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PLANIGRAPHY

I. INTRODUCTION AND HISTORY*†

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INTRODUCTION

PLANIGRAPHY is a method of roentgenographic projection of plane sections of solid objects. This may be effected by moving the point of emission of roentgen rays in one direction while the recording medium is moved in the opposite direction, the two being moved simultaneously in a constant ratio by means of a connecting system which rotates about an axis which lies in the plane of the section to be projected.

The practical realization of this can be achieved in the following manner (Fig. 1). *O* is the object of the plane section, *B*, of which it is desired to photograph. *T* is the anode of the roentgen tube (the point of emission of roentgen rays) which moves in the direction of the arrows during the time of the exposure of the film (the recording medium), *F*. *F* moves simultaneously in the opposite direction, the system, *T* and *F*, moving about an axis which lies in the plane *B* which is the plane to be projected. The ratio $TB:BB'$ is constant and therefore all points in plane *B* will be projected on corresponding points on the recording medium, *F*, while all points in planes *A* and *C* and other planes will be projected on various points on the recording medium. A correct image of the plane *B* will therefore be projected on the recording medium while the images of all the other planes will be blurred, the degree of blurring depending upon the distance of the other planes from plane *B*.

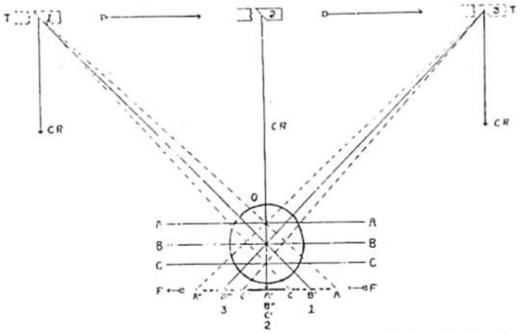

FIG. 1. Diagram illustrating the principle of planigraphy and planigraphic method No. 1 (Bocage). For explanation see text.

This has been demonstrated mathematically by Ziedses des Plantes,[27] Bartelink,[2] and Grossmann.[9]

HISTORY OF THE DEVELOPMENT OF PLANIGRAPHY

Methods No. 1, 2 and 3. Bocage[4] first described the principle of body section roentgenography in a French patent application on June 3, 1921. He proposed, in

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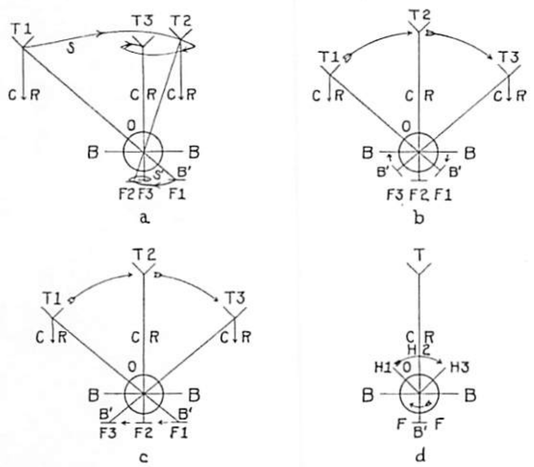
this application, three methods for the practical achievement of planigraphic projection. These were as follows (cited by Ott[11]):

1. The point of emission of roentgen rays moves, during the exposure of the recording medium, in a straight line in a plane parallel to the recording medium which moves simultaneously in the opposite direction. The central ray, *CR*, lies in a plane which is vertical to the plane *B* throughout the exposure. This is the method represented diagrammatically in Figure 1.



.FIG. 2. *a*. Planigraphic method No. 2 (Bocage). *b*. Planigraphic method No. 3 (Bocage). *c*. Incorrect application of the planigraphic principle. *d*. Vallebona's original "stratigraphic" method (cf. Fig. 3). For explanation see text.

2. The point of emission of roentgen rays and the recording medium move simultaneously in parallel planes but instead of moving in straight lines they move in circles, squares, crosses, or in Archimedean spirals. Again, the central ray lies in a plane which is vertical to the plane *B* throughout the exposure. This method is represented diagrammatically in Figure 2, *a*, where *S* is the spiral course which is followed by *T* during the time of exposure. The recording medium moves in a similar spiral fashion, *S'*, and the ratio *TB*:*BB'* remains constant.

3. The point of emission of roentgen rays and the recording medium rotate about an axis which lies in the plane of the section to be projected instead of moving in parallel planes. Again, the central ray lies in a plane which is vertical to the plane *B* throughout the exposure. This method is represented diagrammatically in Figure 2, *b*. By this method the ratio *TB*:*BB'* is fixed throughout the period of exposure of the recording medium.

These methods will be referred to by number throughout this paper.

Figure 2, *c*, illustrates a principle which is very easy of practical application to many of the standard American roentgenographic tables but which represents an incorrect application of the principle. The source of emission of roentgen rays rotates about an axis which lies in the plane *B* and the central ray remains perpendicular to this plane. The recording medium, *F*, however, moves in a plane horizontal to plane *B* instead of rotating around the axis in the plane *B*. The ratio *TB*:*BB'*, instead of being a constant, varies throughout the range of motion of the system *T-F* and the projection of plane *B* will therefore be incorrect.

Portes and Chausse[13] described method No. 2 four months after Bocage and suggested its use in deep roentgen therapy for concentration of the depth dose.[11]

Pohl[12] described the principles of the method in a patent application in 1927.

Method No. 4 and the first practical medical application of the principle. Vallebona[14] was the first to put the method to practical use in the making of body section roentgenograms or "stratigrams," as this author termed them. His original method differed, however, from that of the other authors in that the point of emission of roentgen rays and the recording medium were held in a rigid system while the object itself was rotated during the exposure of the recording medium about an axis which lay in the plane of the section which it was desired to project. This method is represented diagrammatically in Figure 2, *d*, where *T* and *F* are fixed while the object, *O*, is revolved about an axis lying in plane *B*. A schematic drawing of Vallebona's apparatus for the accomplishment of this is shown in Figure 3. The horizontal piece, *S*, supports the film over the center of which the tube is fixed as in ordinary roentgenography. The object to be examined is fixed to the rocker, *R*, which is pivoted, by adjustable pivot points, *P*, on the rocker arms, *A*, at the level of the plane to be examined and rotated by means of the handle, *H*, during the exposure of the film. With this apparatus Vallebona was able to make some planigrams of skulls, reproductions of which were published in his first communication on the subject. This method has not been developed further for medical roentgenography because of the practical difficulties encountered in placing and fixing the patient on the rocker. For this reason this method will not be considered further in this paper.

Vallebona did, however, employ the other methods and further elaborated on them. In 1933 he described a new improvement and published studies on it.[16] This method will be described as planigraphic method No. 4, "stratigraphy."

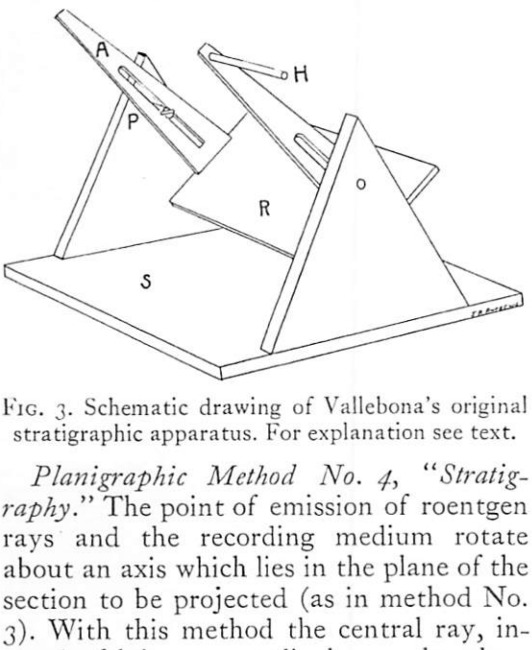


Fig. 3. Schematic drawing of Vallebona's original stratigraphic apparatus. For explanation see text.

Planigraphic Method No. 4, "Stratigraphy." The point of emission of roentgen rays and the recording medium rotate about an axis which lies in the plane of the section to be projected (as in method No. 3). With this method the central ray, instead of lying perpendicular to the plane of the section to be projected, lies perpendicular to the recording medium at all times and perpendicular to the plane of the section to be projected at only one point in the rotation. A schematic drawing of this apparatus is shown in Figure 4. The patient can be placed on a table over the film carriage and the pivot about which the system rotates can be fixed at any desired level on the upright standard while the patient-film distance can be varied by

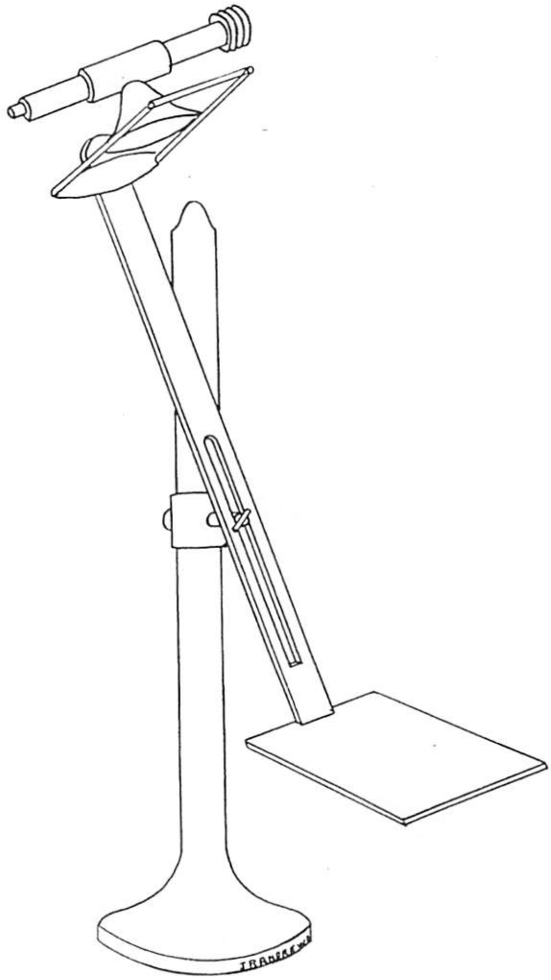


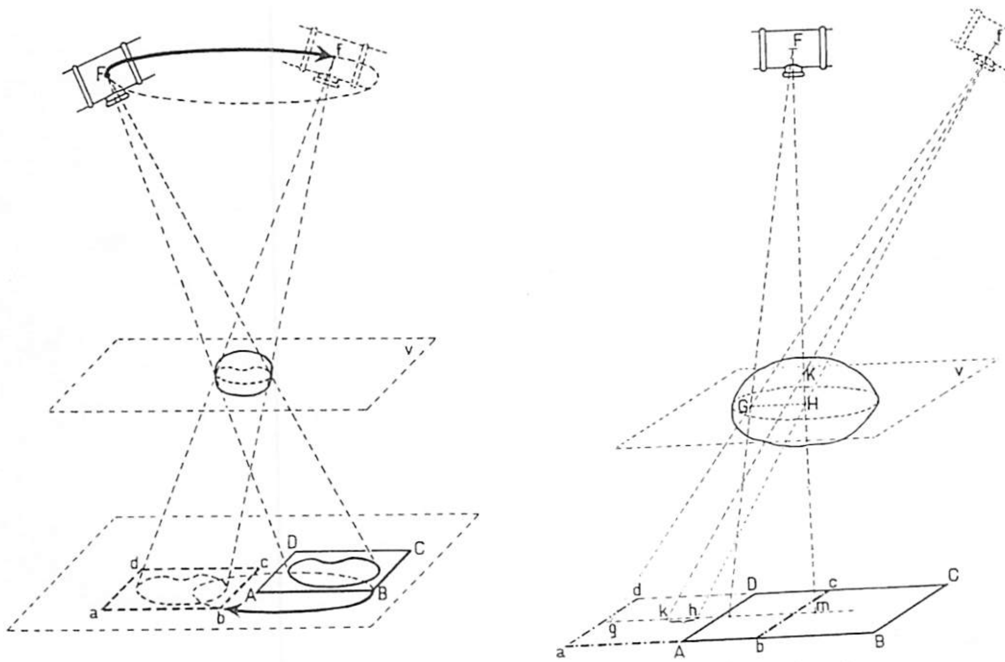
Fig. 4. Planigraphic method No. 4, "stratigraphy" (Vallebona). A pendulum-like arm is attached to the upright standard by a pivot, the height of which is adjustable. At the upper end of the pendulum the roentgen tube is fixed while at the lower end a cassette tray is fixed. The patient is placed on a table between the roentgen tube and the cassette tray.

means of the adjustable slide on the rocker arm. Here the ratio $TB:BB'$ varies with the adjustment of the sliding rocker arm but when this adjustment has once been made the ratio is fixed. This is a very simple and practical method.

Planigraphic Method No. 5 and the further elaboration of the principle. Ziedses des Plantes, in some personal communications and in his thesis for the doctorate degree,[27] states that he invented the method independently in 1921–1922 but was not able to work it out practically until 1928–1931 when he published his first paper.[21] Ziedses des Plantes was subsequently informed, in 1933,[27] that Bocage had taken out a patent in 1921 and Pohl in 1927 but that neither had put the principle to any practical use. He was also subsequently informed of Vallebona's work.

Whether or not Ziedses des Plantes should be given credit for independent origination of the method of planigraphy, although there is no doubt that Bocage, Portes and Chausse, Pohl, and Vallebona put the principle on record before Ziedses des Plantes, it remains, however, that his thesis for the doctorate degree is the most completely elaborated thesis of any of the few writers on this subject. For this reason his method will be described in detail in this communication as method No. 5.

5. The point of emission of roentgen rays and the recording medium move synchronously in parallel planes, circles, or spirals (as in No. 2 of Bocage). The central ray, however, is directed by simultaneous rotation of the tube toward the same point of the film at all times during the exposure (Fig. 7), and in this way this method differs from that of the other authors. This method is represented diagrammatically in Figure 5.



Figs. 5 and 6. Planigraphic method No. 5 (Ziedses des Plantes). For explanation see text.

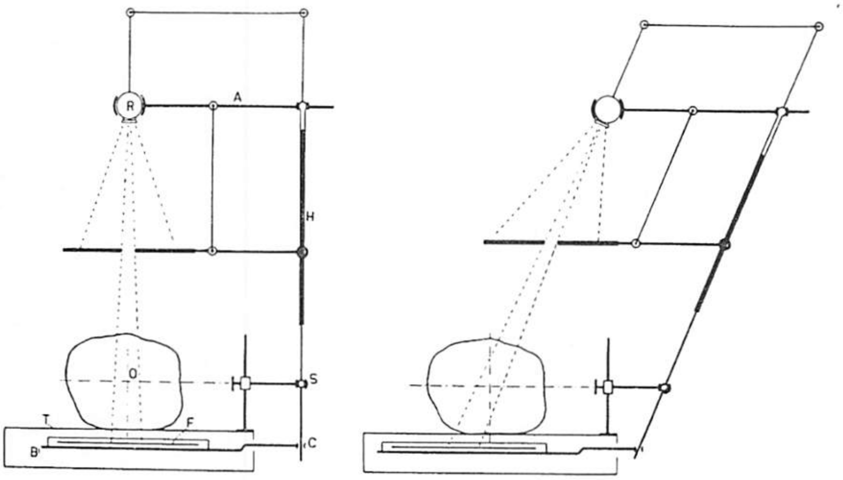
The roentgen tube and the film are moved during the exposure in such a manner that only one plane of the object (the plane v) is continuously projected on one and the same spot of the film. The projections of all other parts of the object are in motion. This is accomplished by simultaneous movement of the tube and film, the film moving from *ABCD* to *abcd* while the tube moves from F to f. This picture depicts a circular movement but in reality

Ziedses des Plantes generally uses a spiral movement in order to obtain greater blurring of the parts lying outside of the desired plane as he feels that with this spiral type of movement the absorbing areas not in the desired section are less disturbing in their projection on the film. This is especially true of parts bounded by straight or curved lines.

What takes place during the exposure can more exactly be demonstrated by reference to Figure 6. When the tube is moved from *F* to *f* and the film from *ABCD* to *abcd* the projections of *G* and *H* remain on the same points on the film. The projection of *K*, however, which at one time during the exposure lies on the same point as the projection of *H*, will later on have moved from *h* to *k*. As a result the image of *K* will be blurred.

Figure 7 is a schematic drawing of the apparatus which shows how the system moves during the exposure. When the tube, *R*, is moving with the support, *A*, the movement is conveyed to the film, *F*, by a lever, *H*, which is balancing at a point, *S*, which can be fixed at different heights. The tube, *R*, rotates during the movement so that the central ray is directed toward the same point on the film at all times during the exposure. A diaphragm for the absorption of scattered radiation may be interposed between tube *R* and object *O*.

Figure 8 is a photograph of the apparatus which Ziedses des Plantes has been using for about five years. The tube, *R*, can be moved simultaneously with the whole supporting frame, *A*, in all directions horizontally, this being possible because the carrier, *K*, slides the length of the table while the frame, *A*, moves perpendicularly to it. The movement of the frame is trans-



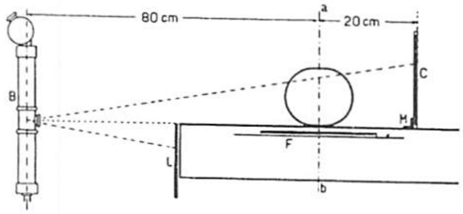


Fig. 7 (above). Schematic drawing of Ziedses des Plantes' planigraphic apparatus.
Fig. 10 (below). Diagram showing how the depth of the plane which is to be projected can be predetermined by making a lateral roentgenogram. For explanation see text.

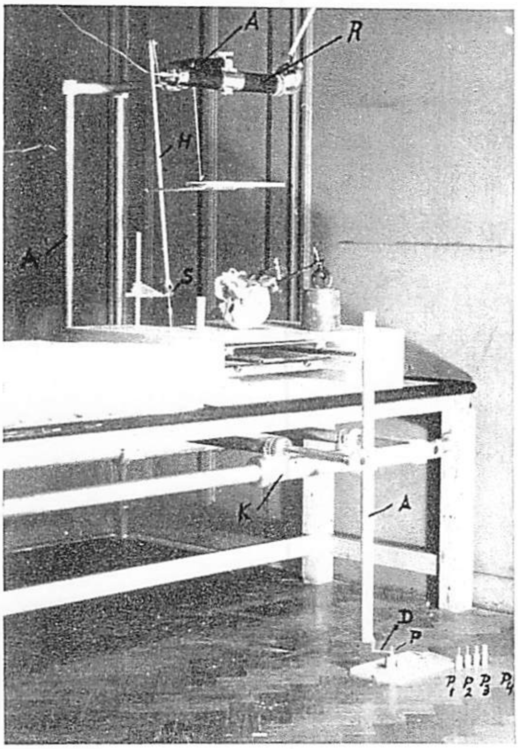


Fig. 8. Photograph of Ziedses des Plantes' planigraphic apparatus. For explanation see text.

mitted to the plate by the lever, *H*, which is pivoted at point *S*.

The lower moving bar of frame *A* is attached by the cord, *D*, to the peg, *P*, on the floor. Manual turning movement of this lower bar of frame *A* during the exposure provides the motive power for the moving system. The turning movement will cause the cord to wind around the peg and therefore the moving bar and also the whole frame comes gradually to the center with a spiral motion. When a heavier peg is used, the spiral turns will be farther apart and therefore pegs of different sizes (*P-1*, *P-2*, *P-3*, and *P-4*) can be utilized according to necessity. Ziedses des Plantes also proposed the use of a slotted diaphragm or grid interposed between the object and the film for the absorption of the scattered rays.

Registration of the Depth of the Section of the Film. The depth of the plane section which is projected can be registered accurately on the film by the use of a small instrument which was designed by Ziedses des Plantes. This is a wood cylinder in which metal numerals have been placed, each numeral indicating its own height. Nine lead shot are placed in the cylinder between each two numerals, each one being placed a millimeter higher than the other. A lateral roentgenogram of this instrument is shown in Figure 9, *a*, while Figure 9, *b*, is a planigram of the instrument at the depth of 5 cm. and Figure 9, *c*, is a planigram at the depth of 5 cm. and 4 mm., the fourth shot being projected in the sharpest detail. In practical planigraphy this instrument is placed in the vertical position on the table beside the object to be examined and exposed simultaneously with the object and the film.

Figure 10 shows how the depth of the plane which is to be projected can be predetermined by making a lateral exposure of the object in the usual fashion and determining directly from the film, after making correction for the distortion of the projection, the height of the plane above the supporting table.

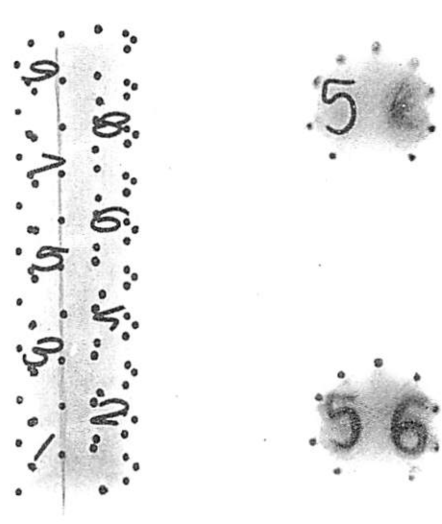


Fig. 9, *a*. Lateral roentgenogram of Ziedses des Plantes' instrument for registering the depth of the plane section which is projected. *b* (right above). Planigram of instrument at depth of 5 cm. *c* (right below). Planigram of instrument at depth of 5.4 cm. For explanation see text.

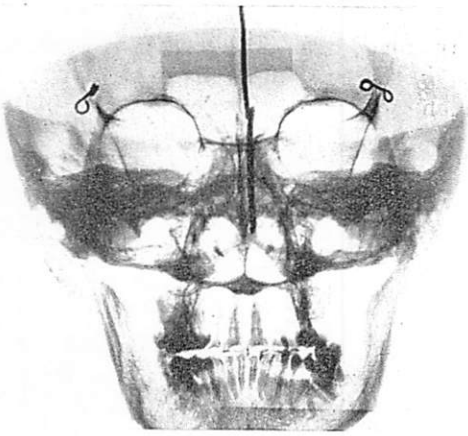


Fig. 11. Roentgenogram of dried skull.

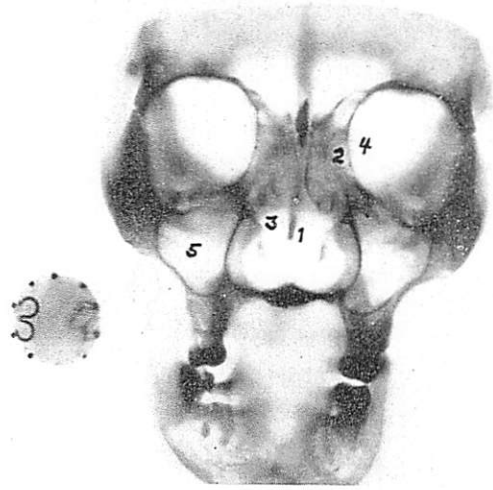


Fig. 12. Planigram of dried skull of Figure 11 made at a depth of 3.2 cm. from the most anterior part of the skull. For identification of numerals see text.

Ziedses des Plantes has made a special study of the normal and pathological anatomy of the skull and its contents. Figure 11 is a roentgenogram of a dried skull made in the posteroanterior projection. Figure 12 is a planigram of the same skull through a frontal plane 3.2 cm. (as indicated by the registering instrument) posterior to the most anterior part of the skull. The nasal septum, 1; some of the ethmoid cells, 2; the lower and middle turbinates, 3; the medial walls of the orbits, 4; and the walls of the maxillary sinuses, 5; are shown in

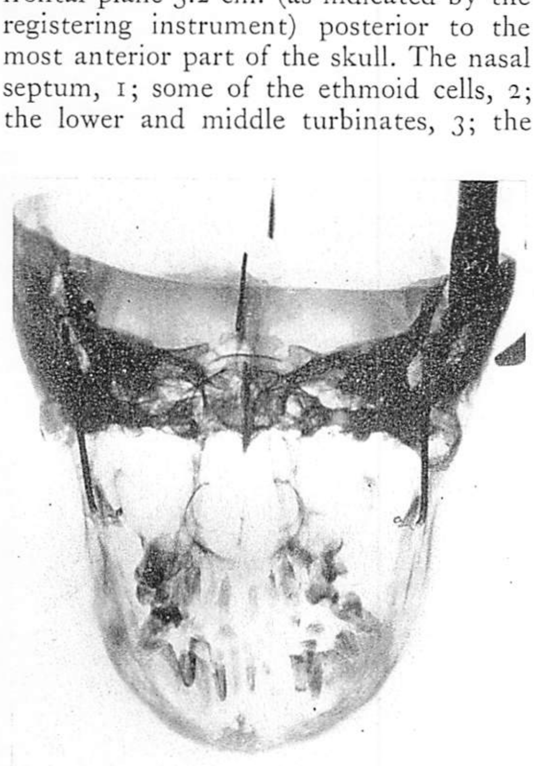


Fig. 13. Roentgenogram of dried skull.

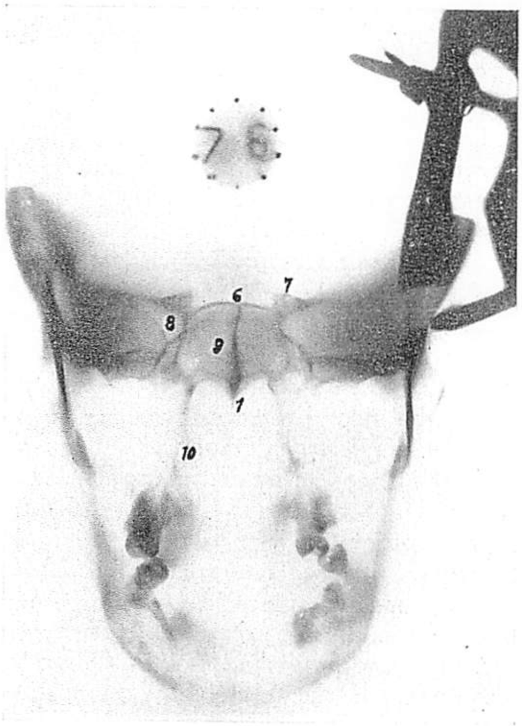


Fig. 14. Planigram of dried skull of Figure 13. For identification of numerals see text.

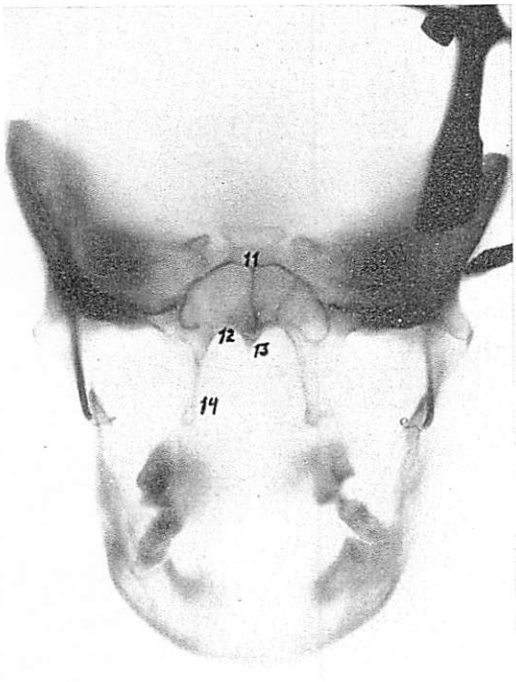


FIG. 15. Planigram of dried skull of Figure 13. For identification of numerals see text.

detail. Figure 13 is a roentgenogram of another dried skull while Figures 14, 15, and 16 are planigrams of the same skull made to show sections of this skull at different levels. Figure 14 shows the sulcus chiasmatis, 6; the anterior clinoid processes, 7; the superior orbital fissures, 8; the sphenoid sinuses, 9; the nasal septum, 1; and the posterior margins of the choanae, 10. Figure 15 shows the floor of the sella turcica, 11; the floor of the sphenoid sinus, 12; the ala of the vomer, 13; and the laminae of the medial pterygoid processes, 14. Figure 16 shows the dorsum sellae, 15; and the laminae of the medial, 14; and lateral pterygoid processes, 16. All of the lines shown on the planigrams are to be found in the ordinary roentgenogram but frequently they cannot be identified because of the confusion caused by the multiplicity of overlying lines and shadows. As shown by the planigrams the detail of any one section is good while the visualization and identification of that section is facilitated by the blurring of lines and shadows in the sections above and below the section which was projected.

After Ziedses des Plantes' first publication in 1931, Bartelink[1] demonstrated the results which he obtained by the use of a similar method at a meeting of the Dutch Association of Electrology and Roentgenology in Amsterdam on November 2, 1931. A schematic drawing of his apparatus is shown in Figure 17. The principle of this method is essentially that of method No. 4. In Bartelink's apparatus, however, the pivot about which the moving system revolved was fixed and the height of the object above the supporting table was altered to change the plane of the projection. This method is not quite so practical as that of Vallebona's.

In January, 1934, the firm of Siemens-Reiniger constructed a research model of a planigraphic instrument.

Planigraphic Method No. 6, "Tomography"; further refinements of the method. Grossmann[9] has made an extensive study of the mathematical and geometrical principles of planigraphy. He concluded that some of the previously proposed methods

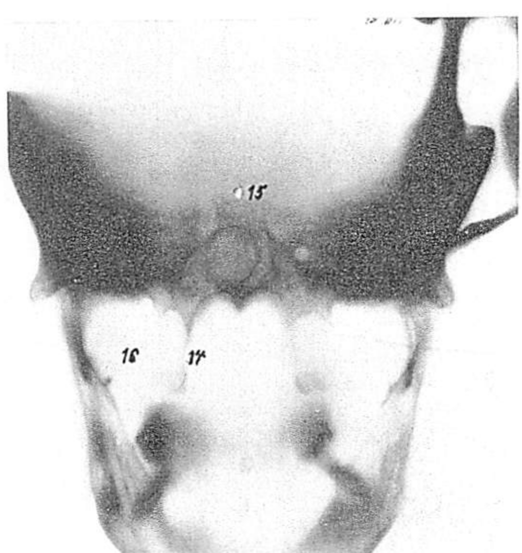


FIG. 16. Planigram of dried skull of Figure 13. For identification of numerals see text.

and devices have many disadvantages. Disturbing shadows of large surface area are not removed in many cases except by the formation of a more dense central shadow. He states that with circular movement not less than three to five times the normal exposure is necessary and, with spiral movement, not less than ten to fifteen times is necessary, which for practical reasons is difficult to obtain. The use of grids for the absorption of scattered radiation further increases the time of the exposure and further limits the application of the method. Furthermore, with the exception of Vallebona's apparatus, all of the devices utilized are very complicated for not only must the tube and film move, but the tube must permit oscillation along its longitudinal and transverse axes (this is especially true of Ziedses des Plantes' apparatus). In order to obtain clear planigrams with such devices, exact correspondence between the film and tube movement is

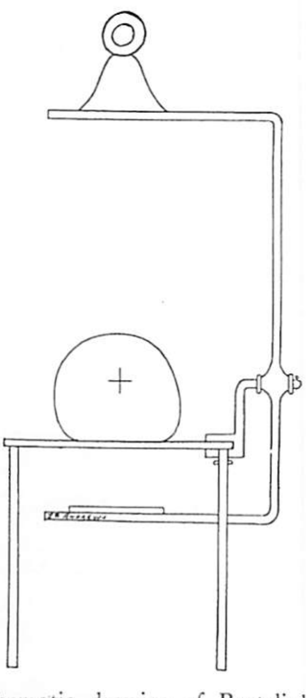


Fig. 17. Schematic drawing of Bartelink's planigraphic apparatus. The roentgen tube and cassette holder rotate about a fixed pivot, the height of the object above the supporting table being altered to change the plane of the projection.

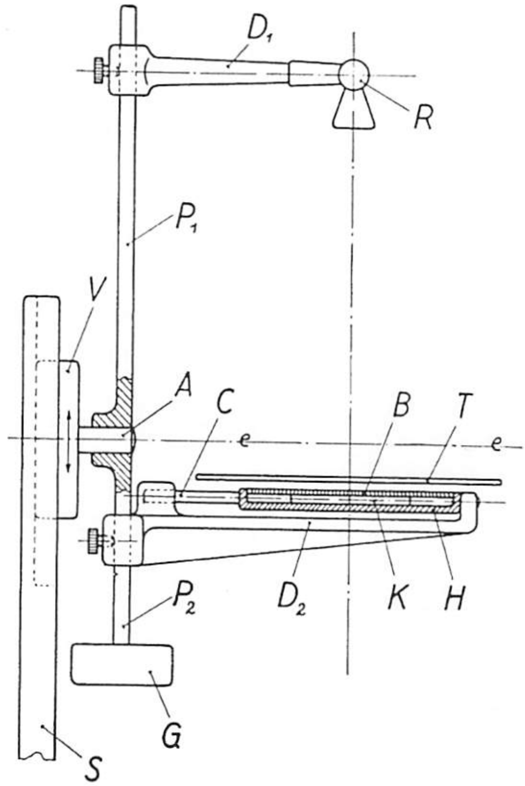


Fig. 18. Planigraphic method No. 6 (Grossmann). Schematic drawing of Grossmann's apparatus (tomograph). For explanation see text.

necessary and exact adjustment of the apparatus is very difficult to obtain.

Grossmann describes a slightly different planigraphic method and has named the apparatus which he employs the "tomograph." The principle embodied in this apparatus will be described as method No. 6.

6. The principle which he employs is a slight modification of methods No. 3 of Bocage and No. 4 of Vallebona. The method and apparatus are represented diagrammatically in Figures 18 and 19. P_1 and P_2 are the two arms of a pendulum which rotates about an axis, *A*, the height of which is adjustable by the sliding frame, *V*, on the standard, *S*, and which lies in the plane *Aee* which is the plane to be examined of the object lying on the table support, *T*. *G* is a counterweight. Attached to arms, D_1 and D_2, which lie perpendicular to *P*

and horizontal to T are the roentgen tube, R, and the support (D_2) for the film cassette and grid. The distance of D_1 and D_2 from A is variable. H is a tray which is fixed to the axle, C, which is pivoted on the pendulum in the line RA and which carries the film cassette, K, and the grid, B. An extension piece is fixed to the tray, H, which is pivoted at Y (Fig. 19) to a movable arm, L, which in turn is pivoted to V and Z which also lies in the plane Aee. This system maintains the horizontal position of the film cassette and grid throughout the movement of the pendulum. It is this system which is distinctive in this apparatus and by which it differs from the methods No. 3 of Bocage and No. 4 of Vallebona. The central ray passes through the center of the plane to be projected at the point defined by the junction of the central ray and the line Aee at all times during the exposure while it is directed perpendicular to the plane to be projected at only one point on the rotation of the pendulum. Here, also, the ratio $RA:AC$ (cf. the ratio $TB:BB'$) is constant throughout the movement of the pendulum.

The pendulum is held by a catch with the tube, R, in position F_1. When the pendulum is released the weight and inertia of the counterweight carry the moving system through the tube position F_2 to tube position F_3 where the pendulum is automatically stopped by another catch. The tube is activated during the rotation of the pendulum, the exposure being started directly after the pendulum has been released and stopped just before the pendulum is stopped. The exposure may be started and stopped automatically by circuit breakers connected to the pendulum arms and stationary support.

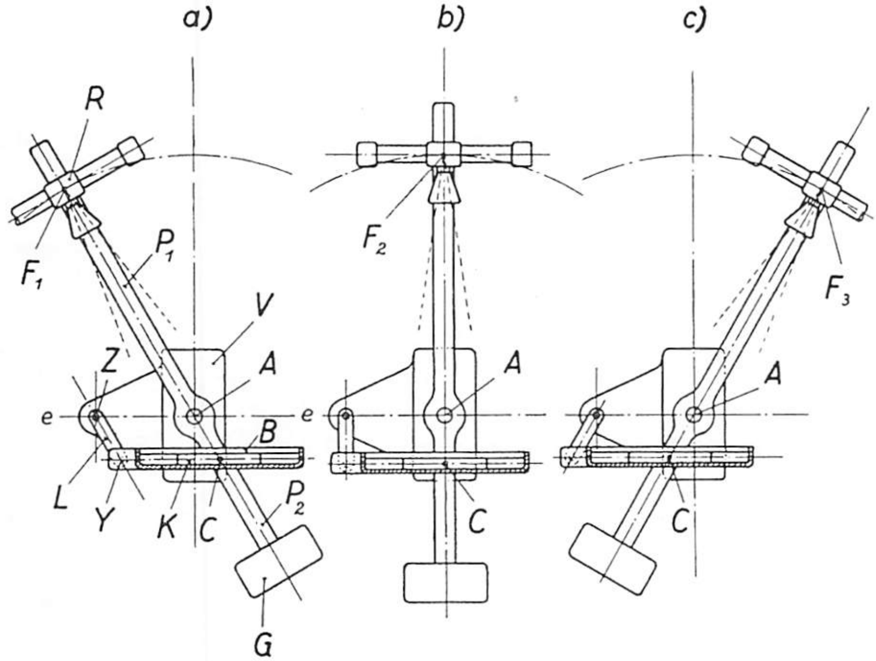


Fig. 19. Planigraphic method No. 6 (Grossmann). Schematic drawing of Grossmann's apparatus (tomograph). For explanation see text.

Grossmann's apparatus is now being manufactured commercially in Germany under the trade name "tomograph."

Grossman claims several advantages for this apparatus and a study of the plans leads to the conclusion that it is one of the simplest and seemingly most practical of the planigraphic instruments yet to be devised. He states that with this method large surface disturbing shadows are diminished while central shadows occur only in a few cases. Grids for the absorption of scattered radiation may also be employed without increase of the exposure time and short exposures (to one second) are rendered possible. He shows,[9] on the basis of geometrical and photophysical considerations, that disturbing shadows are more diminished by spiral motion of the focus than by circular motion. Such shadows, however, are effectively removed by the application of a pendulous motion to the tube focus of the tomograph provided that the focal excursion of the pendulous movement is sufficiently great that the larger disturbing shadows obtain a degree of diminution equal to that obtained with circular or spiral movement. This is shown diagrammatically in Figure 20.

Clinical and Pathological Application of the Planigraphic Method. Chaoul[5,6,7] has made a special study of the normal and pathologic anatomy of the lungs using Grossmann's tomograph. He shows, on the basis of many serial exposures, that the pulmonary vessels and their divisions and the bronchi and their related pathological conditions can be made apparent, cavities defined and localized, and the extension of pathological processes from focal pathologi-

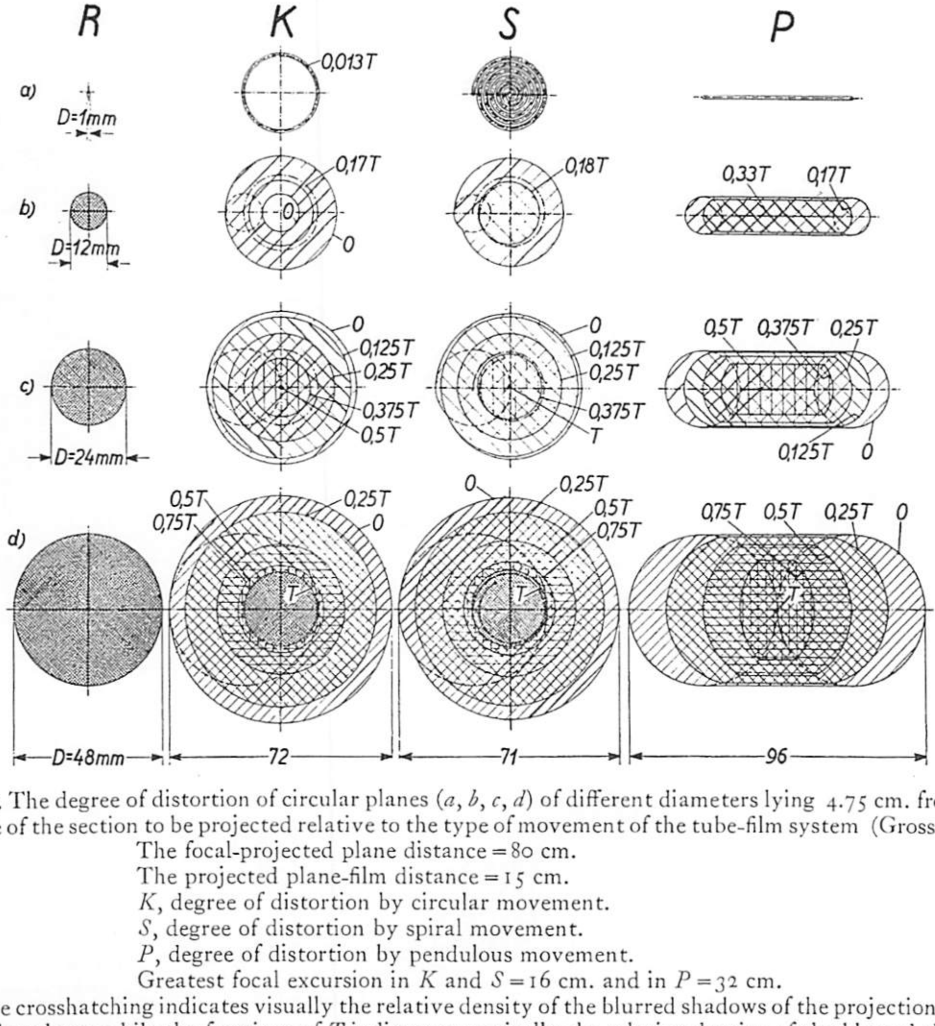


Fig. 20. The degree of distortion of circular planes (*a*, *b*, *c*, *d*) of different diameters lying 4.75 cm. from the plane of the section to be projected relative to the type of movement of the tube-film system (Grossmann).
The focal-projected plane distance = 80 cm.
The projected plane-film distance = 15 cm.
K, degree of distortion by circular movement.
S, degree of distortion by spiral movement.
P, degree of distortion by pendulous movement.
Greatest focal excursion in *K* and *S* = 16 cm. and in *P* = 32 cm.
The crosshatching indicates visually the relative density of the blurred shadows of the projections of the circular planes while the fractions of *T* indicate numerically the relative density of the blurred shadows compared to a standard density *T*.

cal processes can be estimated in a way which is not possible in the ordinary single or stereoscopic roentgenograms. His paper is illustrated with excellent roentgenograms and planigrams of the normal pulmonary anatomy, productive and fibrotic pulmonary tuberculous lesions, with and without cavitation, and pulmonary bronchiogenic cancer.

Figures 3 and 4 are adapted from Vallebona.

Figures 5 to 16 inclusive courtesy of Ziedses des Plantes.

Figure 17 adapted from Bartelink.

Figures 18 to 20 inclusive from Grossmann.

In closing the first part of this study on planigraphy I wish to call attention to the use of the terms "planigraphy," "stratigraphy," and "tomography." The term "planigraphy," although I have not been able to trace its origin, apparently has been in use longer than the other terms. The former is derived from the Latin (planus, level) and refers to a plane surface; stratigraphy is derived from the Latin (sternere, stratum; to spread; biological: a layer of tissue) and refers to a tissue layer; and the latter is derived from the Greek (Τόμος, a piece cut off) and refers to a cut section. I would urge, because of its temporal precedence, the retention and use of the term "planigraphy" and the derivatives thereof when referring to the principle of body section roentgenography in general and the use of the terms "stratigraphy" and "tomography" and the derivatives thereof only when referring to special methods No. 4 (Vallebona) and No. 6 (Grossmann), respectively, in the application of the planigraphic principle.

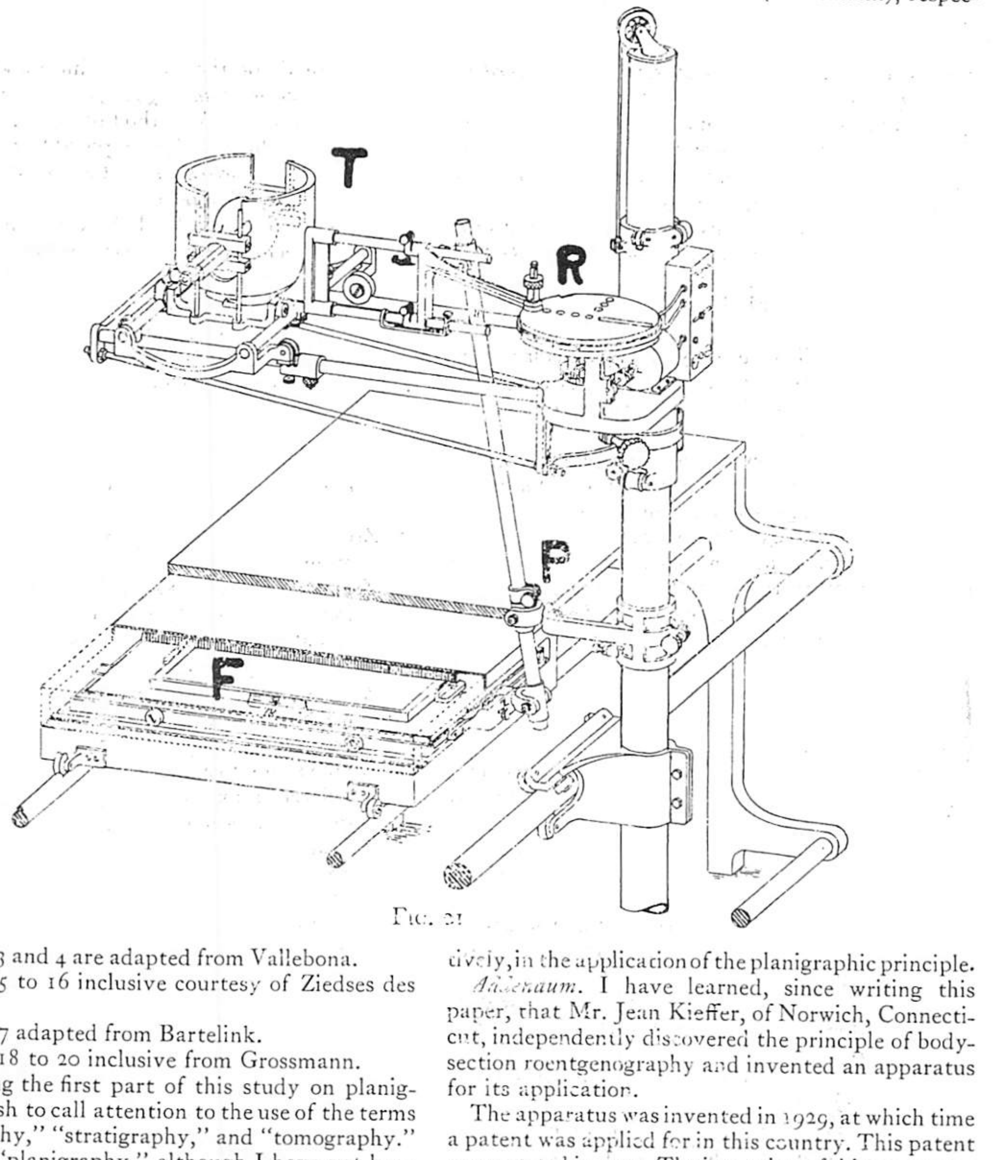


Fig. 21

Addendum. I have learned, since writing this paper, that Mr. Jean Kieffer, of Norwich, Connecticut, independently discovered the principle of body-section roentgenography and invented an apparatus for its application.

The apparatus was invented in 1929, at which time a patent was applied for in this country. This patent was granted in 1934. The invention of this apparatus in 1929, therefore, takes precedence over the work of Vallebona, Ziedses des Plantes, and Grossmann.

The inventor's drawing of his apparatus is shown (Fig. 21) through his courtesy.

The inventor has named his apparatus an "x-ray focusing machine" and the method employed is that which I have termed the "planigraphic" one. The roentgen tube, T (Fig. 21), is mounted on rails so that it may be moved in any direction in a horizontal plane. Motion is imparted to the roentgen tube through a rigid system connected to a rotating disk, R, which is motor driven and by which means a circular or spiral motion may be imparted to the tube. The roentgen tube and rotating disk system are connected to the roentgen film, F, by a lever hung in gimbals at P. The motion of the roentgen tube and rotating disk system is therefore transmitted by the lever to the roentgen film, F, which, with a slotted diaphragm, is mounted on rails so that it also may be moved in any direction in a horizontal plane. The plane of the object which will be projected is determined by the position of point P which is adjustable on the lever and upright tube stand.

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