THE S.O.M. POIVILLIERS TYPE D STEREOTOPOGRAPHER

I. OBJECT AND PRINCIPLE OF EQUIPMENT.

The S.O.M. Poivilliers Type D Stereotopographer was designed by Mr. G. Poivilliers for the "Institut Géographique National" (French National Geographical Institute) with a view to speeding up ordinary surveying work in areas which do not call for very great mapping accuracy. The main object was speed and convenience, and the instrument affords precision in plotting within limits which to-day are easy of attainment; it is necessary in this connection :—

1) that the angle of air photographs with the horizontal plane be less than 10 grades ;

2) that the exposure inclination base be less than 10 grades on the horizontal plane.

The Type D Stereotopographer makes it possible to use the results of surveys made with cameras having a 120 to 300 millimetre focal length, and a size reaching 24×24 centimetres.

Examination of the photographs is effected stereoscopically with sufficient enlargement so that the greatest possible advantage may be taken of the fineness of the photographs.

The equipment is simple, takes up little space, and is easy to adjust and operate. It belongs to the well-known class of plotting instruments that materialize perspective rays by means of two rods. It includes, however, a certain number of original features which appear worthy of description.

The design of Type D Stereotopographer is based upon the following three principles :—

1) Space perspective rays are materialized by two sliding rods rotating around fixed points, each of them shifting a carriage in a plane that can be oriented in the same direction as the negatives during exposure. The plane described by the connection of the sliding rod and of the carriage may be brought to a suitable distance (equal to the focal length of exposure) from the connection materializing the perspective point of sight (the fixed point of the sliding-rod).

2) For observation purposes, plates in the same plane are connected to the carriages by metal bands which give them a vertical motion equal to that of the corresponding carriage. They are examined by means of a fixed stereomicroscope (with an adjustable lens) at the beginning of operations, for focussing and centering of the plates.

3) Distortion of the camera lens is corrected by means of an original device provided with a cylindrical cam.

II. DESCRIPTION OF TYPE D STEREOTOPOGRAPHER. (1)

The equipment consists of a cast-iron frame (1) resting upon the plotter table (2) by means of three levelling screws (3). The table stands on the floor on four strong adjustable legs. The levelling screws have a span of 24 centimetres. Moreover, three intermediate screws, 10, 20 and 30 centimetres long, can raise the frame over the table in the same amount.

The actual mechanism consists essentially of :—

a) A photo-observation device : microscope and photo-holder ;

b) Two carriages which, in this particular instrument, correspond to the plotting cameras in the Type B Stereotopographer ;

(1) The figures in parentheses found in the text refer to both the indications on the diagram (fig. 1) or the photograph (fig. 2). The figures in italics, however, only appear on the photograph.

(2) In the following the image in relief is related to a rectangular axis system, the X axis of which is parallel to the base of exposure (or to the coordinatograph traveller), and the Y axis of which—perpendicular to the same base—is parallel to the rails on which the coordinatograph traveller runs. In the same way each photograph is related to an Ox, Oy rectangular axis system, the Ox axis being parallel to the direction which, on each photograph, connects the center with the image center of the other. When the negatives are in their proper place in the instrument, the Ox axis is approximately horizontal.

c) Sliding rods that materialize space perspective rays ;

d) A block that materializes the plotted point ; the block's motion being controlled by a cross slide carriage system operated by cranks and constituting a coordinatograph. This block holds the lower joints of the sliding rods.

These various features are described briefly below :

(1) Plate observation device.

The stereoscopical observation of plates in done through a bent stereo microscope. The front part of each microscope arm (3) holding the objective lens in connected to the back part (4) by a joint which enables it to rotate around an axis perpendicular to the plane of the photograph. This joint (together with the possibility of moving the whole front part of the microscope a few millimetres parallel to the X axis of the coordinatograph by means of milled knobs) (5) makes it possible to take a sight of the center of the plate when the sliding rod is in its original position, that is, perpendicular to the displacement plane of the carriage.

The microscope arm (3) is provided with a ring for focussing on the photographic image whatever the thickness of the film.

As designed, the equipment allows viewing of positives with their sensitive surface turned towards the lens of the microscope, or of negatives through the material used. The purpose which the "Institut Géographique National" (1) expects this equipment to serve is the following :—The survey to be plotted will essentially concern French Overseas territories, and pictures will be taken either on film or on plates. In the first instance, it does not matter if viewing takes place through the material used owing to its thinness and excellent transparency. Work will therefore be done using the original negatives. In the second case, however, for security reasons due to possible breakage of plates during shipment, the "Institut Géographique National" has long been printing diapositives on the spot (on drawn glass plates backed with a layer of non-sensitive gelatine) of the plate negatives taken overseas.

The orientation of the images seen through the microscope can be rectified by turning a knob (6) which controls a Wollaston prism.

The distance between the eye-pieces is regulated by a knob (7). The plate holder can hold sizes of photographs in use at the "Institut Géographique National" (i.e. 13×18, 18×18, 19×19, 18×24, 24×24). Maximum deflection may reach 10 grades on either side of a mean axis.

Displacement of the photographs is equal to that of the upper connection point of the sliding rods.

(2) Carriages.

On the frame (1) 2 cradles (8) can slide along and be locked at a suitable distance. The cradles carry intermediate cradles (*9*) that can rotate with respect to (8) around axes x_1 and x_2 perpendicular to the exposure base.

The upper joints of the sliding rods that materialize the points of sight of the photo map are connected with the cradles (8).

Joint x_1 of left cradle (*9*) passes through the fixed point of the left sliding rod and joint x_2 of the right cradle (*9*) passes through the fixed point of the right sliding rod.

The rotation around axes x_1 and x_2 is controlled by a knob (*10*) called "convergence knob".

Intermediate cradle (*9*) has rails on which a carriage (*11*) runs on roller bearings. The horizontal projection of the direction in which the carriage runs is the direction of component Bx of the exposure base. Carriages (*11*) is connected to an upright (12) provided with rollers controlling the movement of the photo-holder. The movement take place in a direction perpendicular to that of the cradle roller rails (*9*) and its horizontal projection is the same. Carriage (*11*) supports a part (*13*) that moves in relation to (*11*) around an axis passing through the sliding rod joint and parallel to the cradle rails (*9*).

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(1) With the prototype which is shortly to go into operation at the "Institut Géographique National" (upon completion of a few alterations which are now being made), a very satisfactory plotting test was effected at the works in June-July 1948, by technicians of the Institute.

A second similar instrument was exhibited at The Hague on the occasion of the Sixth International Congress on Photogrammetry. Twelve sets of this equipment are now being built for the "Institut Géographique National".

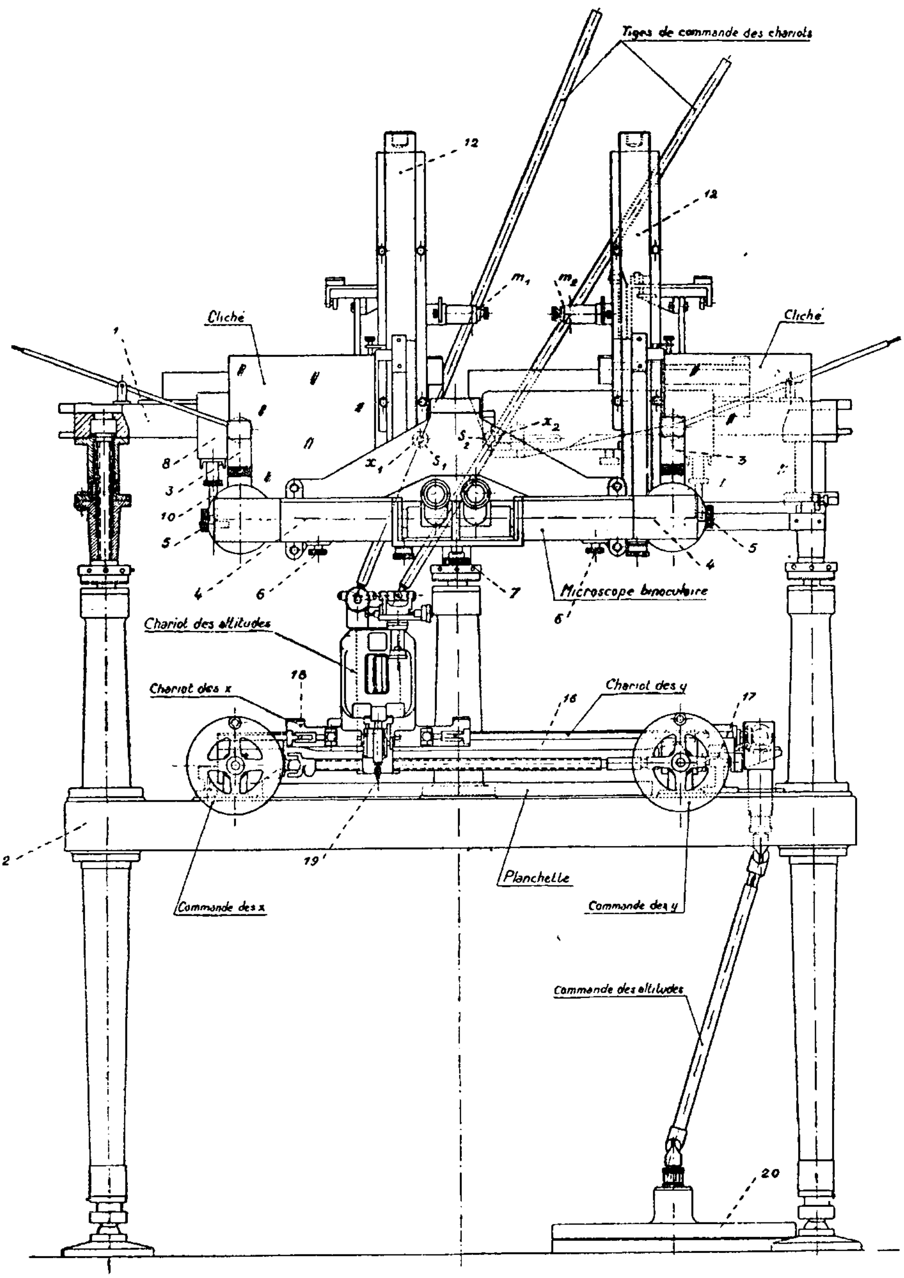

FIG. 1
Diagram of S.O.M. Poivilliers Type D Stereotopographer.

The rotation of (*13*) in relation to (*11*), or rotation for elevation, is controlled by means of a knob (*15*).

Carriage (*14*) rolls on part (*13*), and the rod joint materializing the viewed point of the photograph is connected to the carriage. The direction of its motion is at right angles to the direction of the carriage (*11*) roller rails on cradle (*9*).

A metal tape on a pulley system sets in motion the upper carriage on part (*13*) and the photo-holder in relation to upright (12) simultaneously.

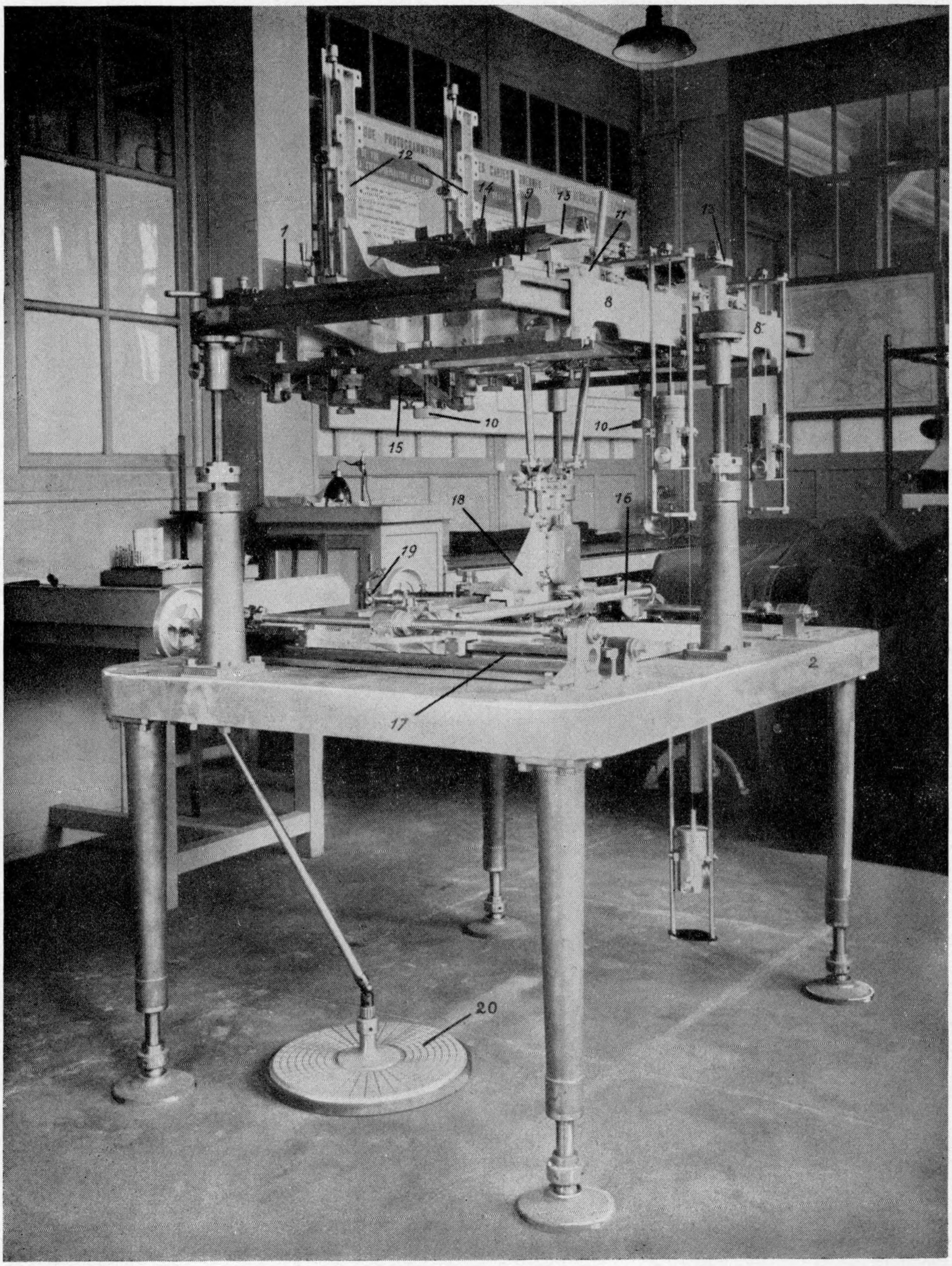

FIG. 2
Model of S.O.M. Poivilliers Type D Stereotopographer.

Y-motion of the photo-holder in relation to a given position of carriage (*14*) is obtained by manipulating a knob controlling one of the metal tape reversing pulleys and by changing the position of the metal tape connected with carriage (*14*). The purpose of this device is to obtain y—sighting of the center of the photograph when carriages (*11*) and (*14*) are in their original positions.

These original positions, in relation to which the rod is at a right angle with the plane of shift of carriage (*14*) are marked on carriages (*11*) and (*14*) by means of an adjustable pointer.

The free end of the connecting tape carries a counterbalance. The part carrying the connection of the rods materializing the viewed point of the photograph and the distortion correction device shift in relation to carriage (*14*) by means of a dove-tail slide controlled by a screw (fig. 3).

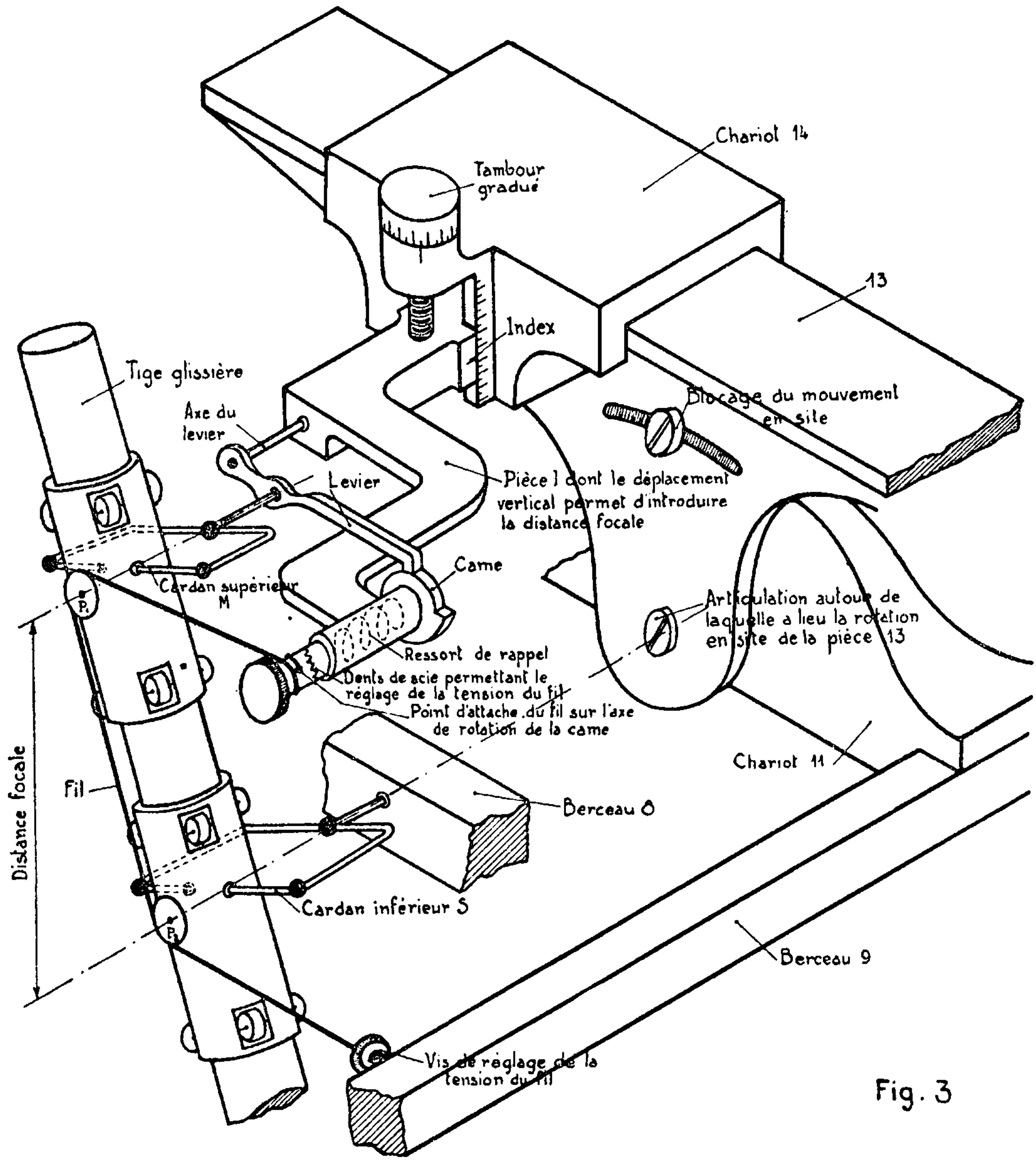

FIG. 3
S.O.M. Poivilliers Type D Stereotopographer.

The distortion correction device for the photographic lens is shown in detail in figure 3 and is described below :

The center of the lower gimbals S materializes the point of sight.

The center of the upper gimbals M materializes the photograph point.

The sliding rod slides through 2 sleeves each provided with 6 rollers and whose common axis passes through S and M.

The lower S gimbals are connected to the frame ; their center is fixed.

Upper gimbals M are connected to carriage 14 which moves in two perpendicular directions ; first running on part 13, enabling elevation to be obtained, and secondly, parts 13 and 11 combined run on cradle 9.

The convergence of the photograph is entered by rotating cradle 9 around a horizontal axis perpendicular to the base and passing through S. The photograph angle of elevation is entered by rotating part 13 in relation to carriage 11 around an axis whose horizontal projection is parallel to the base and also passes through S.

The combination of these two movements causes the center of gimbals M to describe a plane materializing the plane of the plates, the distance of which to point S represents the focal length. To enter this focal length, gimbals M are connected to carriage 14 through part 1, which slides vertically along a dove-tail slide ; the movement is controlled by a screw and marked by a pointer moving in front of a division and by a scaled drum.

As a result of the distortion of the objective, it is as if the focal length varied in terms of angle α formed by the perspective ray with the axis of the lens, or expressed otherwise, as a function of Distance $L = \frac{f}{\cos \alpha}$ connecting the image nodal point of the objective to the viewed point of the photograph.

Distance L is materialized on the instrument by the distance between the centers of the two S and M gimbals.

Variation of focal length as a function of distance SM is obtained in the following manner :

Gimbals M are connected to a lever whose axis is carried by intermediate part 1 and whose extremity rests against a cylindrical cam which rotates around an axis related to part 1.

One of the ends of a wire is connected to a cylindrical part related to the cam and passes over 2 pulleys (P_1 and P_2) on each of the sliding rod sleeves. The axis of one of the pulleys passes through M and the other through S ; the other end of the wire is connected to an adjustment screw on cradle 9 of the corresponding camera.

Variations in the length between S and M produces an equal variation in the length of the wire between pulleys P_1 and P_2, and since the length of the wire is constant, the variation causes a rotation of the cam axis to which the free end of the wire is connected. The position of the lever and that of the cam are therefore solely dependent upon the length of SM. Shifting of the lever end produces a shift in the same direction—though reduced in a ratio of about 1/6—of the center of gimbals M. A release spring concentric to the cam axis keeps the wire stretched ; tension adjustment is obtained in two ways : (1) the screw to which the end of the wire is connected can be screwed in varying degree into the frame and (2) the cylindrical part to which the correcting cam is connected consists of two parts joined together by a sawtoothed coupling.

The cam is cylindrical, then, and easy to compute and to construct. It is determined in polar co-ordinates (ρ a function of angle ω) : angle of rotation ω of the cam is in the same ratio as changes in the length of the wire between S and M, and variations of the vector radius ρ (leaving out the amplification coefficient of the lever arm) are equal to variations in the principal distance.

(3) Sliding Rods.

These consist of two cylindrical solid Stubb steel rods. According to the focal length of exposure or the scale of the plastic image, two types—one 50 centimetres long and the other 1 metre long— are used. Their lower joint, which materializes the plotted point, is mounted on gimbals ; they slide in sleeves fitted with roller clamps and likewise articulated by means of gimbals around one point materializing the perspective point of sight and another the viewed point on the photograph.

(4) Plotting mechanism.

The motion of the plotting mechanism is controlled in X and Y by cranks. The right crank moves a traveller (16) along rails (17) in a direction parallel to the Y-axis. On this traveller a carriage (18) controlled by the left crank and by a conical pinion reversing gear, runs parallel to the X-axis.

A tracer (19) is directly connected to carriage (18) and can be adjusted both as regards distance and direction in order to facilitate setting of the map on the tracing table.

The block which restores the plotted point carries the lower joints of the rods and operates in conjunction with a bar showing heights that slides vertically over a 90 mm. course inside carriage (18). This vertical motion is controlled by means of a pedal (20) and is marked by a millimetre scale fitted with 1/100° vernier. The positions of carriage (18) in X and Y are also marked by scales, the maximum course in X reaching 0 m. 42 and in Y 0 m. 48.

The lower joint of the left rod can move ± 1 cm. parallel to the Y-axis and in relation to carriage (18), whereas the lower joint of the right-hand rod *can move ± 1 cm. parallel* to the X-axis and vertically. The object of these movements is to introduce base components By and Bz and *to bring to completion the setting to scale initiated* by the distance adjustment of the two cradles (8).

To complete the description of the Type D Stereographer, its main features are given below :—

Focal distance of plates	from 120 to 300 mm. (by changing intermediate part *13* ; there is a set of 3 intermediate parts).
Maximum size of photographs	24 × 24 cms.
Base range	0 mm. to 270 mm. (1)
Size of tracing table	0 m. 64 × 0 m. 90.
X carriage course	0 m. 42.
Y carriage course	0 m. 48.
Z bar course	0 m. 09.
Maximum tilt of exposure axes upon the vertical	10 grades.
Maximum base tilt	10 grades.
Distance of plotted point to base	70 to 290 mm. 150 to 390 mm. 250 to 490 mm. 350 to 590 mm. (according to the wedge raising the frame).
Magnifying power of microscope	4, 6, 8 (obtained by changing the eye-piece).
Weight of equipment	About 250 kg.
Maximum bulk	Width : 1 m. 30. Depth : 1 m. 10.
Total height	2 metres.
Height of axis of eye-pieces	1 m. 22 + 0 m. 21. — 0.
Table height	0 m. 76 + 0 m. 06. — 0.

III. ADJUSTMENT AND CALIBRATION OF EQUIPMENT.

The only adjustments necessary and depending solely upon the instrument itself are the following :—

1) Adjustment of the pointers marking the initial position of the rods in X and Y, perpendicular to the carriage movement plane (*14*) ;

2) Calibration of the drum controlling variations in principal distance.

(1) The "zero base" is at present being carried out upon the prototype at the "Institut Géographique National" and on standard instruments. The stereographer exhibed at The Hague has a minimum base of 60 mm.

From measurements taken upon the first adjustment, calibration of the principal distance can be deduced.

There are two carriages to be set, each in relation to the two co-ordinates. Consequently there are four successive and independent adjustments to be made, which are identical in principle.

Thus, for example, to set left carriage (*11*) parallel to the X-axis, there is advantage in having carriage (*14*) almost in its initial position in relation to the Y-axis. A grid of the largest possible size is then placed on the left photo-holder and its tip is regulated in such a way that the microscope micrometer keeps pointing along one line of the grid when only the X crank is operated. Care will have to be taken beforehand to set the carriages in the proper direction through the convergence and elevation movements, so that the roller rails will be parallel to the coordinatograph's. To make this adjustment, it is sufficient to place a spirit level first on the coordinatôgraph rails and then upon the rails of carriages (*11*) and (*13*), and the bubble is made to take the same position. Two points a and b are sighted at the top of the grid, as far apart as possible, and readings l a, l b, l' a, l' b are then marked on the traveller when the bar showing heights is set at o and at h = 90 mm.

From the measurements, the L reading corresponding to the perpendicularity of the rod and carriage is then deduced, as well as the focal length f.

From figure 4 it can readily be seen that

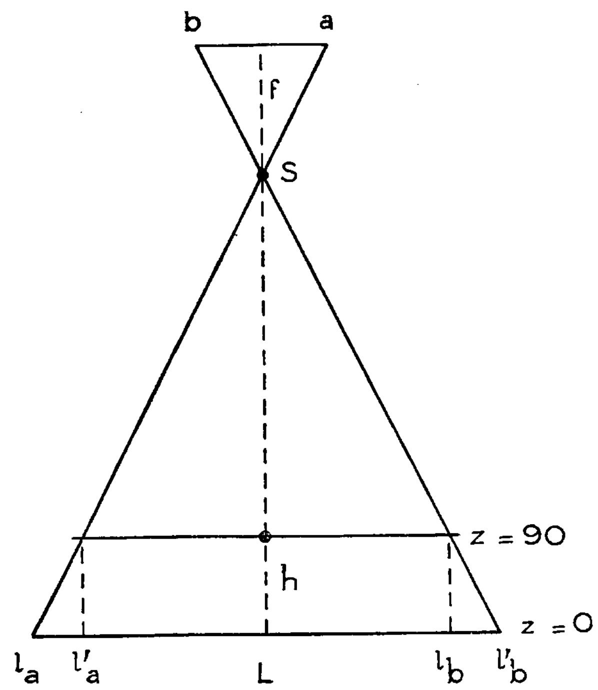

FIG. 4

$$L = \frac{l\,a\;l\,b - l'a\;l'b}{(l\,a - l'a)\;(l\,b - l'b)}$$

$$\text{and } f = \frac{h \times \overline{ab}}{(l\,a - l'a)\;(l\,b - l'b)}$$

The two successive adjustments (in X and Y) supply two f values, which are averaged. A total check of the quality of the equipment can be obtained by placing a grid in each photo-holder and by getting a plastic image from it. The latter must be an image of a cross-section grid drawn on a *plane* surface. A check is made that deviations from the plane are not in excess of tolerated amounts. With respect to all such adjustments, the distortion correction device need only be provided with one circular cam.

It is easy to see that the other determination which would seem to be necessary — as for instance the initial value of Bx, By and Bz, of X and of Y, — are not constants of the instrument, as they depend upon the tilt of the frame which is obtained by means of the levelling screws. Besides, they are not strictly necessary for plotting purposes.

IV. USE OF THE EQUIPMENT.

The following matters will be dealt with in turn :

— formation of the plastic image ;
— setting to scale ;
— orientation of the plastic image verticals ;
— first results obtained.

I.—FORMATION OF PLASTIC IMAGE.

No plastic image formation method suitable for other instruments can be adapted for use with the Stereotopographer. In most restitution instruments, whatever their principle and photo-viewing methods, the formation of the plastic image consists of the following operations :—

— centering of the plate in the cameras after introducing a correct plotting focus into the apparatus ;

— relative orientation of the two perspective beams. Once the plastic image has been formed, the operations that remain to be carried out (i.e. setting to scale and orientation of verticals) do not call for any further going over of what has already been done.

In the Type D Stereotopographer, action upon the elevation and convergence controls decenters the plates, and *it is necessary, therefore, to combine the formation of the two bundles of perspective rays and their relative orientation into one simultaneous operation, by a method peculiar to the instrument.*

It should be noted, moreover, *that if the axis of the photographs is appreciably vertical and if the unevenness of the ground in relation to the altitude of the airplane is small, the effect of decentering may be disregarded even though the decentering be fairly extensive.*

In fact, in this case :—

e) Decentering in Y produces the same parallax throughout both plates ; this parallax can be removed by entering the By required.

2) Decentering in X does not introduce any parallax at all.

Besides, the two components of the plate decentering do not distort the plastic image. It stands to reason, however, that even with the D Stereotopographer care must be taken to recenter negatives several times in the course of formation of the plastic image and one last time (after operations have been carried out) prior to final plotting.

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There exists, however, a simple and rather swift method for the formation of the plastic image which consists in removing the parallax at 6 properly selected points : at nadirs N_I and N_2 and 4 points A, B, C, D having the same abscissa as the nadirs and ordinates as large as possible.

The relative arrangement of the 6 points is then as follows :

A	B
N_I	N_2
C	D

The procedure consists in examining these 6 points, in a certain order, and in either removing the parallax exactly, or overcorrecting it with a coefficient either determined experimentally or computed from the readings of the instrument.

These coefficients depend on the focal length and size of the plates.

This method is based upon the following observations :

1) Tipping of the left-hand camera gives rise, for the six basic points, to parallaxes which are respectively proportional to quantities :—

O	p
O	p
O	p

2) In the same way, tipping of the right camera produces parallaxes proportional to :—

p	O
p	O
p	O

3) Manipulation of the elevation angle control to the left as well as to the right, produces at the 6 control points parallaxes proportional to :—

p	p
$p \times C$	$p \times C$
p	p

As has already been stated, coefficient C depends upon the focal length and format, and is comprised between 1.2 and 1.5. It is in inverse ratio to the focal length and in direct ratio to the format.

4) Manipulation of the left-hand convergence control gives rise to parallaxes that are proportional to the following quantities :—

p	p (1 — M)
p	p
p	p (1 + M)

Coefficient M is comprised between 0.1 and 0.4 and is in inverse ratio to the focal length and in direct ratio to the format.

5) Manipulation of the right-hand convergence control gives rise to the following parallaxes :—

p (1 — M)	p
p	p
p (1 + M)	p

This being granted, in order to obtain the plastic image the first step is to center *the plates*. This operation, which will subsequently have to be repeated several times, must be carried out as follows.

To center the left plate, for example, the left rod is made perpendicular to the left carriage plane of motion by bringing the pointers in front of their respective marks. Then a monocular sight (without changing the position of the carriages) is taken of the center of the left negative by making use of :—

a) rotation of the articulated arm (3) of the microscope ;

b) X—motion controlled by knob (5) ;

c) Y—motion controlled by tke knob that operates one of the metal-tape reversing pulleys.

The center of the plate must be materialized by a dot or a small cross traced on the gelatin.

The sequence of operations is then as follows :—

1) Parallaxes at the two nadirs are successively removed by using the tip adjustment, the parallaxes at the 6 viewed points having then the shape of :—

$l + m$	$l + n$
o	o
$l - m$	$l - n$

The values shown above can easily be deduced from the general expression of the parallax at any given point.

2) The parallax at B is then removed in any way preferred without touching the tip adjustment.

3) Afterwards, D is examined and the residual parallax p is measured either by means of B_Y or with the adjustment knob of the connecting band of one of the carriages. By operating the left-hand convergence knob this parallax is then altered into :

$$P. \frac{(M - 1)}{(2\ M)}$$

As a result parallaxes at B and D have now become equal ; before operating the left convergence knob, the respective parallaxes were O and p, whereas at present, through operation of the left convergence knob, quantities proportional to 1 — M and 1 + M have been added to these values, that is, respectively :—

$$x\ (1 - M)$$
$$\text{and } x\ (1 + M)$$

Equalization of the final parallaxes is sought, whence :

$$x = - \frac{p}{2\ M}$$

The final parallax at D is therefore :

$$p - \frac{p}{2\ M}\ (1 + M) = p \frac{M - 1}{2\ M}$$

4) After equalizing parallaxes at B and D by using the left-hand convergence control, the same procedure is followed for A and C by using the right-hand convergence control.

5) If the preceding operations have been properly carried out, the residual parallaxes at the 6 control points should have the following shape :

p'	p'
O	O
p'	p'

or, if not, they should be easily reduced to it by modifying B_Y in order to remove parallaxes that might still exist at the 2 nadirs.

If such be the case, by standing at any one of the 4 points A, B, C, D, and by working on the elevation angle control of one of the cameras the residual parallax, which was p', is changed into :

$$p' \times \frac{C}{C - 1}$$

After this correction has been made the parallax is the same at all points of the pair, and by merely operating the knob controlling B_Y the formation of the plastic image is completed.

Comments.

1) It is useless to recenter plates every time the elevation angle or convergence has been changed ; this can be done once and for all, at the end of operations.

2) If, after all operations have been effected, any parallax should remain, the various steps can be gone through again. It is simpler, however, to examine the six control points one after the other, and to compute residual parallaxes by taking, as a unit, the length of the micrometer, and then to ascertain how the plastic image can be improved on the basis of previous considerations. It is even possible to use Bz, which has hitherto remained unused, and which produces parallaxes proportional to :

p	p
O	O
— p	— p

Conclusion.

I.—While, in view of the necessity of recentering plates from time to time, formation of the plastic image is undoubtedly a more laborious process than in the case of other restitution equipment, with this particular instrument it is a particularly swift and simple process (1) to pass from one point of the pair to another by disengaging the machinery of the coordinatograph and (2) to effect the convergence correction, which is done by merely operating knobs (10) without having to rotate the elevation pedal to any great extent. It is only when the plate in X needs recentering that the pedal has to be rotated so that stereoscopical contact can be maintained.

II.—SETTING TO SCALE.

This is accomplished by turning the Bx knob that causes the lower joint of the right-hand rod to move in a direction parallel to the X-axis. The verniers placed on the coordinatograph carriages make it possible to effect a computed setting to scale of greater precision than if determined by graphic means.

III.—ORIENTATION OF THE PLASTIC IMAGE VERTICALS.

This could be done by separate rotation of each of the cameras, but it is more advisable to take advantage of the fact that, by means of levelling screws, it is possible to change the relative orientation of the coordinatograph table and of the frame upon which the carriages rest.

In this connection there is but one remark to make: adjustment of the levelling screws does modify the relative elevation of the upper joints of the rods, but not that of the lower joints; therefore, after having rotated the levelling screws a suitable number of times, it is necessary to revise the plastic image by standing at one of the points A, B, C, D, and by removing the parallax through adjustment of By.

IV.—RESULTS OBTAINED.

A first plotting test was made with the prototype.

The plates selected had been taken in a moderately hilly area (Jura) with a 13×18 sized camera, having as objective a Perigraph F = 150 mm. lens of slight distortion.

The plotted map, which was effected at 1 : 15.000, was compared with a print on the same scale of the stereodraft sheet obtained by plotting with the Type B S.O.M.-POIVILLIERS Stereotopographer.

No discrepancy in planimetry in excess of 0.25 mm. was noted. In altimetry, difference $za - \frac{Z}{E}$ betwen the elevations read on the instrument and the true elevations reduced to scale proved to be within 0.2 mm. for the 6 controlling points. The residual error is, besides, partly due to the fact that this first test was made without any distortion cam.

To sum up, the first tests of the Type D S.O.M. POIVILLIERS Stereotopographer are very enocuraging. Certain slight improvements are now being made, however, and initial tests were completed recently.