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BY A. P. C.

E. SANTONI

AUXILIARY AEROPHOTOGRAMMETRIC SURVEYING APPARATUS, INCLUDING THE OBTAINMENT OF PHOTOGRAPHS OF THE SUN AND ENABLING THE REALIZATION OF A NOVEL PROCESS OF AEROTRIANGULATION

Filed Feb. 11, 1939

Serial No. 256,012

5 Sheets-Sheet 1

Fig. 1

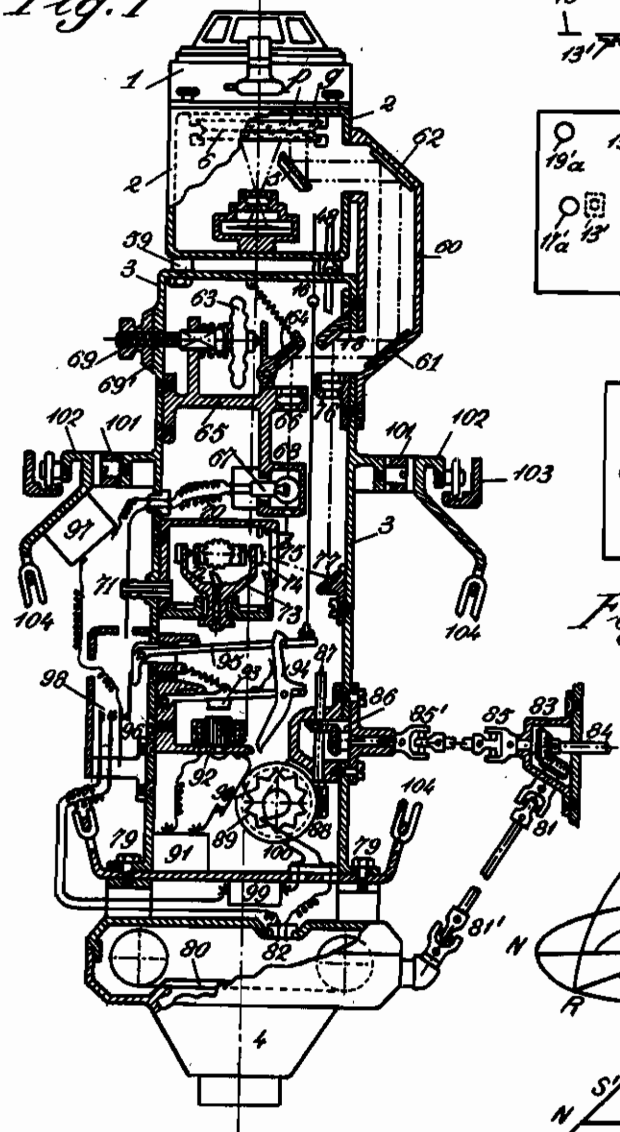


Fig. 3

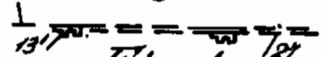


Fig. 4

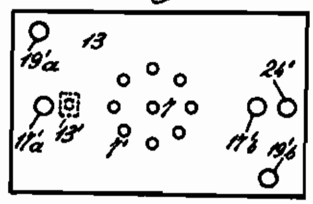


Fig. 5

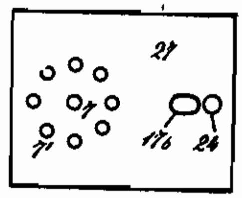


Fig. 6

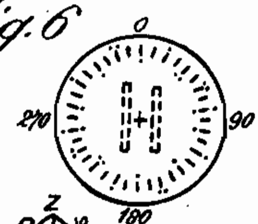
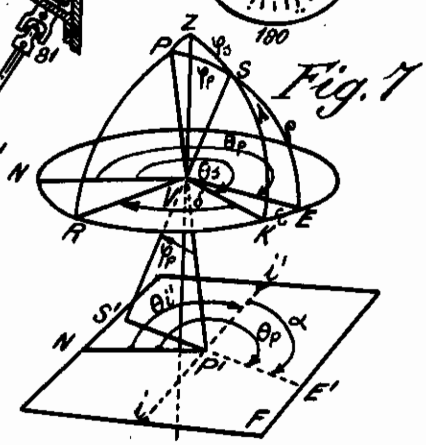


Fig. 7



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5 Sheets-Sheet 2

Fig. 2

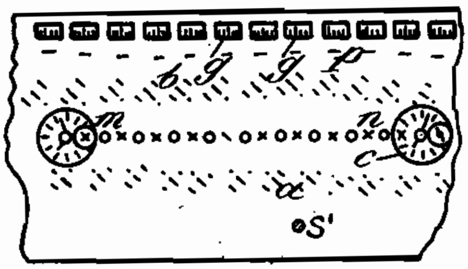

Fig. 8

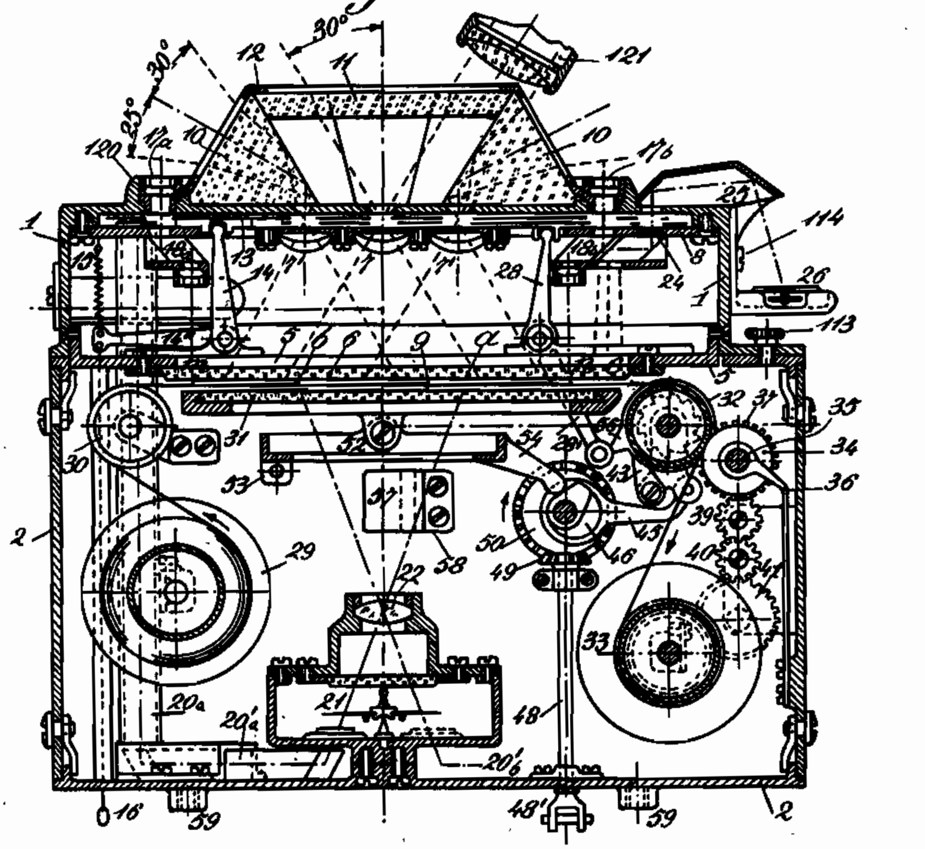

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Fig. 9

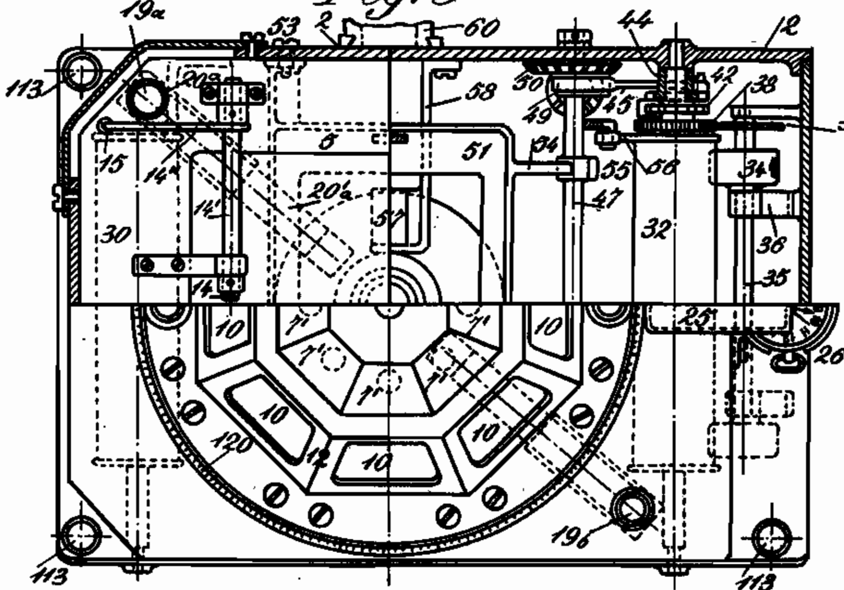

Fig. 11

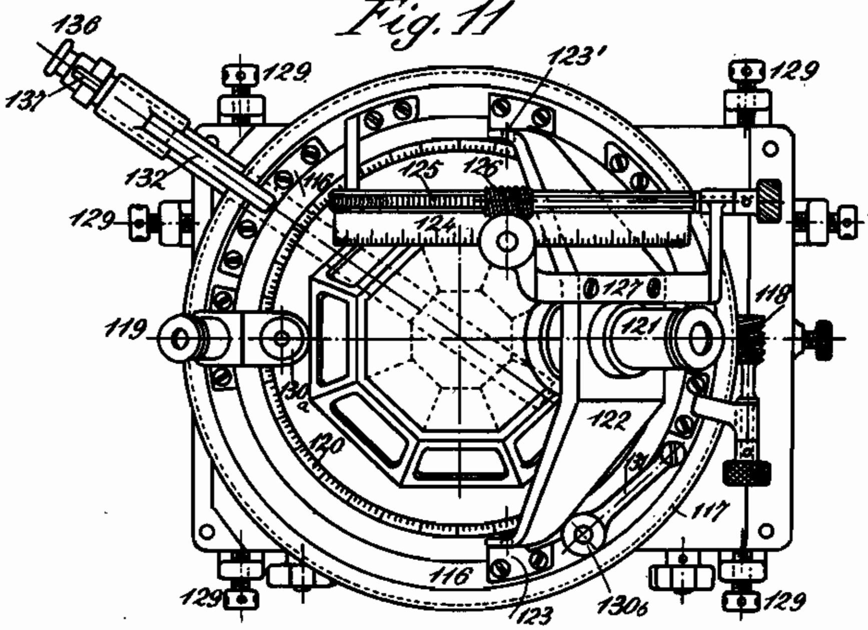

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Fig. 10

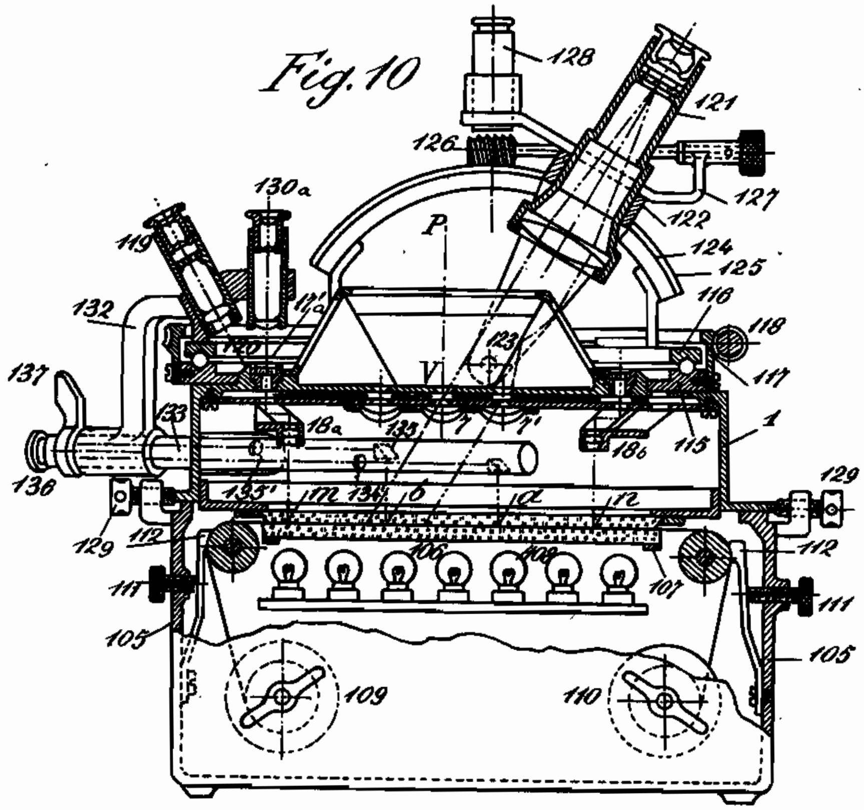


Fig. 12

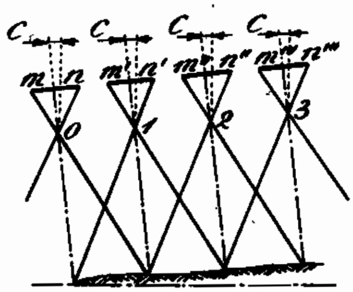
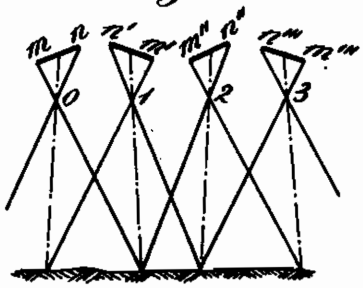


Fig. 13



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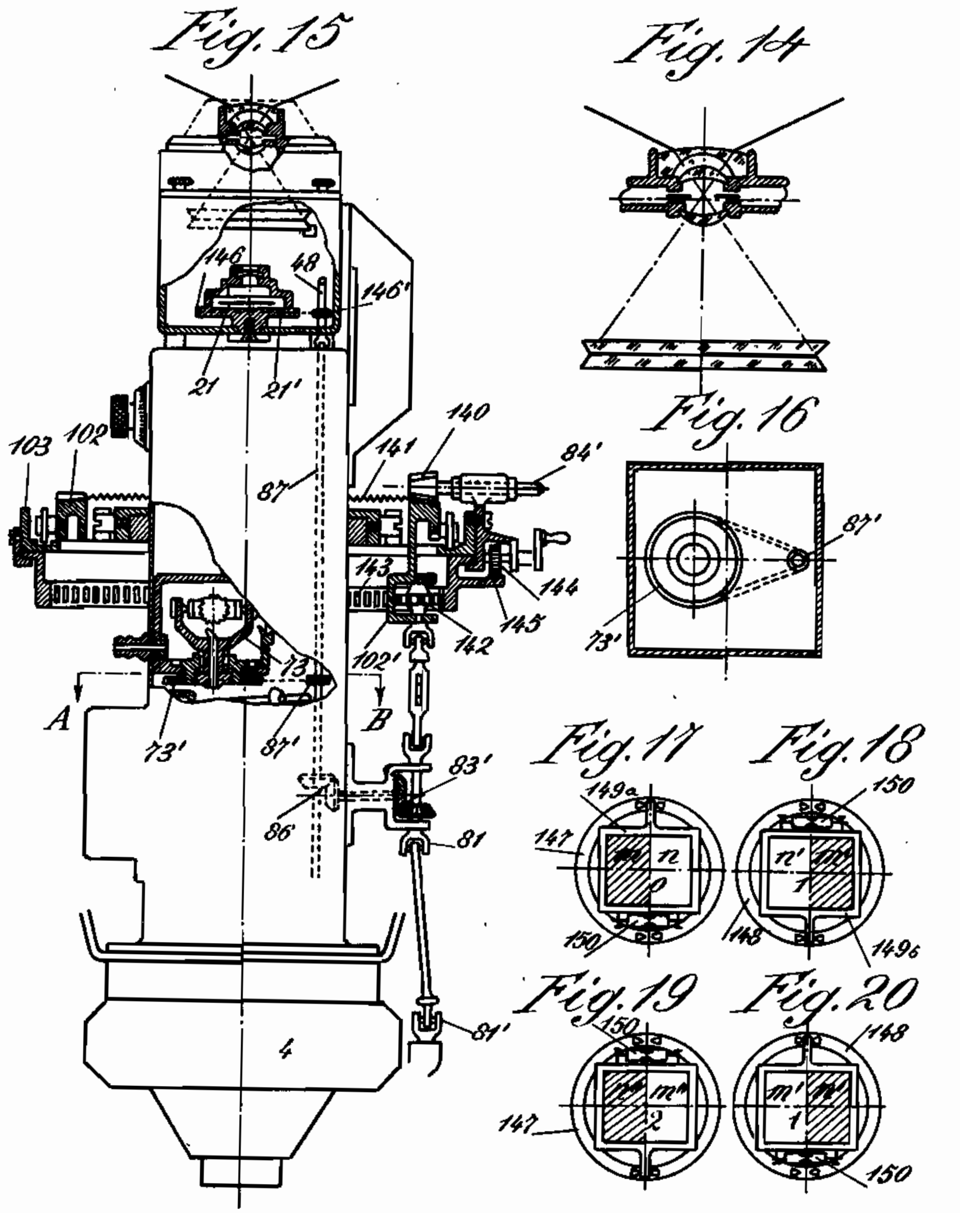
5 Sheets-Sheet 5



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ALIEN PROPERTY CUSTODIAN

AUXILIARY AEROPHOTOGRAMMETRIC SURVEYING APPARATUS, INCLUDING THE OBTAINMENT OF PHOTOGRAPHS OF THE SUN AND ENABLING THE REALIZATION OF A NOVEL PROCESS OF AEROTRIANGULATION

Ermenegildo Santoni, Florence, Italy; vested in the Alien Property Custodian

Application filed February 11, 1939

In the applications of aerophotogrammetry to topographical surveying on a vast and medium scale, the setting of the restitution or plotting apparatus appertaining to each pair of photograms is generally based on a certain number of ground points of known position, whereof the images appear on the said photograms.

In the applications of aerophotogrammetry to the small scale topographical survey of vast regions, the determination on the ground of a sufficient number of points of reference, according to the process alluded to above, would involve too much hard work which would not render the use of aerophotogrammetry advantageous.

With a view to reducing the number of ground points of reference, various aerotriangulation processes have been excogitated which generally allow of plotting from a series of photograms, taken during the course of the airplane, based on a few ground points only appearing in the first and in the last pair of photograms.

The practical carrying out of these processes calls for very delicate treatment and gives rise to considerable progressive errors when all the position elements of each new photogram of the series have to be deduced from the preceding photogram, as is the case, for instance, when use is made of the well-known method based on the elimination of the vertical parallaxes of the optical model.

A special device—already known—(Italian Patent No. 173,863 issued to the present applicant) supplies a position element appertaining to each photogram of the series, independently of the preceding photograms, by means of the chronometrically controlled photograph of the sun. Such device consists essentially in an auxiliary photographic camera, superimposed upon the main camera and connected to same, and destined to photograph the sun and the dial of a chronometer at each point of time when the main camera takes a photograph of the ground.

Assuming the position of two ground points to be known, the images of which appear in a photogram, the ascertainment a posteriori of the spatial position assumed by the photographic survey apparatus for that photogram is based on the following geometrical relations:

1° The approximate knowledge of the geographical co-ordinates of one of the two known ground points and of the time of day as photographed permits the calculation of the direction assumed by the sun rays at the moment of exposure relatively to the vertical and to the meridian passing through the said ground point.

2° The photographic apparatus is adapted to the direction of the said sun rays along the line of conjunction connecting the centre of the sun image with the centre of the objective by which same has been produced (auxiliary camera).

3° The photographic apparatus would be free to turn about the said line of direction, were it not impeded by the lines of vision preceding from the two known ground points which are defined, relatively to the photographic apparatus, (main camera) by the lines connecting the corresponding photographic images with the centre of the lens by which they have been produced.

4° The angular position of the photographic apparatus having once been defined in respect of points 2 and 3, the spatial position of same (orthogonal co-ordinates X Y Z of the centre of vision relatively to one of the known ground points) is defined by the known distance between the two ground points and by the angle formed between the lines of vision issuing from the said points, the value of which is furnished by the main photographic camera. In order to facilitate the determination of the angular values which connect the direction to the sun with the directions to the two ground points, the method already known (in subsequent improvements) provides a special photogoniometer which operates upon the said photographic apparatus (auxiliary and main cameras) into which there are once more introduced—centred relatively to the marks and suitably illuminated—the photograms containing the sun and the ground images, respectively. With the angular values derived from the photogoniometer and with the altazimuthal solar co-ordinates (deduced in the manner already mentioned) the determination of the angular and spatial position (elements of outer orientation) of the photogram may be effected by means of calculation.

By operating on a series of photographs, overlapping each other to the extent of 60% and selecting the two known points in the zone common to the first two photograms of the series, it is possible by the aforesaid method, to determine the elements of outer orientation for these two photograms.

By introducing the said photograms into a standard restitution or plotting apparatus, with the elements of orientation already determined, it is possible to obtain thereby the position of two new ground points selected in the zone common to the third photogram (20%). With these new points there may be determined the spatial position of the third photogram so that the process may be continued indefinitely for all the photograms of the series.

With the aforesaid known method the use of a normal plotting apparatus is necessarily limited to the determination (restitution) of the two necessary ground points at the point of survey $n+2$ when the photograms n and $n+1$ shall have been placed in the restitution apparatus with the outer orientation values already determined by calculation. Said calculation comprises the solution of various spherical and plane triangles. All this, together with the necessary of having a special photographic apparatus for the ground survey at one's disposal (main camera) that is adapted to allow of the re-centring and of the illumination of the photogram for the purpose of operating thereon with the photogoniometer, render the method exceedingly laborious and therefore but little adapted to be applied to aerial surveying on a small scale.

The apparatus for which a patent is being sought, while utilizing the principles of the aforesaid methods as far as the photographs of the sun and of the chronometer are concerned, introduces two new elements represented by the recording of the photogram orientation (lateral swing) by means of a magnetic compass, to which there is added a gyroscopic compass, and by the recording of the differences of flying height, by means of a statoscope. The recording of the photogram orientation by means of a compass and that of the flying height, or of the variations thereof, by means of altimeters or stato-scopes, while not constituting any novelty per se, do realize, when combined with the sun-chronometer complex a novel characteristic ensemble inasmuch as the special combination of same leads to decidedly new results.

In effect, the orientation element furnished by the magnetico-gyroscopic compass constitutes in the first approximation the control of the photogram rotation about the direction to the sun, which according to the known method had to be derived from the two ground points having been determined. This innovation permits a great simplification in the aerotriangulation development. In effect, while it was necessary, with the method already known, to operate with the photogoniometer upon the whole surveying complex (solar device and ground photography apparatus) into which all of the photograms had therefore to be introduced and to be re-centred, with the new method, the photogoniometer operates solely on the auxiliary device which records the images of the sun, of the chronometer and of the compasses. This enables the combination, in a very simple manner, of the said device with an ordinary photographic camera, in which, as is well known, no re-centring or photogram-illuminating systems are provided.

According to the new method, the outer orientation elements (longitudinal inclination (ψ) lateral tilt (τ) and lateral swing (ω) of the compass-sun-chronometer (and consequently of the main photogram) are determined, in the first approximation, without the concurrence of the two known ground points, by means of a very simple calculation (the solution of two spherical triangles, one of which is a rectangle.

The setting, in a normal plotting apparatus, of the first two photograms of the series, comprising the two known points (starting basis) is effected in the first approximation, with great promptitude, by utilizing the angular values ($\tau\psi\omega$) calculated therefor. The plotting apparatus then enables the effecting of the lateral swing rectification ($\Delta\omega$) of the said photograms on the starting basis; which rectification becomes necessary when the initially imposed lateral swing value proves effected by the errors of the compass. For the purpose of ensuring that each photogram shall, in this rectification, (virtually) rotate about the solar direction, there are made in each lateral swing variation $\Delta\omega$ (measured on the plotting apparatus) corresponding variations of longitudinal inclination $\Delta\psi$ and of lateral tilt $\Delta\tau$, according to determinate incremental ratios

$$\frac{d\psi}{d\omega} \text{ and } \frac{d\tau}{d\omega}$$

These incremental ratios may easily be calculated previously together with the first approximation values ($\tau\psi\omega$).

The correct angular setting of the first two photograms having once been ensured, the proper proportioning of the optical model, and therefore, of the first side of the aerial polygon, is effected in the ordinary way, by means of the same starting basis. For the purpose of proportioning the next side of the polygon, and then the contiguous optical model, there is determined in the plotting apparatus, the position in planimetry and in height, of a ground point (connecting point) situated in the zone that is common to the third photogram, in the vicinity of the nadir of the point of survey. After the first photogram has been removed from the plotting apparatus and the second has been caused to take its place (materially or through binocular inversion) the third photogram is set in the place of the second.

The lateral swing rectification ($\Delta\omega$) of this photogram is effected in the ordinary way on the second, the vertical parallaxes at the points of the model approximately contained in the vertical plane passing through the second and third points of survey (vertical epipolar plane).

To this rectification ($\Delta\omega$) there will correspond the rectifications of longitudinal inclination ($\Delta\psi$) and of lateral tilt ($\Delta\tau$) according to the already calculated incremental ratios. The proportioning of the model is effected through the variation of the second side of the polygon to such an extent that the height newly determined for the connecting point shall correspond to that determined with the previous model.

While the transverse component (y) of the aerial base becomes automatically imposed during the lateral swing rectification operation, the vertical component (z) has to be imposed through the elimination of the vertical parallaxes for the two points of the model situated towards the opposite margins of the photograms in a transverse direction relatively to the serial base.

The process may be continued for all the photograms of the series, through a succession of lateral swing rectifications, differential corrections and corrections of longitudinal inclinations and lateral tilt and the equalization of the heights of the connecting points.

According to the new process just described, the errors of the magnetic compass exert no influence on the final adjustment of the photograms as long as the incremental ratios are applied to lateral swing rectification of limted extent.

The knowledge of a base at the beginning of the series and of a base at the end, permits the correction of the systematic errors of the magnetic compass (deflection—declination) so that the values furnished by same for the intermediate photograms only prove effected by accidental errors (oscillations of the needle). As these oscillations are generally considerable, the apparatus also provides for the utilization of a gyroscopic compass. The latter may be selected, for instance, from among the types of simple construction (with an air-turbine motor) already in use as an instrument of navigation on modern airplanes.

These simple gyroscopic compasses are, as is well known, liable to quite a considerable degree of residual precession, so that even during their normal use on board, they have to be adjusted by the pilot in order that they may mark the value indicated by the magnetic compass. They are, on the other hand, more stable than the latter, being effected in a far less degree by the swaying of the plane. The carrying over or transfer of the gyroscopic compass value to that of the magnetic compass by means of the device forming the object of the present invention, instead of being effected materially during flight, as is the case normally, is effected algebraically a posteriori, by comparison between the values indicated by the two instruments and recorded photographically. This carrying over is effected both at the beginning and at the end of the series of photographs, for a certain number of intermediate photograms, suitably selected under the conditions of minimum oscillation of the magnetic needle and is based on the examination of the corresponding photographic diagram.

In short, for all the intermediate photograms of the series the values of the gyroscopic compass (suitably compensated, as previously stated) are utilized as values of lateral swing to be introduced into the respective calculations of the angular outer orientations elements. The remaining corrections of lateral swing ($\Delta\omega$) to be made in the plotting apparatus, prove very slight in this case.

When the remaining errors of lateral swing for the values furnished by the gyroscopic compass are but slight, they may be preferred, for long distance travel, to the method described above, which might be termed one of "transferred orientation" the "independent orientation" method, based on the sole rectification relating to the lateral swing of each pair of photograms.

The recording of the variations of absolute altitude of the airplane at the various points of survey by means of a recording statoscope, does not constitute any novelty per se, but the utilization thereof together with the sun-chronometer-compass complex is substantially different. In effect, according to the already known methods, the statoscope is used to avoid the longitudinal flexion of the assembly of ground models, as reconstructed in the plotting apparatus by the elimination of the vertical parallaxes, being mainly derived from the difference of distortion between the photographic camera and that of the plotting apparatus. To this end, the differences of height furnished by the statoscope for two successive photograms n and $n+1$ of the series, are directly imposed in the plotting apparatus for the corresponding points of survey. The oppositely disposed orientation of the two photograms, the effecting of which is based on the elimination of the vertical parallaxes for the whole field, leads to the determination of the longitudinal inclinations (ψ) of the axes of the photographic cameras, independently of the preceding stations, apart from the accidental and systematic errors (inclination of the barometric level surface) affecting the values furnished by the statoscope. The height of the ground points corresponding to the verticals passing through the points of survey will therefore be subject to height errors, depending on the aforesaid errors of the statoscope.

Furthermore, due to the unavoidable systematic error in the transferring of size from one side of the aerial polygon to the following one, depending on slight optical and mechanical asymmetries of the means employed, the progressive increase (or the decrease) of the size of the grid triangles (formed between the station points and the ground points selected for the connection) determines a progressive error in the height of the model, dependent upon the unvarying imposition of the height of the survey-points in the plotting apparatus, according to the statoscopic data.

In other words, if, for instance, the transferred size error tends to cause a decrease in size of the successive approximately vertical grid triangles, the ground is progressively raised in the plotting apparatus, such raising being equal to a positive error of longitudinal inclination which we will call it. These errors cannot be detected otherwise than by the determining of new ground points.

With the use of the values furnished by the solar device (sun-chronometer-compass) the ground model remains, on the contrary, free from errors of longitudinal flexion, without the aid of the values furnished by the statoscope.

Under such conditions, assuming an error of size transference equalling that of the preceding example, the progressive raising undergone by the ground during restitution will correspond to one-half of the longitudinal inclination it met with when the statoscope is made use of, while the station points will undergo a progressive sinking corresponding to a negative longitudinal inclination, likewise equalling one-half of it. The comparison of the heights obtained in the plotting apparatus for the successive survey points of a first portion of the grid with the values obtained from the statoscope, is therefore capable of furnishing the necessary elements for revealing an error of size transference by enabling a correction beforehand as regards the remaining portion of the grid. The function of the statoscope as a detector of size transference errors, rendered possible through the combination thereof with rest of the mechanism of the device forming the object of the present invention is therefore substantially new as compared with what has been made known until now.

The method indicated above in which use is made of the device in question, in the form as described so far, presupposes that the axis of the camera which photographs the ground and that of the camera which photographs the sun, are coincident, or at least parallel. Assuming that the axis of the solar camera and that of the terrestrial camera form a certain angle, the ground survey or photograph obtained in the plotting apparatus proves inclined by the value of said angle. It is true that when any known ground points are available in the first pairs of photograms, the defect of parallelism of the said axes may be observed and variously compensated on the survey photograph, but it is also true that it is of the utmost interest to be able to counterbalance this defect with means belonging to the machine, which makes it unnecessary to have these points of control on the ground.

In a further form of execution of the invention, the object aimed at is precisely that of effecting the compensation of the defect of parallelism between the axis of the solar camera and the axis of the axis of the terrestrial camera. In the said form the device comprises an assembly of mechanisms which permit the causing of the rotation of the whole photographic complex about its own vertical axis by 180° for each successive photograph of the ground, so that the eventual angle formed between the axis of the terrestrial camera and the axis of the solar camera shall find itself disposed first in one direction and then in the opposite direction. This rotation further allows of the compensation of the defects of projection as well, depending on anomalies of the photographic camera and of that of the plotting apparatus.

As it is advisable, for the purpose of thoroughly compensating all the anomalies of the solar camera, that the same objective operate in the two opposite positions, in the further form of execution the nine objectives of the solar camera are substituted with a single objective of a wide outer field angle. This objective may be of the type already known, constituted by a negative lens placed before a normal objective. In fine, as the rotation of the photographic complex by 180° for each successive ground photograph may be secured through the continuous rotation thereof, and as this rotation would tend to generate a harmful forward movement both of the rose of the magnetic compass and on the graduated circle of the gyroscopic dirigent, the further form of execution provides suitable transmission gearings which, by causing the rotation in opposite directions both of the compass-box and of the gyroscope dirigent, attain the object of maintaining same constantly oriented.

The object of the invention is illustrated by way of example in Figs. 1–11 which represent a first form of execution of the photographic film camera, and of the relative photogoniometer, and in Figs. 12–20 in a further form.

Fig. 1 represents in vertical section, according to the first form of execution, the surveying apparatus in connection with a standard aerophotogrammetric camera;

Fig. 2 represents an example of the various images impressed on the film with the said apparatus;

Figs. 3, 4 and 5 represent a few details of the solar camera shutters;

Fig. 6 represents the magnetic compass graduation;

Fig. 7 represents the geometrical principle of the device;

Fig. 8 represents the solar camera seen in vertical section;

Fig. 9 represents the said solar camera in a plan view and partly in horizontal section;

Fig. 10 represents the photogoniometric apparatus in vertical section;

Fig. 11 represents the said photogoniometric apparatus in a plan view;

Fig. 12 represents the ground inclination as platted when an inclination or tilt exists between the solar camera axis and the axis of the terrestrial camera;

Fig. 13 shows the setting of the photographs obtained with the device in the further form of execution;

Fig. 14 shows an objective detail according to the further form of solar camera;

Fig. 15 shows the photographic surveying apparatus corresponding to Fig. 1 according to the further form of execution;

Fig. 16 shows a horizontal section on line A—B of Fig. 15;

Figs. 17 and 18 show the setting of the first pair of photograms in the plotting apparatus camera, and

Figs. 19 and 20 show the setting of the second pair of photograms in the plotting apparatus.

According to the example shown in Figs. 1 to 11, the surveying apparatus (Fig. 1) is composed of the solar camera 1 placed upon and connected to the box 2 containing the film spool with the appertaining forward movement and unwinding devices, and the magnetic compass. The box 2 is superimposed upon the parallelepiped box 3 which contains the statoscope, the gyroscopic compass and the electromagnetic device for controlling the several shutters. The box 3 is connected at its lower part to a normal aerophotogrammetric camera 4, represented schematically, by way of example. The sun photography camera (Fig. 8) is composed of a rectangular box 1, to the lower part of which there is affixed a frame 5, which carries a glass having plane and parallel surfaces 6. The lower surface of this glass constitutes the main focal plane for a central objective 7 and for eight objectives 7′ arranged in a circle around the latter. The said nine objectives are carried by the plate 8, affixed to the inside of the box.

The film 9 is destined to collect the images formed by the said objectives. In front of each of the eight peripheric objectives 7′ is placed a prism 10, which deflects to the extent of 60°, outwardly, the main axis of the said objective. The eight prisms are secured laterally to one another in accordance with vertical contacting surfaces forming angles of 45° relatively to one another. Over the central objective 7 there is situated the guard-glass 11 held together with the prisms 10 of the cage 12 affixed to the upper wall of the box 1. The available field in a vertical direction for each of the peripheric objectives 7′ lies 25° below and 30° above the main axis, with a deflection of 60° from the vertical. In the horizontal direction, the field available for each of the said objectives is 45°. To the central objective 7 there appertains an octagonal field, whose section, in the plane of Fig. 1, is 60°. As the actual angular field of each of the aforesaid objectives is somewhat in excess of the one indicated above, a slight margin of overlapping results between the available fields of any two contiguous objectives so as to guarantee that solar disk shall always be photographed on the film 9 provided that it be enclosed within a spherical calotte of an amplitude of 170°. The distance between the various objectives is reduced to the minimum value depending on the dimensions of same and of those of the prisms 10, as the respective fields overlap one another largely within the camera. The original arrangement resulting herefrom is rendered possible by the fact that the subject to be photographed (the sun), allows of the apertures of the shutters 7—7′ being considerably reduced and, eventually, of the screening of the light with coloured filters, disposed, for instance, outside the prisms 10 and the glass 11.

The nine objectives may therefore all be opened simultaneously without any fear of the film being damaged. As the telescope appertaining to the photogoniometric apparatus (which will be described) may be approximately oriented in accordance with the known general surveying conditions, the condition is ensured of enabling the observation of the sun-image through the objective whereby same has been produced. The original arrangement of the eight prisms and the relative objectives constituted per se a considerable technical improvement as compared with already known devices realized for obtaining photographs of the sun, the use of which called, in each instance, for the approximate orientation towards the sun of the solar camera itself, or of auxiliary organs, such as prisms or the like, with a view to conveying the sun-image into the field of the photographic camera.

The use of the new device proves, furthermore, simpler it eliminates the causes of error depending on the auxiliary rotary organs of the known devices.

The shutter of the nine solar objectives is formed of a thin metal plate **13** (Figs. 8, 3, 4) through which are bored nine holes **7—7'** set in relative positions corresponding to those of the nine objectives. To the plate **13** is welded the cam **13'** provided with a groove within there acts the extremity of the lever **14** fixed to one end of the shaft **14'** (Fig. 9). The shaft **14'** is rotatable upon two supports fixed to the plate **5** and carries at the other end the lever **14''** to which are clasped at the upper part thereof the spring **15** (Figs. 1 and 9) and at its lower part a steel wire terminating in the ring **16**. The spring **15** acting on the lever **14''** tends to keep the shutters closed, while the traction exerted upon the ring **16** brings about the opening of same according to the position represented in Fig. 8.

The shutter-plate **13**, Fig. 4, presents furthermore the holes **17'*a*** and **17'*b***, which determine the passage of the light from the openings **17*a***, **17*b***, Fig. 8, produced in the cover and provided with two small silver-coated or varnished glasses upon which are engraved a small circle and a small cross, respectively, which are transparent. By means of the lozenge prisms **18a**, **18b** and of the underlying objectives, the images of the small circles and crosses are impressed on the film at *m* and *n* (Figs. 2 and 8). These images constitute the so-called "repère" indexes and serve the purpose of permitting the successive re-establishment of the film position during the use of the photogoniometer. The shutter-plate **13** further presents the perforations **19'a** and **19'b** (Fig. 4), which determine the passage of light through two holes pierced in the box-cover **1** in the corresponding positions **19a**, **19b** (Fig. 9). In correspondence with these two holes there are arranged within the box **1** two vertical tubes, of which that marked **20a** is to be seen in Figs. 8 and 9. On passing into this tube, the light is doubly reflected by the prism **20'a** so as to illuminate from below upwards a portion of the magnetic compass rose **21** (Fig. 8). As the rose graduation may be engraved, for instance, on transparent material, the objective **22** conveys the image thereof to *a* on the film **8**. To the vertical tube situated below the hole **19b** there corresponds a prism similar to that marked **20'a** (represented by the dashes in Fig. 9) so that on the film **8** there is also formed at *b* the image of a portion of the rose, disposed at an angle of 180° relatively to the preceding portion.

More simply, the rose of the compass **21** may consist in a thin metal plate into which there are cut small notches, from **10** to ten sexagesimal degrees. A number of auxiliary perforations, disposed, for instance, according to Fig. 6, permit the values of the "tens" of degrees corresponding to the photographed notches to be recognized.

The shutter plate **13**, (Fig. 4), finally presents a hole **21'** which determines the opening of an objective **24**, (Fig. 8). This objective, through the medium of an underlying lozenge prism and of the prism **25** located above, conveys to c on the film **8** the image of a small chronometer **26**.

To each traction of the ring **16**, exerted for a very short space of time by an electromagnetic device, which will be described; there would therefore be impressed upon the film **8** the image of the sun, that of the so-called "repère" indexes *m—n*, those of two diametral portion of the rose of the compass **21** (*a—b*) and that of the dial-plate of the chronometer **26** (*c*) Fig. 8.

The said photographs, according to the general principle already described, would be effected at each of the moments when the main camera takes a ground photograph.

But as the rose of the compass **21** is subject to oscillations, the device permits the obtaining of the diagram concerned by means of nine supplementary photographs, intercalated between those corresponding to two successive ground photographs. To this end, the film instead of running continuously for one time only, along the length extending from *m* to *c*, corresponding to the total field, advances at ten different times, equivalent to $\frac{1}{10}$ of the said length, alternating with as many stopping positions during which the electromagnetic device acts on the shutter-plate **13** for the purpose of enabling the taking of as many photographs of the compass. In order to avoid the taking—in the nine supplementary positions—of photographs of the solar disk and of the chronometer as well, there is arranged underneath the plate **13** an occulting plate **27**, Fig. 5, provided with holes corresponding to the positions of the nine objectives **7** and **7'** and of the objective **24**. In register with the objective **17*b*** a slot is provided. The sliding of this plate is controlled by the levers **28—28'** (Fig. 8) through a cam **59** connected to the film-unwinding cylinder. Within the box **2** the film to be exposed is unwound from the spoool **29** and passes successively round the roller **30**, between the glass plates **6** and **31** (where it receives the impression), on to the roller **32** and is finally wound round the spool **33**. The roller **32** is destined to cause the film to move forward by sections. To this end, two rollers **34** being integral with the shaft **35**, are driven against the shaft **32** by the springs **36** in order that the film way be compressed between the said rollers. Upon the shaft **35** is mounted the toothed wheel **37** which remains in mesh with the wheel **38** being integral with the roller **32**. The rotation of the rollers **34** is controlled by the rotation of the roller **32**, through the wheels **37—38**, so that the rollers **34** themselves also become motors with a view to the effecting of the forward movement of the film. The wheel **37** through the medium of the three intermediate gears **39—40—41**, transmits the motion to the recuperating spools **33**. The toothed wheel being co-axial with the spool **33**—as in all apparatus of this kind—is not integral therewith, but is mounted frictionally so as to permit the winding of that amount of the film only as is supplied by the motive rollers **32** and **34**. The rotation of the roller **32** is obtained through the action on the toothed wheel **42** of the small cam **43** carried by the sleeve **44**. The reciprocating motion of the sleeve **44** is obtained by means of the connecting-rod **45** and of the eccentric **46** being integral with the shaft **47**. The latter is, in turn, driven by the vertical shaft **48** through the couple of bevel gears **49—50**. As the wheel **42** is provided with ten cogs, at each revolution of the shaft **47** the film advances $\frac{1}{10}$ of the circumference of the roller **32** and in ten revolutions it advances by the length corresponding to the section *m—c*. In order that the film **9** may remain smoothly in contact with the glass plate **6** during its exposure, the lower glass plate **31** is mounted in a metal frame carried by the framing **51** by means of the bolts **52**. The framing **51** is supported on one side by the bolts **53** fixed to the box **2**, and on the other, by the appendages **54** resisting upon the eccentrics **55**, being integral with the shaft **47**. During the dextrous rotation of this shaft and the period of the stoppage of the forward movement of the film (return of the connecting-rod **45** towards the right) the eccentrics **55** cause the pressing of the film against the glass plate **8**. At the edge of the roller **32** a projection **58** acts on the lower appendage **28'** of the lever **28**, already described, so as to move the occulting plate **27** towards the right and to permit the opening of the solar objectives **7—7'** and of the chronometer objective **24**, once every ten partial forward movements of the film. In Fig. 2 are shown the various images formed on the film. There may be noted thereon the images, *m* and *n* of the so-called "repère" indexes, and the images *a—b* of two diametral portions of the compass graduation, in the ten positions corresponding to the partial forward movements of the film, while the images of the sun *s'* and of the chronometer *c* appear once only; in the period corresponding to the ground photography. At the film upper part there may also be noted, for each of the ten positions assumed thereby, the images *g* of a portion of the gyroscopic compass, and the images *p* in the form of a segment which illustrate through their shifting on the film, the slight pressure variations measured by the statoscope. These latter images *g—p* are thrown upon the film from below through the mirror **57** which is supported by the part **58** fixed to the box **2**. The said images proceed from special contrivances arranged within the lower box **3** to which the box **2** is rigidly connected by screws, in correspondence with the cams **58**. The box **3**, Fig. 1, carries laterally, at its upper part, a small box **60** which is fitted through a suitable guide-way against one of the walls of the box **2** in register with an opening which permits the mirrors **61—62** to throw back upon the mirror **57** the images of the gyroscopic compass and of the statoscope. A part of the box **60** is visible in Fig. 9 likewise. The statoscope, Fig. 1, is composed of a vacuum case **63** whose free wall acts on the tail-piece of a rotatable mirror **64** so that the slight atmospheric pressure variations cause corresponding rotations of the mirror. The case support **65** carries an objective **66** and a small box containing a small electric lamp **67**. A narrow slot **68** is cut in the upper wall of the box and the focus of the objective **66** so arranged that the slot image shall be formed on the film **9** through the successive reflections to the mirrors **64—61—62—57**. The slightest pressure variations are therefore recorded on the film with the shifting of the slot image. The said shiftings may be measured by any means, relatively to the central line defined by the indexes (repères) and a sampling may allow of the reception of the corresponding atmospheric pressure variation values. The manipulation from the outside of a button **69** provided with a disk **69'**, graduated according to the altitude concerned, allows of the conveying—at the starting of the flight—the image *p* of the slot **68** to an approximate fundamental position. The gyroscopic compass is constructed according to already known models, being composed for instance of a closed box **70** from which there starts an air-port **71** which there is connected a vacuum pump or a Venturi tube suction-tube, so as to draw a strong current of air out of a blast-pipe **72** which causes the rapid rotation about a horizontal axis of a small turbine constituting the gyroscopic mass. The axis of this small turbine is supported by a horizontal ring, supported, in turn (in the direction of a horizontal axis being normal to the preceding one), by a fork **73** that is rotatable about a vertical axis. This fork carries externally a ring **74** upon which a graduation is engraved. One wall of the gyroscope-containing box **70** is provided with a glass to which is fastened a small prism **75** destined to illuminate a portion of the graduation **74** by means of the lamp **67**. In correspondence with the illuminated portion, an index or nonius carried by the box **70** permits the reading off of the graduation indication. An objective **76**, with the aid of the mirrors **77—78—61—62—57**, produces on the film **23** the image of the illuminated portion of the graduation and of the relative index or nonius. The formation of the images of the slot for the statoscope and of the gyroscope graduation at the pre-determined moments, is effected through rapid lightings of the lamp **67** by means which will be described.

The box **3**, supports, by means of the bolts **79** and of suitable stays, the aerophotogrammetric apparatus **4** which, as already stated, is one selected from among already known types. In the connection of the apparatus **4** with the box **3** it should be ensured that the focal plane **80** (Fig. 1), of the apparatus and the focal plane **8** of the solar camera shall be parallel, with good approximation. The apparatus should, furthermore be selected from among those plate or film cameras in which the unwinding of the film (or the changing of the plates) and the winding up of the shutter are automatically effected through the turning, from the outside, of a cranked handle or the like, a determinate number of entire revolutions, for a cycle corresponding to the taking of a photograph. This external actuating organ has been represented by way of example by the cardan transmission **81—81'**. The said photographic apparatus must further be provided with an electromagnetic device for causing the instantaneous opening of the shutter of the appertaining objective, the circuit of which shall terminate, for instance, at the connectors. As aerophotogrammetric cameras provided with such device are already known, we will not describe the relative mechanisms thereof, which are to be understood to be excluded from the present invention. In order to the securing of synchronism between the running of the device forming the object of the present invention and the running of the apparatus **4**, a box **83** is provided containing two bevel gears by means of which the continuous rotary motion of a shaft **84** is simultaneously transmitted to the apparatus **4** and to the said device by the transmissions 81—81' and 85—85'. The transmission 85—85' causes, through the gears 86 (ratio 1/1) the rotation of the shaft 87, which is extended at the upper part, through the box 3 becoming connected through the joint 48' to the shaft 48 (Fig. 8). As the ratio between the gears 49—50 is equal to 1/2, 20 revolutions of the shaft 87, and therefore of that marked 84 also, are required in order that the roller 32 may perform one entire revolution. The ratio between the gears contained in the box 83 must be determined according to the camera at one's disposal. In the example of Fig. 1 the ratio 1/1 corresponds to the case in which 20 revolutions are also required to enable the apparatus 4 to complete an entire cycle. The shaft 87 terminates at its lower part in the tangential screw 88 which acts on the worm-wheel 89 so that the latter performs one revolution for every 20 turns of the screw. The wheel 89 is provided laterally with a star-disk having ten points, which, at each tenth of a revolution, cause the closure at 90 of an electric circuit comprising the battery 91 and the electromagnet 92. The latter, when the circuit is closed, attracts the armature 93, which, by means of the hook 94 carries along with it the lever 95. The end of this lever is connected by a steel wire to the ring 16 controlling the solar camera shutters (Fig. 8). Towards the end of the downward rotation of the lever 95 the lower appendage of the hook 84 strikes against the end of the support of the electromagnet 92, causing the disengagement of the lever 95 which is urged upwards again by the spring 15, (Fig. 8). The opening of the objectives effected by the shutter 13 is therefore instantaneous, independently of the closure of the electric circuit 90—91—92. The lever 95 is further provided with a tail-piece, carrying a metal tongue 96, insulated therefrom, by means of which there is closed an electric circuit comprising the battery 97 and the lamp 67 having the functions already described. The instantaneous lighting of the lamp 67 therefore occurs simultaneously with the opening of the solar shutters. The closure of the circuit at 96 brings furthermore about, through the medium of an insulating cam, the closure at 98 of an electric circuit comprising the battery 99 and the interrupter 100 which terminates at the binding-screws 82 of the inner circuit of the apparatus 4. The complete closure of the circuit of the apparatus 4 occurs in one position only of the wheel 89, in which, through the effect of a special eccentric mounted there upon, the interrupter 180 is also closed. The regulation of the transmission of the various movements is so effected that the closure of the circuit of the apparatus 4, and therefore the opening of the appertaining shutter, shall occur during the most suitable period of the cycle of the said apparatus and during one of the stoppages of the advance of the film in the solar camera 1.

The continuous rotary movement of the shaft 84 controlling the whole device, may be obtained through a variable speed electric motor, or else through a regulatable pitch fly, selected from among already known types. The whole device may be cardanically suspended by means of the gimbals 101, 102, while it may turn relatively to the fixed gimbal 103 in order to correct the deviation. A number of elastic tie-rods 104 may limit the pendulating oscillations about the joint 101—102. The aeroplane fuselage must be provided with an upper aperture adapted to permit the taking of sun photographs and with a lower aperture for ground photography.

To recapitulate—the photographic surveying apparatus as described by way of example, permits the taking of photographs of the sun, of a chronometer, of two compasses (one magnetic and the other gyroscopic) and of a statoscope at each of the moments when the main camera takes a ground photograph. Furthermore, in the interval between one photograph and the next following the apparatus allows of the taking of nine further auxiliary photographs of the two compasses and of the statoscope.

The photogoniometric device forming an integral part of the surveying apparatus, is represented in Figs. 10 and 11. It comprises a box 105 containing a glass plate 106 supported by four springs 107 fixed to the box sides and a set of lamps 108 for the illumination of the film. The film obtained by means of the camera as described, is wound, after necessary operations of developing, fixing and drying, on to the spool 109 from which it is unwound in order to pass on to the glass 106 and to be taken up by the spool 110, as the photogoniometric measurements are made, one after the other. With a view to immobilizing the film in each position approximately corresponding to the duration of an exposure, the screws 111 acting on the cams 112 are tightened. By the unscrewing of the four buttons 113 (Figs. 8 and 9) connecting the box 2 to the solar camera 1, the latter may be removed from the photographic apparatus and mounted on the photogoniometer box 105, as is apparent from Figs. 10 and 11. The chronometer 26 and the prism 25, together with their support, may be removed from the solar camera by unscrewing the screw 114. There may then be applied on the solar camera the photogoniometric device properly so-called, which is constituted by the fixed ring 115 upon which rests the ring 116, rotatable upon balls. The ring 115 is integral with the ring 117 which carries a helicoid teeth-ranges acted upon by the tangential screw 118 carried by the ring 116. The turning of this screw by means of the appertaining button, occasions the rotation of the ring 116 while a microscope (estimation microscope, for instance) 119 carried by same permits the angular readings of a graduated ring 120 integral with the solar camera. The telescope 121, destined to effect the pointing at the sun image is carried by the bridge 122 rotatable on the pivots 123—123' (Fig. 10) about an axis normal to that of the ring 116. A graduated sector 124, also carried by the ring 116 is provided with a helicoid teeth-rack 125 acted upon by a tangential screw 126 carried by the support 127 connected to the bridge 122; wherefore the turning of the screw 126 causes the turning of the telescope about the axis 123—123', while an (estimation) microscope 128 carried by the support 127 permits the effecting of angular readings on the graduation 124. The telescope 121 is therefore endowed with two angular movements, one which will be termed azimuthal in the plane of the ring 116, or about the normal to the focal plane 6; the other, which will be termed zenithal, about the axis 123—123'. The origin of the graduation on the sector 124 is so established that the microscope 128 shall observe zero when the telescope axis is normal to the focal plane 6. The telescope 121 is, as a rule, adjusted for infinity. The axis 123—123' is decentred relatively to the axis V P of the solar camera in order to permit the telescope lens to collect the rays proceeding from two or three solar objectives 7—7′ in the conjunction zones of the relative fields of view. In order to secure the re-establishment, as regards the solar camera, of the positions assumed by the film during the successive exposures, the small tubes which in the camera carry the small glasses 17a—17b (upon which a small black circle and a small black cross are, respectively, engraved upon an opaque background) are replaced by the small tubes 17′a and 17′b carrying small glasses upon which a small black circle and black cross are respectively engraved upon a transparent background. As soon as the film has been fixed in an approximate position by means of the binding screws 112, the screws 129 are acted upon, thus causing the solar camera to perform slight shiftings relatively to the film until the small circle and cross (repères) images *m*—*n* are brought by the objectives 18a—18b into correspondence with 17′a and 17′b. The coincidence is observed at 17′a through the microscope 130a whilst it is observed at 17′b through the microscope 130b, which is brought into the correct position through the rotation of the arm 131 and subsequently excluded in order to permit the complete zenithal rotation of the telescope 121.

The connection between the solar camera and the ground photography camera 4 is established in such a manner that the microscope 118 points to zero on the graduation 120, when the plane in which the telescope 121 rotates zenithally is parallel to one of the axes of the photogram in the camera 4, defined, for instance, by the (so-called repères) indexes *i*—*i′* of Fig. 7. Considering, in this figure, the centre of sight relating to the solar objective (utilized) to be hypothetically coincident at V with that of the camera 4, and at F the (positive) ground image, the angles $\alpha\phi_p$ shown in the figure correspond, respectively, to the azimuthal angle read off the graduation 128 and to the zenithal angle read off the graduation 124, during the collimation to the sun image on the film. In order to the effecting of the reading off the azimut indicated by the magnetic compass the ring 119, (Figs. 10 and 11), carries, by means of a support 132, a special microscope 133, composed of a tube within which are arranged the right prism 134—135 and the objectives 134′—135′ which bring the images *b*—*a* of the diametral compass graduations in to the focal plane of an eye-lens 138 wherein a vertical thread index is disposed. The angular movements of the microscope 133, required for obtaining the collimation, are effected through the turning of the screw 118, while the angular readings are still effected by means of the microscope 119. Instead of two successive collimations at *a* and *a*—*b* being effected, and therefore, two angular readings, the simultaneous collimation at both points may be obtained through the tube of the microscope 133 being rotated about its own axis by means of the appendage 137, which eliminates the rose eccentricity effect. As the azimuthal angle formed between the axis of the microscope 133 and the plane of movement of the axis of the telescope 121 has a known constant value γ, and as the value is also known, in tenths of degrees Cr corresponding to the couple of collimated compass marks *a*—*b*, the reading of the angle β effected with the microscope 133 permits the reception of the magnetic azimut ($\theta\, i^1 m$) at the valve for the photogram axis *i*—*i′* by means of the algebraic sum $\theta i^1 m = Cr(\beta+\gamma)$. The magnetic azimut, corrected by the known local declination and by the eventual deflection induced by the magnetic masses on board, assumes a value θi^1 expressing the geographical azimut assumed by the axis *i*—*i′* of the photogram of the camera 4, at the moment of exposure (Fig. 7). By the addition to the angle θi^1 of the azimuthal angle α read off the photogoniometer in the collimation to the sum image S[1], the azimuth θ_p is obtained of the plane containing the solar direction and passing through the periscope axis (and hence through the axis of the camera 4) ($\theta i^1 + \alpha = \theta_p$). The azimut θ_p would be identified with the true solar azimut θ_s (obtained together with ϕ_p of the astronomical calculation, being based on the time of day when the photograph was taken and on the approximate geographical coordinates of the camera station) should the periscope-camera axis P V P[1] lie in the vertical plane Z V S.

Instead, there generally exists a difference ($\theta_s - \theta_p = \epsilon$) that may be transfered with sufficient approximation to the horizontal plane N R K and which, precisely, permits the calculation of the angle λ forwed between the two planes P V S & Z V S. In effect, by resolving the spherical right angled triangle S K E, at K (known: $SK = 90° - \phi_s$ and ϵ) it is possible to ascertain the value of the angle λ. By successively resolving the spherical oblique angled triangle ZPS (known: ϕ_s, ϕ_p and λ) the angle at Z and the side ZP may be calculated. The angle at Z expresses the azimutal difference between the vertical plane ZS (of known azimut θ_s) and the vertical plane ZP containing the periscope axis V P, while the side ZP expresses the value of the inclination of the said axis relatively to the vertical V Z. In fine, the value of the angle at P, that may be deduced from the said triangle Z P S, subtracted from the angle α, expresses the swing of the axis *i*—*i′* of the photogram F (orientation) relatively to the plane PVZ, of already known azimut. In case there should, instead, be pre-established a restitution azimut $VR = \theta_s + \delta$ (corresponding, for instance, to the component x of the aerial base and to the axis X of the plotting apparatus writing table) there being predisposed in the said apparatus in order to the outer orientation of the photogram, as the primary axis that of transverse inclination τ, coinciding with the bass component x, as secondary axis that of longitudinal inclination ψ, and as the tertiary axis that of the swing (ω), the calculation may proceed as follows:—First the right-angled triangle SKE is once more calculated, from which there are deduced the values of the angle $\hat{E}$ and of the side SE (p). Thereupon the triangle P E R is calculated there being known the side $ER = \epsilon + \delta$, the angle $\hat{E}$ and the side $PE = \phi_p + p$ from which the values of the angle at R, of the side RP and of the angle at P. The value at R defines the value of the transverse inclination τ of the periscope-camera axis (PVP[1]) referred to the horizon RE. The side RP expresses the value ψ of the longitudinal inclination, referred to V R and the angle at P, added to the angle α, defines the value (ω) of the swing of the axis *i*—*i* of the photogram referred to the plane PR.

As the value of the angle ϵ is approximate, inasmuch as it proceeds from an azimut furnished by the compass a fresh calculation of the aforesaid triangles S K E and P E R may be effected, a new value being attributed to ϵ, varied, for instance by ½ a degree. There will thus be obtained a new trio of values ($\omega' \psi' \tau'$) whose differences $(d\omega d\psi d\tau)$ with the preceding values, allow of the establishing of the incremental ratios

$$\frac{d\psi}{d\omega}, \frac{d\tau}{d\omega}$$

and between a slight variation of swing and the consequent variations of longitudinal and transverse inclinations. According to the mode of procedure already described, as soon as the first pair of photograms (I & II) has been placed in the plotting apparatus, containing the starting base, with the primitive angular values $(\omega I \psi I \tau I, \omega II \psi II \tau II)$ the swing of each photogram is rectified on the said base, and the variations of swing $(\Delta\omega I \Delta\omega II)$ obtained, which on being multiplied by the aforesaid incremental ratios, permit of the rectifications being made in the longitudinal and transverse tilt, the definitive correct angular setting of each photogram being thus obtained, as if each of same had actually turned during the rectification of the swing, about the appertaining solar direction. The proportioning of the optical model on the starting base is effected in the ordinary way while the connection to the successive photograms is realized in the manner already indicated by means of rectifications of the swing of each photogram relatively to the preceding one and the consequent incremental rectifications in the longitudinal and transverse tilt. The size transfer from one model to that next following is effected in the already known manner, by means of the height of a feature selected in the zone of conjunction of two successive models.

The use of the gyroscopic compass is effected as follows:—After the first pair of photograms has been placed on the starting base, there are obtained from the plotting apparatus the values of the actual swingings $(\omega I \omega II)$ of the axis i—i' for the said photograms, which enables the determination of the initial state of the gyroscopic compass. After the final pair of the series has been placed in the plotting apparatus, on the arrival base, the final state of the gyroscopic compass may be similarly determined and the total precession value then computed. This value, divided by the number of intermediate view points plus one, enables the making of the gyroscopic azimut corrections **9** for all the intermediate photograms of the series.

When effecting the calculations of the triangles SKE and PER, it is possible with the (corrected) values obtained from the gyroscopic compass, to obtain, in work of limited requirements, to effect the definitive angular setting of the photograms without any incremental corrections having to be made. In case in which it is deemed advisable to rectify the swing of each photogram in respect of the preceding one, the use of the gyroscopic compass enables the attainment of greater precision and rapidity owing to the fact that the extent of the rectifications is reduced.

The statoscope registrations, as already stated, are made use of with the solar apparatus in order to reveal systematic errors in the size transferring from one optical model to the next, by means of the progressive differences made manifest between the heights supplied by the statoscope and those recorded by the plotting apparatus.

The height variations of the view-points furnished by the statoscope may similarly to the already known methods, also be directly utilized for the purpose of imposing on the successive view-points the vertical (bz) component of the air base, in the exceptional cases in which the course of the airplane is nearly normal to the direction to the sun and that the height of the latter above the horizon is inconsiderable. In this case, too, after the said vertical component (bz) has been imposed, the photograms are set in the plotting apparatus according to the angular values $(\omega\psi\tau)$ supplied by the solar apparatus. Successively, suitable rectifications of longitudinal tilt $(\Delta\tau)$ combined with corresponding rectifications of swing $(\Delta\omega)$ and of transverse tilt $(\Delta\psi)$ are effected according to the computed incremental ratios

$$\left(\frac{d\omega}{d\tau} \frac{d\psi}{d\tau}\right)$$

until the vertical parallaxes have been annulled for four points of the model approximately situated at the corners. The definite longitudinal tilt for each photogram of the series is obtained in function of the statoscopic values, as in the known processes, but with the simultaneous use of the other elements supplied by the solar apparatus, the swing and the transverse tilt values are defined with considerable exactitude, independently of the corresponding values of the preceding photogram, which constitutes a real progress as compared with what is known.

In the form of execution so far described, assuming that the camera axis instead of being parallel to the solar camera axis forms an angle **c** with the latter, the plotted ground model proves tilted by the same angle **c**, as shown in Fig. 12. In a further form of execution (Figs. 13 to 20, inclusively) the surveying photographic complex is caused to rotate alternately during flight by 180°. Thus, (as shown by Fig. 13)—the two halves of the photogram being designated *m* and *n* the exposure field *m* of the photogram **0** will be found to correspond, on the ground, to the exposure field *m'* of the photogram **1**, and successively, *n'* to *n* and so on, so that the plotted model is not subject to the tilting depending on the defect of parallelism, referred to above, between the terrestrial camera axis and the axis of the solar camera. By this proceeding there are also compensated the defects of projection depending on an erroneous definition of the principal point which is equivalent to a tilting of the photogram relatively to the axis, as shown in the said Fig. 13, and on other anomalies due to optical or mechanical causes, of one half of the field appertaining to the camera *m* relatively to the other half *n*. The compensation also takes place in connection with the projection anomalies of the plotting apparatus camera, inasmuch, as is apparent from Figs. 17, 18, 19, & 20, the photograms are rotated by 180° when proceeding from the plotting of one pair to that of the next.

With a view to obtaining the continuous rotation of the photographic complex, the external controlling means instead of terminating at the small shaft **84** of Fig. 1 of the principal patent, terminates at the small shaft **84'** of Fig. 15, which, through the gearing **140**, acts on the spur-gear **141** derived from the ring **102**. The latter is thus able to rotate continuously relatively to the ring **103** (fixed to the airplane) carrying the whole photographic apparatus along with it.

The ring **102** carries an appendage **102'** supporting a cylindrical pinion **142** (Fig. 15) in mesh with a spur-gear **143** carried by the ring **103**.

During the continuous rotation of the whole photographic complex about its own vertical axis, the pinion **142** is compelled to turn, transmitting its motion to the photogrammetric apparatus **4** through the transmissions **81'**—**81**, and to the solar camera through the couples of gears 83'—86.

As in the example described in the first form of execution, the connecting shafts to the apparatus 4 and to the solar camera were required to perform 20 revolutions in order to the completion of an entire photographic cycle (corresponding to one ground photograph) the ratio between the pinion 142 and the spur-gear 143 must be 1/40 so that to each half-revolution of the photographic complex there corresponds one whole photographic cycle. The various phases of the apparatus may readily be adjusted in such a manner that the release of both the shutters occurs when the pinion 142 is brought into correspondence with two opposite teeth of the spur-gear 143, situated on a diameter being parallel to the longitudinal airplane axis.

For the purpose of ensuring that at each moment at which a ground photograph is taken one of the sides of the terrestrial photogram shall be found oriented in accordance with the actual course of the plane, the spur-gear 143 may be turned in one direction or in the other of the deviation angle value by means of the pinion carrying the crank 144 which acts on a sector 145 connected to the said spur-gear 143.

With a view to avoiding any dragging effects on the rose of the compass 21 during the continuous rotation of the photographic complex, the appertaining box 21' is mounted rotatably and carries the spur-gear 146 round which passes a small continuous chain receiving motion from a pinion 146' mounted on the small shaft 48 which, according to the first form of execution, acts on the solar camera controlling organs. The ratio of movement between the pinion 146' and the spur-gear 146 is, according to the said example, 1/40, and the direction of rotation of the box 21' is opposed to the direction of rotation of the whole complex, whereby the box 21' is oriented.

With a similar end in view, the support 73' of the fork 73 of the gyroscope directing means is made rotatable and receives movement through a small chain from a pinion 87' mounted on the small shaft 87. Fig. 5 shows, in section, the schematic arrangement being also available for the transmission connection to the compass.

In the plotting apparatus cameras the photograms, corresponding, for instance, to the exposure points o and *l* of Fig. 13, are mounted as indicated in Figs. 17 & 18. To this end, the rings 147 & 148 of the cameras carry, at their upper and lower parts, a pair of projections with supporting counter-screws, which be engaged by each tail-piece of the small photogram-carrying frames 149*a* & 149*b* in an upward and in a downward direction, alternately.

In order to ensure that the photogram 1, for instance, shall turn by exactly 180° during its passage from the positions of Figs. 17 & 18 to that of Figs. 19 & 20, there is connected to the said small photogram-carrying frame a double curvature level 150 with its relative bubble-centring screws. Suitable reversing organs of known type, previously disposed in the plotting apparatus between the carriage and the writing board enable the preservation of the orientation of the drawing.

The second form of execution further provides a new objective in the solar camera, of an extensive external field of view: same is composed—as shown in Fig. 14—by a negative lens placed before a normal objective. This objective takes the place of the nine objectives according to Figs. 8 & 9 of the first form of execution.

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