MACHINE FOR CALCULATING POSITION (*)

(Le Sort System — *Patented*)

Constructed by the Ateliers J. Carpentier, 20, Rue Delambre, Paris (14e)

It is generally known that the problem of fixing the ship's position at sea consists in calculating the unknown quantities *H* (altitude of the heavenly body) and *Z* (azimuth of the heavenly body) in terms of the data: — *L* (estimated latitude), *D* (declination of the heavenly body) and *P* (the hour angle of the body).

H must be determined very closely. It is usually calculated by logarithms by means of the following formula :—

$$\sin H = \sin L.\ \sin D + \cos L.\ \cos D.\ \cos P$$

The azimuth may be determined to the nearest degree.

For a trained and experienced navigator the calculation of the ship's position requires about ten minutes. It necessitates considerable mental concentration however, if no error is to be made in the signs, the logarithms or in the various operations.

The fear of making a mistake in the calculation, the result of which may cause the vessel to be put off her course or even lead to the loss of the ship, is ever present in the minds of navigating officers, because they know from experience that even the most expert are never entirely exempt from error, since there is no possible method of checking the calculations.

For the past fifty years a large number of seamen and scientists have sought to simplify the calculations for position in order to diminish the chances of error and above all to make them more rapid. They have endeavoured to substitute the use of special tables for that of logarithms (in France, for instance, the tables of Delafon, of Souillagouet, of Bertin, of Commander Guyou, Member of the Institute, and others have appeared).

None of these new methods has succeeded entirely in gaining the favour of the mariner who has always preferred, and always will prefer, the use of logarithms because with this method he knows what he is doing and therefore there is less chance of a mistake. All of the above-mentioned tables are based on special and complicated theoretical considerations which may easily be forgotten, the more so since one is required to recall the various and numerous cases which may arise in each of them. The user is therefore compelled to follow blindly the rules given for the employment of the tables without understanding them — a practice which fails to inspire complete confidence in them.

(*) Extracted from a pamphlet published by Ateliers J. Carpentier, Paris.

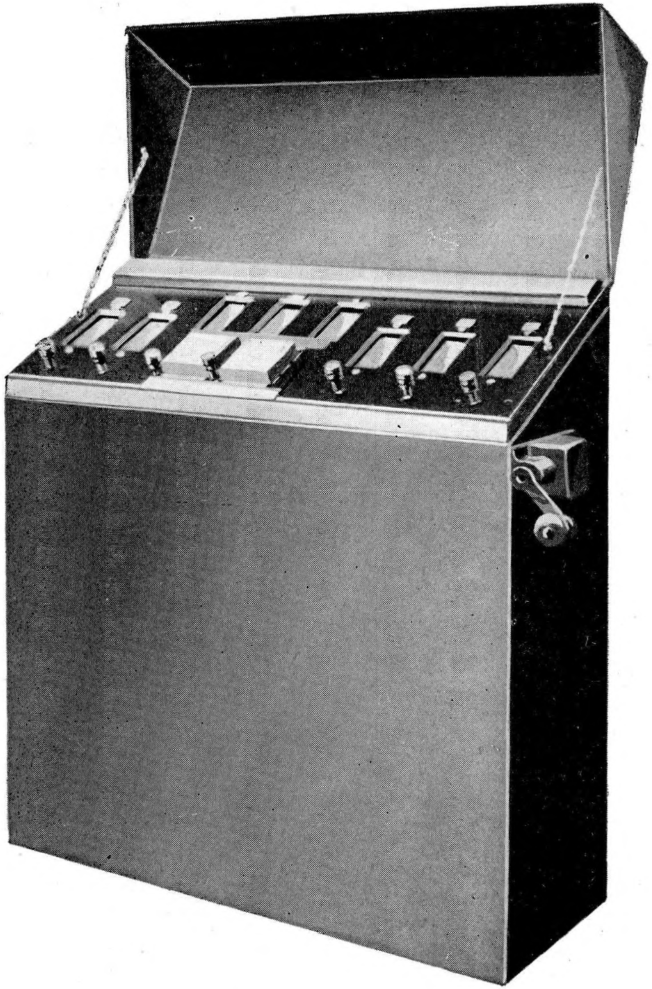


Fig. V. — Type M.

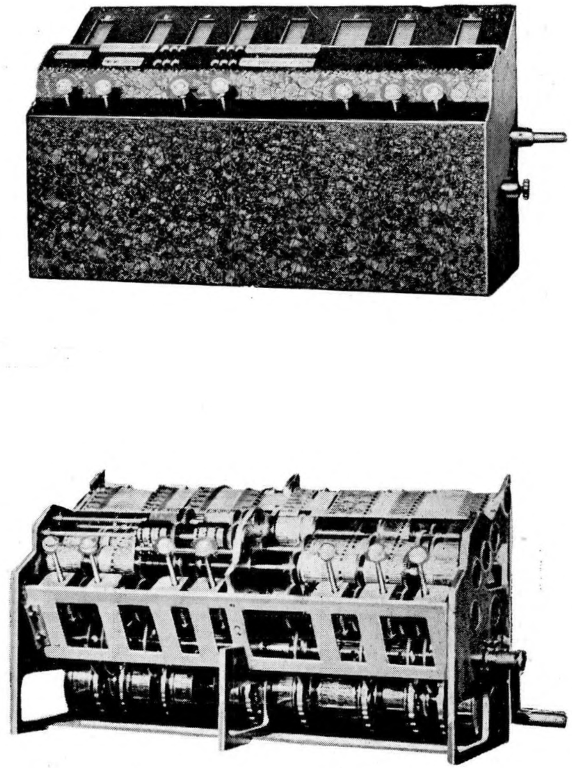


Fig. VI — Type A

Machine for calculating position — Machine a calculer le point

When the art of diagrammatic representation first appeared, an attempt was made to solve the problem of fixing the position by the use of diagrams such as, for instance, the FAVÉ and ROLLET DE L'ISLE diagram. Little success was achieved along these lines however, because a diagram, except of dimensions which are prohibitive, is not always able to give the requisite degree of accuracy.

Advantages of the calculating machine. — In the calculation of the ship's position at sea, the main object is to obtain the results with :—

1. the greatest possible rapidity ;
2. every possible guarantee of accuracy.

It may be stated that there is no other problem in which the use of a calculating machine would be better than in that of fixing the ship's position at sea.

The machine invented by Captain LE SORT and constructed by J. CARPENTIER'S Works, appears to have solved the problem completely. Based on a novel principle it is simple and incapable of derangement, since it has gear wheels which are always in mesh and are not thrown in and out of gear. Consequenlty there is nothing to get out of order.

The three principal advantages *viz,* great rapidity of calculation ; great accuracy in the result and elimination of the causes of error, are fundamental. With this machine, which can be installed in the wheel house, the calculation can be made on the bridge itself or in the chart house and requires only the time necessary to determine the data to be set on the dials. The position can therefore be plotted on the chart a few moments after the observation.

In practice, it is usually only the navigating officer who takes observations and makes the calculations. In any case the Commanding Officer has confidence in the results furnished by this officer only, since he alone is experienced and is less liable to make mistakes. The other officers, unless they receive direct orders to do so, take few observations because the calculations which must follow are tiresome, because they have too little time for this work and also because they do not wish to take the trouble to make calculations to which they are not accustomed and the result of which may perhaps be wrong. Sextant observations are not displeasing to them and might prove a welcome distraction were it not for the disagreeable calculation which follows. In those vessels which have a calculating machine all the officers will doubtless amuse themselves by determining the ship's position. Further, the petty officers and even the other ratings such as the helmsmen may readily be trained to manipulate the sextant, which simply requires a slight amount of practice. As soon as they are competent to take observations they are able to calculate the position of the ship since no theoretical knowledge is necessary. The vessel may then navigate at sea by star observations almost as easily as in sight of land by bearings of the coast.

When sextant observations are taken it is usual to take several altitudes of the heavenly body observed. Since it is impossible to work out all these altitudes by the ordinary methods, it is customary to make the calculations with one or two altitudes which are chosen from the series — those being selected which inspire the greatest confidence. The machine has the very great advantage of permitting all of the observations in the series to be used. Therefore, by comparing the results, we have a means of determining which of the observations are in harmony and of eliminating those which are poor, thus getting rid of accidental errors of observation and using the mean of the results which are retained.

It is evident that in aircraft it is impossible to make calculations by logarithms. Besides, in aircraft of very high speed the result of an observation must be known immediately after the observation. A quarter of an hour

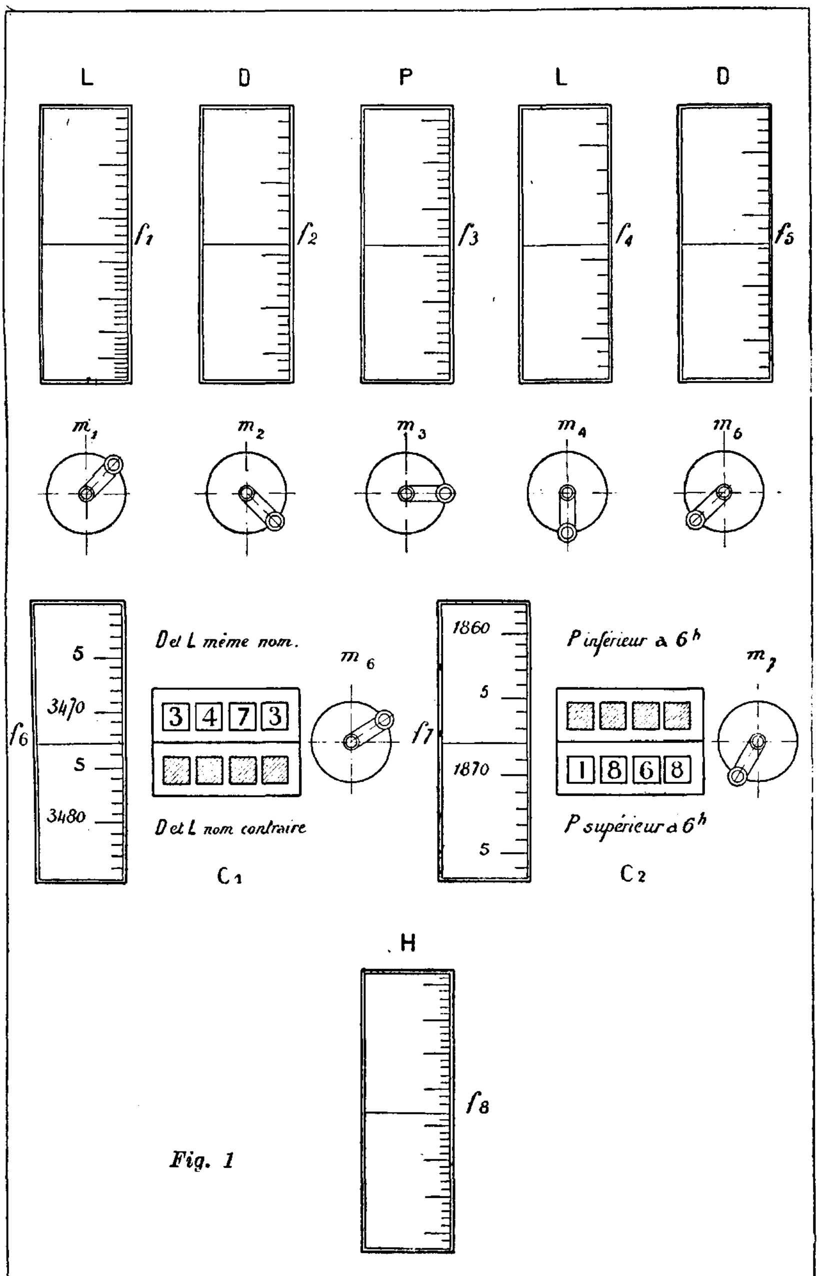


Fig. 1

later the aircraft may have moved a distance of 40 or 50 kilometres and drifted an unknown distance; the result of the calculation has therefore lost all interest.

If the calculating machine is useful for navigation at sea, it may be said that it is indispensable for aerial navigation.

DESCRIPTION OF THE MACHINE

External appearance. The calculating machine patented by LE SORT is in an hermetically sealed box in the form of a parallelepiped, on one of the sides of which there are the eight windows, f_1, $f_2 \ldots f_8$ and the two dials C_1 and C_2. (Fig. I)

Each of these windows is fitted with a glass, in the middle of which is engraved a fine horizontal line which serves as an index. Under the glass a celluloid band, graduated either in numbers or in angles, may be moved either automatically or at will. (Fig. II)

The voluntary displacement of the bands is done by means of the handwheels m_1, m_2, m_3, m_4, m_5. In order to set to a certain angle or number, the handwheel is turned until the desired graduation appears under the fine line engraved on the glass.

The windows f_1, f_2, f_3, f_4, f_5 are marked L, D or P, and the window f_8 is marked H.

In order to obtain the unknown quantity H the following operations suffice :—

1. Set f_1, f_2, f_3, f_4 and f_5 to the values of the data L, D and P.
2. Turn the dial C_1 to the number indicated by f_6 and the dial C_2 to the number shown by f_7.

Operation of the machine. We have stated that the formula which gives the value of the unknown quantity H in terms of the data is :—

$$\sin H = \sin L \sin D + \cos L \cos D \cos P \qquad (1)$$

Let :

$$a = \sin L \sin D \qquad (2)$$
$$b = \cos L \cos D \cos P \qquad (3)$$

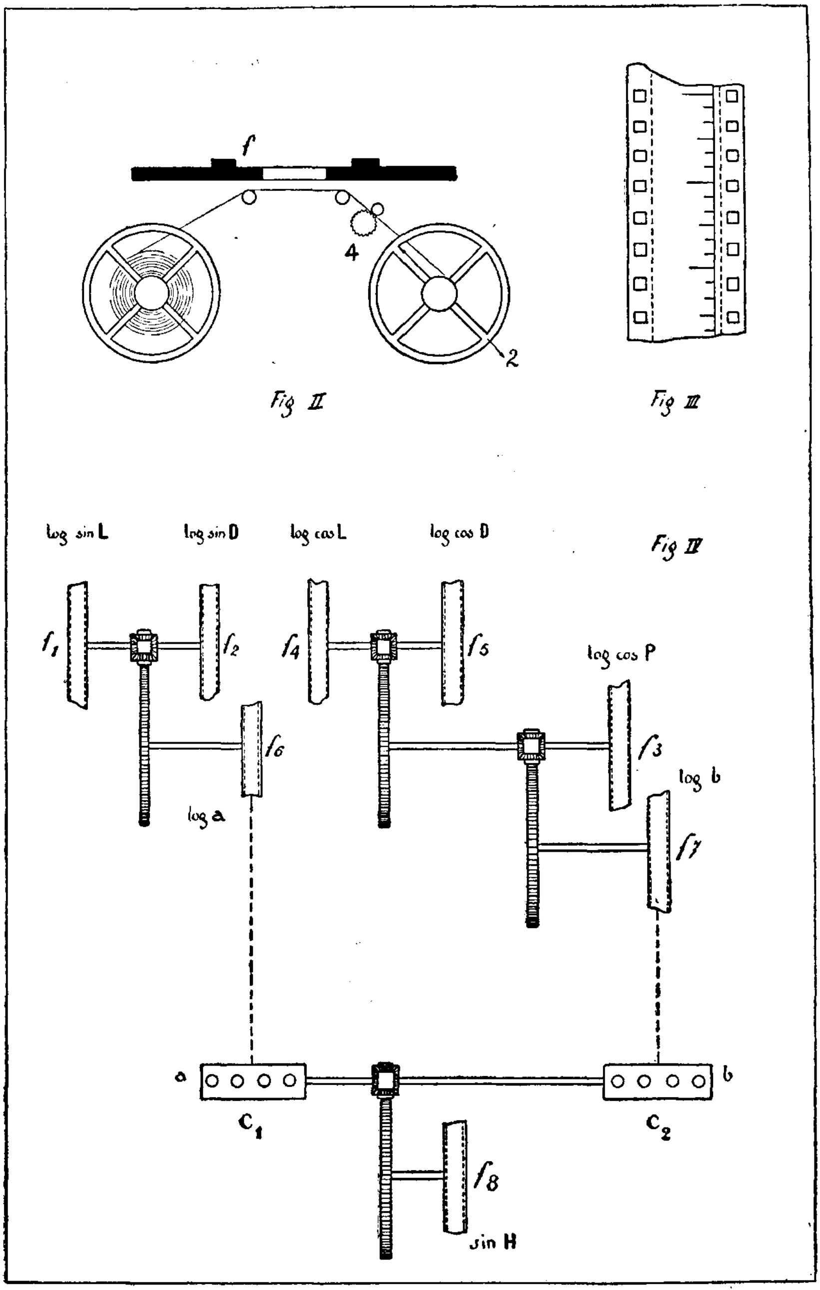
Then :—

$$\log a = \log \sin L + \log \sin D \qquad (4)$$
$$\log b = \log \cos L + \log \cos D \log \cos P \qquad (5)$$
$$\sin H = a + b \qquad (6)$$

The celluloid bands f_1, $f_2 \ldots f_8$ are the usual type of commercial cinematograph films. These films are graduaded in *log sin*; *log cos*; and the logarithms of numbers. (Fig. III)

All the materials used in the construction (films, hand-wheels, gear-wheels, rollers, etc.) are identical in all respects with those employed in the cinematograph industry, and they have already been fully tested in practice.

In cinematography, the gear wheels play a very important role; they not only serve to wind the film, but above all to hold the film in rigorously exact position in front of the objective. In this machine the wheels have an



equally important role. While they serve to move the film, one may say also, that the film serves to regulate the position of the gear wheels; or, in other words, when the film, starting from the zero position, is unrolled until the graduation *m* appears on the index line of the window *f*, it causes the gear wheel to be turned through a certain number (and fraction) of revolutions which is exactly proportional to *log sin m*, *log cos m* or *log m* as the case may be.

It follows directly from these considerations that a lengthening or a shortening of the film will have no influence whatever on the accuracy of the result.

a) Solution of equation (4) (Fig. IV)

Equation (4) is solved by films f_1, f_2 and f_6.

The films f_1 and f_2 are graduated in *logs sines*.

Film f_6 is graduated in *logs* of numbers.

If we set the value of L on film f_1 and D on film f_2, the gear wheels operating these films will turn through a certain number of revolutions (and fractions of a revolution) exactly proportional to *log sin* L and *log sin* D. A differential then adds the number of revolutions made by these gear wheels and film f_6 records the number required by equation (4).

b) Solution of equation (5)

Equation (5) is solved by the films f_3, f_4, f_5 and f_7.

Films f_3, f_4 and f_5 are graduated in *logs cos*.

Film f_7 is graduated in *logs* of numbers.

If the values of L, D and P are set on films f_4, f_5, f_3 respectively, the train of gears will function as described above and the differential will produce the result recorded by film f_7 or the number b required for the solution of equation (5).

c) Solution of equation (6)

The number a recorded by film f_6 is set on dial C_1.

In the same way the number b recorded by film f_7 is set on dial C_2.

C_1 and C_2 are simply revolution counters the figures of which are totalled by a differential which drives film f_8. This is graduated in *sin* H and therefore the required value H may be read off directly from film f_8.

Details of Construction :

a) In actual practice there is not a special handwheel for each film, as represented diagrammatically in fig. 1.

There is a single crank M and 7 clutch knobs b_1, b_2... b_7. These knobs are milled and serve also for the fine adjustment of the film in its proper position. By turning one of these knobs the corresponding film is moved very slightly and thus the exact adjustment of the graduations on the film on the index line can be made with ease.

b) Each of the counters C_1 and C_2 is composed, in reality, of two identical but distinct counters which are geared into each other. They are so adjusted that both will indicate zero at the same time. If the cranks are turned in the positive direction, the upper counter will indicate zero, 1, 2, 3, etc. and the lower counter zero, 9999, 9998, 9997, etc. successively.

The reverse occurs when the cranks are turned in the negative direction.

Otherwise stated, the sum of the two numbers marked by the two counters is always equal to 10,000.

This arrangement is made for the purpose of taking into consideration the signs of the numbers a and b given in equations (2) and (3) and to obtain the result of the algebraic addition $a + b$ on film f_8.

An automatic device, operated by a lever in the counters, causes a shutter to be moved in such a manner that if a or b is positive, the corresponding counter will be uncovered or the reverse. The lever acts on the shutter at the moment the two counters pass through zero.

Instructions are plainly engraved alongside the counter to inform the operator which counter should be used.

The upper counter is marked : *D* and *L* of the same name, and the lower counter : *D* and *L* of opposite names.

The operator then knows without the slightest hesitation that if *D* and *L* are of the same name the upper counter should be used for the number *a*. If the counter is closed by the shutter, he then turns the crank *M* in the direction necessary to bring the lower counter to the zero point, which automatically causes the shutter of the upper counter to lift.

In the same way, the upper counter of C_2 is marked : *P* less than 6 hours, and the lower counter : *P* greater than 6 hours.

With this arrangement error in the sign becomes absolutely impossible. The advantage derived from this is considerable as it is well known how often errors in determining the ship's position have been caused through a mistake in the signs during calculation.

Calculation of Z.

In making the calculation for the ship's position it will suffice to take the azimuth to the nearest degree.

A special slide rule which gives the value of *Z* immediately is attached to the lower cover of the machine . One has but to move the graduation *P* opposite the graduation *H* and read off *Z* opposite *D* (1).

ACCURACY OF THE MACHINE.

The operation of the machine may be compared exactly to a slide rule of very great length. The closeness of the approximation of the result is evidently dependent on the length of the films used.

The CARPENTIER Works have constructed two types of machines : one for maritime navigation (Type *M*) and the other for aerial navigation (Type *A*). These two types differ in the lengths of the films only.

Machine for Maritime Navigation (Type *M*). (Fig. V)

The calculations for the ship's position at sea need not give results closer than one half minute of arc, but navigating officers have been accustomed, when working with logarithms, to seek accuracy to within about 3/10ths of a minute.

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(1) It should be noted here that the machine permits the determination of *Z* with very great accuracy once *H* has been determined.

We have the formula :

$$\sin D = \sin L \sin H + \cos L \cos H \cos Z.$$

Consequently we proceed as follows :—

Turn the two films *D* to record the value of *H*.

Turn the counter C_1 to the number indicated by f_6.

Work counter C_2 until the film f_8 indicates the value of *D*.

By moving film f_3, cause film f_7 to show the number indicated on counter C_2.

Read off *Z* on the film *P* (f_3).

Since this machine can very easily give the desired approximation, it was considered necessary to construct it to give an accuracy at least equal to that which officers are accustomed to reach.

The machine gives H rigorously correct within 3/10ths of a minute of arc To obtain this result the films employed have lengths of between 50 and 100 metres.

The type M machine (maritime navigation) is of the following dimensions: $0.50 \times 0.50 \times 0.20$ metres ($20 \times 20 \times 8$ inches).

The weight is about 41 kg. (90 lbs.)

Machine for Aerial Navigation (Type *A*). (Fig. VI)

For aerial navigation the approximation is not generally required to exceed 5 minutes of arc.

The machine, of the aerial navigation type, gives H within 3' ; that is, the position is determined with an error not exceeding 6 kilometres (3.25 nautical miles).

It is fitted with films, the length of which varies from 4 to 25 metres only. The relatively short length of these films has made it possible greatly to reduce the dimensions of the machine which are as follows :—

Length 0.35 m. (13.8 ins) ; breadth 0.135 m. (5.3 ins.) ; height 0.20 m. (7.9 ins.).

The machine weighs about 7kgs. (15.4 lbs.)

NOTES ON THE USE OF THE MACHINE.

Check on Calculations.

In most calculating machines a check on the accuracy of the calculation can be obtained only by repeating the entire operation. In this machine, all data used remain "recorded". It is easy therefore to see at a glance whether the films had been properly arranged in accordance with the data and the counter settings correctly made.

Work preliminary to the calculation.

The quantities L (latitude) and D (declination of the sun) vary very little from day to day. Consequently the positions of the films L and D need only be changed by a few centimetres from one observation to the next. Further, they may be set approximately before the observation is taken.

This feature is of particular importance in the M type in which the films are relatively long.

For the machine of A type, in which the films are short, the setting of the films is accomplished very rapidly whatever their initial position may be.

Treatment of a series of Altitudes.

When using several altitudes of one series of observations, the settings of the four films L and D and the counter C_1 need not be changed, for they remain the same for all observations of the series. It will be necessary to change the film P and the dial C_2 only. This is very quickly done.

General Use.

The uses of the machine are very general. It may be employed for all star observations (except Polaris) in all latitudes and at every season of the year. It may be employed also for circummeridian and circumzenithal observations.

However, it cannot be used for values of P comprised between 5 h. $57^m 42^s$ and 6 h. $02^m 18^s$; that is, during $4^m 36^s$ — a negligible interval.

Special Plate.

Inside the cover of the machine there is a plate made of special material on which the tables of altitude corrections are engraved. The principal elements of the observable stars may be inscribed on this plate in advance. Finally there is a special frame, prepared as a form for calculation, in which the additions and substractions necessary for the preparatory work of the calculation can be made in pencil. This may also be employed to plot the results, obtained with the machine, graphically.

The machine for calculating the position appears to provide a final solution of the problem of astronomical navigation in aircraft.

It has been seen that the machine is so arranged that the calculation for position may be made without books, notebooks or even a sheet of paper. These practical advantages are of great importance; in aviation they are indispensable.

Not only is the calculation made much simpler, more rapid and sure, but, above all, it is made accessible to everyone. Air-pilots are marvellous men of action but they are not all mathematicians. In any case they have usually not studied astronomy and theoretical navigation by which naval officers fix their positions by ordinary methods of calculation.

These pilots would soon become accustomed to taking observations of heavenly bodies with great accuracy; the machine takes care of the rest. It will suffice to give air navigators some idea of "lines of equal altitude", the characteristics of which the machine provides, and of the use of these lines of position, to enable them to determine the positions of the aircraft by observations of heavenly bodies.