THE EVOLUTION OF PHOTOGRAMMETRIC INSTRUMENTS

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SUMMARY

Historical Account :

Ground Photogrammetry :
Instruments for the Measurement of Single Images;
Stereophotogrammetry;
Automatic Instruments (Stereoautographs).

Aerial Photogrammetry :
Cameras;
Special Plates and Films;
Radial Triangulation Instruments.

Instruments for Graphic Measurements on Photographs :
Stereoscopes;
Camera Lucida, Various Types of Plotters.

Photograph Rectifying Instruments.

Restitution. General :
Classification of Restitution Apparatus;
Various Optical Combinations used in such Apparatus;
Restitution Instruments using Mechanical Projection;
Restitution Instruments using Optical Mechanical Projection;
Restitution Instruments using Optical Projection.

Bibliography.

The idea of using measurements taken from vertical images of the terrain in the development of topographic surveys, is attributed to Ingénieur-hydrographe Beautemps-Beaupré. It is believed that he employed this method while exploring the coasts of Van Diemen's Land and the Santa Cruz Islands on board the *Recherche* during d'Entrecasteaux' expedition of 1791-1793. However, it was only after photography had been brought to a high degree of perfection between 1829 and 1839 by Niepce and Daguerre, and following the obtaining by Archer in 1850 of negatives on glass, that the method was able to attain full development.

Nearly a century has elapsed since Major Aimé Laussedat (1819-1907) developed in France, under the name of « metrophotography », methods of geodetic photography (1859-1861) for the measurement of angles and the compilation of maps, the principles of which he expounded in 1864.

In Italy, Professor Ignazio Porro (1801-1875), the inventor (1855) of the quadruple reflection prism which, under his name, has become a standard type for optical instrument, designed for the measurement of images a photograph-measurement instrument (1871) which, subsequently improved by C. Koppe in Brunswick (Bildmess-theodolite), was called the « photogoniometer » and on the fundamental principle of which are based numerous modern restitution instruments.

Previous to 1870, in Germany, A. Meydenbauer and S. Finsterwalder (Munich), had contributed to the application of this new technique.

In 1874, Jordan applied photogrammetric processes to a survey carried out in the Libyan Desert during the Rohlf Research Expedition in Africa.

In 1875, Ing.-Geografo Pio Paganini (ca. 1840-1915) designed, at the Florence Military Geographical Institute, a horizontal-axis photographic camera called the Paganini camera transit (1875 model).

It was also he who, in 1884, invented the « graphical sector », by means of which it is possible to obtain the graphical intercept of planimetrical distances, by measuring the abscissae and ordinates on the photographs and thereafter by using the « graphical square for heights », the difference in elevation for each of the considered points on the photograph of the terrain.

In 1889 the Galileo Office of Florence constructed under his direction a precision camera transit with a central telescope, and he used this combination of instruments in applying the method for development of surveys to which his name has remained attached (the Paganini method).

From 1892 on, photogrammetric surveys were carried out in various countries using photographic apparatus set up on tripods on the ground and consisting of theodolites transformed into « phototheodolites » for application of the Koppe (Braunschweig) system. The earliest instruments included the following :

1895 : The S. *Finsterwalder* Phototheodolite, manufactured by Ott, at Kempten (Bavaria) and Carl Zeiss, at Jena, with adjustable tilt (*Kippbarer* Phototheodolite).

1896 : The *Koppe* Universal Phototheodolite (Carl Koppe : 1844-1910) with level and eccentric telescope constructed by Günther and Tegetmeyer (Braunschweig).

1901 : The *Torroja* Phototheodolite used by Lt-Colonel A. Mas y Zaldua for work covering the Pyrenees.

At this time, however, the use of photographic views, although offering certain advantages, could not be substituted for topographic procedure by the intersection method with the plane table, and methods remained at the same stage until about 1905.

As improved types of phototheodolites should be mentioned the *Hugershoff* C3 b model, constructed by the C. Zeiss Aerotopograph G.m.b.h., Jena, fitted with an autocollimator prism telescope orientation system; the *Wild* (Henri) Universal Phototheodolite, manufactured at Heerbrugg (Switzerland); size : 10 cm. × 15 cm.; f./165 mm.; with a camera that could be pivoted for several tilts, and the *Santoni* Phototheodolite with concentric telescope, passing through the camera at 90° from the optical direction of exposure; the lightweight Zeiss TAL Phototheodolite, size : 6 1/2 × 9 cm., f./5.5 cm., *Topogon* lens with distortion-corrector glass plate; the *Fairchild* Camera Transit using 4" × 5" glass plates : 12 exposures taken at 30° intervals enables the entire 360° of the horizon at each station to be covered; and the U.S.N. *Hydrographic Office Camera Transit Model F.* 227, field 30°. (See *Hydrog. Review,* Vol. XXV, n° 2, Nov. 1948, p. 60)

The *Fairchild* Phototheodolite measures 30" in azimuth; it is fitted with a *Goerz Aerotar* lens, f/210 mm., F/6.8 to F/32; shutter : 1/50, 1/25, 1/10, 1/5 and 1/2 sec., with red, yellow and minus blue filters. It is used with the « photo-transit » for transferring the horizontal angles from the photographs to the work sheet : weight: 28 lbs. Also, « photogoniometers » such as the *Wilson* photo-alidade (1942) are used for the measurement of angles on horizontal photographs.

In terrestrial photogrammetry, in order to simplify graphical constructions or computations of the bearings and depression angles, the photograph is generally exposed in a vertical plane. Thus two photographs taken from the extremities of a known base render it possible to make a complete survey of the whole ground visible within the area common to both photographs. To avoid graphical intersections at angles too acute for fixing the points, a long base is selected with the result that difficulties occur in the identification of corresponding features in the two widely dissimilar photographs.

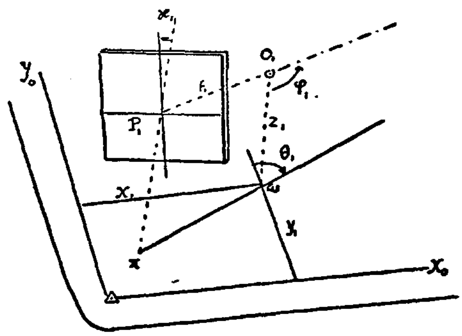


Fig. 1

On Figure 1 have been marked the elements of outer orientation of a photograph, i. e.: X_1, Y_1, Z_1, the rectangular co-ordinates of the objective lens the focal distance of which is f_1; φ_1, θ_1, are the tilt and lay of the perspective axis, and κ_1, the angle between the axis of the plate and plate plumb point of line passing through the axis of exposure P_1O_1.

Restitution consists in locating, with the aid of two photograms (1) and (2) (fig. 2) taken from two points O_1 and O_2 and containing the images a_1, b_1, c_1; a_2, b_2, c_2, of three identical points of the subject ABC, in terms of the elements X_1, Y_1, Z_1, φ_1, θ_1, κ_1, and X_2, Y_2, Z_2, φ_2, θ_2, κ_2, the spatial positions of points A B C, their orthogonal projections A'B'C' on the reference plane and their elevations A'A, B'B, C'C in relation to this plane.

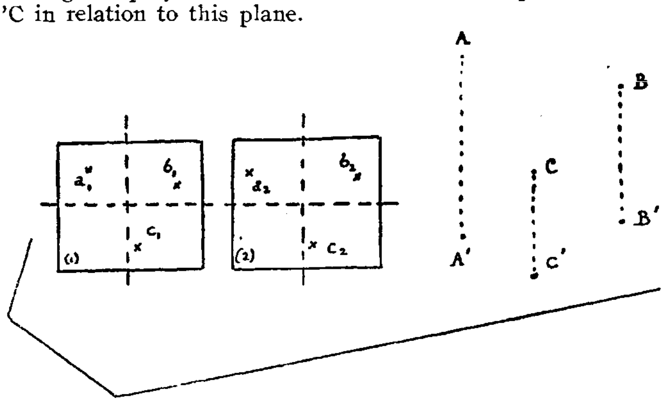


Fig. 2

The combination of points A' B', C', correctly selected, constitutes the planimetric representation of the terrain. It is evident that this determination might be made by computation, using the co-ordinates, of the image points a, b, c, etc., measured on the photograms in their relation to the plate axes. The phototheodolite provides the elements θ and φ. κ is generally equal to zero, but now-a-days the use of automatic plotting machines using optical and mechanical means is preferred to laborious calculation.

INSTRUMENTS FOR THE MEASUREMENT OF SINGLE IMAGES

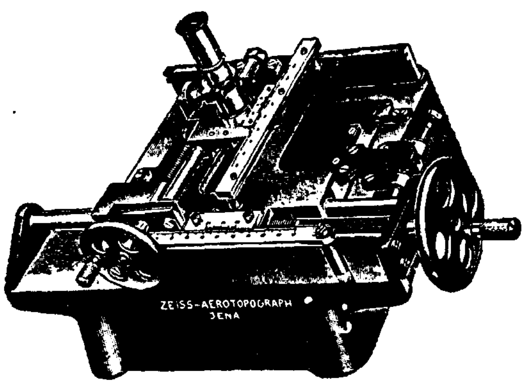
Various instruments have been designed for extracting the co-ordinates from single images :

1) The « *grids* » of Dr. E. Deville, Surveyor-General, Ottawa, 1895 and those of Gautier.

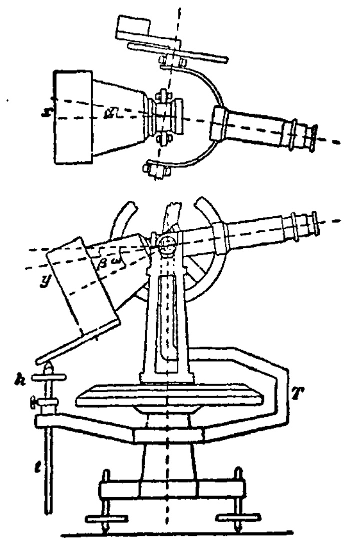
The *Mœbius* projection grids obtained by homographic perspective sets of lines, used for the plotting from tilted photograms and oblique views.

The perspective planimetric, or « Canadian » grids drawn on sheets of transparent plastic for measurements on tilted photographs.

2) The Hugershoff *Plattenkomparator,* manufactured by the firm of G. Heyde, Dresden, in 1912, known as the « photogrammeter », furnished with vernier scales read through by microscopes. Another model is constructed by the Zeiss-Aerotopograph G.m.b.h.; the Santoni Stereoscopic « Puntinatore » serves the same purpose.



Hugershoff Plattencomparator



Porro-Koppe Bildmess theodolite

3) Special theodolites in which a special view-finder, added in front of the object-glass, enables the operator to identify on the developed plates the vertical and horizontal parallactic angles of the image-points in their relation to the axis of exposure, as :

The Carl *Koppe Bildmesstheodolite,* Braunschweig, 1896, which took its origin from the photogoniometer conceived by *Porro* in 1871; that of R. Hugershoff constructed by Carl Zeiss at Jena in 1910, with an angular view-finder and improved in 1919 by Carl *Pulfrich.*

4) Special panoramic instruments with rotating lens were also employed, such as the P. *Moëssard* « cylindrograph » or that of *Pelletan* (1910). In 1932, the Zeiss-Aerotopograph G.m.b.h. constructed under the name of *Panoramakammer* an improved cylindrograph producing marked films of 10 cm. x 58 cm.

The *Wild* panoramic camera, 10 x 15 cm., f/24 cm. lens, with yellow, orange and infra-red filters, makes use of a grid divided into « millièmes d'artillerie » (6.400 for the circle) or "millièmes tangente" (i.e.: arc 3'26") printing itself on the negative at the time of exposure. When the camera is tilted, squared glass plates for each particular degree of tilt accurately supply the corrected cross lines printed on the negative.

The *Rafaelo Silvestro* Stereodiopter (I.G.M. 1933) consists of a double cylindrical camera combined with a topographic plane table and is used for taking the photograph as well as plotting the cylindrical vertical-axis terrestrial photographs on a plane surface.

STEREOPHOTOGRAMMETRY

Stereoscopic viewing makes identification of corresponding points on two photographs more reliable owing to the effect of relief produced by binocular viewing and makes easier the measurement by means of appropriate instruments producing a plastic image of the ground and of the mark, such as the *Pulfrich Stereocomparator* or the *Von Orel Stereoautograph.*

In this case the same photographic apparatus is used, but constructed for double images (twin stereometrical camera), with more or less widely separated lens. The picture is taken with the optical axes horizontal and perpendicular to the base.

From Figure 3 which is self-explanatory, we deduce :

$$X = x_1 \frac{z}{f} \qquad Y = y \frac{z}{f}$$

$a = x_1 - x_2$ is the « stereoscopic parallax » ;

$Z = f \frac{B}{a}$ gives the distance

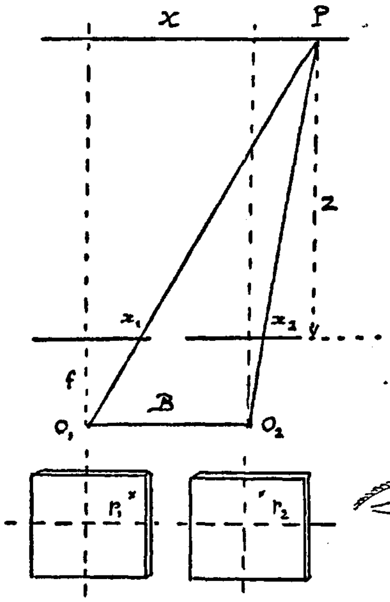


Fig. 3

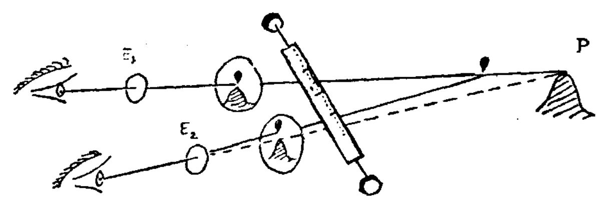
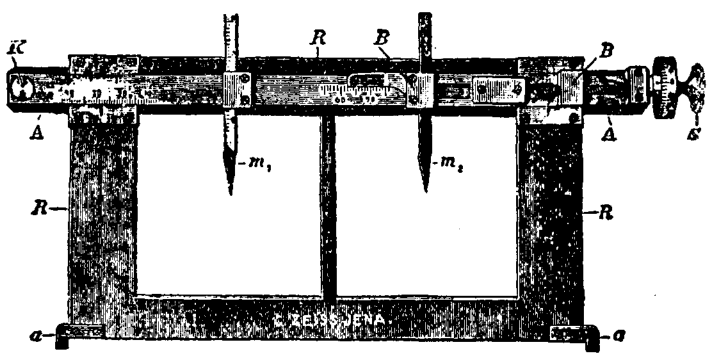


Fig. 4

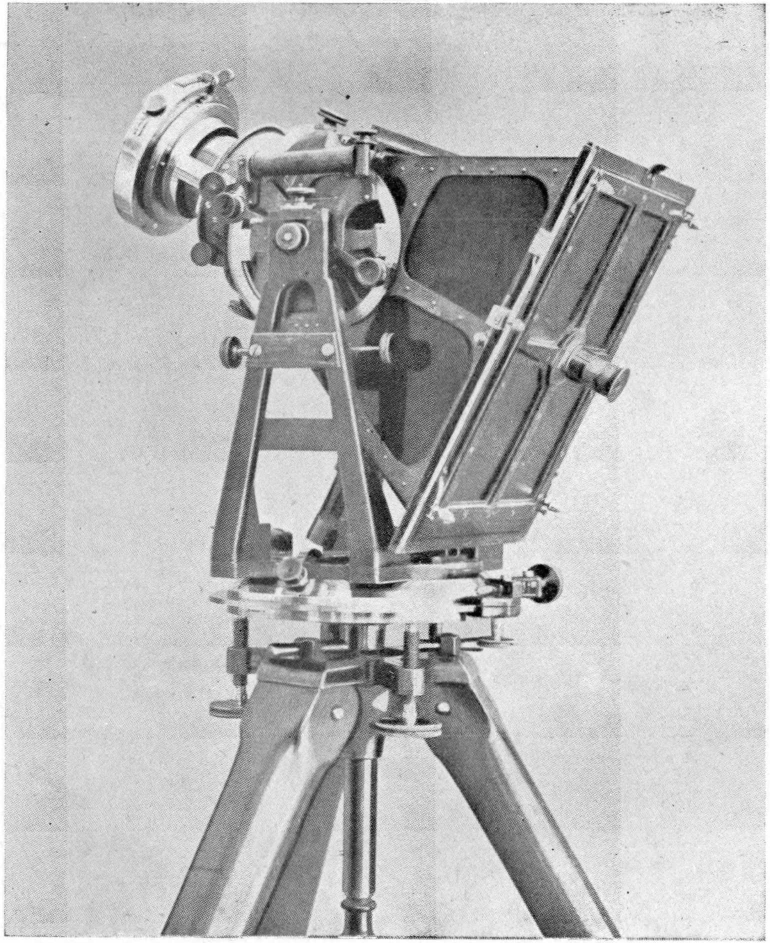
The negatives are examined with a variable eye-piece distance stereoscope fitted with a *stereomicrometer* — this allows the parallaxes of the identified points to be measured on a vernier scale operated by means of a micrometric screw, as, for instance, in the *Santoni Stereoscopic Puntinatore.*



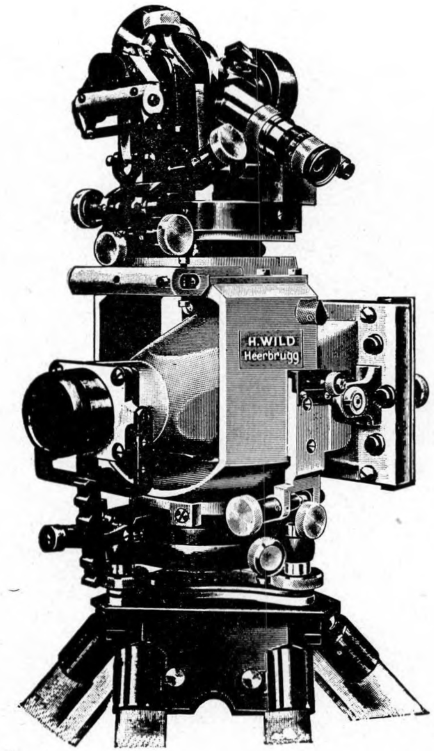
Zeiss Stereomicrometer

The principle of the stereometric method for distance measurements seems to be due to F. *Stolze* (1893) (*). The same year, Hector de Grousilliers, of Zeiss, had constructed a binocular instrument equipped with a « floating mark » (Wanderude

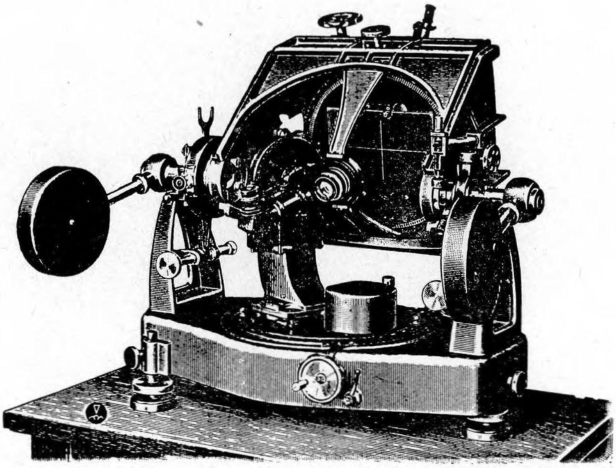
(*) The first coincidence range finder (Barr and Stroud system) was on the contrary designed by Adie and Christie from 1889 to 1896.



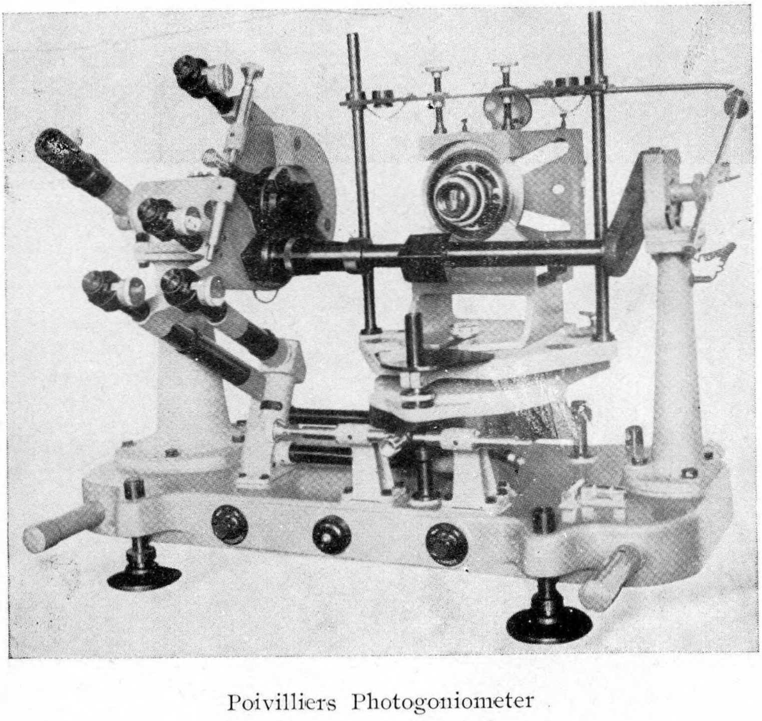
Paganini Phototheodolite (1889 Model)



Henri Wild Phototheodolite



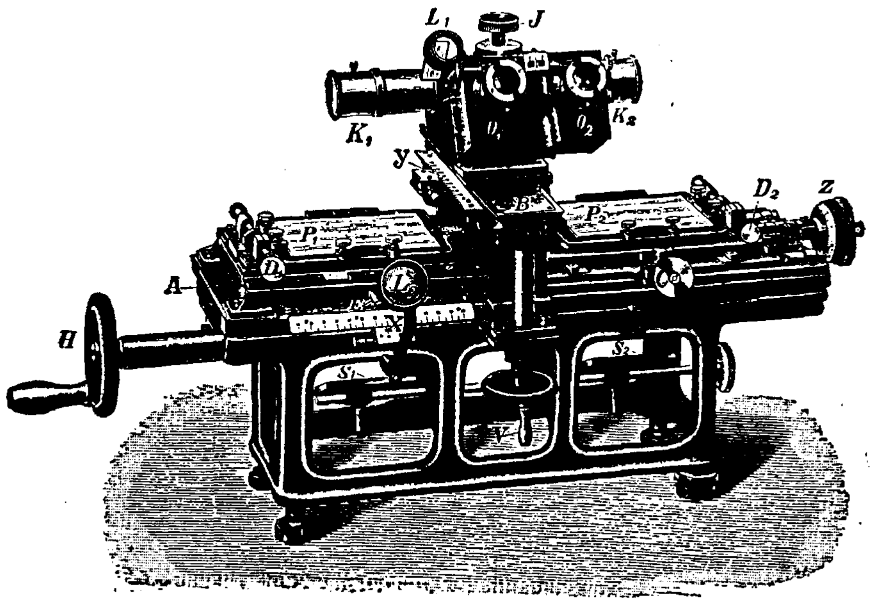
Heyde-Hugershoff Photogoniometer



Poivilliers Photogoniometer

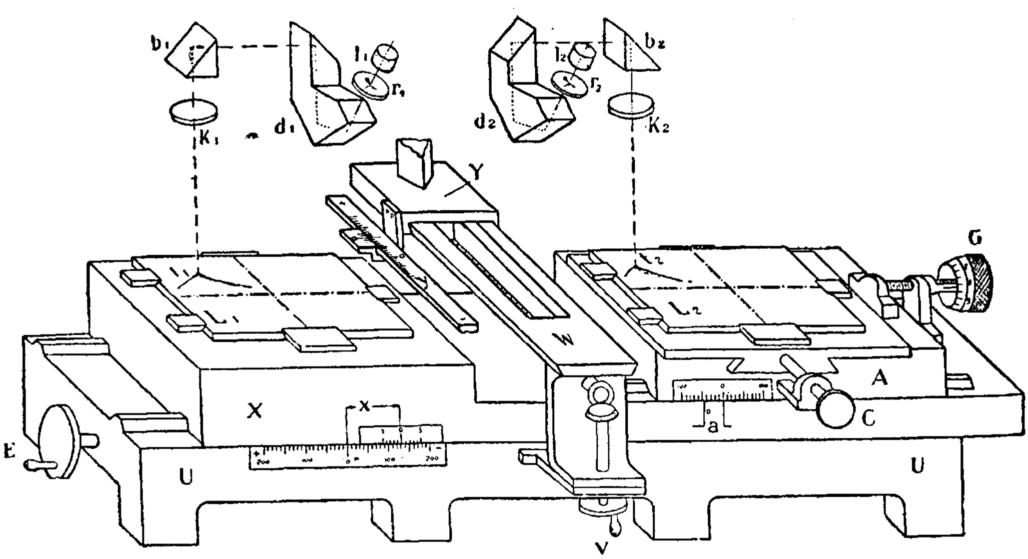
Marke) (Fig. 4) from which Pulfrich drew inspiration for his construction of the stereoscopic range finder (1900) and of the stereocomparator, the first model of which was produced by Zeiss in 1901. Another model was constructed in 1909 and still another in 1921.

In the procedure using the stereocomparator, a relatively short base is used and, at the same time, the indetermination due to acute graphical intersection is eliminated by the parallactic measurement of distances.



Pulfrich Stereocomparator

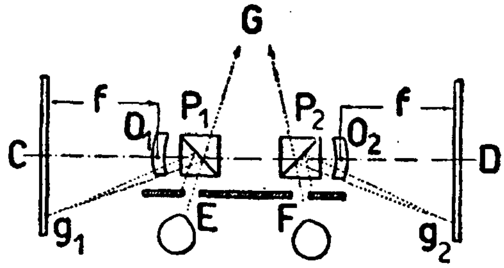
Both photographs are taken in the same vertical plane, although not necessarily at the same height, and these are placed, in the same plane, in the comparator. Here again bearings and elevations are computed from the co-ordinates, derived from the photographs, of the points of one of the pictures while distances from the base



Pulfrich Stereocomparator (diagram)

are calculated by stereoscopic measurement of the parallax by means of the lateral shift of one of the plates relative to the other, until the stereoscopically reconstructed image of the selected point seems to be situated at the same distance for the observer as the fused image of a pair of « floating marks » contained in the binocular eyepiece microscope used in examining the photographs.

In the *Hugershoff Stereocomparator* (Gustav Heyde, Dresden, 1926) the plates being examined are placed back to back and parallel to each other. Another model of stereocomparator was constructed in 1930 by Zeiss Aerotopograph G.m.b.h., Jena.



Deville Stereoplanigraph

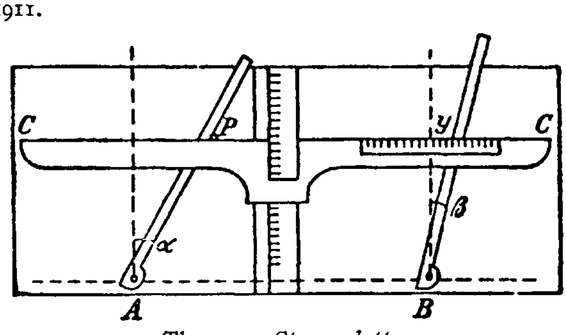
The E. *Deville* (Ottawa, 1902) *Stereoplanigraph* uses a Wheastone reflecting stereoscope.

In France, the *Prédhumeau Stereotopometer* was constructed in 1922, and a new model of this instrument was produced in 1926 by the firm of Sécretan, Paris.

In Italy, the E. *Santoni Stereoscopic Puntinatore* is used.

AUTOMATIC INSTRUMENTS (STEREAUTOGRAPHS)

In the *Thomson Stereoplotter* (London) (1907-1908 model), the principle of which is the same as that of the stereocomparator, calculation of the co-ordinates in space consecutive to each independent measurement is avoided by adjunction in the machine of a system of levers which automatically reproduces terrestrial photograms; but even so, the disadvantage of point-by-point plotting remains in the *Thomson* apparatus, and it was not overcome until the appearance of the *Von Orel Stereoautograph* in 1909-1911.



Thomson Stereoplotter

After 1908, the goal of optico-mechanical technicians lay in the designing of fully automatic plotting instruments.

Dr. E. Ritter Von Orel (Vienna 1877-1941), produced the first model of his *Stereoautograph* (Autostereograph), a sort of partially automatic stereocomparator, constructed by R. & A. Rost, Vienna, in 1908, and by Zeiss in Jena, 1909, followed in 1911 by the plotting machine known as the *Orel-Zeiss Stereoautograph,* then by a 1914 model. The latter was due to the combined efforts of Von Orel, Pulfrich, Sander (1913) and Bauersfeld. Dr. Ing. H. Lüscher has given a description of a model of this type constructed in 1922.

The *Orel-Zeiss* Stereoautograph is the first automatic plotter eliminating plotting computations and for the first time enabling continuous plotting of the hypsometric contours to be made; this is an entirely mechanical instrument for terrestrial views only. (See: *Hydrogr. Review*, Vol. XV, n° 1, May 1938, p. 105)

A variant of this apparatus, in which the plates are superposed, with the binocular microscope between them, and known as the *Ordovas-Kern Photocartograph* (or Ordovas Stereoautograph), was constructed in 1930 by the firm of Kern, Aarau.

The *Von Orel* apparatus is a stereocomparator to which two azimuthal levers have been added (LP, RP) (Fig. 5), coupled to the lateral shift of the plate-holder and jointed at the extremities of the base (L, R). Their intersection gives the plotted point P.

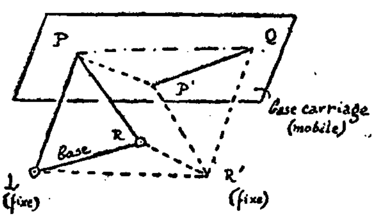


Fig. 5

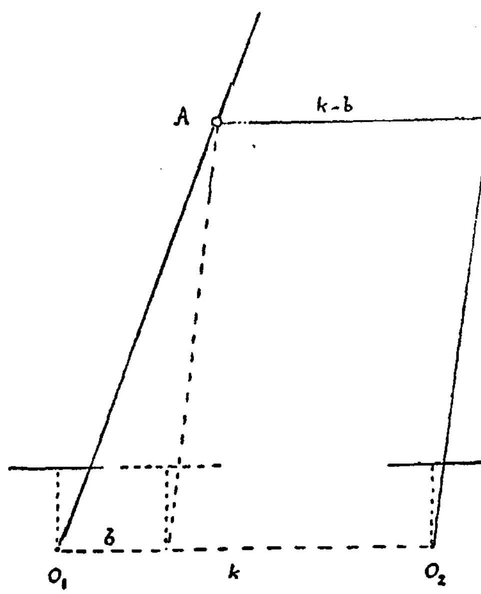


Fig. 6

Let LR' = PQ and QP' = RL. LP and R'P' still represent the true directions of the azimuth levers, R' is a fixed point. This simple principle is due to Von Orel and is known as the *Zeiss parallelogram* : L P Q R'. Since 1909-1910 it has been applied to the majority of graphical plotting machines. Perfected by Bauersfeld and Pfeiffer, its principle is geometrically derived from Figure 6, which is self-explanatory, and in which *b* represents the base selected for the distance *k* between the two camera stations.

By combining the movement of the three controls (azimuth, distance and height) the « floating mark » may be displaced along the details of the stereoscopically reconstructed image, of which the pencil fixed to the base carriage automatically plots the plan.

By clamping the height lever at certain height, the instrument loses a degree of freedom and, if the distance and azimuth controls are then moved so that the floating mark seems to move along the surface, the pencil will plot the level contour corresponding to the height at which the lever is clamped.

The stereoautograph is capable of rapid automatic plotting but the photographs must have been exposed *in the same vertical plane.* But the extensive development of aerial photography has led to the taking of photographs which are horizontal and generally not exposed in the same plane because of variations of tilt of the airplane, and this necessitated the construction of plotting machines possessing a « universal » range of permissible orientations in space of the axes of the photographic apparatus.

— WILD Stereometric Camera : 120 cm. base, range : 600 metres.

These cameras are used in conjunction with the Wild A4 Autograph for examination of pairs of negatives obtained (short-distance photogrammetry).

— WILD Recording Statoscope (1934) is a kind of barometer constituted by a very sensitive differential manometer (liquid), for use in horizontal flight of airplane.

— The MAHAN Micrometer Tilt Meter is used for horizontal flight control and correction.

— ZEISS Single-Camera, RMK P. 21 type (*Reihen Mess Kammern*) Apparatus, *Orthometar* lens, f : 210 mm., film, range : 60 metres, magazine 285 photographs, 18 x 18 cm., held flat by exterior air-duct, *Zeiss* bar-shutter; overlap adjustable by *Cinedriftmeter* (Cinédérivomètre) with chromatic filters.

— ZEISS RMK C/2 Apparatus : used for series of automatic exposures. (See : *Hydrog. Review,* Vol. IX, n° 1, May 1932, p. 204).

— ZEISS Model 2. RMK 13.5, Orthometar lens (object-lenses), f : 135 mm., F : 4.5; 2 12 x 12 cm. cameras, 36° tilt cameras, which can be orientated either in length or in width; capacity : 60 metres of film, i.e. 450 exposures; total field 82°; operated by electric motor with overlap adjuster.

— ZEISS Model 4 RMK 13.5; 4 cameras, tilt 54°, arranged in pyramid form; total field : 83°.

— ZEISS Model RMK. P 10, large angle monocamera; Zeiss-Topogon 95° lens; f : 100 mm, F : 1/6.3 with photographic level ; usable diameter : 21 cm. on 18 x 18 cm. film; shutter adjustable to 1/50th - 1/300th second.

— ZEISS large-size instruments RMK 20/30, 30 cm. and RMK P. 50/30, 30 cm., *Tessar* lens 1/5.

— ZEISS Model RMK 20/30, 30, f = 200 mm., size : 30X30 cm.

— ZEISS Aerophotogrammetric instrument P. 50/3030, *Tessar* lens, f : 500 mm., F : 1.5, size : 30 x 30 cm., for large-scale surveys.

— ZEISS, Two-Cone Instrument S. 1818; *Orthometar and Triplet* lens 1/4.8; f : 500 mm.; 18X18 cm. on film held in position by compressed air pressure; shutters with synchronized release; and instrument RMK HS 1818 convertible model; « Orthometar » lens; f : 210 mm. and Topogon, f : 100 mm. permitting photography of horizon.

— ZEISS Model 2 MK.21 twin camera.

— HUGERSHOFF Panoramic Camera manufactured by Zeiss-Aerotopograph G.m.b.h.; *Tessar* lens 1 : 4.5, f : 180 or 200 mm. plates or film, 13 x 18 cm.

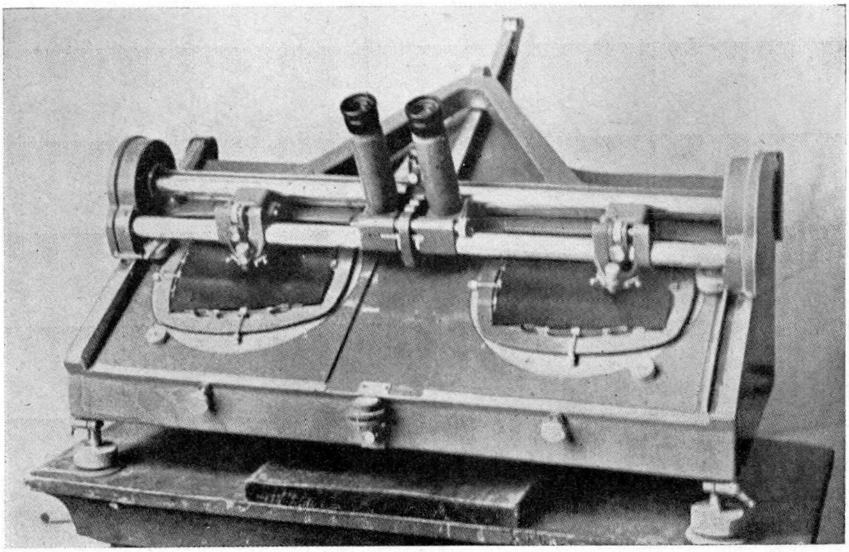
— C. ASCHENBRENNER Instrument PK 33, 1927 model (PK-9 lens Panoramic Camera) of the Photogrammetrie G.m.b.h., Munich, 9-lens (f : 54 mm.) — one central and eight panoramic, special for radial triangulation; field : 5 flight altitudes = 130°; film magazine : 50 metres for 250 exposures; automatic operation by electric motor; total weight : 50 kilos. This arrangement necessitates a special rectifier (Umbildegerät) for use with views giving 25 x 25 cm. proofs, wide angle type for surveying vast areas on a small scale (1 : 50.000).

— SONNE S-7 Continuous Stereoscope Strip Aerial Camera for 9 1/2" (24 cm.) and 70 mm. film with stabilization of cones and automatic synchronized speed of unwinding of film. (*Harrison Ryker,* Berkeley, Cal., U.S.A.).

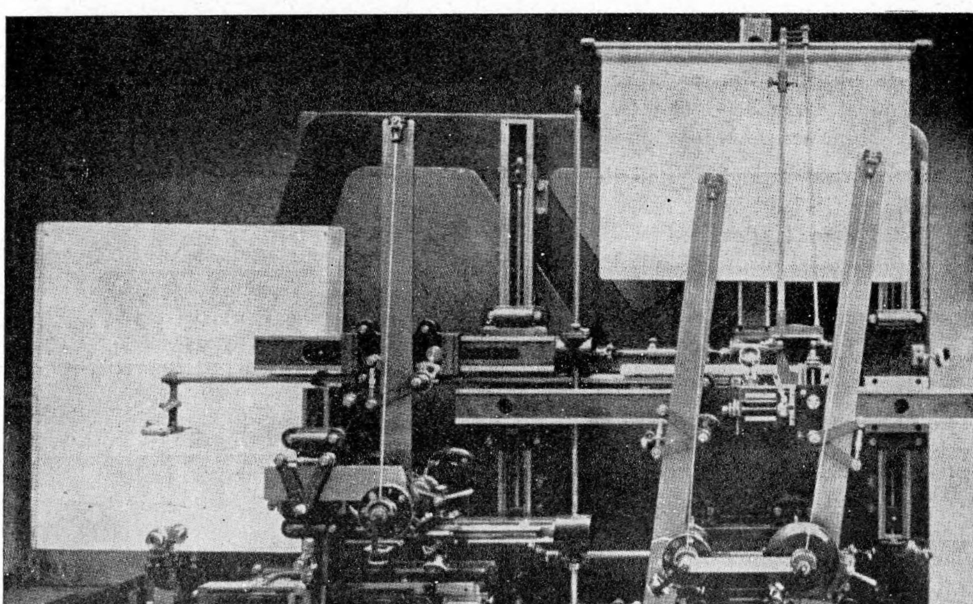
Instead of a shutter the Sonne instrument has a groove along which the film unwinds continuously at a rate synchronized with the apparent rate of speed of the terrain.

— SKa 5 Aerophotogrammetric Camera of Swedish manufacture.

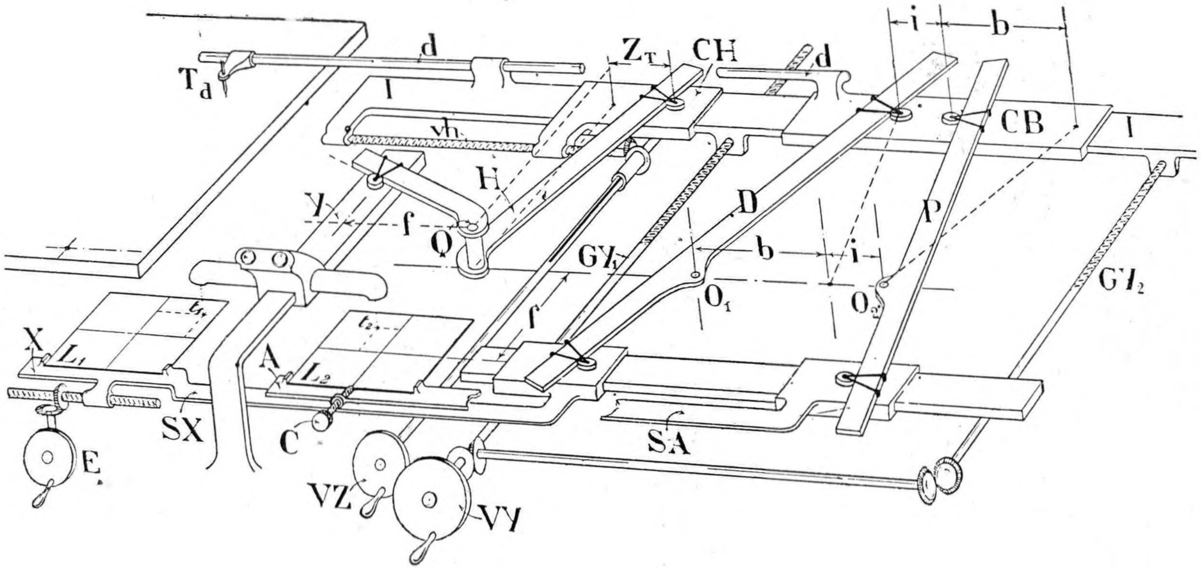
— LABRELY Altiphote (Jules Richard. Paris) : *Olor Berthiot* lens, F : 5.7 or *Flor Berthiot* F : 4.5; f : 20, 25 or 30 cm.; three speeds 1/250, 1/300, 1/350 sec.; weight : 5 kilos..



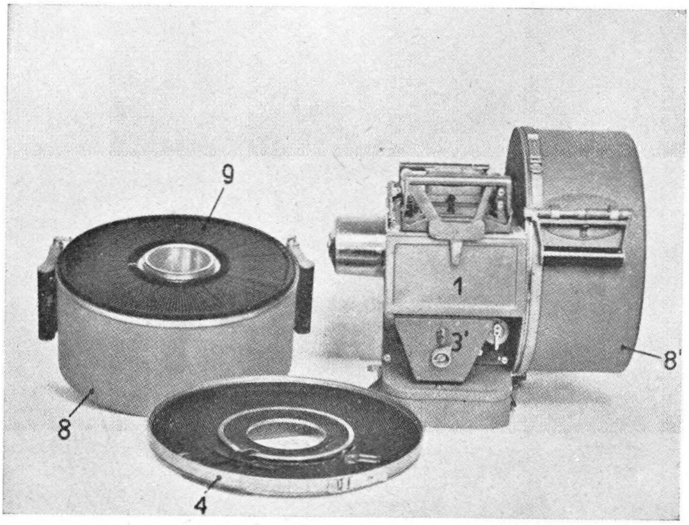
Santoni Stereoscopic Puntinatore



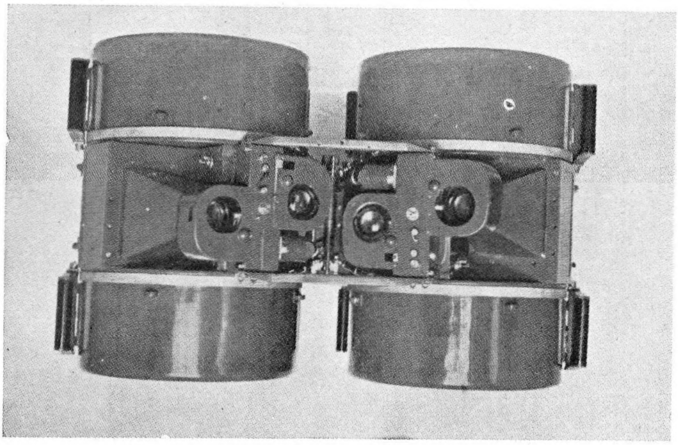
Orel-Zeiss Stereoautograph (1914 model)



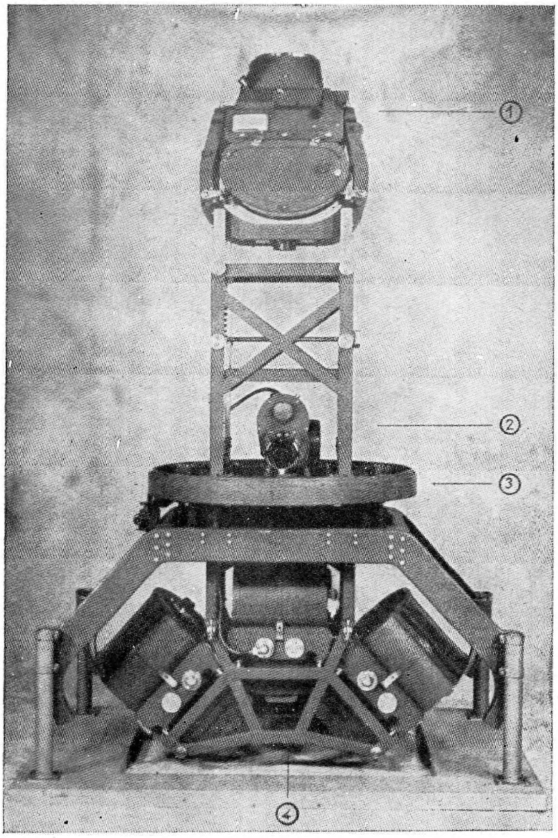
Stereoautograph von Orel-Zeiss (diagram).



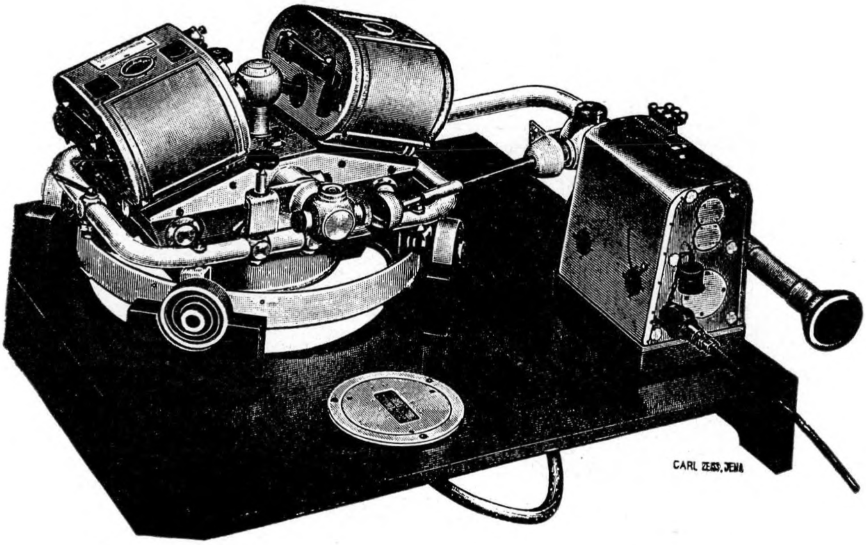
Santoni Double Camera, dismounted magazine



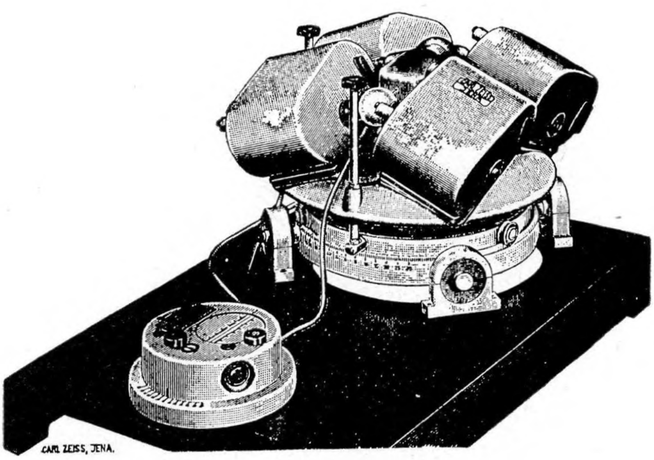
Santoni Quadruple Oscillating Camera



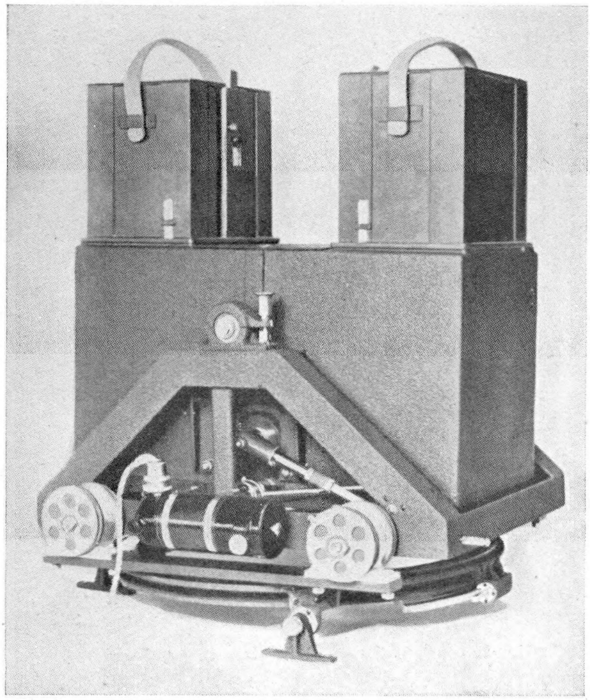
Santoni quadruple Camera with Solar periscope



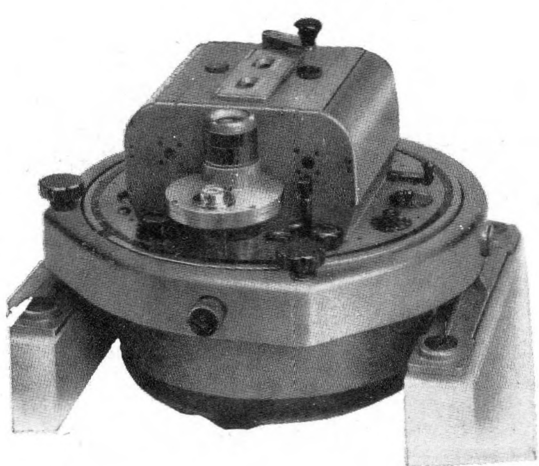
Zeiss RMK Twin Camera



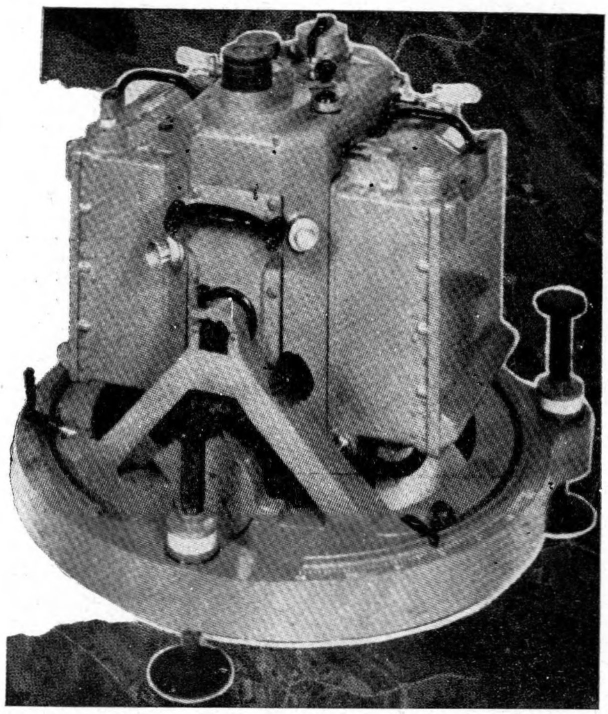
Zeiss RMK quadruple Camera



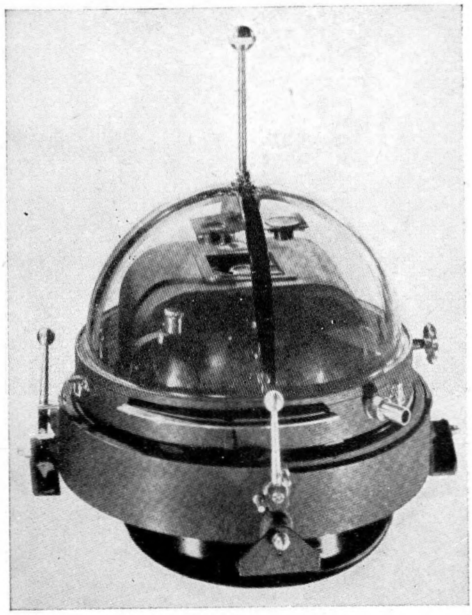
Nistri AFL. 92 Camera



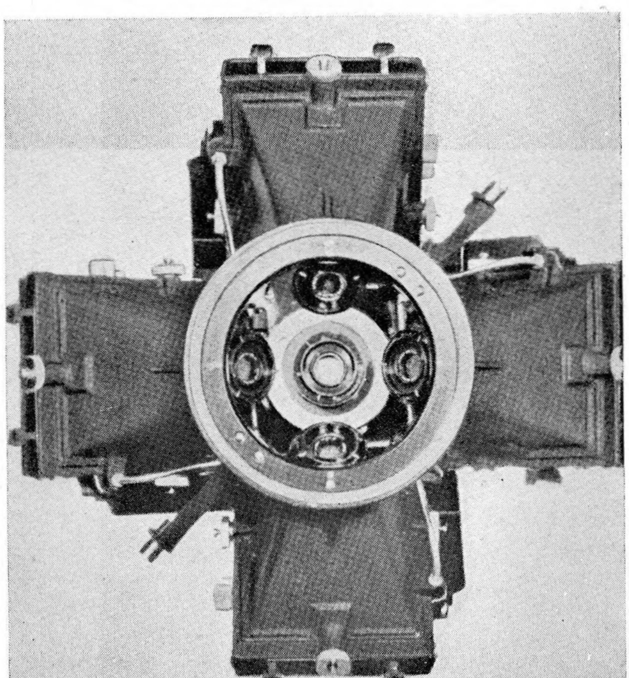
Wild R. C. 3/21 automatic Camera



Wild RC-7 Camera



Williamson Photogrammetric
Air Camera
Type O.S.C. Mk. II



Fairchild Five lens T3-A Camera

— LABRELY-RICHARD Planiphote Apparatus; lens = 300 or 500 mm., F : 4.5 or F : 5.7; size 18 x 24 cm.; Pathé-topo 178 mm. film; 200 views, interchangeable, shutter 1/250, 1/300, 1/350 sec., automatic, or hand-operated.

— FERBER-GALLUS G. 20 Topophote; f : 200 or 300 mm.; 18 x 18 cm. monocamera; 24 easily removed plates, Gallus Aviation shutter, 1/100th to 1/300th sec.

— CADASTRO-GALLUS Camera.

— SOM Poivilliers Automatic Plate Camera (1946); size 13 x 18 cm. 192 plates, 3 removable cones; intervalometer with 4 to 75-second automatic release;
cone 200 mm. *Olor* lens; f : 200 mm. F : 5.7.
cone 150 mm. *Perigraph* lens; f : 150 mm., F : 6.8
cone 125 mm. *Aquilor* lens; f : 125 mm., F : 6.2;
yellow filter; SOM shutter 1/85th to 1/170th sec.; size 96 x 64 x 96 cm., total weight : 130 kilos.

To avoid plate distortion, these are held directly in the grooves of the magazine without plate holders. Made of drawn glass 1.7 mm. thick; they are coated on the back with non-emulsified coating which, when dry, counteracts the contractions of the emulsified coating.

— SOM Poivilliers Automatic Film Camera, *Aquilor* lens; f : 125 mm.; F : 6.2; 189 mm. x 50 metres film; square negatives 18 x 18 cm., 200 exposures, at automatically adjusted rate of 5 to 60 seconds.

— SOM Poivilliers Automatic Apparatus (1949) with plates; 19 x 19 cm., 96 plates for aerial triangulation operations.

Williamson Instruments for Aerial Surveying :

— WILLIAMSON F. 24 Aircraft Hand Camera, *Dallmeyer* lens, 8" diameter, f = 2.9"; size 5 1/2 x 5 1/2"; film; film magazine for 125 exposures; shutter in focal plane, footage indicator for aerial reconnaissance.

F. 26 Wide Angle Apparatus, f : 10"4; 4 plate magazines, 12 plates each 7 x 9 1/2".

— WILLIAMSON Eagle Series V, Ross lens; f : 3 1/4" for wide angle survey; aperture F : 5.5; size 5 x 5" magazine for 250 exposures, adjustable shutter speed to 1/300 sec.

— WILLIAMSON Eagle Series IX « F.49 » Ordnance Survey Camera, known as the Williamson O.S.C., Ross standard wide angle 6" focal distance lens, F : 5.5, size 9" x 9" ; temperature and humidity control ; fully automatic operation; fore-and-aft overlap 60 %, lateral 55 %; uses film specially prepared for topography (Topo-base film) to keep distortion to a minimum; magazine for 200 exposures.

— WILLIAMSON O.S.C. Instrument Mark 1, similar to preceding with additional strip on which readings of the various auxiliary instruments are photographically recorded.

— WILLIAMSON O.S.C. Mark 2 and 3 Instrument, with remote drift and fore-and-aft tilt indicators and remote servo controls.

— BROCK Glass Plate Camera, f = 8 1/2 in., 50 plates 6 1/2 x 8 1/2"; Brock and Weymouth Inc., Philadelphia.

— FAIRCHILD F.3 Camera with Ross Express lens, f = 8 1/4", F: 4.0, size 7" x 9".

— FAIRCHILD F.51 Precision Camera, metrogon lens 6", 400 exposures with centimetric lattice printed on each exposure.

— FAIRCHILD Cartographic Camera with Bausch and Lomb f = 5.2" metrogon lens, F : 6.3 or Goerz Aerotar f = 8 1/4" lens, F : 6.8, between lens type shutter 1/100th, 1/200th and 1/300th second with interchangeable film magazine, 250 exposures, size 9" x 9"; film maintained flat by vacuum system. Fiducial marks are rigidly attached to the inner cone and independent of magazine; their relationship to the lens is therefore constant.

This precision camera is used by the U.S. Coast and Geodetic Survey for the restitution of contours with the *Multiplex* and *Stereoplanigraph*.

Fairchild T3, T5 and T9 Cameras for Air Photographs:

— FAIRCHILD T3 Film Camera with 3 simultaneous exposures : the central being planimetric with objective-lens f = 6 1/2"; the 2 lateral ones tilted 35° from the central axis with objective-lens f = 7 1/2". Is used with a transforming printer to obtain a large rectified photograph in the plane of the vertical photograph. This arrangement requires a lesser number of ground control points to be determined.

— FAIRCHILD T5 Camera with 5 simultaneous exposures, the central one planimetric, the 4 lateral ones tilted 43° on the central one; f = 150 mm., 200 exposures for each master and slave camera on film 36 metres long, 15 cm. width, operated by hand with a crank; also a transforming printer is necessary for the use of oblique exposures.

— FAIRCHILD T9 Precision Mapping Camera (O.S. Reading Nine-Lens Camera) with 9-objective Ross metrogon lens, f = 210 mm., Aschenbrenner system total field 130° square with mirrors with moving film and electronic shutter; integral vacuum system of film flattening; 400 feet of film, removable single-bladed shutter, 1/100th to 1/350th of a second; size 70×70 cm. and 90 × 90 cm. after transformation; weight of apparatus : 140 kilos; total weight : 340 kilos. The mirrors have a tilt of 19° on the central axis, i.e. a tilt of 38° for the 8 obliques.

The Nine-Lens Camera of the U.S. Coast and Geodetic Survey (O.S. Reading) is similar and is used together with the U.S. Coast and Geodetic Survey Rectifying Camera, also with the Reading Plotter. (See : *Hydrogr. Review*, Vol. XIII, n° 2, Nov. 1936, p. 132; Vol. XXV, n° 1, May 1948, p. 87)

— FAIRCHILD K-1 Camera, objective-lens : Hawk Eye Aerial f = 12"; F : 4.5, magazine with 70 18 × 24 cm. exposures.
K-3 and K-8 Cameras for 100 negative exposures.
K-3A Camera for oblique photographs.
U.S. Army K-7A Automatic Camera; size 23 × 46 cm. with film 24 cm. wide and 45 metres long.

— FAIRCHILD K-17 Camera, Aerostigmat objective lens f = 12";
— — — objective lens f = 40";
— — — metrogon objective lens f = 6".

— FAIRCHILD K-17 Camera for trimetrogon photographs (Trimetrogon photography consists of a central vertical, a port oblique and a starboard oblique. The set of three simultaneous exposures covers an area from horizon to horizon) with 6" Bausch and Lomb metrogon F : 6.3 lens, 90° field, size 8 1/2×8 1/2". (In the so-called « metrogon » objective lens, distortion is reduced to less than 0.1 % for nearly all the area of the field and even more in the Multiplex transformers).

The Trimetrogon Camera consists of 3 K-17 Cameras mounted together with a 60° lateral tilt. Total field is 180° and provides horizon position from which tilt can be deduced.

— FAIRCHILD K-20 Camera, anastigmat objective lens f = 6 3/8" ; F : 4.5, for hand operation for horizontal axis photographs taken also with theodolites; 50 exposures 5×4" on roll film 20 feet long; film is kept in position by means of vacuum produced by spring piston.

— FAIRCHILD K-37 Aircraft Camera with photoflash bombs or synchroflash equipment for night photographs from high altitudes with shutter trip control.

— FAIRCHILD K-40 Camera 12, 24, 36, 48 and 96 inch focal length; size 9 × 18"; magazine capacity 500' or 1000' film; continuous operation, 60 % overlap, thyratron drive motor, electronic control.

— FAIRCHILD Ballistic Camera used in sets or pairs in separate location and synchronized so as to obtain complete co-ordinate data; synchronized exposure between master and slave camera to within less than 1/2 millisecond.

— FAIRCHILD Polaroid Oscilloscope Camera for oscilloscope recording.

— FAIRCHILD Navigator or Solar Compass.

ACCESSORIES :

SPECIAL PLATES OR FILMS FOR AERIAL PHOTOGRAPHY

Kodak Aerographic Films :

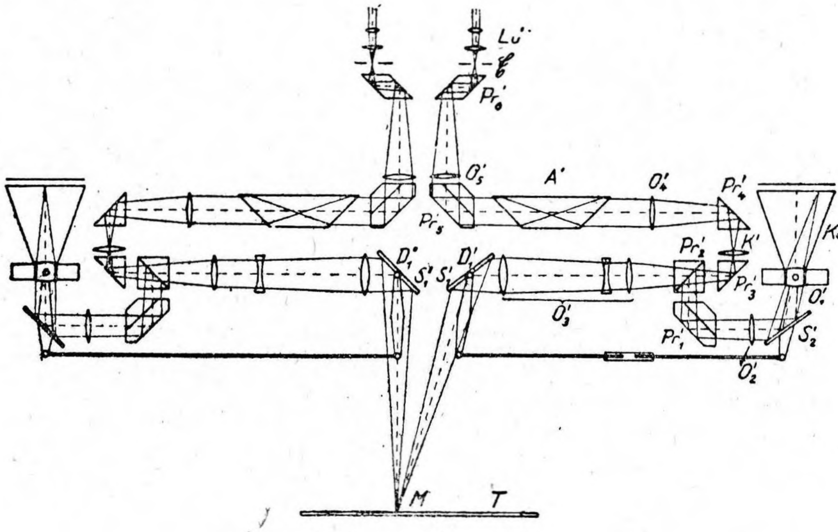
— Kodak Low-shrink Safety Base.
— Kodak Aerographic Infra-red, for haze penetration.
— Kodak High Speed Panchromatic, for night photography.
— Kodak-Pathé Super XX Aviation Panchromatic Film.
— Eastman Kodak Ektachrome Aero Film (High-and Low-Contrast).
— Kodagraph Auto-positive Film, for printing directly to a positive, matte-surfaced both sides, capable of taking ink or pencil and of erasure by mechanical means or correction fluid.
— Kodagraph Auto-positive Cloth, for contact production of a positive copy from a positive original drawing free from the distortion introduced by the use of paper negatives (30-and 100-foot rolls, width : 20, 30, 36, 42 inches).
— Kodabromide Projection Paper for aerial photography.
— Kodacolor Aero Reversal Film, High Contrast.
— Guilleminot Panchro 2.000.
— Gevaert Avi-microgran Emulsion.
— Vinyl-plastic Translucent Dinobase.
— Reprolith Ortho Vinyl Base.
— Ozalid of the General Aniline and Film Co.
— Ansco Color Positive Films — with use of filters yellow (minus blue); 25A filter (red).

RADIAL TRIANGULATION APPARATUS

Radial or Nadiral Triangulation is a direct consequence of the properties of vertical or nearly-vertical photographs following the assumption that the angles measured from the principal point of the photograph are equal to the horizontal angles formed between the corresponding points on land (Application of the so-called *Arundel* method).

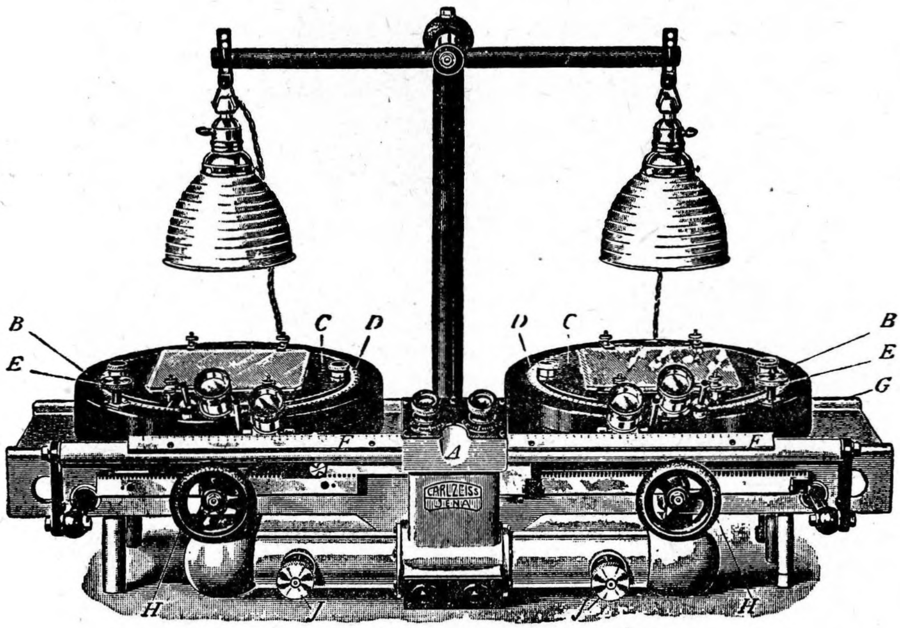
Mechanical triangulators for radial line plotting :

1921 — Triangulator of Lieut.-Commander BOYKOW.



Boykow Triangulator

— Radial Triangulator Z - A, of Zeiss (von Grüber) of « Photogrammetrie G.m.b.h. », Munich, size 18 × 18 cm. — is a kind of radial triangulator stereocomparator acting as stereographometer for angle measurement on two photograms of a stereoscopic series.



Zeiss Radial Triangulator

— H. G. Fourcade Stereogoniometer. (See : *Hydrogr. Review,* Vol. VII, n° 1, May 1930, p. 103-105).

1930-32 — (I.G.M.) Santoni Triangulator of the *Istituto Geografico Militare.*

1938 — Schermerhorn Radial Triangulator (G. de Koningh - Arnhem), Radial Triangulating Stereocomparator.

— Kail Radial Planimetric Plotter for transferring planimetric details directly to the map from the stereoscopic aerial photographs.

— O.M.I. (Ottica Mecanica Italiana), Rome. Radial Triangulation Stereocomparator.

— O.M.I. Nistri Stereographometer, Rome — size 18×24 cm.

1944 — Menestrina (I.G.M.) Photogrammetric Triangulator : an improved version of the Paganini graphic sector.

APPARATUS FOR GRAPHICAL MEASUREMENTS ON NEGATIVES

Under this heading we have comparatively simple instruments for :

1°) Stereoscopic examination of photograms;

2°) Stereoscopic, linear or angle measurements on the photograms by means of Stereographometers (Zeichen stereometers);

3°) Plotting planimetric details from photographs.

On 25th June, 1838, the English physicist Charles Wheatstone (1802-1875) invented the two-mirror stereoscope. In 1849, David Brewster (1781-1868) presented his special design under the name of *refraction (lenticular) stereoscope.* H. von Helmhöltz (1821-1894) in his « specular stereoscope » increases the parallax by separating the outer mirrors, i.e. perception of field depth, by amplifying the stereoscopic faculty of the eye system. In 1858, by adding lenses to his system of mirrors, he achieved the « telestereoscope ».

In stereoscopic view-finders, the ratio of the distance separating the object-glasses to that of the eye-pieces $\frac{B}{\varepsilon}$ is called the *specific relief*. Taking G as the magnifying power of the instrument, $\frac{B}{\varepsilon} \times G$ is the coefficient of the *total relief*. In an ordinary telescope, the result of the enlargement is to flatten the apparent relief. The idea of succession in depth of the different frontal planes is suggested in the apparatus where $\frac{B}{\varepsilon} = G$ in which the *stereoscopic effect* or total relief is equal to G^2; this is the *normal* stereoscopic effect, while an exaggeration of the base B develops the effect of « plasticity » resulting from a special stereoscopic visual acuity of the eyes.

In figure 7, we have $\frac{\alpha'}{\alpha} = \frac{B}{\varepsilon}$

$$\alpha' = \frac{B}{\varepsilon}\,\alpha$$

$$\alpha'' = G\,\frac{B}{\varepsilon}\,\alpha = K\,\alpha$$

K is the « depth coefficient ».

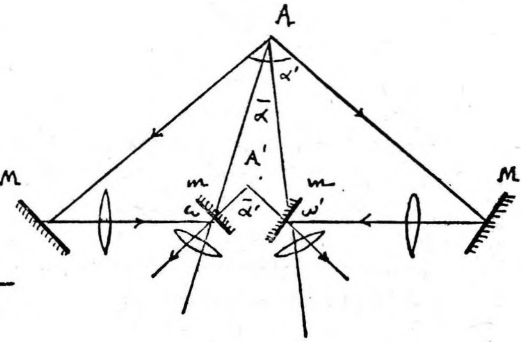


Fig. 7

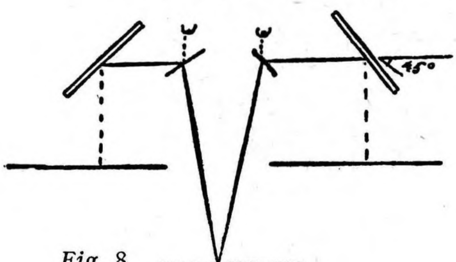
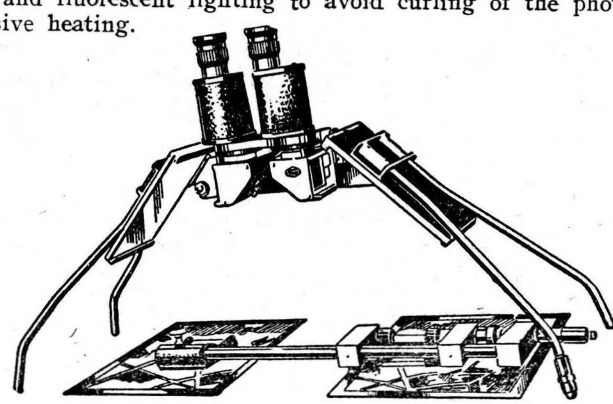


Fig. 8

Stereoscopic-cartographical instruments use pairs of air photographs overlapping one another. The stereoscopes used may be of the mirror, lens, or prism system and more or less mounted on flexible supports, like certain drawing instruments, according to the ingenuity of the makers.

The following instruments fall within this category :

— Brewster Mirror Stereoscope.
— Porro Mirror Stereoscope with Micrometer.
— Casella Pocket Stereoscope with adjustable Eye Base (55 to 75 mm.).
— Casella Folding Mirror Stereoscope N° 3100 with parallel guidance mechanism and fluorescent lighting to avoid curling of the photographs due to excessive heating.



Casella folding stereoscope N 3100

— CASELLA Stereometer or Parallax Measurer N° 3104 with 12.5 mm. micrometer range.

— SONNE Stereoscope Viewer.

— BROCK'S Stereometer.
Large-mirror Stereoscope for Stereomosaics.

1902 — DEVILLE Stereoscope with semi-silvered mirrors and index for the examination of photographs taken on land.

— ZEISS Stereoscope with Stereomicrometer screw for the measurement of parallax.

1903 — PULFRICH Reflection Stereoscope with semi-silvered prisms and objective lens interposed in front of the photogram.

From ZEISS Aerotopograph, Munich : —

— ZEISS Pocket Stereoscope : f = 3 1/2 inches = 88 mm. Magnifying Power x 2.8.

— ZEISS Mirror Stereoscope.

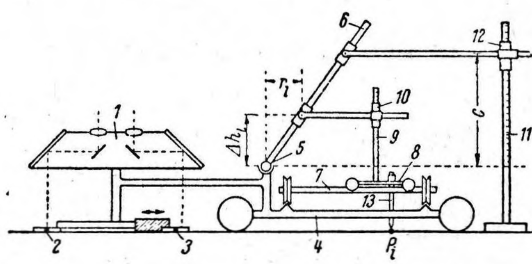
— ZEISS Prism Stereoscope with jointed stand.

— ZEISS Stereometer (Zeichenstereometer) for micrometric measurement of parallax.

— ZEISS Stereopantometer.

— SCHNEIDER Stereoscope, field 9" x 9" = 23 × 23 cm., mounted on ball bearings; lateral displacement on rails.

— W. KERN Orthostereometer.



Kern Orthostereometer (schema)

From HARRISON C. RYKER INC., Berkeley (Cal.), U.S.A.: —

1936 — RYKER Model D-10 Lens Stereoscope with prismatic lens allowing wide spacing of image-pairs (positive image-pair separation of 3 1/2 to 4 1/2 inches). The counterweight base holds the stereoscope conveniently. When up-tilted rearward the counterweight base rests on a rear leg, completely clearing the picture for inking or marking. The stereoscope can be returned to operative position without loss of orientation.

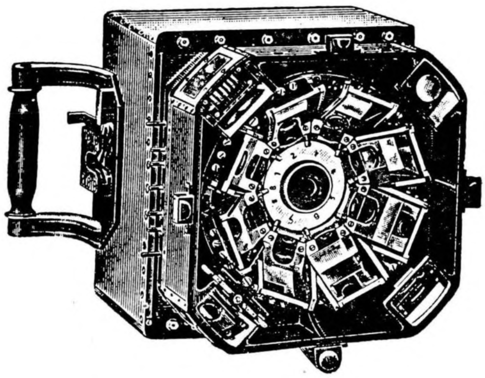
— RYKER Model D-12 Pocket Stereoscope.

— RYKER Model M-11 Magnifying Stereoscope.

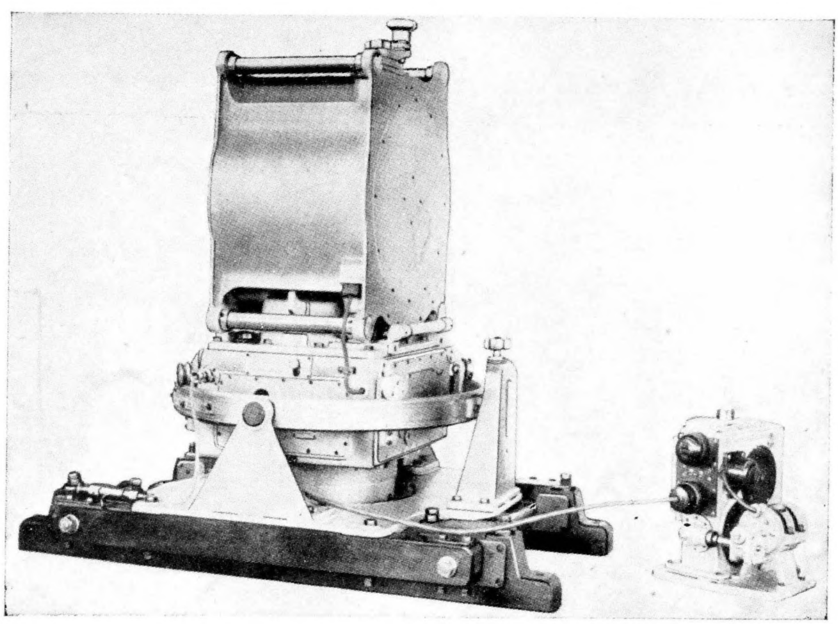
— RYKER Reflecting Mirror Stereoscope Model M-11 X of the series for pairs of 9"×9" photos, with binocular variable magnification adjustment and rhodium-coated mirrors.

— RYKER Vertical Sketchmaster, Model L-1 : A wide-field Camera Lucida for rapid sketching from photographs, etc., object mirror detachable to permit sketching from large objects or wall copy. With a set of 9 lenses, enlargement range up to 2.6 times the picture scale — reduction scale down to 1/4 picture scale.

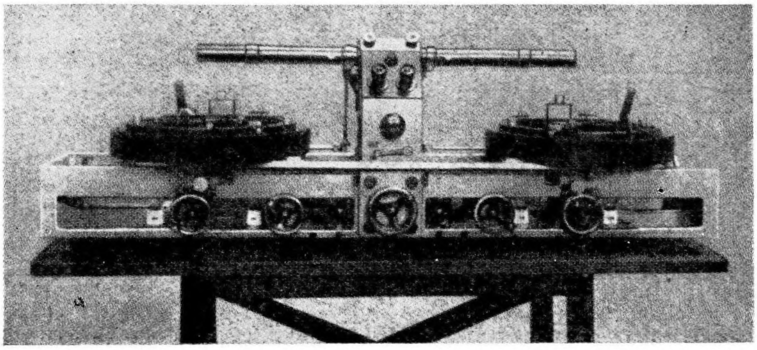
— RYKER Oblique Sketchmaster, Model L-2.



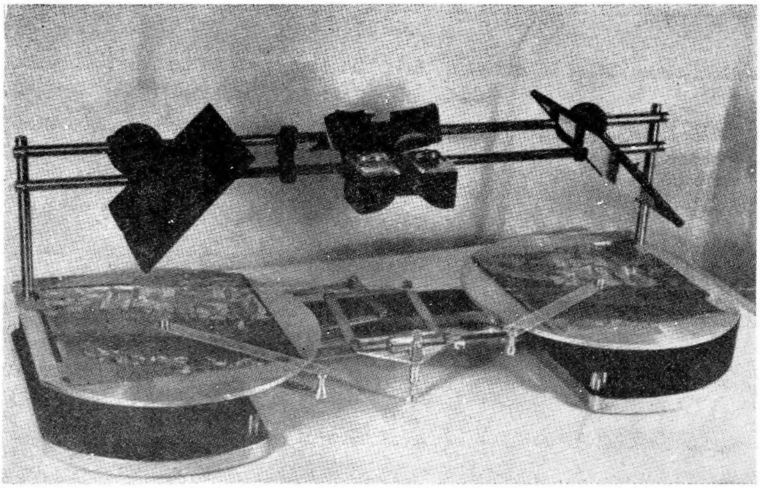
Zeiss-Aschenbrenner PK. 35
nine lens panoramic camera



SOM-Poivilliers Automatic Camera



Schermerhorn Radial Triangulator



Philip B. Kail Radial Planimetric Plotter

1942 — RYKER Model PL-3 Topographic Stereoscopic Plotter, Wernstedt-Mahan type for contouring and planimetry, based on the principle of the *Wernstedt* Floating Dot; focal length 210-300 mm. and 150 mm.

— ABRAMS folding Pocket Stereoscope Model CF-8; used in conjunction with Abrams Height Finder Model HF-2 attachment with « y » adjustment of left floating dot.

— ABRAMS 2-4 Stereoscope Model CB-1 furnishes either 2-power or 4-power, magnification, distorsion free lenses, interpupillary adjustment, foam rubber headrest, made of molded nylon.

— ABRAMS Mirror Stereoscope, Model SF-1, magnifying and large field 24"×9".

— ABRAMS Contour Finder Model FC-3 for general contouring work over a pair of overlapping vertical aerial photographs — magnifying stereoscope 2 1/2 — the pair of fine floating dots are inscribed on plastic lenses. Parallax displacement is indicated on a dial scale calibrated in 1/100th millimetre.

— FAIRCHILD F-271 Folding Pocket Lens Stereoscope — adjustable interpupillary distance 50 to 72 millimetres.

— FAIRCHILD F-71 Magnifying Mirror Stereoscope — rhodium-coated lateral mirrors eliminating double images — right-angle 45° central prisms free of colour, silvered and lacquered on the hypotenuse surface — lenses 11 1/4 inch focal lengths — with FAIRCHILD Parallax Bar for measuring elevations or delineating form lines — with two adjustable floating dot assemblies and drawing attachment, mounted on four legs, one of which is adjustable for tilt — with binocular eyepiece and adjustable eye base (4 magnifying power).

— FAIRCHILD Stereocomparagraph.

— FAIRCHILD Rectoplanigraph with slow motion vertical control for rectifying and transferring planimetric detail from serial photographs to maps and charts, based on the principle of Camera Lucida — 3 focal lengths — 6, 8 1/2 and 12 inch — accurate screw adjustment for variation in scale — universal adjustments for rectifying angles of crab, tip and tilt — picture holder to accommodate photographs from 4×5 inches to 9×9 inches.

— FAIRCHILD Rectangular Co-ordinate Plotter — 40" × 40" (1 m. × 1 m.) with short lead screws and Veeder Root counters.

— The SEELYSCOPE : Simple transfer device for transferring details from air photographs to maps with reduction or enlargement or at even scale.

The *Seelyscope* has been evolved from the Seely *Duoscope* (1941) and from the *Monoscope* of George R. Sonley (1946) combining the proven advantages of both instruments with addition of special features.

The instrument consists of two bars supported horizontally, two large mirrors set at 45° and a center assembly having two frames for holding either fully silvered or semi-transparent mirrors, and two clips for holding simple plano-convex lenses of varying focal lengths. It may be used as a "camera lucida" for transferring details from air photographs to maps by inserting a semi-transparent mirror into one side of the center assembly.

Reductions in scale of from 2 to 5 diameters may be obtained, depending on the distance from the center assembly at which the large mirror is set. Enlarging is done by reversing the position of map and photograph. — The introduction of a third smaller mirror at an angle beneath the center assembly (G. A. Spear, 1948) permits transferring of details at even or near-even scale. — Balancing of the illumination on map and photograph is obtained by "lumitrol" (controlled illumination).

1945 — The MULTISCOPE for work with vertical aerial photographs or plotting stereoscope with 1 or 2 semi-transparent mirrors — provides a simple means of superimposing the stereoscopic image of the photograph on a map. May be used as a :

Camera Lucida.
Mirror Stereoscope.
Rapid Stereoscopic Plotter.
Compensating Stereoscopic Plotter.

Manufactured by : North Eastern Engineering Inc., Manchester, New Hampshire, U.S.A. The reduction or enlargement ratio reaches 2 1/2. Phasing is obtained by introduction of lenses the object of which is to equalize optically the luminous path-finder.

1912 — PULFRICH Stereocomparator.

— SANTONI Stereoscopic Puntinatore.

— CAMBRIDGE INSTRUMENT Co. (Major E.H. THOMPSON, R.E.) : Model 1937 and Model 1939 Stereocomparator — measures precisely the rectangular co-ordinates of the images — (accuracy : 0.01 mm.).

— CAMBRIDGE INSTRUMENT Co. Stereocomparator.

— ZEISS — Aerotopograph G.m.b.H. — Stereoscopic Plotter.

— NISTRI Stereophotogrammeter of O.M.T. (Ottica Mecanica Italiana), Rome — 13 × 18 and 18 × 24 cm. — with drawing-table and polar pantograph plotter for examination of glass or film negatives and positive photo-prints.

1932 — BARR and STROUD Topographic Stereoscope — portable and precision types — for examining and contouring upon pairs of photographs — Portable type Z. D. 4. Based on the principle of the *Wheatstone* stereoscope, permits examination of large-surface photograms — fitted with parallactic grids permitting measurement of parallax differences on the photos. (See : *Hydrogr. Review,* Vol. VII, n° 1, May 1930, p. 103-105)

— BARR and STROUD (Fourcade model) Stereogoniometer — for determing the data of height and tilt preparatory to plotting from photographs.

— H.G. FOURCADE Stereogoniometer.

— PORRO-KOPPE Metrophotographic Theodolite (*Bildmess* theodolite).

— SANTONI Photogoniometer (1930-1932) of I.G.M.

1912 — PULFRICH Stereocomparator and Reflection Stereoscope.

— POIVILLIERS (S.O.M.) Photogoniometer.

— POIVILLIERS Stereotopometer.

— POIVILLIERS S.O.M. Stereoscope, Type A : a mirror stereoscope permitting binocular examination with or without magnification of pairs of air or land photographs, maximum size 24 × 24 cm. with a maximum overlap of 75 %. Its advantage is the quick transfer of examination without magnification of the overlap to the detailed study of the same area with successive magnifications of 3 centimetres in diameter simply by moving the photogram holders and the bar bearing the magnifying lenses.

— WILD Model A-4 Autograph for Short-Range Photogrammetry : Consists of two restitution cameras, focal length 9 cm. for 6.5×9 cm. negatives *obtained with the Wild Stereometric Camera.*

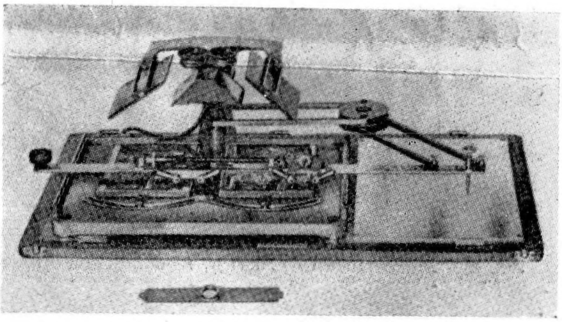
The autograph is adjusted for a tilt recorded when taking the photograph and for any desired scale according to length of photographic base.

The binocular telescope enables examination of the area photographed, greatly magnified and showing relief to a marked extent.

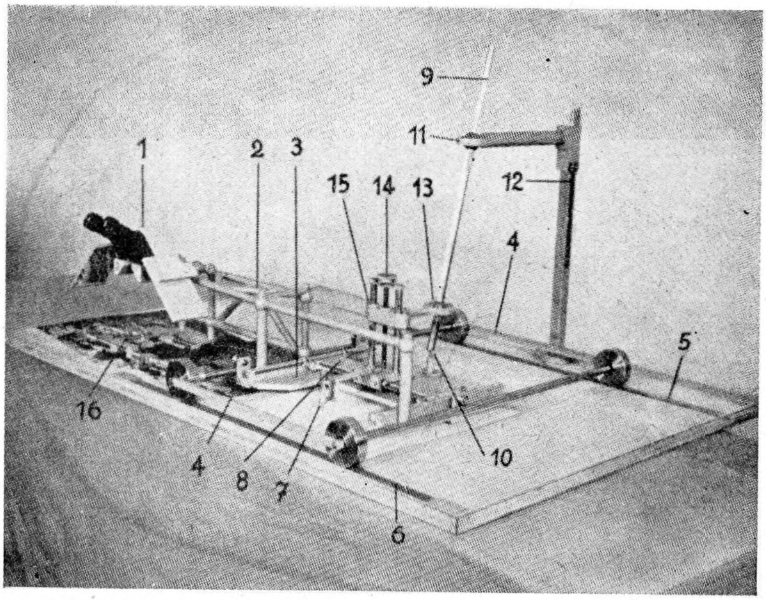
By operating two cranks and a pedal (disk) the T-shaped index mark is superimposed on any observed point of the image.

A 75 ×75 cm. drawing-table with glass top is associated with the autograph, and the pencil lead exactly follows the vertical projection of the mark and plots on the plane of the table points or lines of the measured object, the altitudes of which are read in centimetres or millimetres on the drum.

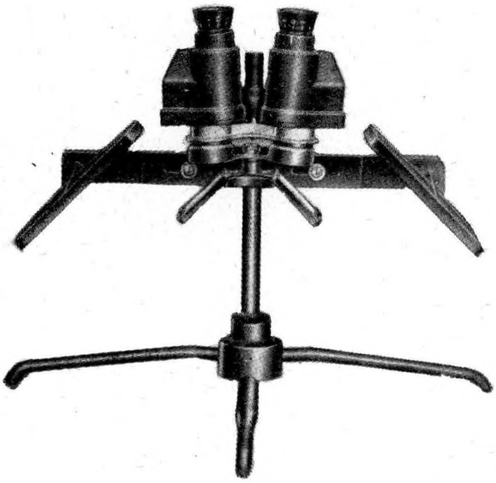
Accuracy : By means of stereophotogrammetry an object 10 metres long at 50 metres' distance can be measured with an accuracy of from 1 to 2 cm.



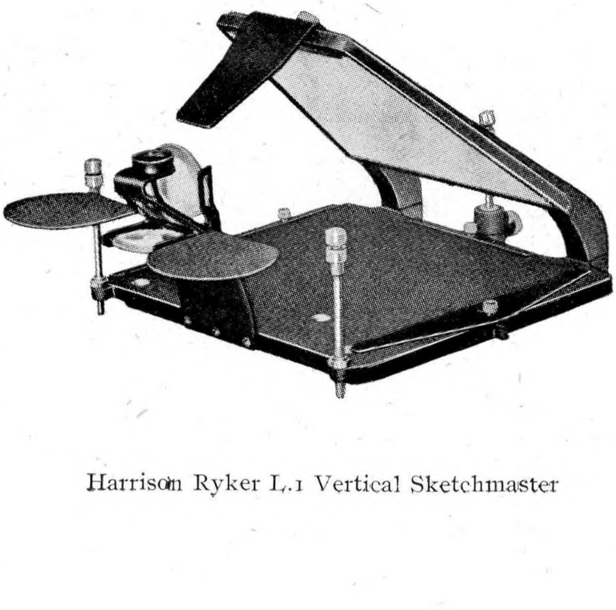
Nistri Stereographometer



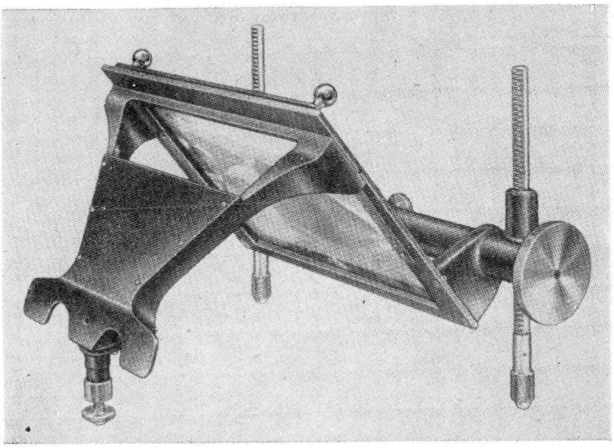
W. Kern Orthostereometer



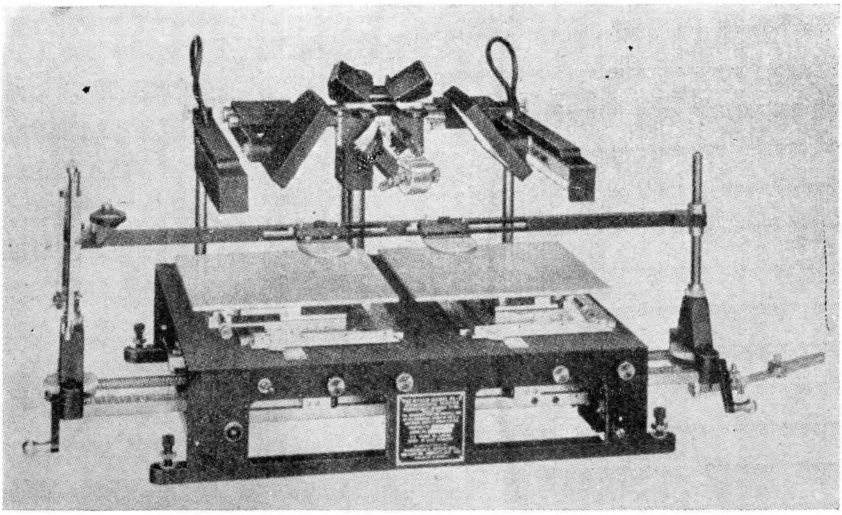
Ryker M. 11 Magnifying Stereoscope



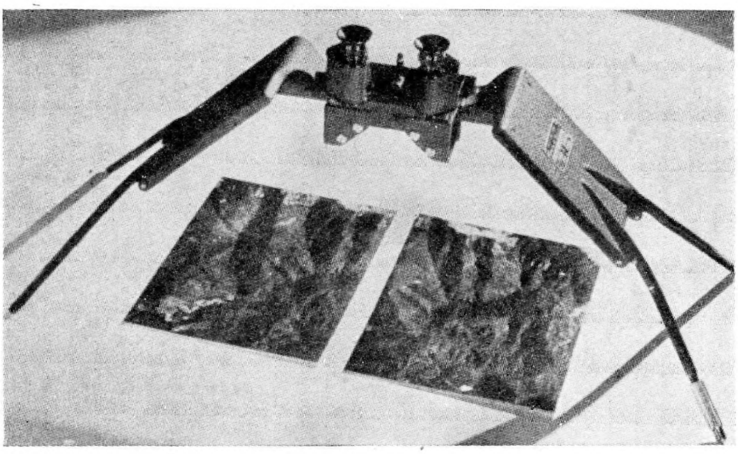
Harrison Ryker L.1 Vertical Sketchmaster



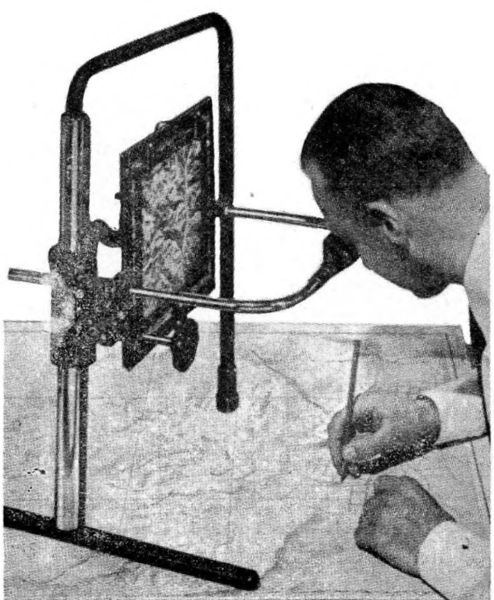
Ryker L. 2 Oblique Sketchmaster



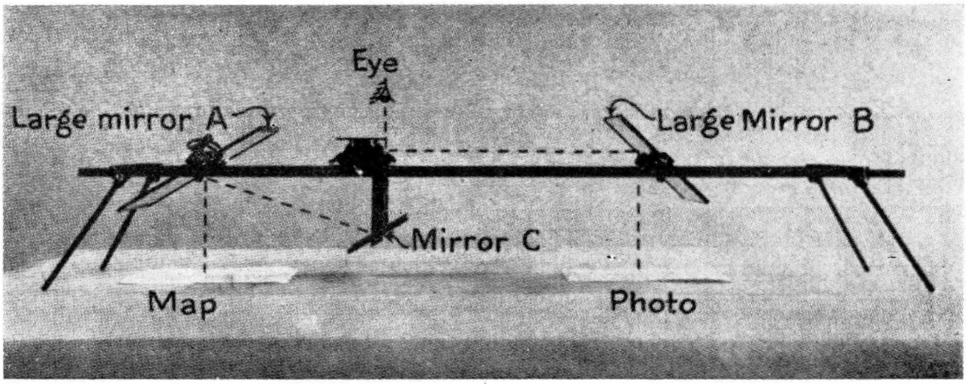
Ryker PL-3 Stereoscopic Plotter Wernstedt-Mahan type



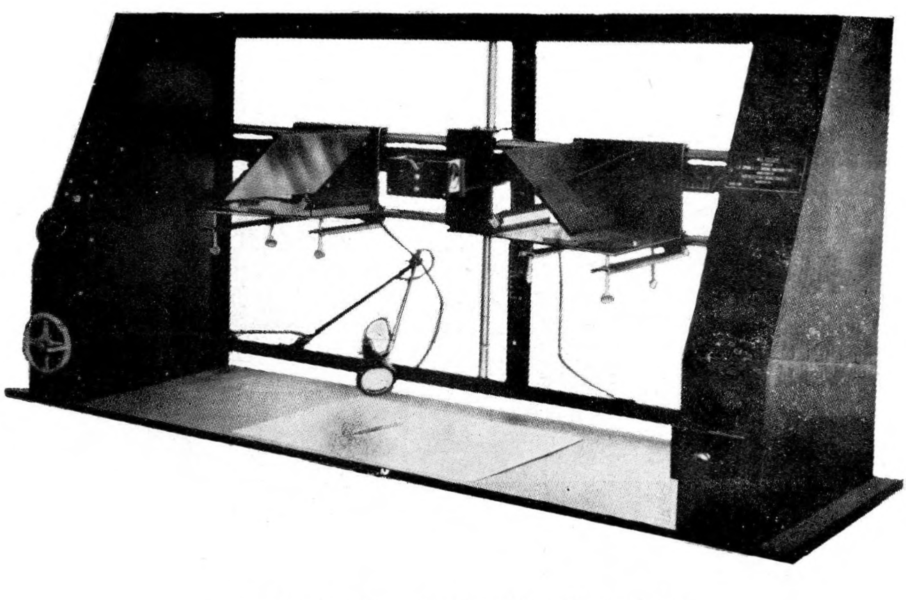
Fairchild F. 71 magnifying Mirror Stereoscope



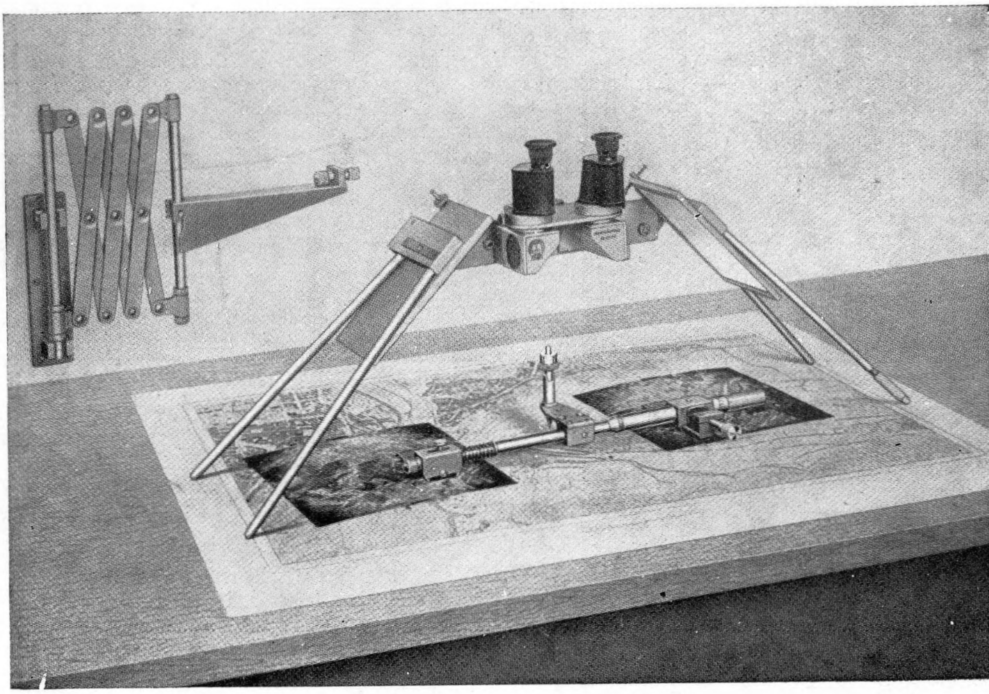
Fairchild Rectoplanigraph



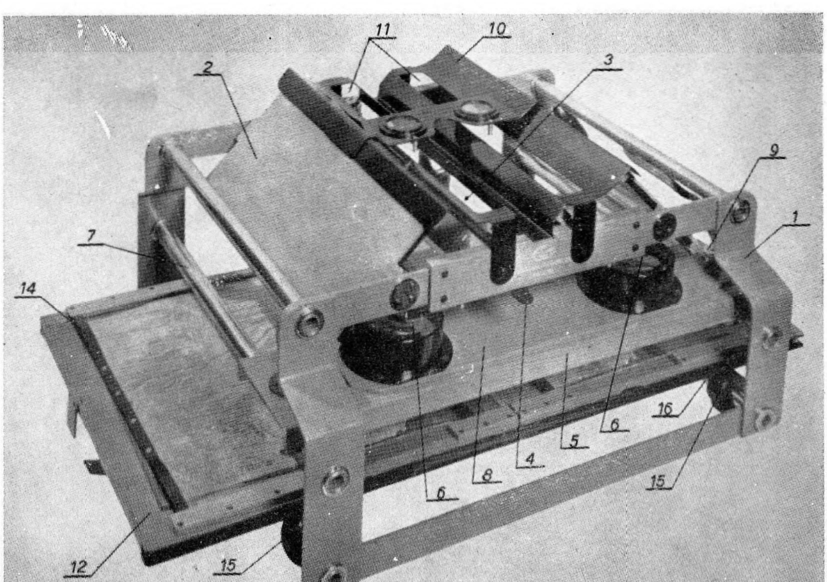
The Seelyscope



North-Eastern Engineering Multiscope



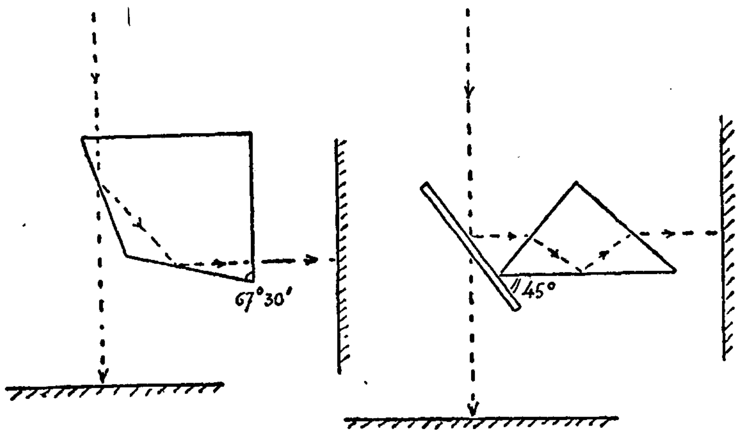
Zeiss Aerotopograph Stereoscopic Plotter



Poivilliers-SOM Stereoscope, type A

APPARATUS BASED ON THE CAMERA LUCIDA PRINCIPLE

The « camera lucida » diagraph or megalograph claimed as having been invented by Robert Hooke (1635-1703), was actually mainly constructed in 1804 by Dr. William Hyde Wollaston (1766-1826) and improved in 1816 by a professor from Modena : J.-B. Amici (1786-1864). (Figure 9).



Wollaston *Fig.* 9 Amici

The principle of this invention, which is that of the *Sketchmaster* instrument, by means of which the lines of an original drawing can be transferred onto a different surface either on the same scale or on a different scale, using a pencil, is shown in Figure 10 : a mirror or a semi-silvered prism enables the pencil point to be seen as if it were on the model to be reproduced. Exact focussing is obtained by means of lenses, and by means of an additional 45° tilted mirror the plates can be examined flat. Occasionally the instrument includes a head-rest for fixing the monocular position.

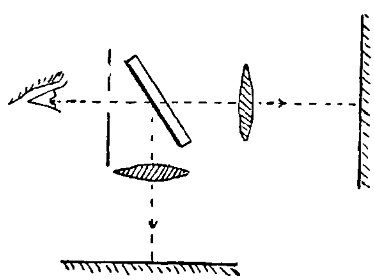


Fig. 10

Aero Service Corporation (Eng. J.L. Buckmaster, Geological Survey) :

The Vertical Sketchmaster serves for examination of flat photographs. The support includes a compensator part for the correction of slight tilt.

The Oblique Sketchmaster : The principal feature of this instrument is a semi-silvered mirror by which the oblique photograph and the corresponding planimetric chart can be seen simultaneously. In this way the photograph appears rectified and correctly superposed on the chart so that the operator can plot the details of the photograph directly on the cartographic work sheet.

Universal Sketchmaster : This model serves for oblique photographs taken with the trimetrogon and for tilts which may vary from 0° to 80°. It includes a stuck-on prism instead of a mirror. The viewing of the sheet is through a circular aperture while that of the photograph comes from the annular surface surrounding the aperture. The relative lighting of the two superimposed images can be varied by means of an adjustable lamp.

Abrams Instrument Corporation, Lansing, Michigan (U.S.A.) :

Vertical Sketchmaster, VS-1 Model, for transferring planimetry from 9" x 9" vertical or near vertical aerial photographs to a map plane. Adjustment for tip, tilt and selection of scale is made by means of three legs fitted with adjusting screws. Mirrors are silvered on the front face in order to avoid any refraction parallax in the thickness. 6 lenses are used for varying magnification from 0.35 to 1.14. Photographs are kept tight by means of Alnico magnets.

Oblique Sketchmaster, VO-1 model : Three adjusting screws carrying the plate-holder permit adjustment of scales, tilt and tip.

K.E.K. Stereoscope Plotter (King, Elliot, Kail) — Philip B. Kail Associates, Denver, Colorado : This instrument is for charting the topography and planimetry directly on the work sheet, using contact photographic prints. (See : *Hydrogr. Review*, Vol. XXV, n° 2, Nov. 1948, p. 79).

It consists of a front surface mirror stereoscope for viewing a couple of photographs placed on a pair of photo-tables that are movably mounted and can be raised or lowered vertically in relation to the stereoscope by means of a handwheel on the left side of the plotter. The photo-tables are also provided with movements for rotating, tilting and tipping the photographs so as to reproduce the relative position of the camera at the time of the original exposures. The « floating mark » interposed, on the line of sight, between the stereoscope and the photo-tables, is adjusted so as to move freely in the horizontal plane. The movement of the movable index is transferred to the tracing pen by means of a pantograph through which the motion is magnified or reduced. Variation of height of the horizontal planes is obtained by varying the distance between the two dots which make up the floating mark. The stereoscopic model is placed in contact with these planes by raising or lowering the photo-tables. The K.E.K. Stereoscopic Plotter draws, in one operation, planimetry and contours.

The Reading Plotter of the Coast and Geodetic Survey, Washington, Model A : (See : *Hydrogr. Review*, Vol. XXV, n° 1, May 1948, p. 87)

The O.S. Reading Plotter produces an orthogonal projection of contours and planimetry from 35" x 35" non-tilted photographs taken with the special nine-lens camera of the C. & G.S. These photographs are first passed through the « Transforming Printer », then through the « Rectifying Camera » which gives a rectified proof.

The stereoscope is suspended so that it may freely be moved above the surface of the photographs; it is maintained parallel by joint mounted steel bands as is the case with many systems of drawing-machines. On the reticle of the stereoscope are « floating marks », the movement of which drives the pencil point of the pantograph. The object-glasses of the stereoscope are about 40" apart.

The movement of the stereoscope is accomplished by means of a handle, the operation of which is similar to that of a pencil, to make the floating index mark appear to draw the lines of the photographic image. The floating mark is made to appear vertically on the image by the use of a foot-wheel. The photographs are separated by a hand-wheel to obtain stereoscope blending of the images.

The tracing pencil is raised up by means of a solenoid actuated through an electric contact. Correct stereoscopic orientation is maintained in the eye-pieces by geared rotating Dove prisms.

Accuracy obtained : 20-foot difference of contours on 1 : 20.000 scale.

Efficacity of apparatus per man-day : 1.25 sq. miles. (Multiplex Production Rate is 0.7 sq. miles per man-day.)

In model B the stereoscope is fixed while the photographs are moved under it by hand-wheels.

PHOTOGRAPH RECTIFYING APPARATUS

(For Single Photograph)

Principle : The parabolic Reflector *R* (Fig. 11) provides a parallel light beam on the negative plate *P*, the combined objective of which (O) provides the projection on the table *T*.

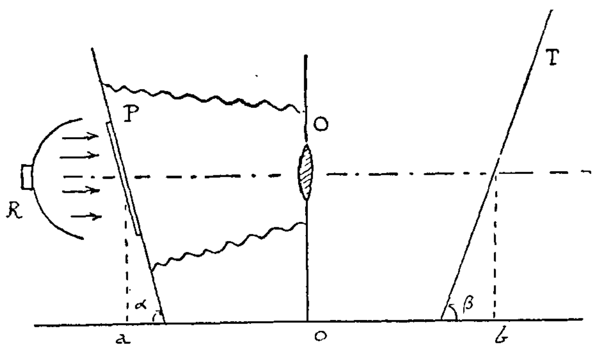


Fig. 11

Usually the optical axis is vertical and the projection table horizontal. The following may be varied :

1.) Magnifying power;

2.) Inclination of planes of the negative and of the projections;

3.) The rotation of the negative in its proper plane;

4.) Displacement of the negative in direction perpendicular to the axis of tilt;

5.) Displacement of the negative in direction parallel to the axis of tilt, i.e. 5 degrees of freedom for the apparatus.

Available instruments are as follows :

1920 — ZEISS Entzerrungsgerät (Rectifier), based on principle of Scheimpflug Photoperspectograph (Scheimpflug-Kammerer Universal Transformer-Rectifier).

1924 — ZEISS Entzerrungsgerät of Konsortium Luftbild-Stereographik G.m.b.H., Munich.

— ZEISS Entzerrungsgerät, additional model, 1926 (C. Aschenbrenner).

1927 — ZEISS-AEROTOPOGRAPH G.m.b.H., (R. Hugershoff) Entzerrungsgerät, Jena.

— ZEISS Automatic Rectifier, type S E G. I (Rectifying Enlarger).

— ZEISS Automatic Rectifier, type S E G. II.

— ZEISS Automatic Rectifier, simplified model S E G. IV, enlargement from 0.7 to 2.5 with automatic focussing.

— ZEISS Universal Reduktionsgerät for sizes from 30×30 cm^2 to 4×4 cm^2. Enlargement from 2 : 1 to 1 : 11.

— SALTZMAN autofocus Precision Reflecting Projector for negatives giving ratio-prints enlarged or reduced from the original size. In the stereoplanigraph, arrangements obtained with the Saltzman projector adjusted for ratio 1 : 1 or, again, obtained directly by contact print from the original negatives, are used.

— FRED M. MOFFIT Transforming Printer, used by the U.S. *Geological Survey* for rectifying trimetrogon photographs.

— Major BAGLEY Transforming Printer, used in combination with the T. 1 Bagley Tri-Lens Camera, of Moffit or Major Theodor Scheimpflug (Austrian) instrument type.

— ARVID VON ODENCRANTS (WILD-ODENCRANTS) Rectifier : focal length = 178 mm., vertical axis, maximum size of negatives : 18×24 cm., adjustable magnification from 0.3 to 4.2 times with 5 freedom motions :

1.) Tilt of the negative and of the projection plane (left pedal);
2.) Change of magnification (right pedal);
3.) Rotation of negative in its plane (right button);
4.) Displacement of negative in direction parallel to tilt axis (left inner button);
5.) Displacement of negative in direction perpendicular to tilt axis (left outer button);

Weight : 530 kilograms.

— WILD E2 Automatic Rectifier.

— WILD U2 Reduction Printer.
Rectifying Apparatus E.-5.

— BROCK Correcting Projector. (See : *Hydrogr. Review*, Vol. VI, n° 1, May 1929, p. 189).

— ROUSSILHE (Ingénieur Hydrographe H.) Rectifier, of the *Société Cinéma Tirage* L. Maurice, Genevilliers. (See : *Hydrogr. Review*, Vol. VI, n° 2, Nov. 1929, p. 93).

— TROREY Anharmonic Rectifier. Constructed by the Williamson Manufacturing Company, London.

— GALLUS-FERBER I.G.N. Rectifier for panoramic photographs.

— NISTRI-BUCHOLTZ (O.M.I. — Ottica Mecanica Italiana) Rectifier. (See : *Hydrogr. Review*, Vol. XIII, n° 1, May 1936, p. 119).

— INTERNATIONAL AERO-SERVICE CORPORATION Universal Rectifier.

— U.S. COAST and GEODETIC SURVEY Rectifying Camera, focal length = 23" = 580 mm., automatic focussing for near vertical photographs only.

Overhead Ratio Reflecting Projector with movable upper assembly in lamphouse unit. Mirror rectifier at 45° to project on horizontal table; ventilated by electric blower with symmetrical lens permitting magnification or reduction.

— REED Reflecting Projector with automatic focussing.

— BAUSCH and LOMB Autofocus Rectifier : provides rectified photographs for compilation of mosaics; fitted with 5"5 Metrogon lens, maximum size 9"×9"; magnification 0.55 to 4 times; maximum tilt 35°.

Transformer (Umbieldgerät) for multiple-camera panoramic instruments

— ASCHENBRENNER Fixed Angle Transformer for 9-lens PK33 instrument.

— CARL JANZER (Stuttgart) « Integrator » (30° rectifier).

— SANTONI *Raddrizatore* (photographic rectifier).

— SANTONI 30° Fixed Angle Transformer; rectifies for nadiral plane the lateral photograms produced with the Santoni Oscillating apparatus.

— SANTONI (I.G.M.) 60° Fixed Angle Transformer : used for rectifying panoramic photographs.

— COAST and GEODETIC SURVEY 9-lens Stereocartograph for plotting maps stereoscopically using air photographs taken with the 9-lens camera.

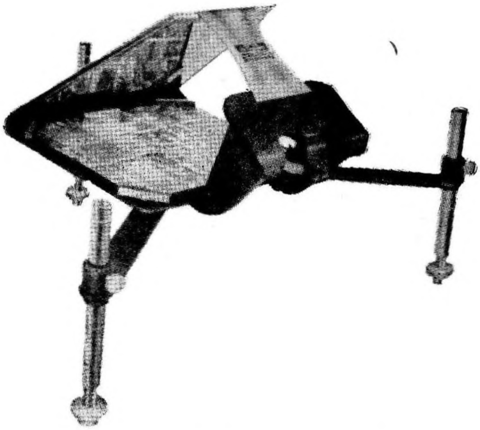
— ALFREDO FIECHTER Camera Lucida : is an optical rectifier constituted by a Wollaston prism which is used for bringing up to date the topography of flat lands by projection on already existing maps.

— FAIRCHILD Rectoplanigraph (Camera Lucida).

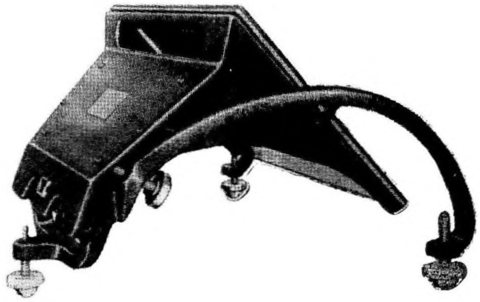
— PLEON Rectifying Printer.

— BARR and STROUD Epidiascope for mapping from single photographs of moderate tilt and for amending and adding new details to existing maps (1932); replaces the Camera Lucida for drawing. (See: *Hydrogr. Review*, Vol. VII, n° 1, May 1930, p. 103-105)

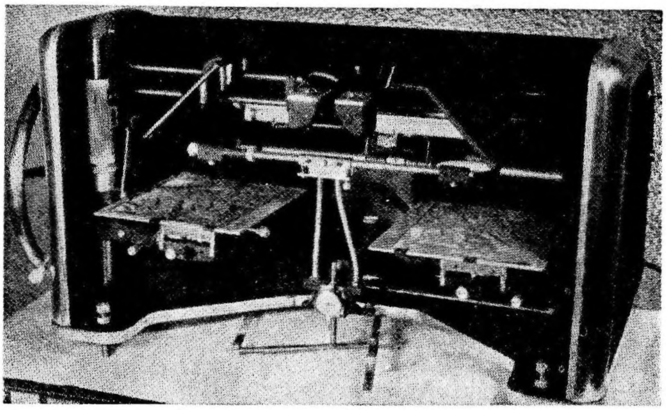
— MASSON D'AUTUME (S.O.M. — Société d'Optique Mécanique) Plotting Apparatus for plotting plans from rectified panoramic negatives (1949).



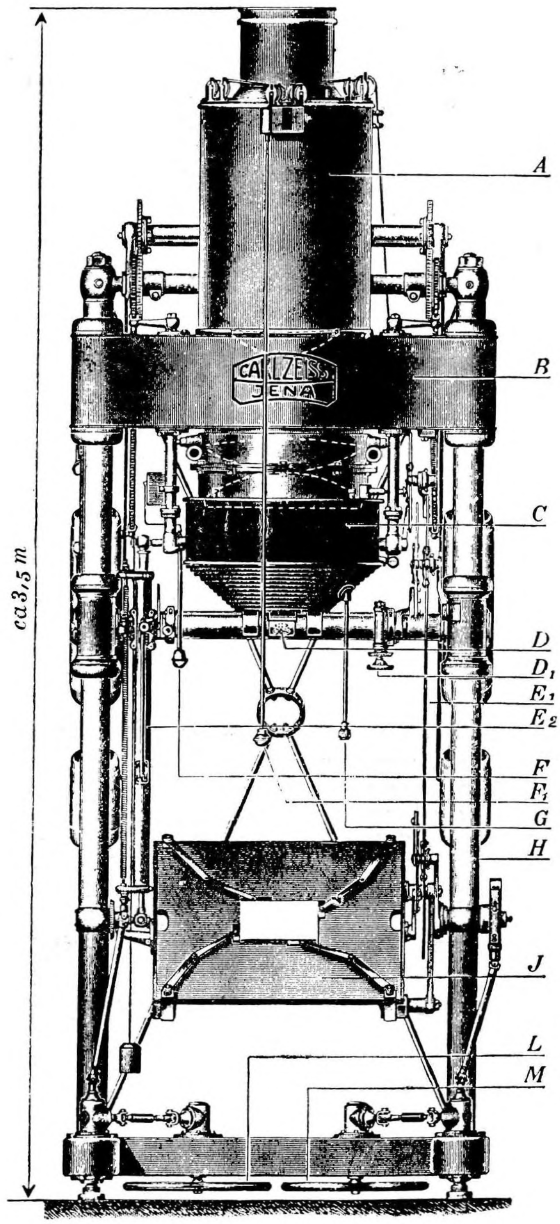
Abrams Vertical Sketchmaster VS-1



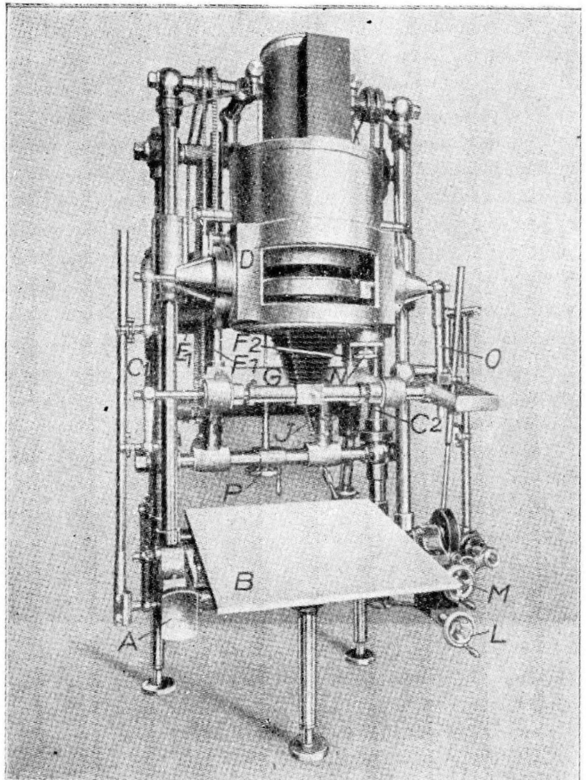
Abrams Oblique Sketchmaster VO-1



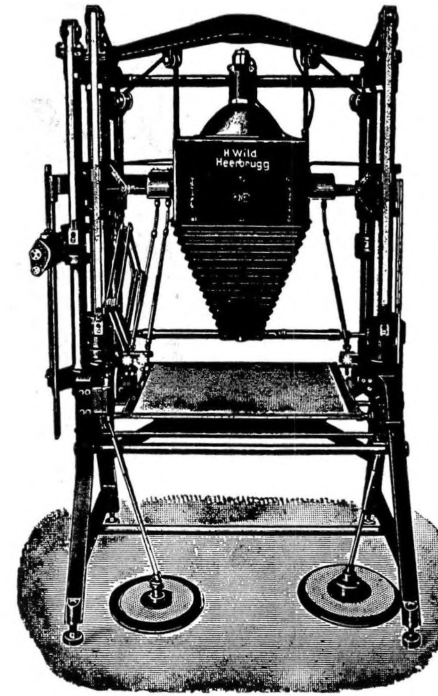
The KEK Stereoscopic Plotter



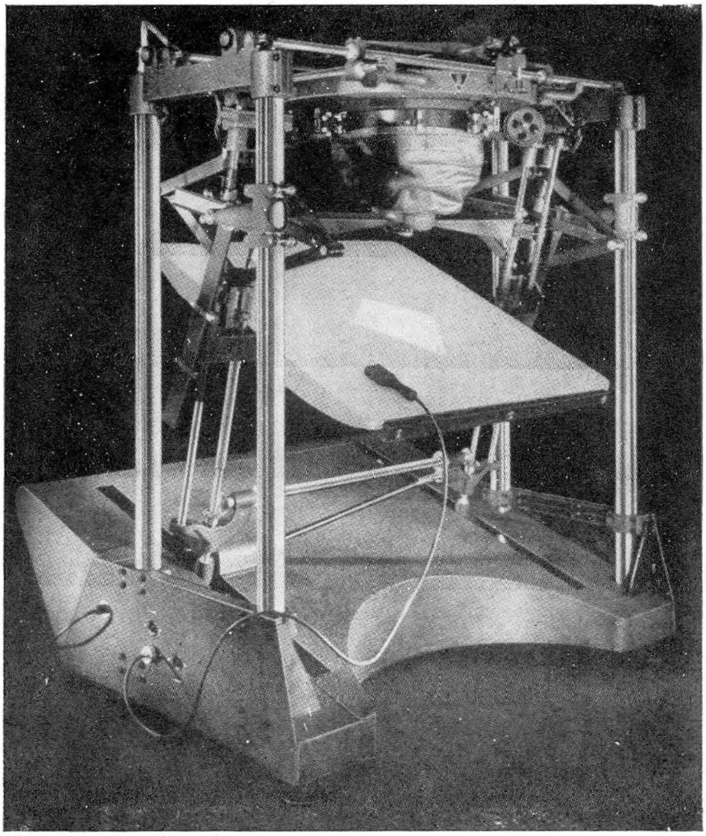
Zeiss Rectifier



Konsortium Automatic Rectifier



Wild-Odencrantz Rectifier



Bausch and Lomb Auto-focus Rectifier

— Special Multiplex Printer for diapositives : used for establishing from negative photographic plätes the small-sized diapositives which are used in the Multiplex Projector restitution apparatus. The printer carries a lens for compensating the distortion of the Metrogon photographic lens.

RESTITUTION

In terrestrial photogrammetry, the estimated orientation can be measured at the time of exposure; this is impossible in aerial photogrammetry and here measurement of the co-ordinates and the abscissae in relation to the principal axes of the plate cannot serve any useful purpose; it is necessary, however, to consider the true direction in space of the visual pairs and to obtain, optically or mechanically, the required intersection.

Seeking *a posteriori* the position of the point of exposure in space and its three Cartesian co-ordinates in relation to the origin of the representation plane, virtually means solving the problem of the vertex of the pyramid — or the problem of Snellius in space — in relation to three basic ground points, the images of which are clear-cut on the photographs; in this way the three angles α, β, γ at the vertex of the pyramid will be found by a 4th degree equation giving 4 solutions from which a selection is made by means of a 4th known ground point. The numerical-mathematical solution of such a problem (*), which necessitates hours of calculation, has, however, been put aside in favour of a practical optical and mechanical solution (Gasser, Nistri, etc.).

Restitution Apparatus in General

Generally speaking, in order to examine photograms from a fixed point of the instrument while the photograms themselves must be rotated in order to reconstitute exposure conditions, every restitution instrument must allow reconstitution of the relative position in space of the two photographic cameras O_1 and O_2 (fig. 12); the setting of the base O_1 O_2 to restitution scale; the rotation of the restitution cameras about points O_1 and O_2 and the placing of the photograms on the plate-holders by means of screws V.

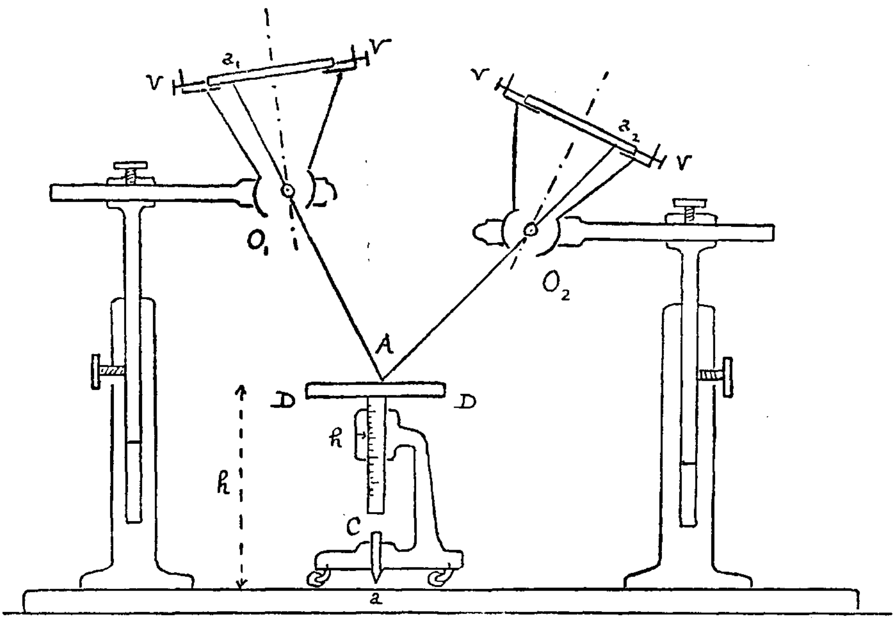
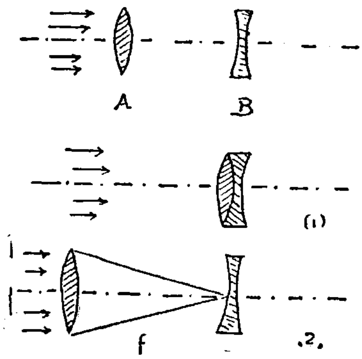


Fig. 12

(*) See : « I.H Review », Vol. IV, N° 2, Monaco, November 1927, page 69.

Distance AB can be varied from O to f.



For AB = O ,fig. 1), the lenses cancel one another and the beam of parallel rays passing through the system remains parallel upon issuing from the system.

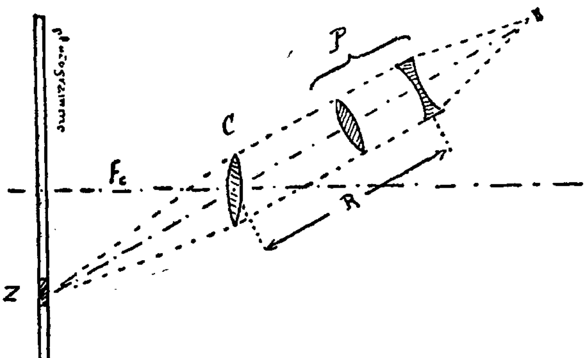
For AB = f (fig. 2) the effect of B is null and the image of the object is produced in the plane of the negative lens.

During the movement of A, the second principal plane of the system remains at a fixed distance from B.

This combination is used in optics, for instance in telescopes, to achieve a variable magnifying power without changing the length of the telescope. (pan = all; kratos = strength).

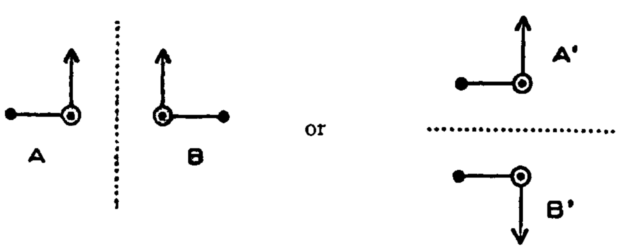
It serves in various photogrammetric restitution instruments to obtain the projection by zones of an extensive object (in this case the photogram) at variable distance, without changing the projection axis corresponding to the perspective centre C.

For this reason, the pancratic system P is set up to rotate about point C (fig. 7), the distance R remaining constant for each of the zones Z successively examined on the photogram.



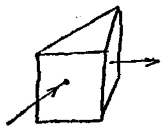
(7)

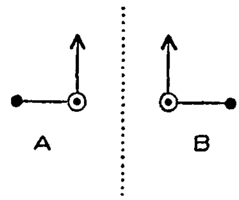
8. *The Single Mirror* gives a « reversed » image of the object.



(8)

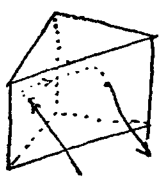
9. *The Single Reflection Right Prism* (entrance of the light beam on one side) produces a rotation of 180° of the image in relation to the edge of the prism; the direction of the incident beam on the prism is thrown back at a right angle.

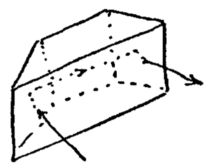


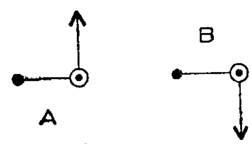


(9)

10. *Double Reflection Right Prism* (the prism is often truncated which gives it the shape of a trapeze); (entrance of light beam by the hypotenuse face). The direction of the incident beam is reversed and undergoes a displacement perpendicular to the edge (fictitious) equal to the mean length of the trapeze. The image is reversed.





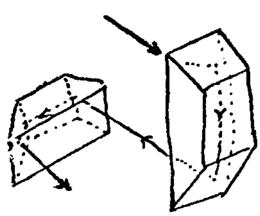


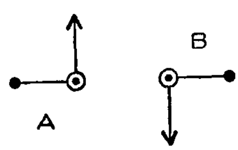
(10)

If the prism is rotated through an angle α in the plane of its hypotenuse, the emergent beam is rotated through 2α.

11. *Porro System :* A lens supplies an image rotated 180°

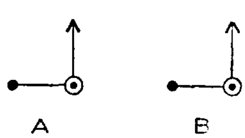
in its plane of an object.

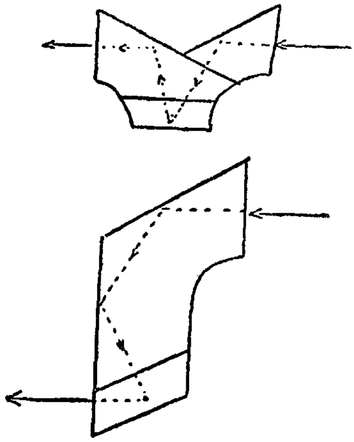




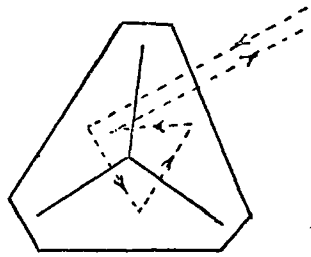
(11)

The astronomical eye-piece does not rectify this position. Ignazio Porro had the idea of introducing, between the lens and the eye-piece, an arrangement which bears his name, and consisting of two double reflection, right prisms 90° one from the other, which rectifies the whole.



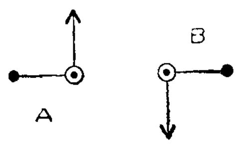


(19) Amici



(20) Triedron

19. *Amici Roof Prism :* The incident beam being here tilted in relation to the edge of the right dihedron, the roof prism produces a symmetrical and reversed image, which is equivalent to a rotation through 180° for the emergent beam.



20. *Trihedral Trirectangular Reflecting Prism :* Any incident beam on the hypotenuse face is thrown back after reflection on the three faces according to its own direction.

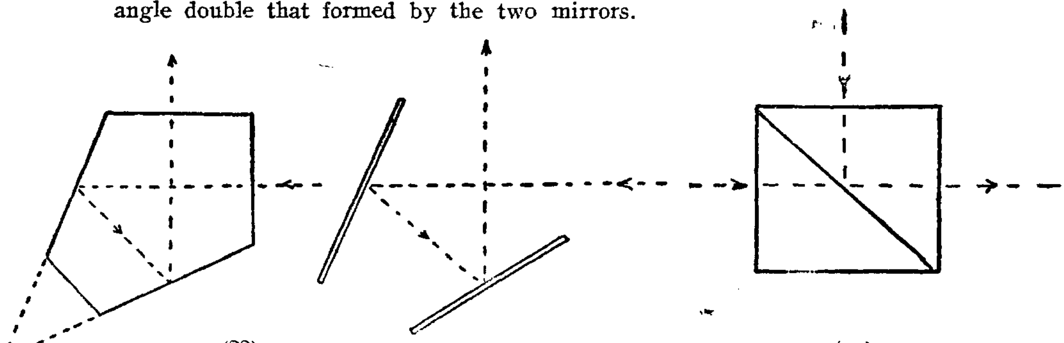
This geometrical property is used in reciprocal distance signalling by projector, in Radar reflectors and automobile or bicycle « cataphote » reflectors.

21. *Tetrahedron Prism and Huet Tetrahedral Image Rectifier:* Each tetrahedron prism is equivalent to 3 reflections on 3 mirrors at 45°, changes the sense of direction of the incident beam and submits the image to rotation through a right angle.

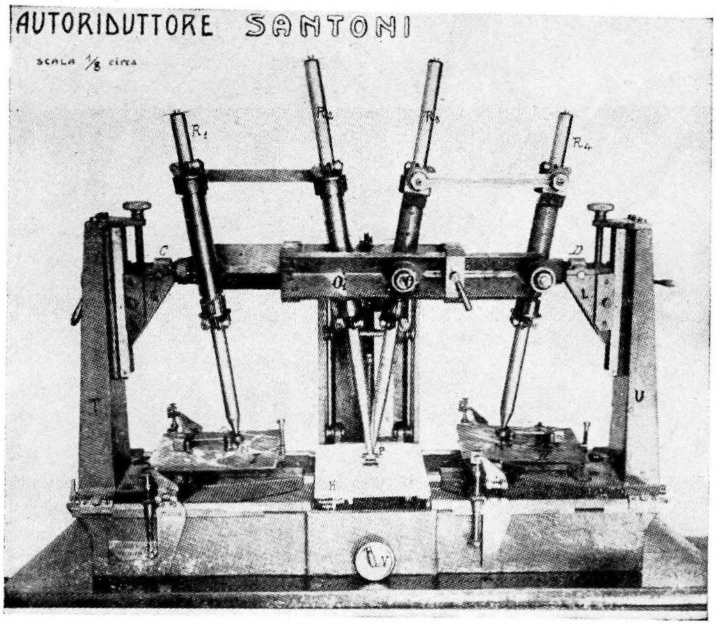
The contrivance, consisting of two tetrahedron prisms set in an appropriate direction, orients the beam in its original direction by rotating the image through 180°.

22. *Pentagonal* or *Pentahedral Prism* (or Symmetrical Truncated Quadrilateral) equivalent to one 45° dihedron (Optical Square); after double reflection the incident beam is deviated by 90° *whatever the angle of incidence of the beam may be;*

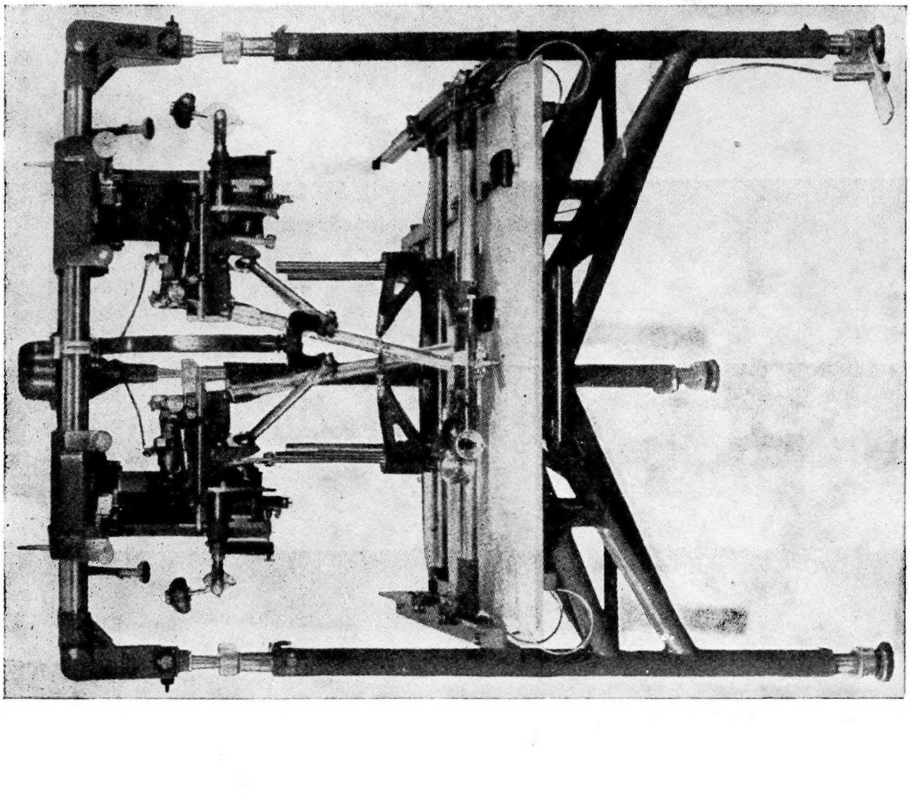
Or : *Two mirror (Specula) System :* the emergent beam is deviated at an angle double that formed by the two mirrors.



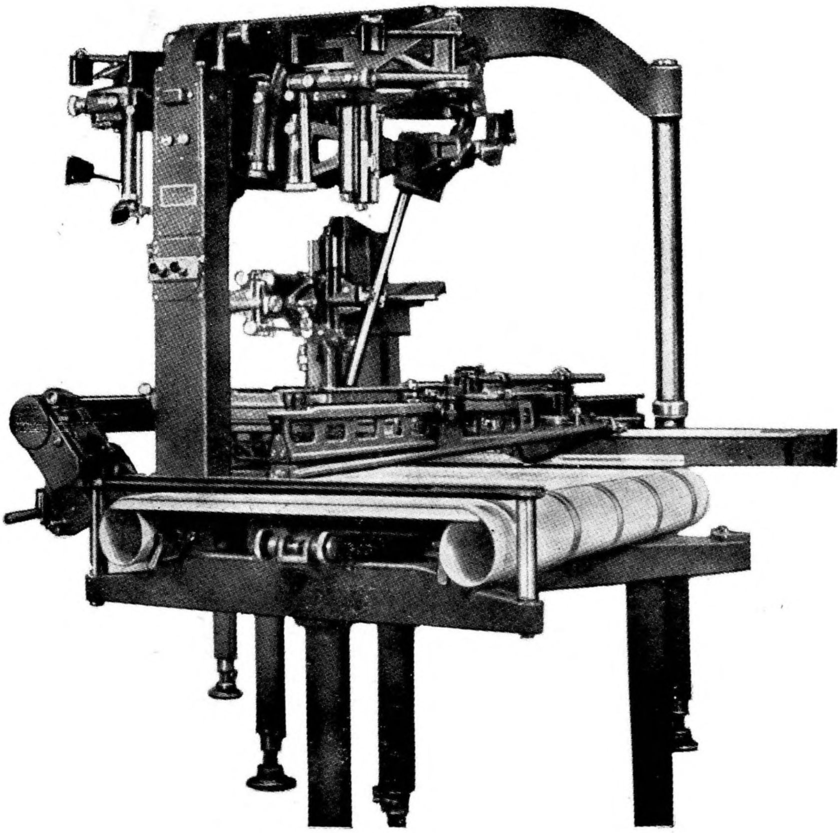
(22) (24)



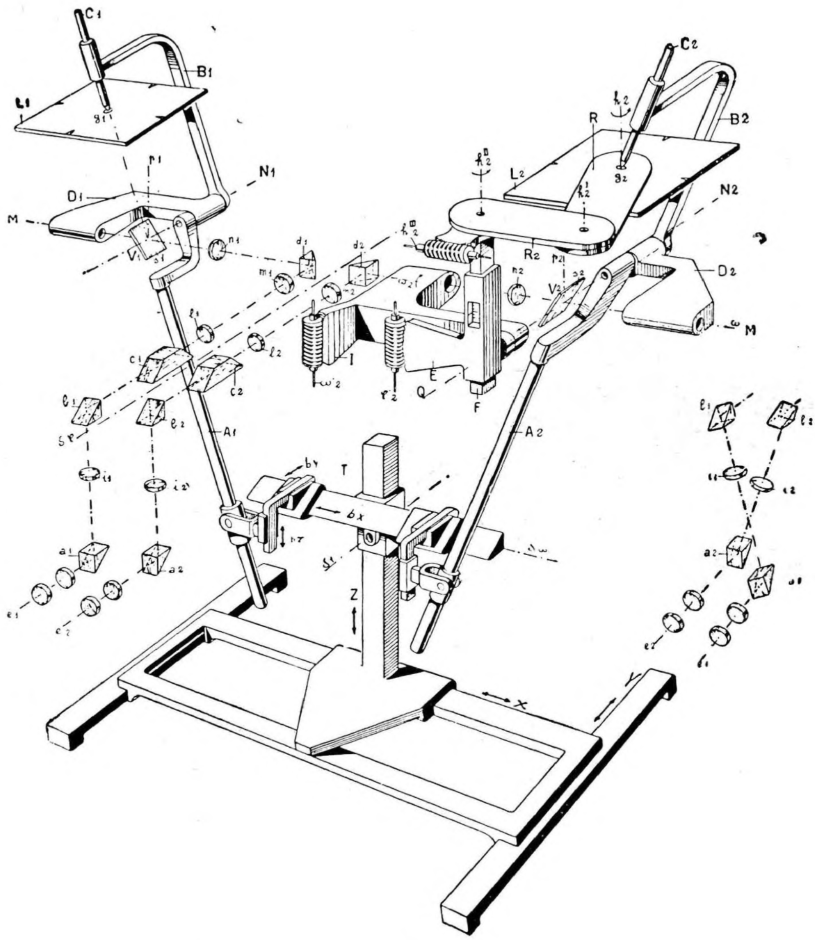
Santoni Autoreductor



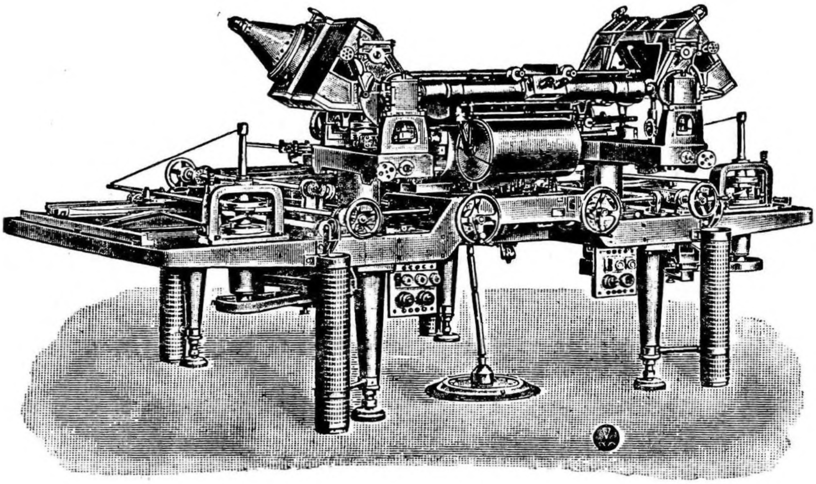
Santoni Stereosimplex, Model II



Santoni Stereocartograph, Model IV



Santoni Stereocartograph, Model IV (diagram)



Heyde-Hugershoff Autocartograph

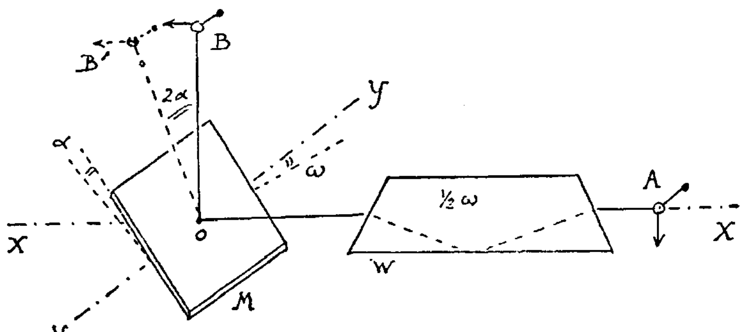
23. *Separator Prism :* Central prism in monostatic coincidence range-finders operating the selection of the beams towards the eye-piece.

24. *Govi Prism :* includes two isosceles rectangular prisms with the hypotenuse faces cemented together so as to constitute a cube, one of the faces in contact having been previously covered by a semi-transparent layer of gold or silver; this produces a sufficient reflection while allowing the direct rays to pass through; used in view-finding collimators it provides lateral viewing as in reflecting telescopes.

    This contrivance is employed for another purpose in bi-refracting prisms to serve as micrometer by duplication of the image.

25. *Dove Prism :* See : 15, Crova Prism.

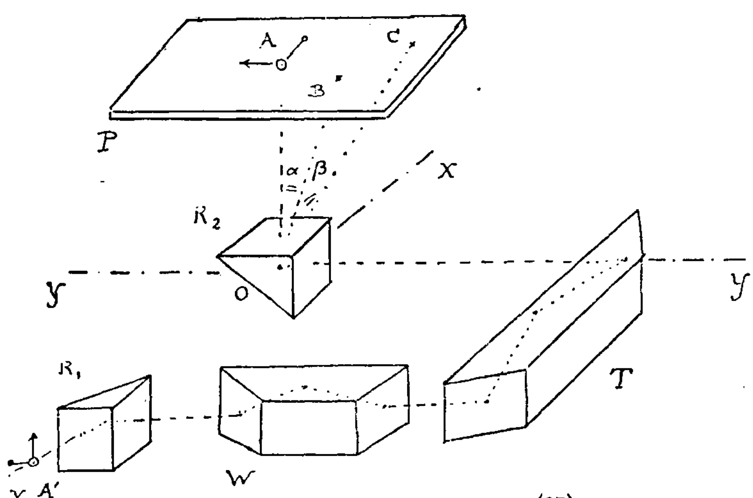
26. *Optical Cardan Joint with Mirror :* is composed of a Wollaston prism in conjunction with a mirror M. The latter can be rotated about two axes XX and YY rectangular at O where they form a mechanical cardan joint. Let α be the



(26)

angle of rotation of the mirror about YY and ω its angle of rotation about XX. The Wollaston prism is mounted by gearing in such a way as to pivot in the opposite direction by $1/2\ \omega$ about XX; this rectifies the relative incidence of the beam on the mirror after a ω rotation of the latter.

27. *Prismatic Optical Cardan Joint :* The prismatic optical cardan joint is composed of 2 right-angle prisms R_1 and R_2, of a trapeze prism T, and of a Wollaston prism W assembled as indicated by the adjoining figure. The R_1 and T prisms are fixed in a mounting which can be rotated about XX (angle α). The R_2 prism is fixed on a cylindrical collar which can itself rotate about the axis yy in the same mounting (angle β).



(27)

The instrument is combined with a drawing-table, similar to that of Model A2, which serves as a co-ordinatograph. The surface of this table is formed by a 100 x 100 cm. plate of ground glass, including graduations for the displacement of the carriage in x and y, declutching keys facilitating adjustment, and the use of the table as a co-ordinatograph, with a device for raising the tracing pencil, operated by a pedal-wheel, sighting microscope and rotating table-top.

1938 — WILD A.6 Stereoplotting Machine : a simplified instrument for the restitution of tilted photographs; size 24 x 24 cm.; f = 98 to 278 mm. (See : *Hydrogr. Review,* Vol. XIII, 1946, p. 124).

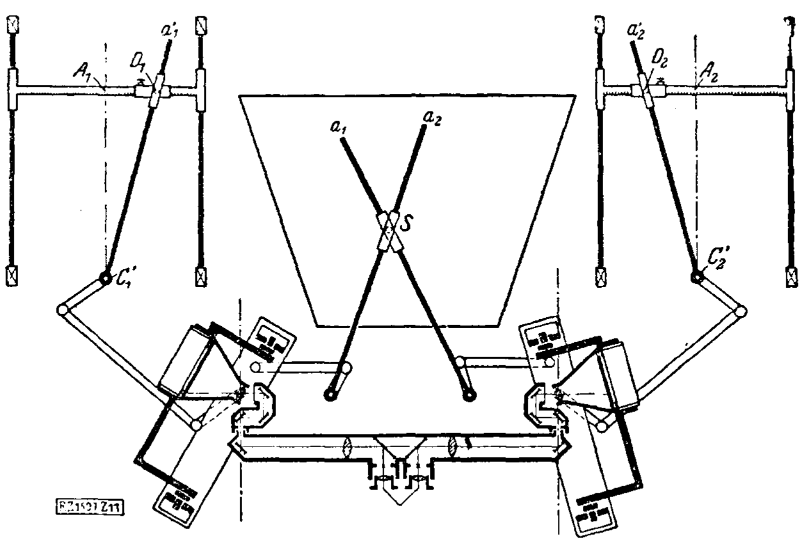
— WILD *A-7 Precision Autograph* for stereoscopic plotting of aerial and terrestrial pictures at any scale, and for aerotriangulation. Accomodates all picture sizes up to 23×23 cm. (9×9 inch). Focal length adjustable from 98 to 217 mm. Accurate mechanical plotting and orthogonal observation of pictures.

The A-7 plots pictures taken with any aerial camera and with phototheodolites without changing lenses, plotting cameras or picture carriers. — Optical compensation of distorsion, direct height readings in meters or feet, precision gears for 12 different conversion factors between autograph and drawing table with fast motions for orientation.

— WILD *A-8 Stereo Plotter* for plotting vertical photograph of pictures up to 9×9 inch and with focal lengths f = 98 to 217 mm. The measuring mark is guided in the stereo model with X and Y handles. The transmission from autograph to drawing table permits an enlargement of 4 ×.

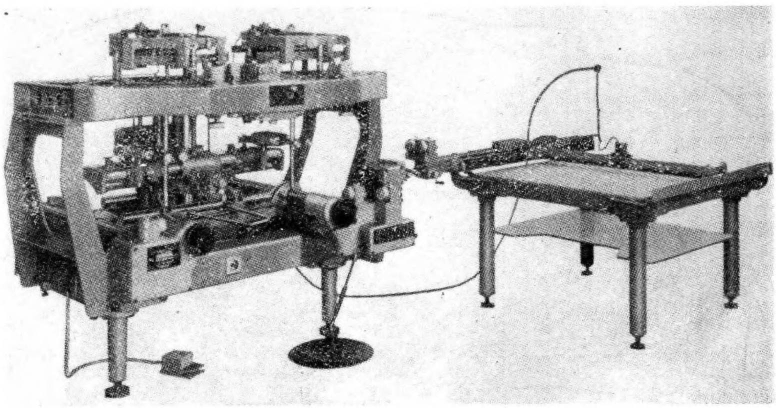
II. — Optical and Mechanical Restitution Instruments

1919 — HUGERSHOFF-HEYDE (Dresden) Autocartograph, constructed by Gustave Heyde on the principle of the Porro-Koppe (1896) photogoniometer improved by Pulfrich (Grisel (1911) Photogoniometric plane-table) for the restitution of panoramic views of 30° tilt.

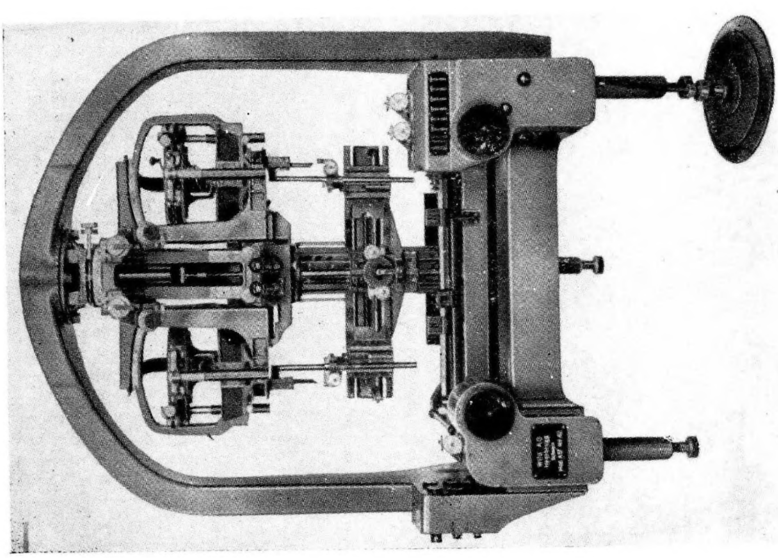


Heyde-Hugershoff Autocartograph (diagram)

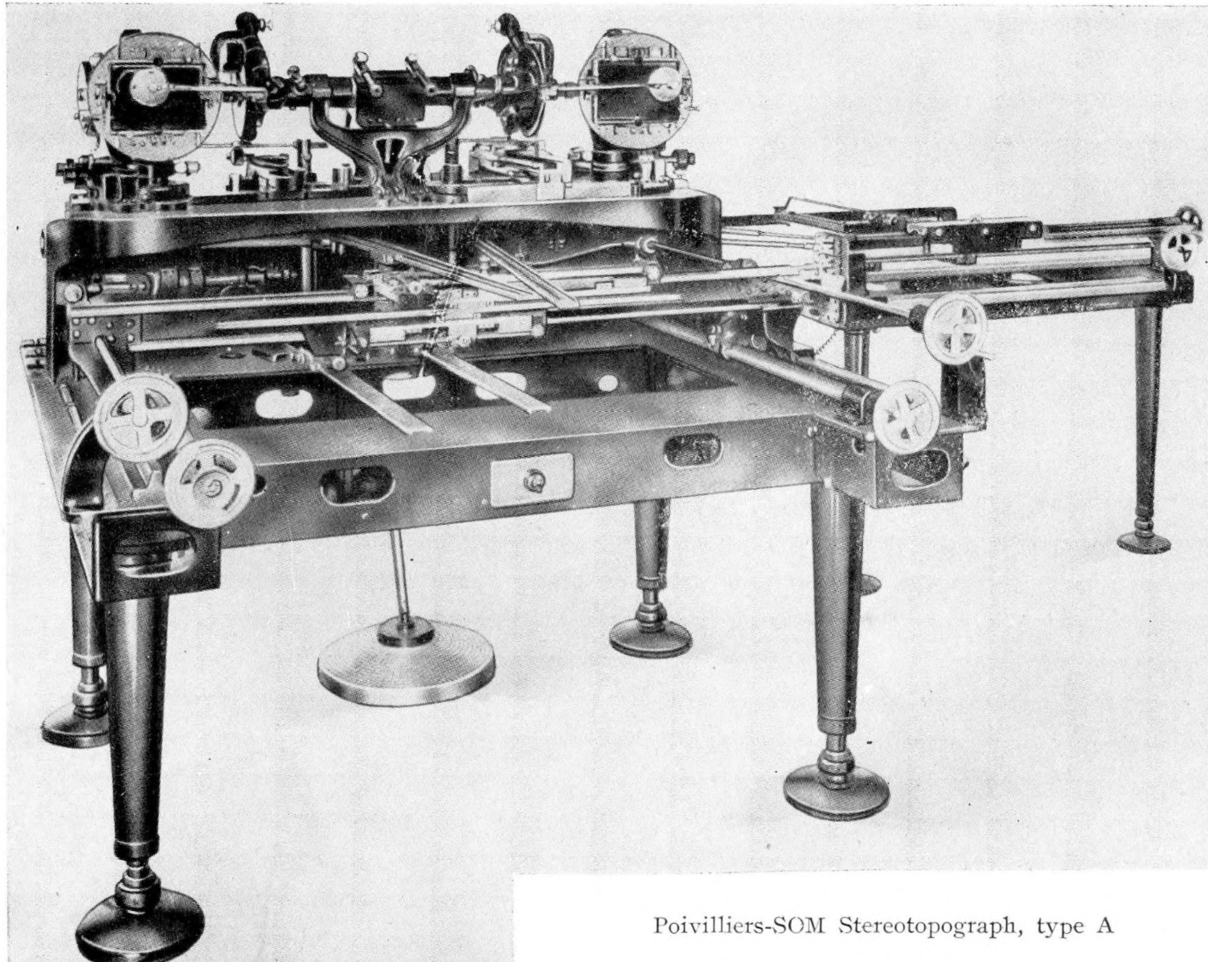
By sighting in the apparatus, two rulers intersecting at the desired point can be guided.



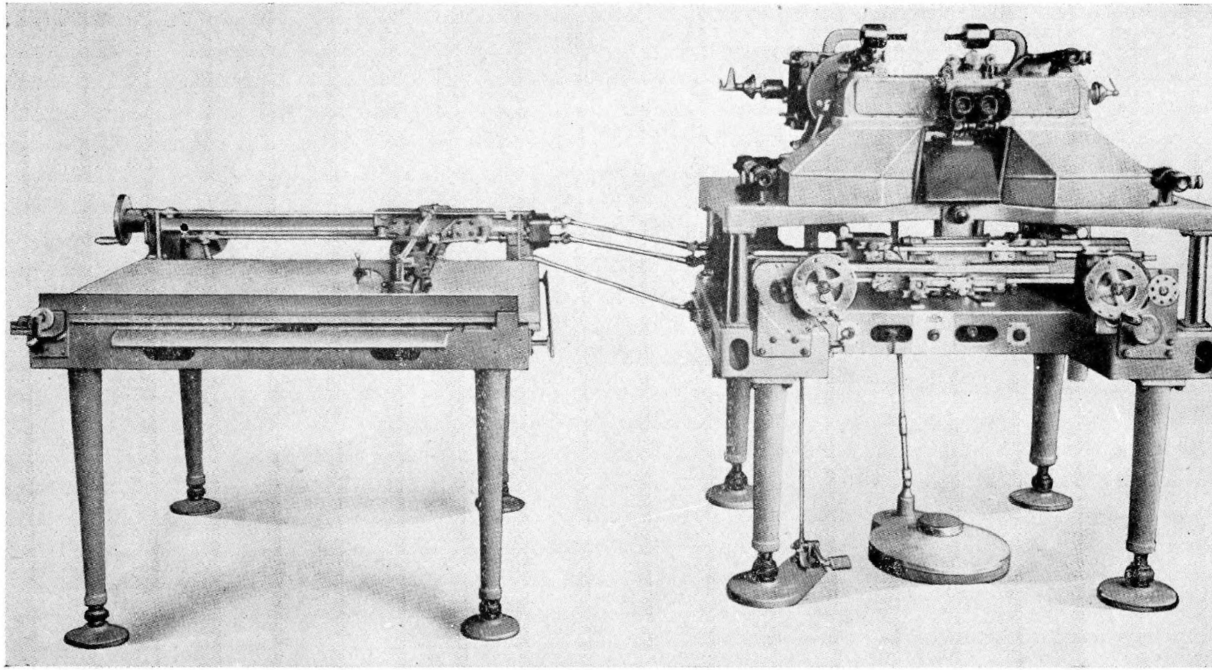
Wild A.7 Precision Autograph



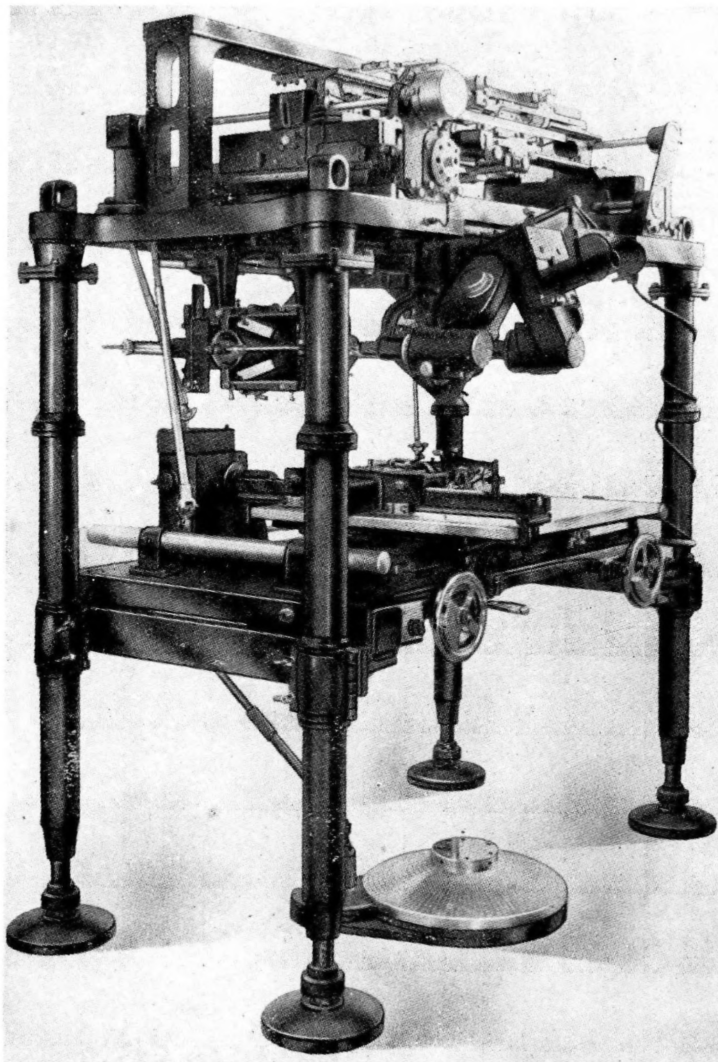
Wild A.5 Autograph



Poivilliers-SOM Stereotopograph, type A

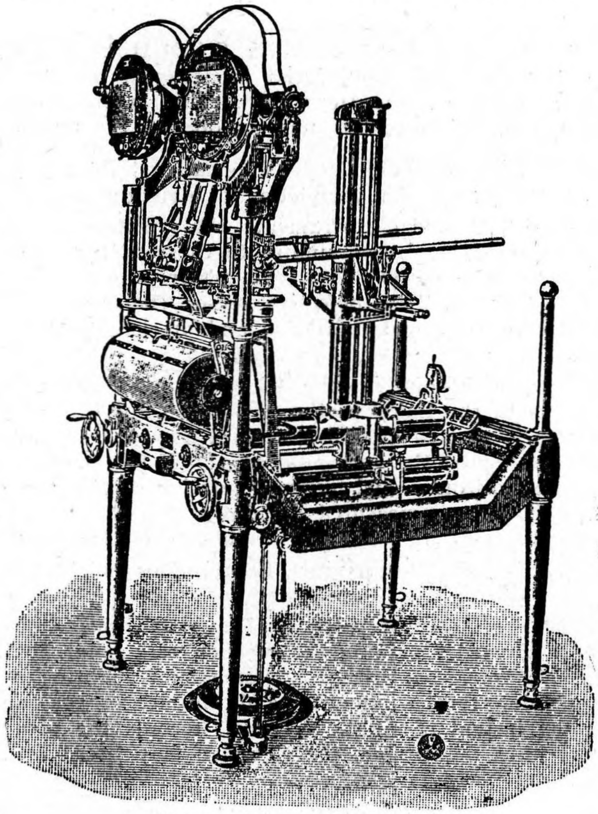


Poivilliers-SOM Stereotopograph, type B

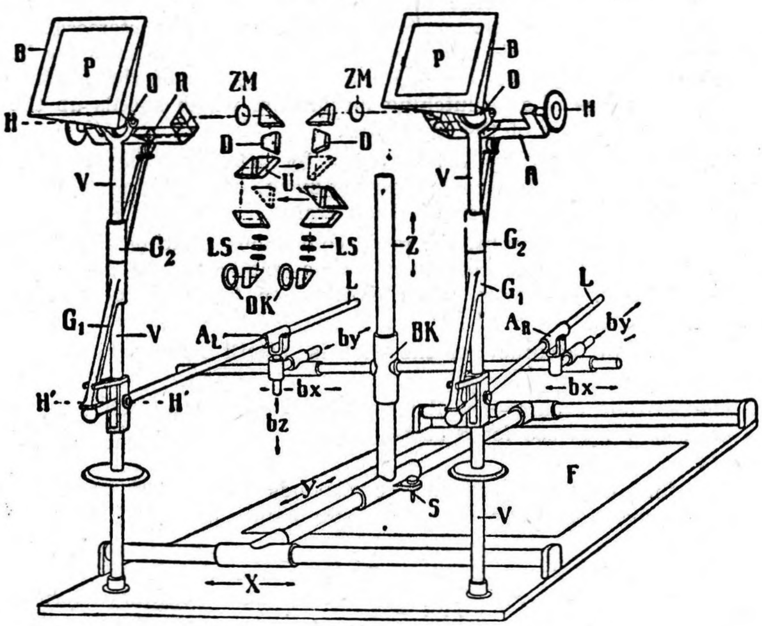


Poivilliers-SOM Stereotopograph, type C.

1926 — HUGERSHOFF Aerocartograph (Gustav Heyde, Dresden — also **manufactured** by the Zeiss-Aerotopograph G.m.b.H., Jena), with an additional and **cylindrical** drawing-board, placed in front of the operator.



Hugershoff Aerocartograph



Hugershoff Aerocartograph (diagram)

1927 — DEVILLE Plotter : (See : *Hydrogr. Review*, Vol. XII, n° 2, Nov. 1935, p. 129)

1919 — POIVILLIERS Stereotopograph, formerly Model Type A, designed in 1923-1927; sighting guides driving 2 intersecting rulers. (*Service Géographique de l'Armée,* Paris.)

Model B (1936) manufactured by the S.O.M.H.P. (Société d'Optique et Mécanique de Haute Précision, Paris) is designed on the same principle as the Hugershoff apparatus (1917-1919). This is the most accurate and modern apparatus. It takes two men to operate the machine.

— POIVILLIERS S.O.M. equipment, Model C, smaller, lighter and easy to move; for middle scale surveys for completion of existing maps.

In the Type A, B and C instruments, the 2 plates are inserted in cameras fitted with objective lenses similar to those of the photographic apparatus. A binocular telescope fitted with a stereoscopic index mark is used for observing through these objective lenses (Porro-Koppe system). This permits highly accurate materialization and precise location of the perspective beams.

The viewing of a point is achieved by bringing this point into stereoscopic contact with the index of the telescope. For this purpose, each one of the cameras is pivoted around a vertical axis and the corresponding rod of the telescope around the horizontal axis. If the cameras have been correctly set, the horizontal and vertical rotation angles are equal to those which might have been measured by means of a theodolite by an operator stationed at the point from which the photograph has been taken.

In the Type A and B apparatus, these angles can be measured on divided circles.

A system consisting of rulers and carriages materializes the graphic plane constructions determining the position of a point by the intersection method and is connected with the stereoscopic sighting system. It also directly provides the planimetric and altimetric position of the point viewed at the instant of sight. A pencil records the planimetric position of the point on a plane-table, the elevation being read on a divided scale or on a counter.

Two cranks govern the displacement of the stereoscopic index-mark along two perpendicular horizontal directions of the image of the relief of the terrain; a pedal governs the vertical displacement; these enable any point to be viewed and the continuous shifting of the stereoscopic index, for instance along the axis of a road. The plotter then records the horizontal projection at the required scale. Rapid examination of the photographs is achieved by means of a declutching mechanism which speeds up the adjustment and positioning of the apparatus.

The contour lines are « followed » by actuating the cranks only, in order to shift the stereoscopic floating-mark, maintaining it in apparent contact with the relief image of the terrain.

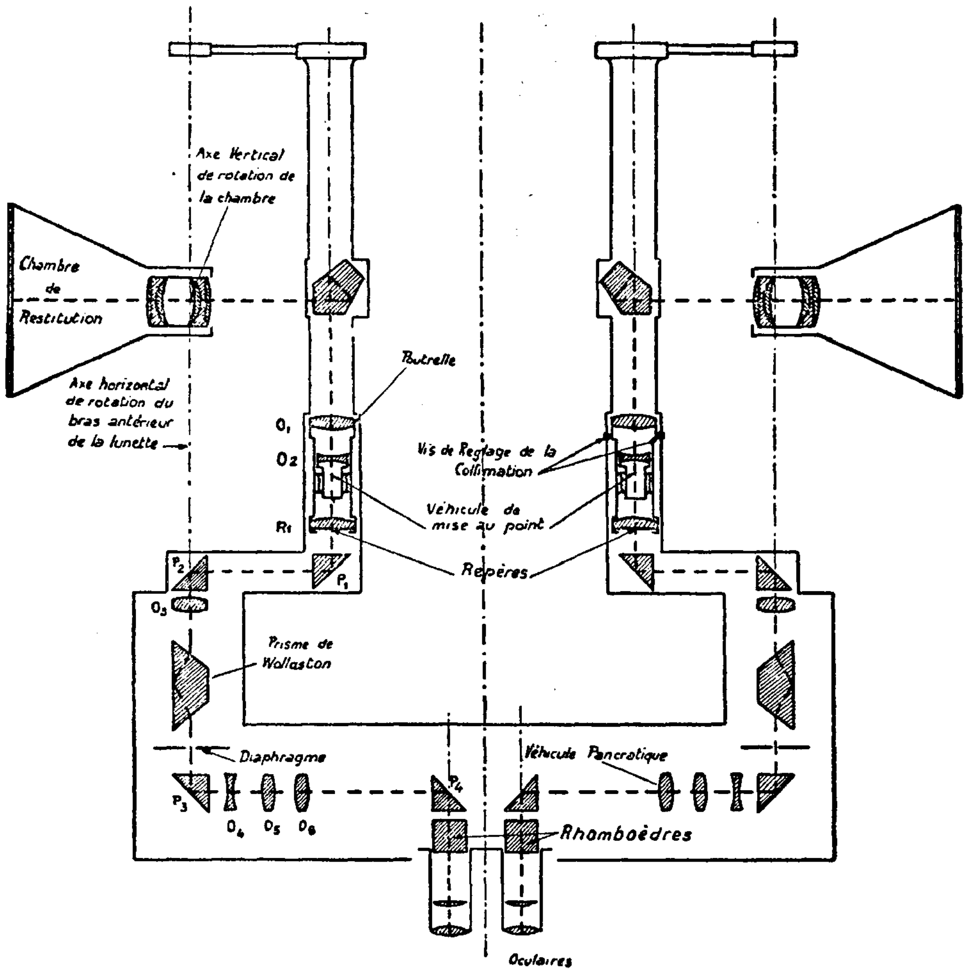
In the stereotopographs, the rapid continuous plotting of the planimetry and of the contour lines corresponds to a rate of speed on the terrain of 200 to 300 kms. per hour, when plotting on the scale of 1 : 20.000, for instance.

The graphic accuracy of the plot is 1/10th mm., whatever the scale used.

The altitude accuracy of the contour lines, using good photographs at the scale of 1 : 25 000 for a survey at 1 : 20 000, is distinctly higher than 1 metre.

The final degree of accuracy corresponds to 1/100 th mm. with respect to the relative position of corresponding points of the photographs in the apparatus.

The stereotopograph permits not only the restitution of photographs taken in the most varied positions, but also permits determination of these positions with very high accuracy in a very short time, with personnel rapidly trained.



Poivilliers-SOM Stereotopograph (diagram)

The apparatus is based on the materialization of plane graphical constructions.

Instead of materialization of sighting lines, the projections of the latter are materialized by means of rulers pivoting around fixed vertical axes of great stability. The motions of the rulers take place in a horizontal plane; the guiding surfaces are vertical. The parts are very light and influence of warping has been eliminated.

Recoil is corrected by means of spring fulcrums; no sliding friction occurs, the axis being mounted on ball bearings. The guiding rods are made of stainless steel; no greasing is necessary, which eliminates the action of dirt.

Stereoscopic viewing of the photographs by means of binocular telescope enables :

— Sighting a point of the terrain difficult to identify from each separate photograph (such as a tree in a forest, any point of a field, etc.);

— Perception of all details of the shape of the relief (thalwegs, hillocks, etc.) and consequently none of them to be passed over;

— Working in well-lighted draughting-rooms;

— Greatly magnified measurements to be made.

The adjustable focussing optical system adopted automatically effects equalization of the apparent diameters of the two images.

A special fully automatic arrangement adequately orients the images in the field of the eye-pieces to effect correct stereoscopic fusion, whatever the tilt of the sighting lines.

— The *B-Type* machine is fitted with devices ensuring automatic orientation of the images in the field of the eye-pieces and automatic variation of the magnification. This arrangement considerably facilitates the utilization of photographs taken with a wide-angle camera, and also permits utilization of large bases.

Ease of angular setting of the cameras has been increased.

By increasing the length of travel of certain parts, the introduction of larger positive and negative bases has been made possible, an indispensable requirement in aerial photogrammetric traverse.

A co-ordinatograph is used concurrently with the apparatus, consisting of a table with a recording pencil carried by two perpendicular carriages, the travel of which is actuated by a system of screws and nuts; they may be linked together with the carriages or the bridge of the Stereotopograph in variously amplified or reduced ratios of motion.

The plotting mechanism control is so arranged that the ratio between speed of plotting and the rotation speed of the crank remains constant, whatever the ratio of the restitution and plotting scales.

1948 — Som Poivilliers Stereotopograph Model D (simplified), for small-scale operations with two rods representing the perspective beams, requires only one operator; designed for rapid execution of work with air photographs of less than 10 grade horizontal tilt, the exposure base being itself of less than 10 grade tilt on the horizontal plane. Photographs taken with focal lengths between 120 and 300 mm. and sizes up to 24 × 24 cm. can be examined stereoscopically. (See : *Hydrogr. Review*, Vol. XXVI, n° 2, Nov. 1949, p. 162).

The perspective beams are materialized by two sliding rods; each of them rotates around a fixed point which acts as the node of the lens; distortion of the object-glass is corrected by means of a special part with cylindrical cam. Orientation of the images in the microscope is adjusted by operating a knob which acts on a Wollaston prism.

The formation of the plastic image necessitates occasional re-centring of the photographs, but disengaging the co-ordinatograph associated with the apparatus allows easy passage from one point of the pair to another.

The Type-D instrument can be equipped with a *co-ordinatograph,* as Type B.

— Wild (Henri) Autograph, (Model A2) : Universal apparatus for the stereoscopic restitution of terrestrial or aerial, negative or positive photographs; size 10 × 15 cm. and 13 × 13 cm. It includes 2 restitution cameras f = 165 mm., combined with glass-topped drawing-board which can be used as a co-ordinatograph 100 × 100 cm. with declutchable carriage and counter of x and y co-ordinates, with two Gauthier nets.

1937 — Photorestitutore I.R.T.A. (Istituto Rilievi Terrestri ed Aeri), Zurlinden, Milano (similar to preceding).

1934 — Zeiss Small Short-Distance Autograph with mechanical projection of images, resembling the von Orel Stereoautograph with fixed stereocomparator and two movable rods, not in a plane but in space; restitution with tilted plates is possible; size 6 1/2 × 9 cm.; new (1945) model.

1935 — Santoni Stereo Simplex or Santoni Stereocartograph, Simplex Model, Galileo, Florence : Universal terrestrial or aerial plotting machine, based on principles of Deville (1902) and Pulfrich (1903) instruments. This apparatus is transportable without being dismounted. It is fitted with a special system of convergence prisms. Suitable for small-scale restitution of photograms.

1939 — Santoni Stereo Simplex, Model II.

III. — Restitution Instruments based on System of Optical Projection of Metrophotographic Theodolite (i.e. on Porro-Koppe System, properly so-called)

1902 — E. DEVILLE (Ottawa) Stereoplanigraph, using Wheatstone Mirror Stereoscope. (See : *Hydrogr. Review,* Vol. XII, n° 2, Nov. 1935, p. 129).

1903 — C. PULFRICH Stereocomparator.

— SANTONI Stereoscopic « Puntinatore ».

1915 — GASSER Doppelprojektor (or Plastic Double Projection Camera) designed 1915-1921, adopting the ideas concerning double projection expressed in 1898 by Theodore Scheimpflug (Skioptikons). Setting of the projection apparatus is made on three small discs placed horizontally and carried on movable elevation keys representing control points (See : *Hydrogr. Review,* Vol. VII, n° 2, Nov. 1930, p. 184).

1922 — PRÉDHUMEAU Stereotopometer : Universal apparatus, a model of which (1926) was constructed by the firm of Secrétan for the *Service Géographique de l'Armée, Paris.*

1921 — BOYKOV (Lieut.-Commander) Triangulator, constructed by firm of Goerz.

— MILLER (O.M.) (of Mann Instrument Co) Restitutor : monocular, mirror, sight-vane apparatus. (See : *Hydrogr. Review,* Vol. XV, n° 2, Nov. 1938, p. 158).

— BROCK-WEYMOUTH Restitutor, Philadelphia (U.S.A.).

— ZEISS Stereoplast.

1922 — UMBERTO and A. NISTRI BROS Photocartograph. Constructed 1918-1922 by O.M.I. (Ottica Mecanica Italiana), Rome, on same principle as Gasser Double-Projector. Optical setting of the apparatus is made on four small control discs (keys), adjustable for height following the Pulfrich (1904) system. Locating and plotting the various points in space are carried out on the surface of a small movable key whose motion is connected with the apparatus measuring the co-ordinates and with the drawing pencil.

A second model was designed in 1925, and another in 1927 for plates of size 13 × 18 cm. (See : *Hydrogr. Review,* Vol. XV, n° 1, May 1938, p. 106).

1935 — NISTRI Photostereograph (Fotostereografo) or Nistri Stereographometer (O.M.I., Rome), size 18 × 24 cm.

— ZEISS-BAUERSFELD Stereoplanigraph, entirely optical :

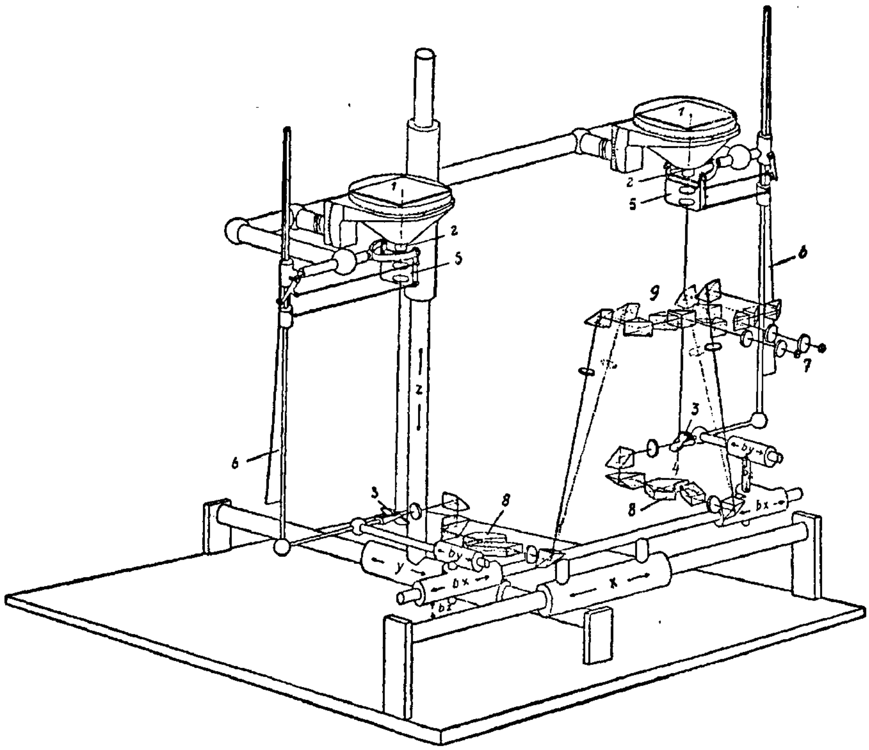
Type C/1 — 1920
Type C/2 — 1923
Type C/3 — 1925
Type C/4 — 1930.

1938 — ZEISS Stereoplanigraph : Model C/5.

1940 — ZEISS Stereoplanigraph C/7.

While the Hugershoff Autocartograph (1920-21) is based on the principle of the Porro-Koppe Photogoniometer, the Bauersfeld-Zeiss Stereoplanigraph, like the Multiplex Restitutors, owes much to the Scheimpflug idea of double projection of two images, giving, by the intersection in space of the homologous beams, a sort of spatial optical relief model of the terrain. Applied by Gasser in 1915, green and red light, or alternative flashes on a small horizontal vertically movable disc, are used in this double projection as in the Nistri Photocartograph (1918).

In 1924, Professor Dr. von Gruber had recommended the simultaneous orientation of the two cameras of the apparatus (Autograph or Stereoplanigraph) on the three control points (optical-mechanical solution of resection in space) located at the four corners of the plate, thus effecting a sort of interpolation within the polygon of the control points.



Zeiss Stereoplanigraph C/7

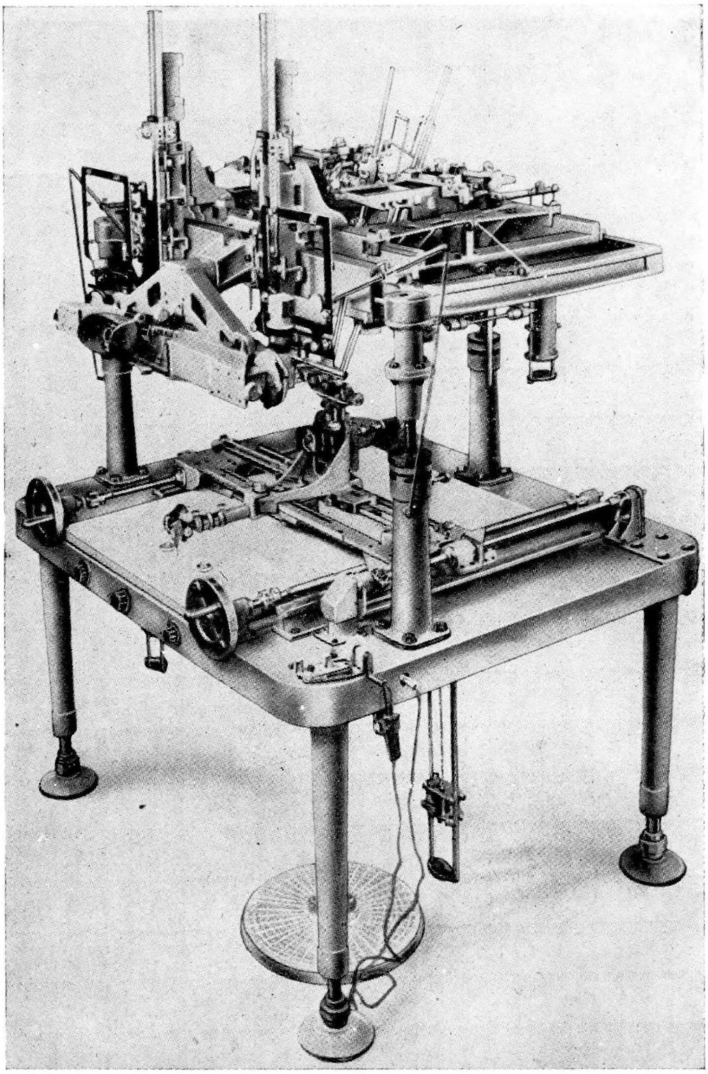
Once the external setting accomplished, the photographs are viewed with a binocular-stereoscope, of rather complicated construction (depending on the apparatus), so as to maintain the eye-pieces in a fixed position during examination of the various points on the plate.

While not stereoscopic viewing in its proper sense, image superposition is used in these double projection instruments, and image coincidence is accomplished by « *blinking* » as in the Zeiss stereocomparator with Pulfrich « blinkmicroscope » or, again, through *anaglyphic effect*.

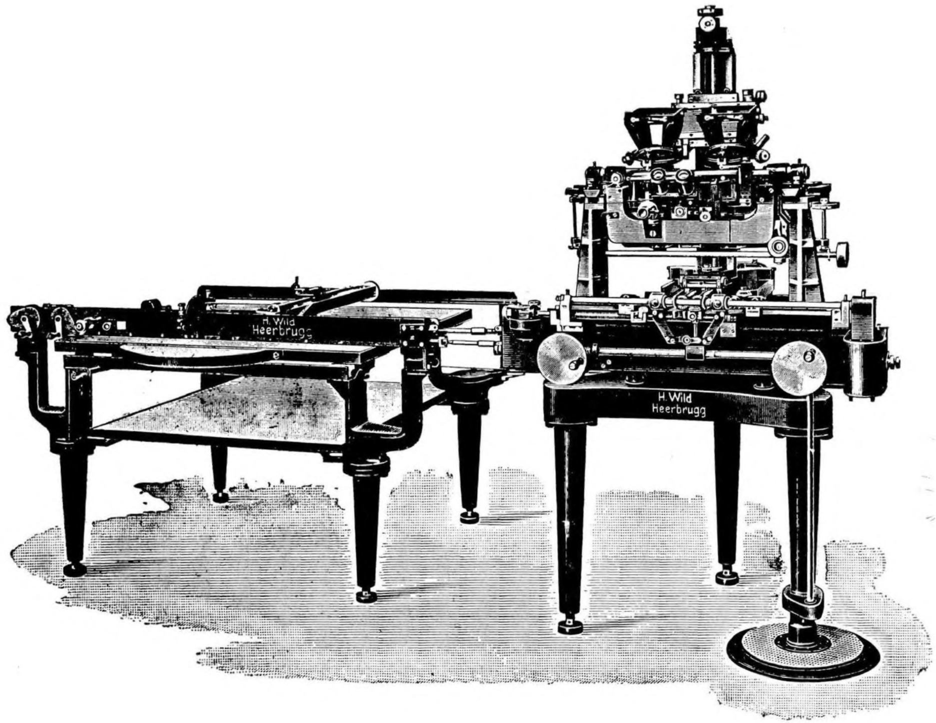
In the Zeiss Stereoplanigraph, full size diapositives obtained by contact of the aerial film on 5 mm. glass diapositive plates are used; the plates are lighted by small electric lamps which move automatically behind the part to be examined. They are projected by a lens identical to the photographic lens to correct distortion (Porro principle). The beams are paralell as they emerge from the objective and are automatically projected towards the focus by a lens of the pancratic system (the section of a cam provokes the rotation of the tubular mounting governing the movement of the convergent glass of the system). This focalization is effected at the viewing point constituted by the centre of a steel mirror marked by a black dot which is examined through the intermediary of a rather complicated optical system which leads the two images towards the two eye-pieces. In this way the instrument serves as a stereoscope, in full daylight, with + 5 magnifying power, and the images obtained are of great brilliance owing to the use of the mirror instead of a simple diffusion screen.

The mirrors are moved in relation to the diapositives by means of handwheels, the movements of which are mechanically transmitted to a separate drawing-table called a « co-ordinatograph ».

The Zeiss Stereoplanigraph, Model C/7 (1940) is a universal precision instrument for cartography and triangulation. It is applicable to all sizes up to 9" x 9" and to any photograph taken with any sort of topographical



Poivilliers-SOM Stereotopograph, type D.



Wild Model A2 Autograph with drawing table survey camera of any focal length. It corrects the distortion of the Topogon photographic lens. It is constructed by Zeiss-Aerotopograph, Munich, Germany (U.S. Zone).

The two projectors are clamped at fixed distances. The scale of the spatial model results from the projection distance, which can be varied considerably. A foot-wheel drives the floating dot upwards by raising the projector assemblage in relation to the mirrors. The righthand flywheel which also acts on the 2-projector assemblage, makes the floating index advance or recede. The lefthand wheel, which acts on the mirror parts and on the floating dots, displaces the dot towards the right or left. The horizontal movement of the dot is mechanically transmitted to the co-ordinatograph and a system of gearings makes the ratio of the drawing scale vary by 1 : 10 to 5 : 1 in relation to the scale of the photograph.

The Stereoplanigraph carries a system of prism - scamping by means of a knob to transpose the tracks of the luminous beams travelling towards the left and the right eye-pieces. By means of this pseudoscopic transposition, the successive views taken during the flight can be « bridged » in the stereoscope without having to rotate the apparatus through 180° in order to pass from one spatial pair to the following. It is possible to « bridge » or « extrapolate » the control by replacing the first by the third diapositive of a series while inverting the optical system by acting on the single knob and repeating the orientation simply by acting on the projector containing the third photograph and so on.

An accuracy at least three times greater than that of the Multiplex system is attributed to the instrument under discussion.

By means of the *co-ordinatograph*, i.e. the drawing-table in combination with these machines, the co-ordinates of all the plotted points can be determined in numerical sequence. Read from the autograph, they are recorded in a special file, with those of the trigonometrical and control points.

Original cadastral plans are compiled through use of the co-ordinatograph, on 70 x 100 cm. aluminium plotting sheets.

The U.S. Army Map Service, Washington, uses the Zeiss co-ordinatograph.

— ZEISS *Stereoplanigraph Model C/8* of the Zeiss-Aerotopograph G.m.b.h. — München (1951), prints à *Table of Coordinates* free from reading an transcribing errors. Registers on the *Printing Counter* the values of x and y in millimeters at the machine scale, for z in meters of feet above sea level.

Large, indirectly illuminated *Indicator Dials* permit easy and convenient reading of all elements of orientation by the operator. Direct charting on the co-ordinatograph at 22 different scale ratios without conversion of the metric coordinates.

The Aerocartograph (1926) is simpler than the Stereoplanigraph and of smaller dimensions.

It contains the Hugershoff device for stereoscopic inversion and in this way the first plate in the instrument can be replaced by the third without the second having to be removed. This arrangement is also adopted in the 1930 model of the Stereoautograph.

The Barr & Stroud Photogrammetric Plotter, know as « Big Bertha »; is a universal instrument of similar type. (See : *Hydrogr. Review*, Vol. VII, n° 1, May 1930, p. 103-105).

In this universal apparatus, as well as the 1919 Autocartograph or the 1926 Aerocartograph, a pair of photogoniometers equipped with movable telescope of the Porro-Koppe type are also used.

1928 — HUGERSHOFF Aerosimplex (G. Heyde, Dresden) : a double-projection stereoscopic instrument operating, however, with separate plates.

A model of this apparatus has also been constructed by the Zeiss Aerotopograph G.m.b.H., Iena.

1928 — FERBER-GALLUS Double Projection Cartograph or Aerotopograph, constructed by the firm of Gallus, Paris; similar to the previously mentioned Nistri Photocartograph, but without the eight optical positioning discs (keys). Instead, a Bauersfeld patent of the lens system (used in the Zeiss stereoplanigraph) is used which maintains the images in focus at various distances.

— KELSH Plotter : (Harry T. Kelsh; manufacturers : Instrument Corporation, Baltimore) & Kelsh Wide-Angle Plotter. This instrument does not require any expensive rectifier or the use of diapositives of reduced size. It consists of two projectors creating a spatial anaglyphic model on the movable top of a drawing-table which is covered with a 46" × 48" sheet of aluminium. The instrument uses diapositive plates or films. True dimensions : 9" × 9".

— *Multiplex Projectors* : In the Multiplex process, more than one pair of projectors is used at a time. Aerial negatives are reduced to small diapositives so that they may be introduced into the successive projectors. Using numerous projectors, the topographic controls established at certain known ground-points can be extended or « bridged ». The apparatus renders possible reconstruction of the relation in space between each other of the various topographic details and the quick and accurate conversion of these into level contours.

In the Multiplex, the projectors are mounted on a bar and placed at about 40 cm. above a table. The projectors can be moved in every direction to adjust the various tilts and swings and differences of flight altitudes.

Also in this instrument : two overlapping photographs are projected in a camera obscura; the beams of the image intersect, forming in space the visual reduced plastic model of the terrain above the table. Using a tracing stand the elevation of each point of the model can be measured and projected orthogonally on the plotting sheet of the chart.

Stereoscopic viewing is accomplished by anaglyphs : in each alternate projector, green and red filters are placed and the operator wears glasses having one eye-piece green, the other red, so that each eye sees only the image of a single projector.

The special printer for diapositives reduces the photograms to suit the focal length of the Multiplex (30 cm.) and adjusts for the objective lens distorsion.

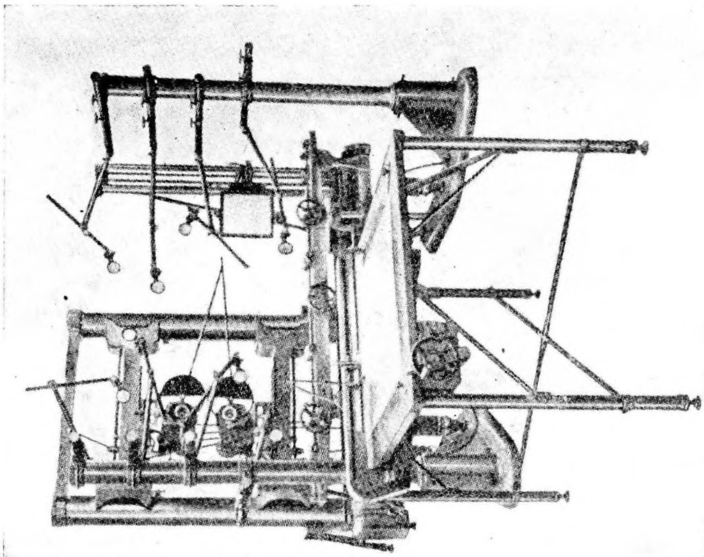
The two first projectors having been set, the third is orientated on the second so that the scale of the model formed by the 2nd and 3rd projectors may be equal to that of the first model; overlap points common to the two models must for that purpose have the same positions and the same elevations. In the same way the 4th, 5th, etc. projectors are added.

The « horizontality » of the model is adjusted in relation to the drawing-table by acting on the bar carrying the projector group. The distance separating the projectors on the bar controls the scale.

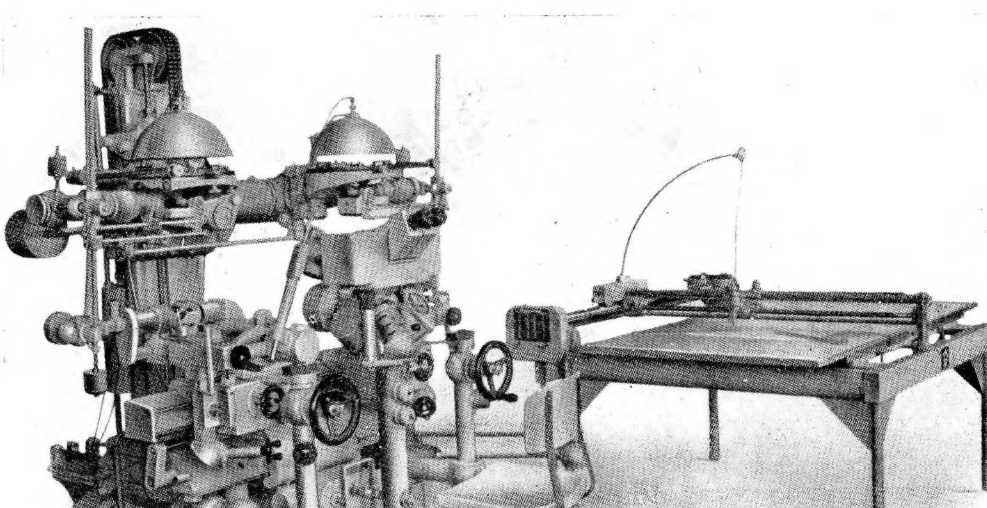
If horizontal control points can be made available in the first and last model, a « horizontal bridging » has been obtained.

If horizontal control points exist in the first model only, extension of horizontal control has been operated. In current operations, up to 7 and 10 projectors or even more may be used.

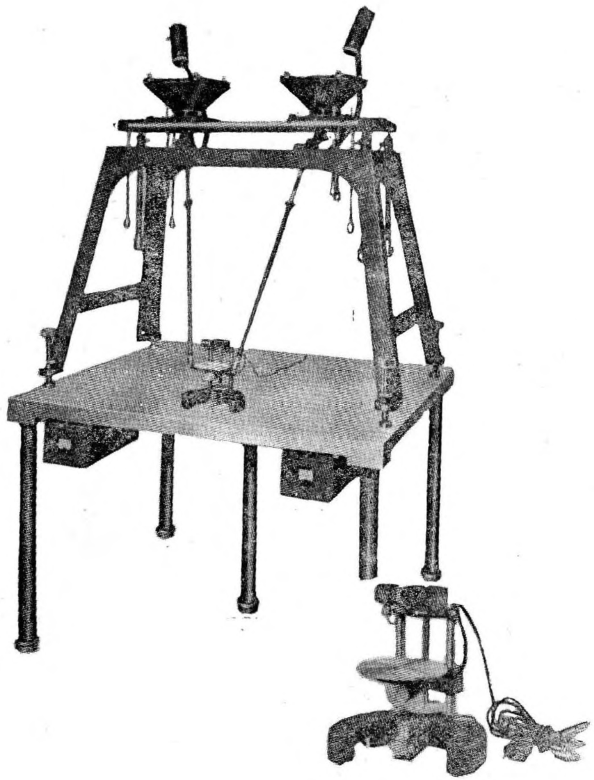
The stereoscopic image of the consecutive points is formed on a white disc pierced in the centre; the hole thus formed is rendered luminous by an electric lamp placed below it, and this luminous spot appears as if it were part of the stereoscopic model. The height of the disc which can be raised or lowered on its stand by means of a micrometric screw reads to 0.01 mm.; the pencil point marks orthogonally just below the luminous point. With a minimum of friction due to three agate balls, the disc mounting slides over the plotting sheet, and the draughtsman follows the details of the terrain with the luminous spot. To draw a level contour line it suffices to fix the support of the disc at the desired elevation. Only two projectors at a time are lighted. The operator can separate contours differing



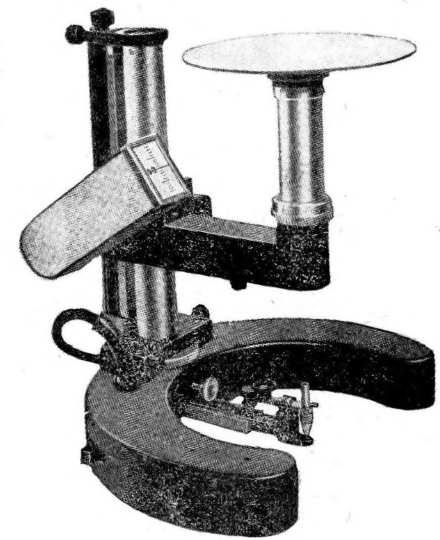
Fotocartografo Nistri



Zeiss Model C/5 Stereoplanigraph, with drawing table



The Kelsh Plotter



Multiplex Tracing Table

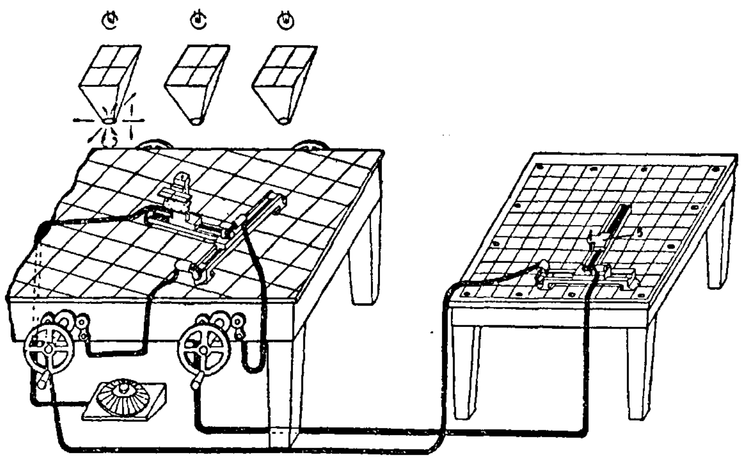
by 0.7 mm. and estimate differences of elevation of 0.15 mm. on the perspective relief model.

— ZEISS *Multiplex Aeroprojector* (Multiplex machine) : for charting from serial photographs. Each of the projectors in the system is set according to the line of flight and is orientated and adjusted with reference to 4 ground control points by means of the anaglyphic or blinking system.

6 —, 9 —, 12 —, etc., up to 21 — projector (Multiplo-Zeiss) models exist, using anaglyphs for spatial identification on the discs (keys).

— NISTRI *Photomultiplo* (O.M.I., Rome) is similar to the preceding; also operates either with the anaglyph or the blinking-light system; consisted of two or three projectors in 1934, then of six projectors; the new model (1940) includes twelve projectors fitted with O.M.I. Orthosix lens, focal length 55 mm., aperture 1 : 7, size 45 × 45 mm. There are 6 settings for each projector. The photograms are reduced by the Nistri Rectifying-Reductor. (See : *Hydrogr. Review*, Vol. XV, n° 1, May 1938, p. 106).

The apparatus can also be used in combination with a pantograph. The new model permits bridging of photograms.



Nistri Electro-coordinatograph

The NISTRI *Electric Co-ordinator* may be used with the Multiplex machine in replacement of the articulated parallelogram.

1948 — *Standard* WILLIAMSON-ROSS *O.S.C., SP3 Mapping Equipment : Multiplex Projector* associated with Williamson-Ross Multiplex Optical Reading Tracing Table. This unit is used for seven-row stereoscopic cartography for the topographic plotting of the drawing. Is used with an SP3 Reduction Printer which utilizes photographs taken with the Williamson 6" Wide Angle Camera.

The firm of WILLIAMSON also produces Williamson *Wide-Angle Multiplex Equipment*. Groups including up to 14 SP 3 projectors, focal length 26 mm. are obtained. The plotting of the map is done on an SP3 Tracing Table.

In the latest Williamson Tracing Table vernier indication has been eliminated in favour of optical reading ; a glass scale, divided at intervals of 0.1 millimeter with a precision of 0.001 mm. is magnified fifteen times, enabling 0.05 mm. to be easily scaled and approximations to 0.01 mm. The centering system of the pencil lead is sensitive and freedom of movement improved by four jewelled supports (fig).

— U.S. WAR DEPARTMENT *Multiplex Mapping Equipment.*

— BAUSCH & LOMB *Standard Large Multiplex Equipment.* The single bar instrument accomodates up to 9 projectors; the double-bar instrument accomodates up to 21 projectors for the mapping of vast areas requiring few ground controls.

The Bausch & Lomb Multiplex Reduction Printer makes a reduction print photographically on transparent glass diapositives which is a correct proportional reduction of the aerial negative for use in the Multiplex Projector and Tracing Table.

1947 — BAUSCH & LOMB 2 *Multiplex Projector Unit.*

— BAUSCH & LOMB *Oblique Wide-Angle Multiplex Projector.*

— BAUSCH & LOMB *Auxiliary Multiplex Projector Unit* : for plotting topography by means of diapositives of the photograms and based on ground control image. Consists of 2 (or 3) standard Multiplex Projectors, also an adjustable drawing table 92 × 92 cm. (3' × 3').

— In the BAUSCH & LOMB *Multiplex Aerial Stereo-Mapping Equipment* each projector is connected to the bars by means of a bracket with a horizontal pivot permitting three translation movements and three rotation movements; the latter provide a correct adjustment through a micrometric screw for transverse tilt or pivoting around the « y » axis, longitudinal tilt or pivoting around the « x » axis, i.e. the line of flight; and swing or pivoting around the « z » vertical axis. These six degrees of freedom, therefore, permit the reconstitution, by orienting the projectors, of the exact reproduction of the spatial position of the photographic camera : and the main advantage of the Multiplex is that this relative orientation of the plastic model is accomplished without necessity for recourse to any other data than record of the aspect of the terrain on a stereoscopic diapositive pair.

The movable disc on which the image is formed can be tilted up to 30° on the horizontal axis passing through the floating dot to fit with the relief shape of the terrain.

In the new Bausch & Lomb Universal Tracing Table direct reading of elevation is provided in easy-to-read numerals on four-digit counter and vertical measuring range is increased to 125 mm.

Sapphire lens "floating" mark are clearly visible from any viewing angle. Gear ratios are quickly changed; also metrical readings providing 5 to 6 scales within the depth of focus for any flight altitude from 1.000 to 10.000 meters.

Current for the projector system is supplied through a transformer and a voltage regulator, each of the projectors using a 20-volt 100-watt bulb. A ventilator blows filtered air into the condenser chamber of each projector in order to prevent over-heating. By means of a rheostat the intensity of light provided for each projector is adjusted to improve the stereoscopic appearance of each point of the terrain.

The drawing table on which the plotting is done is made of aluminium, and is usually 3' × 7' (90 × 210 cm.) in size.

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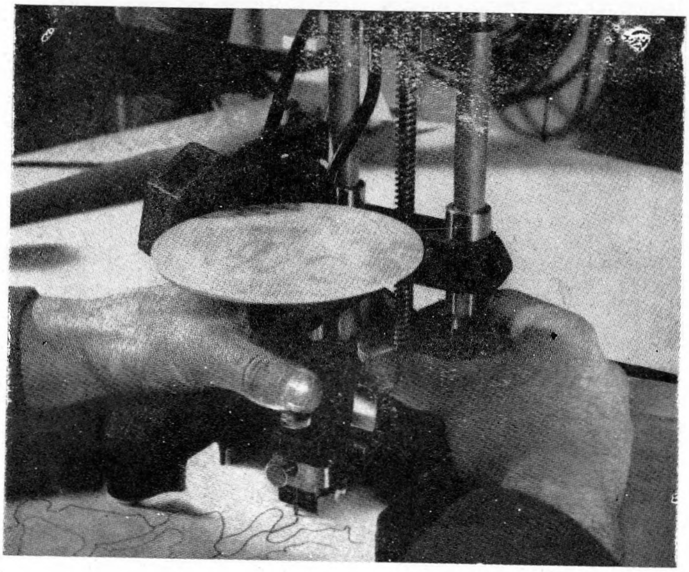
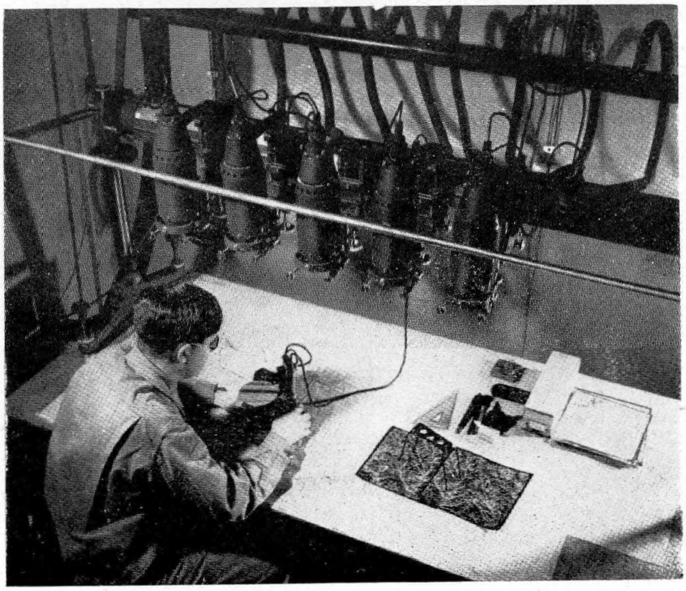
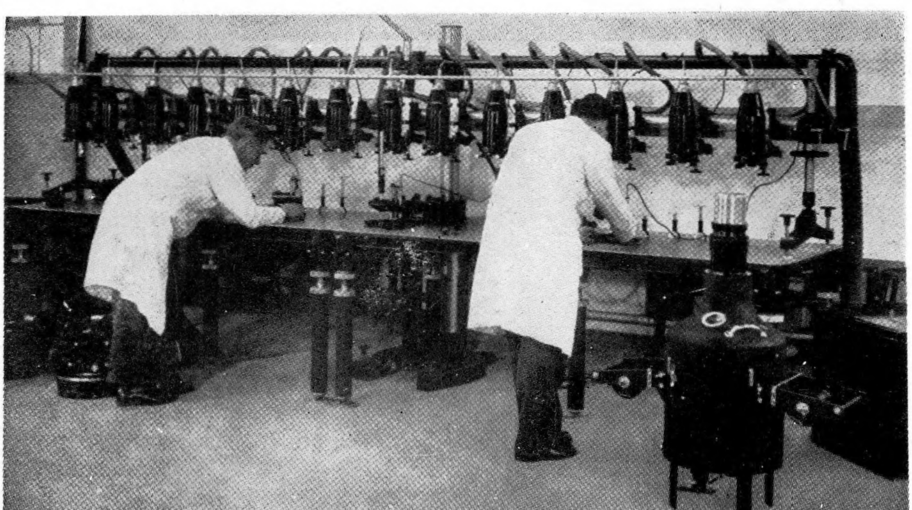


Bausch and Lomb Multiplex Tracing Table

Bausch and Lomb Universal Tracing Table



Bausch and Lomb Multiplex Equipment



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