscopic parallax tables are best. These tables are included in a technical manual, *Topographic Drafting TM 5-230*, published by the Superintendent of Documents. (See the tables at end of this book.)

Contouring may be done with the stereocomparagraph by the use of spot elevations. This would correspond to the common method of topographic surveying known as transit stadia. Some control points are necessary and readings are taken from the micrometer with the fused floating mark in contact with each of the control points. Readings are next taken on new points, such as tops and bottoms of hills. Differences of parallax are determined from the readings on control points and the readings on new points. Using these differences of parallax in the equation or using a table, determine the difference of elevation between a control point and a new point. Proceed in this manner through the entire photograph and then interpolate for the contours desired, in the same manner as with the transit stadia method.

The Abrams Contour Finder

This small and compact instrument is equipped with a drawing attachment for obtaining topographic information from vertical aerial photographs. It consists of the following parts: stereoscope, parallax measuring unit, drawing attachment, lighting unit, and alignment mechanism. This instrument is illustrated in Figs. 57*a*, 57*b*, and 57*c*.

Operation of the Contour Finder. Assume that the contour finder has been assembled and attached to the drafting machine.

1. Set the dial gages at the midpoint of their range and place a stereoscopic pair of aerial photographs under the instrument so that the indicating dots cover exactly the same point in both photographs.
2. The photographs must be at right angles to the instrument and the dots in direct line with the line of flight or base line of the photographs.
3. Now fasten the photographs securely to the table, and they are ready for measurements for changes in elevation.
4. If the hand on the large dial (right side) is turned clockwise, the dot will appear to rise in the stereoscopic model. If the hand on the dial is moved counterclockwise, the floating dot will move lower.
5. Keep the instrument in alignment with the photograph and, by moving the instrument with the floating dot always in contact with the ground, a level line on the ground can be traced onto a map to the same scale as the photograph.
6. Higher or lower contour lines can be traced by raising or lowering the floating dot an amount computed for each contour level.

Figure 61 shows the Abrams photogrammetric computer which has been designed to solve parallax and scale equations. It may be used to determine the scale of a photograph when the altitude and focal length are known. The altitude may be found if the focal length and scale are known, or the focal length of the camera lens may be found if the altitude and scale are known. In other words, it solves the scale fraction formula $S = \frac{H}{f}$, when two of the quantities are known and one unknown.

The same computer may be used to determine the difference in elevation from the measured parallax difference, the elevation of the plane, the focal length of the camera lens, and the air base distance measured on the photograph.

The precisions of the various plotting instruments are usually expressed in terms of the altitude and are of the following order:

The stereoplanigraph	$\frac{1}{1500}$	of the altitude.
The aerocartograph	$\frac{1}{1000}$	of the altitude.
The multiplex	$\frac{1}{500}$	of the altitude.
The stereocomparagraph	$\frac{1}{300}$	of the altitude.
The contour finder	$\frac{1}{300}$	of the altitude.