PATENT SPECIFICATION

581,906

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PROVISIONAL SPECIFICATION

True Wind Calculator for Use on Aircraft

We, FRANCIS STANLEY BURT, B.Sc., A.S.G.I., D.I.C., A.F.R.Ae.S., and CHARLES SEYMOUR WRIGHT, C.B., O.B.E., M.C., M.A., Director of Scientific Research, both of the Admiralty, London, S.W.1, and both of British Nationality, do hereby declare the nature of this invention to be as follows:—

This invention relates to apparatus for use on an aircraft for calculating the strength and speed of true wind. The apparatus is based on a known method termed the "Four Point Bearing Method", and before the present invention can be described it will be necessary to explain briefly the functioning of this method.

The said method and the present invention will now be described with reference to the accompanying drawings, in which:—

Fig. 1 is a diagram illustrating the principle of the method.

Figs. 2 and 3 are respectively front and back views of one form of instrument according to the invention, and

Fig. 4 is a diagram illustrating the operation of the part of the instrument shown in Fig. 3.

The "Four Point Bearing Method" will now be described with reference to Fig. 1. An artificial cloud is released from the aircraft when vertically over a datum D and a stop watch is started. The aircraft then turns 180° either to port or starboard and flies on this reciprocal course until it has passed both the cloud and the object; after an interval of about 1½ to 2 minutes the aircraft is turned through 180° again in the same direction. (If the turns have been made uniformly the cloud will now be directly ahead). The aircraft is flown through the cloud and the time T_1 is noted; the position of the aircraft at this instant is denoted by the point E on the diagram, DE thus representing the direction of the true wind. The aircraft continues to fly on the same course, represented by the direction EF, and the times T_2 and T_3 are taken when the datum point bears 90° and 135° respectively from the course. It is also noted whether the datum point bearings were to port or starboard of the course. The actual track of the aircraft is represented by the line EH, its position with respect to the ground at the instants T_2 and T_3 being represented by the points G and H respectively.

If W represents the true wind speed, θ the true wind direction relative to the aircraft course (a head wind being represented by $\theta=0$) and V represents the true airspeed (i.e. speed of aircraft relative to air) it may be shown that

$$W \cos\theta = V(1 - T_1/T_2) \quad \ldots (i)$$

$$W (\cos\theta + \sin\theta) = V(1 - T_1/T_3) \quad (ii)$$

According to the present invention, true wind calculating apparatus for use on aircraft comprises an instrument for obtaining the values of W and θ in terms of the above simultaneous equations (i) and (ii). According to a preferred feature of the invention the apparatus comprises a logarithmic calculating element adapted to determine the parameters A and B, where $A = V_1(1 - T_1/T_2)$ and $B = V_1(1 - T_1/T_3)$ V_1 being any convenient assumed value of true airspeed, and a trigonometric calculating element adapted to determine W and θ for the assumed value V_1 in terms of A and B. If the actual true airspeed is other than V_1 the corrected value of W may then readily be obtained by using the logarithmic calculating element as an ordinary slide rule as hereinafter described.

A typical example of the calculating instrument based on an assumed value of 100 for true airspeed (i.e. $V_1=100$) will now be described with reference to Figs. 2 and 3. It may be noted here that V_1 may be expressed in any convenient unit (e.g. knots or m.p.h.), the value of W simply being read in terms of the same unit.

Fig. 2 shows the front of the instrument incorporating the logarithmic calculating element. This comprises three scales; the outer scale (1) is called the

" A and B Scale ", the next scale (2) is the " Time Scale " and the inner scale (3) the " Wind Scale "; all these scales can be moved relative to one another.

Fig. 3 shows the reverse side of the instrument, incorporating the trigonometric calculating element. On this side the outer scale is a " Bearing Scale " (4) graduated in degrees (0—360°), the next plate (5) is engraved with a non-rectilinear grid with one set of lines corresponding to the values of A, 100 $(1-T_1/T_2)$, running at right angles to a datum line (7), and a second set on either side of the datum line running at 45° to the first set corresponding to values of B, 100 $(1-T_1/T_3)$. These sets of lines are marked A and B on Fig. 3, and may conveniently be differently coloured, the " A " lines being red and the " B " lines green, for example. Over the grid formed by the A and B lines is a transparent pointer (6) which can be swung to any desired intersection point of the A and B lines of the grid giving the wind speed and its bearing.

The operation of the instrument will now be described, after which its theory will be considered. The instructions for operation are as follows:—

Rotate the " Time scale " (2), (Fig. 2) until the value of T_1 is against the index " set T_1 " on the outer scale (1), then opposite T_2 on the Time scale (2) read the value of A on the outer scale (1) and opposite T_3 similarly read the value of B. These values of A and B are noted and used on the grid on the opposite side.

Next turn the computer over (Fig. 3) and rotate the plate (5) until the aircraft's course is shown against the index C. The pointer (6) is then rotated to the point of intersection on the grid of A (horizontal red lines) and B (diagonal green lines), the side of the grid being used appropriate to whether the datum point bearings were to port or starboard of the course. The pointer then shows the Wind Direction on the " Bearing scale " (4) and the reading on the pointer at the intersection points gives the value of the Wind Speed in knots (or m.p.h.) assuming the True Airspeed is 100 knots (or m.p.h). If this is not the case turn the calculator over again, set the Wind speed reading as shown on the pointer (6) on scale (3) against the 100 index on scale (2), then opposite the True Airspeed on scale (2) the corrected value of the Wind speed may be seen on the scale (3).

The following example will illustrate the procedure.

EXAMPLE.

Course through cloud	110°
True Airspeed	120 knots
Bearing of Datum point to starboard	
Time T_1	187 seconds.
T_2	210 seconds.
T_3	250 seconds.

1. On front of instrument rotate scale (2) until 187 comes against the arrow engraved " Set T_1 ". Opposite 210 seconds in the " Time scale " read +11 on the " A and B scale " (this is A) and opposite 250 seconds on the " Time scale " read +25 (this is B).

2. Turn the calculator over and set the index C against 110° on the bearing scale. Turn the transparent pointer (6) to the intersection of +11 (red horizontal) and +25 (green diagonal) on the starboard half of the grid. The end of the pointer then shows the true wind bearing 164° and the reading on the pointer at the intersection point is shown at 18.

3. Turn the calculator over again, set 18 on the Wind Scale (3) opposite the 100 index on the " Time Scale " (2) and opposite 120 on scale (2) read the value of the wind speed 21.5 knots on scale (3).

The theory of the calculator will now be considered, attention first being directed to scales (1) and (2) (Fig. 2). Let p be the angular distance measured clockwise from the index " Set T_1 ", to any marked indication x on scale (1), and let q be the angular distance measured clockwise from an arbitrary datum position on scale (2) to any marked indication t thereon. The scales are then constructed according to the following formulæ:—

$$\text{Scale (1)}\quad p = K\,[\log V_1 - \log (V_1 - x)] \quad \ldots \quad \text{(iii)}$$

$$\text{Scale (2)}\quad q = K \log t \quad \ldots\ldots\ldots\ldots \quad \text{(iv)}$$

In these equations K is a constant (the same for both equations) depending upon the base to which the logarithms are taken and the maximum value of t for which it is required to legislate on scale (2).

Considering the scales to be set as described above, and letting $q = q_1$ when $t = T_1$, it will be seen that the values of p and q for any corresponding values of x and t are related by the equation, $q = q_1 + p$. Substituting from (iii) and (iv) we get:—

$$K \log t = K \log T_1 + K[\log V_1 - \log (V_1 - x)]$$

Whence $x = V_1(1 - T_1/t)$.

Thus when $t = T_2$, $x = A$, and when $t = T_3$, $x = B$, The theory underlying the construction of the reverse side of the instrument (Fig. 3) may be readily understood with reference to Fig. 4. In this figure let P represent any point on the grid, O represent the centre of the grid and let OY, OX^1 and OX be three axes through O which are respectively vertical, horizontal, and inclined at 45° to the horizontal as shown.

If OP is of length W, and at an angle θ to the vertical OY, then the vertical distance of P from OX^1 is equal to W cos θ and the vertical distance of P from the diagonal axis OX is equal to

$$W\ (\text{Cos}\ \theta + \text{Sin}\ \theta).$$

Now the horizontal A lines on the grid are such that the value marked against any one represents its vertical distance above OX^1, while the diagonal B lines are such that the value marked against any one represents its vertical distance above OX; thus it will readily be seen that the A and B line which intersect at P will have marked values equal respectively to W Cos θ and

$$W\ (\text{Cos}\ \theta + \text{Sin}\ \theta).$$

Hence if the pointer (6) is set in accordance with the values of A and B as described the values of W and θ may be read directly therefrom in the manner previously indicated.

If V is not equal to V_1 the value of W obtained by the calculator must be multiplied by V/V_1 to obtain the correct answer. For this purpose the scale (3) (Fig. 2) is provided; this scale is a simple logarithmic one, and forms, together with scale (2), an ordinary circular slide rule on which the necessary calculation may be performed.

The special features of a calculator according to the invention may be summarised as follows. The transparent pointer (6) shows the wind vector graphically. The grid is uniformly divided so that the intersection point can be plotted with equal accuracy throughout the range. The calculator solves the four point bearing problem for any value of T_1, whereas most of the previously proposed calculators for this problem are limited to a fixed value of T_1, so that the pilot has to control his flight very carefully between the moments of releasing the cloud and flying through it again in order to adjust T_1 to the standard value.

The uniform grid and the flexibility of the calculator are obtained by introducing the quantities A and B, enabling the problem to be solved for any values of T_1, T_2 and T_3. Using logarithmic scales on the front of the calculator to calculate $V_1(1-T_1/T_2)$ and $V_1(1-T_1/T_3)$ allows a simple graphical solution of W and θ on the other side of the calculator. The calculator can incidentally be used to solve any ordinary slide rule problem.

The invention is not limited to the precise construction shown; the logarithmic and trigonometric elements may, for example, both be incorporated on one side of the instrument, enabling the other side to carry further calculating elements for other navigational problems.

Dated the 19th day of July, 1943.
A. J. EDWARDS,
Acting for the Applicants.

COMPLETE SPECIFICATION

True Wind Calculator for Use on Aircraft

We, FRANCIS STANLEY BURT, B.Sc., A.S.G.I., D.I.C., A.F.R.Ae.S., and CHARLES SEYMOUR WRIGHT, C.B., O.B.E., M.C., M.A., Director of Scientific Research, both of the Admiralty, London, S.W.1, and both of British Nationality, do hereby declare the nature of this invention, and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to apparatus for use on an aircraft for calculating the strength and speed of true wind. The apparatus is based on a known method termed the "Four Point Bearing Method", and before the present invention can be described it will be necessary to explain briefly the functioning of this method.

The said method and the present invention will now be described with reference to the accompanying drawings, in which:—

Fig. 1 is a diagram illustrating the principle of the method,

Fig. 2 is a diagram illustrating the operation of part of the instrument shown in Fig. 3, and

Fig. 3 illustrates one form of instrument according to this invention.

The "Four Point Bearing Method" will now be described with reference to Fig. 1. An artificial cloud is released from the aircraft when vertically over a datum D and a stop watch is started. The aircraft then turns 180° either to port or starboard and flies on this reciprocal course until it has passed both the cloud and the object; after an interval of about $1\frac{1}{2}$ to 2 minutes the aircraft is turned through 180° again in the same direction. (If the turns have been made uniformly the cloud will now be directly ahead). The aircraft is flown through the cloud and the time T_1 is noted; the position of the aircraft at this instant is denoted by the point E on the diagram, DE thus representing the direction of the true wind. The aircraft continues to fly on the same course, represented by the direction EF, and the times T_2 and T_3 are taken when the datum point bears 90° and 135° respectively from the course. It is also noted whether the datum point bearings were to port or starboard of the course. The actual track of the aircraft is represented by the line EH, its position with respect to the ground at the instants T_2 and T_3 being represented by the points G and H respectively.

It is also possible to carry out this method of wind finding without using a cloud. In this event, at the moment of passing over the seamarker or some selected object a stop-watch is started and a turn of 180° is commenced. At a suitable interval after the turn has been completed, another identical 180° turn is made in the same direction as the first. A steady course is then steered until the beam and quarter bearings of the datum have been taken. In this case, the "time of passage through the cloud" (T_1) is now twice the interval between the commencement of the first turn and the commencement of the second turn. In every other respect the procedure is identical to that followed when using an artificial cloud.

If W represents the true wind speed, θ the true wind direction relative to the aircraft course (a head wind being represented by $\theta=0$) and V represents the true airspeed (i.e. speed of aircraft relative to air) it may be shown that

$$W \cos\theta = V(1 - T_1/T_2) \quad \ldots \text{(i)}$$

$$W (\cos\theta + \sin\theta) = V(1 - T_1/T_3) \quad \text{(ii)}$$

According to the present invention, true wind calculating apparatus for use on aircraft adapted to evaluate W and θ in terms of the above simultaneous equations (i) and (ii) is characterised by the provision of a main logarithmic calculating element adapted to determine the parameters A and B, where $A = V_1(1 - T_1/T_2)$ and $B = V_1(1 - T_1/T_3)$ V_1 being any convenient assumed value of true airspeed, and a trigonometric calculating element adapted to determine W_1 and θ in terms of A and B, where W_1 is the value of W if the true airspeed is V_1. If the actual true airspeed is other than V_1 the corrected value of W may then, according to a preferred feature of the invention, readily be obtained by the use of a further logarithmic calculating element as hereinafter described.

A typical example of the calculating instrument based on an assumed value of 100 for true airspeed (i.e. $V_1=100$) will now be described with reference to Figs. 2 and 3. It may be noted here that V_1 may be expressed in any convenient unit (e.g. knots or m.p.h.), the value of W_1 simply being read in terms of the same unit.

As shown in Fig. 3, the main logarithmic calculating element comprises two relatively movable annular scales arranged round the periphery of the instrument; these comprise an inner scale (1) called the "A and B Scale", and an outer scale (2) called the "Time Scale". The remainder of the instrument constitutes the trigonometric calculating element. The outer scale (4) of this part of the instrument is termed the "Bearing Scale" and is graduated in degrees (0°—360°); it may, as shown, conveniently be formed integrally with the scale (1). Within this is a rotatable plate (5) engraved with a non-rectilinear grid comprising one set of lines corresponding to the values of $A(=100(1-T_1/T_2))$ running at right angles to a datum line (7), and a second set on either side of the datum line running at 45° to the first set and corresponding to values of

$$B \ (=100(1-T_1/T_3)).$$

These sets of lines are marked A and B on Fig. 3, and may conveniently be differently coloured, the "A" lines being red and the "B" lines green, for example. Over the grid formed by the A and B lines is a pointer (6) which can be swung to any desired intersection point of the A and B lines of the grid, giving the wind speed and its bearing.

The operation of the instrument will now be described, after which its theory will be considered. The instructions for operation are as follows:—

Rotate the "Time scale" (2) until the value of T_1 is against the index "set to T_1" on the scale (1); then opposite T_2 on the Time scale (2) read the value of A on the scale (1) and opposite T_3 similarly read the value of B. These values of A and B are noted and used on the grid on the plate (5).

Next rotate the plate (5) until the aircraft's course is shown on the scale 4 against the index C. The pointer (6) is then rotated to the point of intersection on the grid of A (horizontal lines) and B (diagonal lines), the side of the grid being used appropriate to whether the datum point bearings were to port or starboard of the course. The pointer (6) then shows the Wind Direction on the "Bearing scale" (4) and the reading on a scale 6^1 on the pointer at the intersection points gives the value W_1 of the Wind Speed in knots (or m.p.h.) assuming the True Airspeed is 100 knots (or m.p.h.). If this is not the case the reading W_1 on the scale 6^1 must be multiplied by $V/100$ (V being the actual True Airspeed) in order to obtain the true Wind Speed W; this may be done by a further logarithmic calculating element (equivalent to a slide rule) which is arranged, together with other related calculating elements forming no part of the present invention, on the reverse side of the instrument.

In the instrument described in the Provisional Specification the logarithmic and trigonometric calculating elements each occupy one whole side, and an additional scale (3) (Fig. 2 of the drawings accompanying the Provisional Specification) co-operates with the scale (2) to form the further logarithmic calculating element referred to above. This instrument is identical in principle with that described in the present specification, but has the disadvantage that it provides no room for the further calculating elements referred to.

The following example will illustrate the method of using the instrument.

Example.

Course through cloud	110°
True Airspeed	120 knots
Bearing of Datum point	to starboard
Time T_1	3 mins. 7 seconds.
Time T_2	3 ,, 30 ,,
Time T_3	4 ,, 10 ,,

1. Rotate scale (2) until 3 mins. 7 secs. comes against the arrow engraved "Set to T_1". Opposite 3 mins. 30 secs. on the "Time scale" (2) read +11 on the "A and B" scale (1) (this is A) and opposite 4 mins. 10 secs. on the scale (2) read +25 on the scale (1) (this is B).

2. Set the index C against 110° on the bearing scale (4). Turn the pointer (6) to the intersection of +11 (horizontal lines A) and +25 (diagonal lines B) on the starboard half of the grid. The end of the pointer then shows the true wind bearing 164° and the reading on the scale (6^1) at the intersection point as shown as 18.

3. By means of the further logarithmic calculating element (not shown) evaluate $18 \times 120/100 = 21.6$ knots.

The theory of the calculator will now be considered, attention first being directed to the main logarithmic calculating element. Let p be the angular distance measured clockwise from the index "Set to T_1", to any marked indication x on scale (1), and let q be the angular distance measured clockwise from an arbitrary datum position on scale (2) to any marked indication t thereon. The scales are then constructed according to the following formulæ:—

Scale (1): $p = K\ [\log V_1 - \log (V_1 - x)]$ . . . (iii)

Scale (2): $q = K \log$ . . . . (iv)

In these equations K is a constant (the same for both equations) depending upon the base to which the logarithms are taken and the maximum value of t for which it is required to legislate on scale (2).

Considering the scales to be set as described above, and letting $q = q_1$ when $t = T_1$, it will be seen that the values of p and q for any corresponding values of x and t are related by the equation, $q = q_1 + p$. Substituting from (iii) and (iv) we get:—

$$K \log t = K \log T_1 + K[\log V_1 - \log (V_1 - x)]$$

Whence $x = V_1(1 - T_1/t)$.

Thus when $t = T_2$, $x = A$, and when $t = T_3$, $x = B$,

The theory underlying the construction of the trigonometric calculating element may be readily understood with reference to Fig. 2 of the accompanying drawings. In this figure let P represent any point on the grid, O represent the centre of the grid, and let OY, OX^1 and OX be three axes through O which are respectively vertical, horizontal, and inclined at 45° to the horizontal as shown.

If OP is of length W_1, and at an angle θ to the vertical OY, then the vertical distance of P from OX^1 is equal to $W_1 \cos \theta$ and the vertical distance of P from the diagonal axis OX is equal to $W_1(\cos\theta + \text{Sin}\,\theta)$. Now the horizontal A lines on the grid are such that the value marked against any one represents its vertical distance above OX^1 while the diagonal B lines are such that the value marked against any one represents its vertical distance above OX; thus it will readily be seen that the A and B lines which intersect at P will have marked values equal respectively to $W_1 \text{ Cos}\,\theta$ and $W_1(\text{Cos}\,\theta + \text{Sin}\,\theta)$. Hence if the pointer (6) is set in accordance with the values of A and B as described the values of W_1 and θ may be read directly therefrom in the manner previously indicated.

Finally, if V is not equal to V_1, the value W_1 obtained by the calculator must, as previously described, be multiplied by V/V_1 to obtain the correct answer.

The special features of a calculator according to the invention may be summarised as follows. (a) The pointer (6) shows the wind vector graphically. (b) The grid is uniformly divided so that the intersection point can be plotted with equal accuracy throughout the range. (c) The calculator solves the four point bearing problem for any value of T_1, whereas most of the previously proposed calculators for this problem are limited to a fixed value of T_1, so that the pilot has to control his flight very carefully between the moments of releasing the cloud and flying through it again in order to adjust T_1 to the standard value.

The uniform grid and the flexibility of the calculator are obtained by introducing the quantities A and B, enabling the problem to be solved for any values of T_1, T_2 and T_3. Using logarithmic scales to calculate $V_1(1-T_1/T_2)$ and $V_1(1-T_1/T_3)$ allows a simple graphical solution of W_1 and θ.

The invention is not limited to the precise construction shown; the logarithmic and trigonometric elements may, for example, be arranged in various other ways according to circumstances.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performd, we declare that what we claim is:—

1. A true wind calculator for use on aircraft and adapted to evaluate the speed W and bearing θ of the true wind from the simultaneous equations $W \text{ Cos}\,\theta = V(1-T_1/T_2)$ and $W(\text{Cos}\,\theta + \text{Sin}\,\theta) = V(1-T_1/T_3)$, where V is true airspeed and T_1, T_2, and T_3 are times determined by the known Four Point Bearing Method as herein described, characterised by the provision of a logarithmic calculating element (hereinafer referred to as the "main logarithmic calculating element") adapted to determine parameters A and B, where $A = V_1(1-T_1/T_2)$ and $B = V_1(1-T_1/T_3)$, V_1 being any convenient assumed value of V, and a trigonometric calculating element adapted to determine W_1 and θ in terms of A and B, where W_1 is the value of W if the true airspeed is V_1.

2. A calculator according to Claim (1) in which a further logarithmic calculating element (either combined with the main logarithmic calculating element or constituting a separate part of the calculator) is provided for evaluating W from the equation $W = W_1 V/V_1$ in the general case in which V is not equal to V_1.

3. A calculator according to either of Claims (1) or (2) in which the main logarithmic calculating element comprises a pair of relatively rotatable circular scales, namely a "time scale" on which the values of T_1, T_2 and T_3 are read and an "A and B" scale on which the values of A and B are read, substantially as herein described.

4. A calculator according to Claims (2) and (3) in which the further logarithmic calculating element comprises either a single rotatable circular scale co-operating with the A and B scale, or a separate pair of relatively rotatable circular scales, substantially as herein described.

5. A calculator according to any of Claims (1) to (4) in which the trigonometric calculating element comprises a plate marked with intersecting sets of parallel lines representing values of A and B, a circular scale which is set with respect to an index on the said plate to indicate the course of the aircraft, and a graduated pointer adapted to co-operate with both the plate and the scale for determining the values of W_1 and θ, substantially as herein described.

6. A calculator according to any of the preceding claims in which the main logarithmic and the trigonometric calculating elements are both located on the obverse side of the instrument, substantially as described with reference to Fig. 3 of the accompanying drawings, while the further logarithmic calculating element (if provided) and other calculating elements are located on the reverse side of the instrument.

7. A calculator according to any of

Claims (2) to (5) in which both logarithmic calculating elements are located on the obverse side, and the trigonometric calculating element is located on the reverse side of the instrument, substantially as described with reference to Figs. 2 and 3 of the drawings accompanying the Provisional Specification.

8. True wind calculators for use on aircraft constructed, arranged and operated substantially as described and illustrated herein and in the Provisional Specification.

Dated this 18th day of August, 1944.

A. J. EDWARDS,
Acting for the Applicants.

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SHEET 1

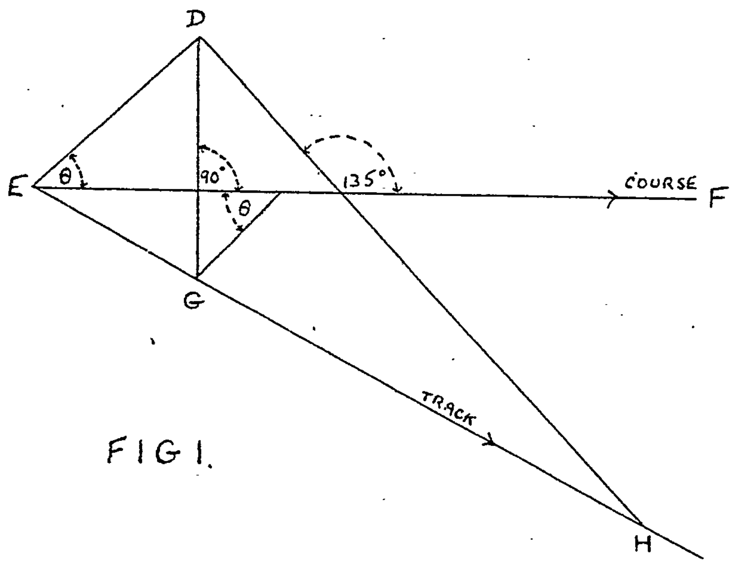


FIG 1.

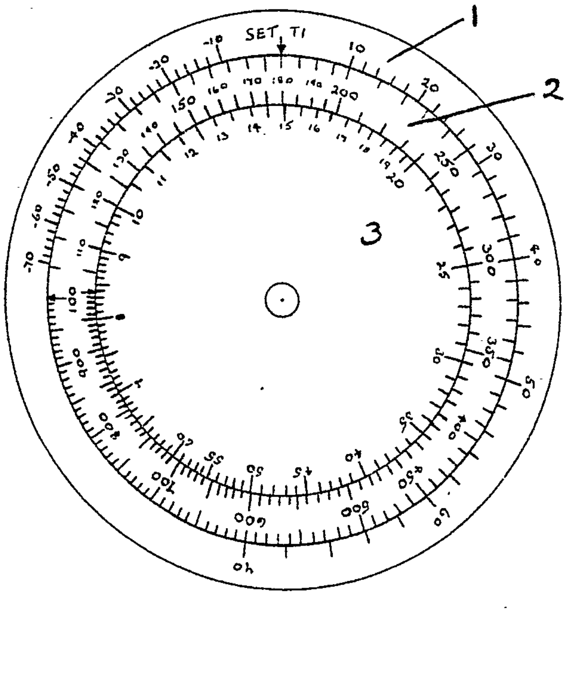


FIG 2.

2 SHEETS

SHEET 1

SHEET 2

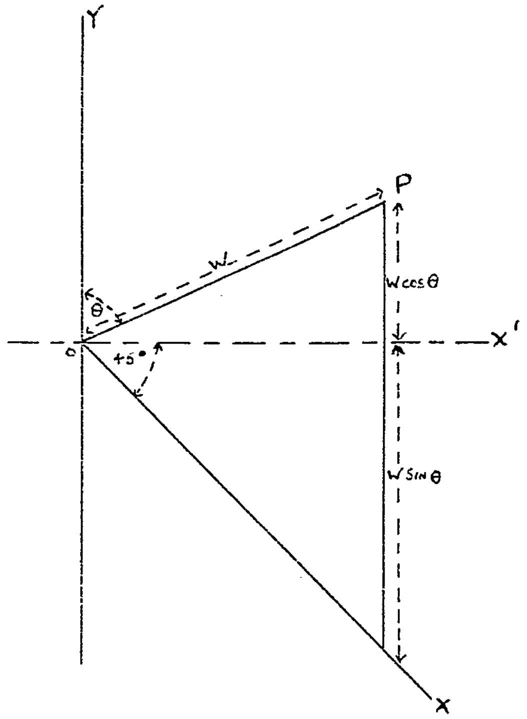


FIG 4.

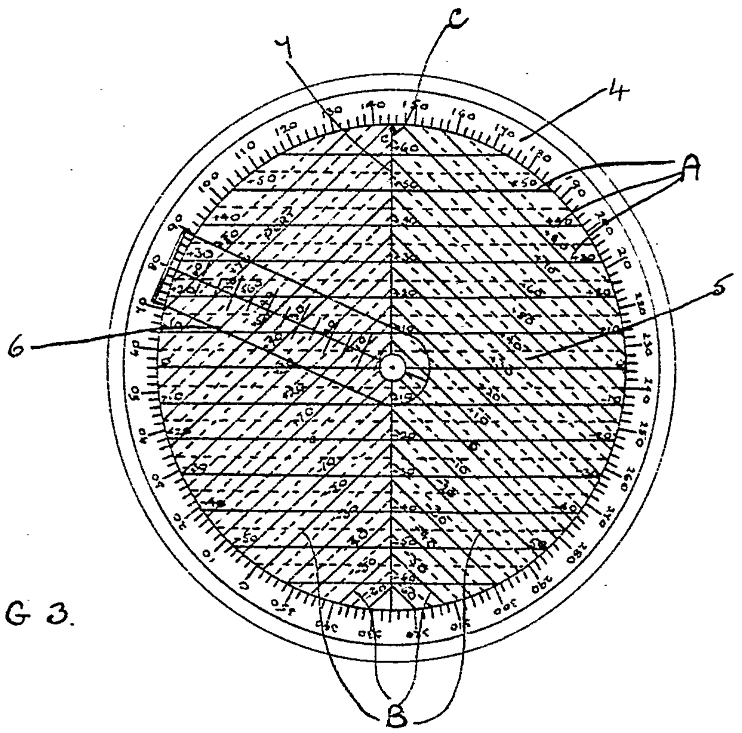


FIG 3.

H.M.S.O. (Ty P)

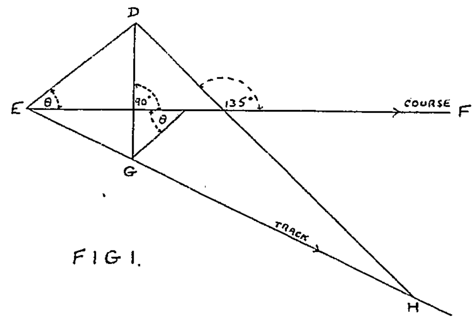


FIG 1.

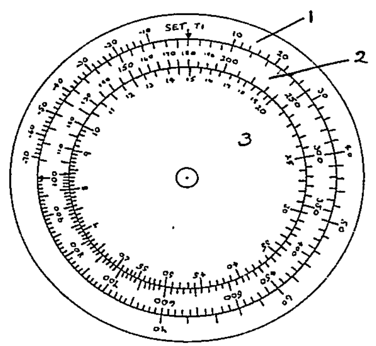


FIG 2.

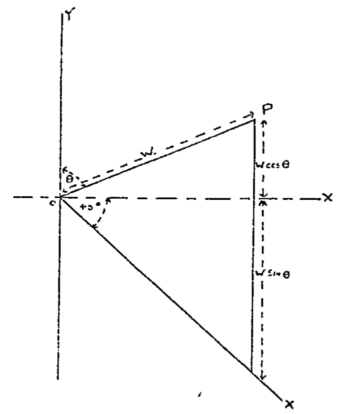


FIG 4.

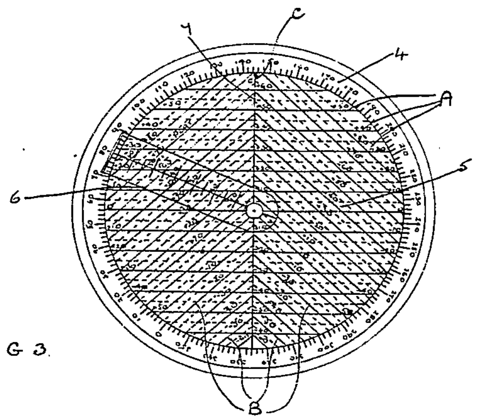


FIG 3.

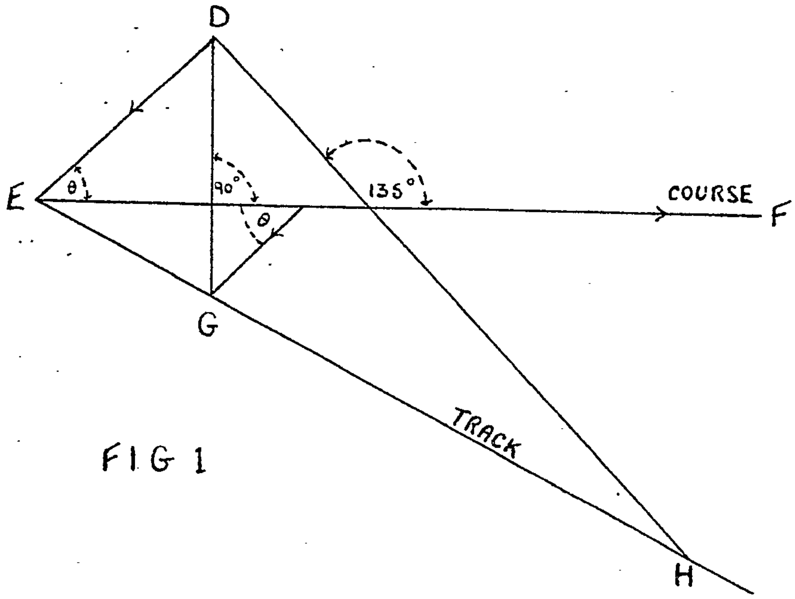


FIG 1

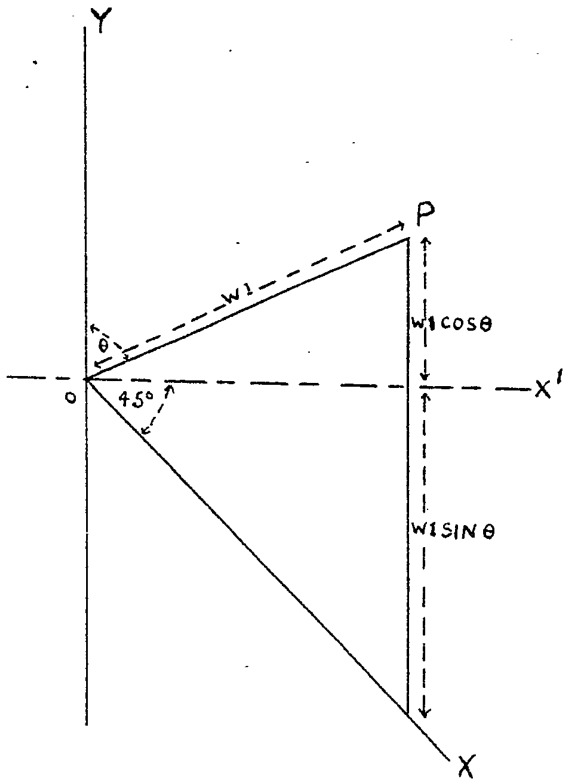
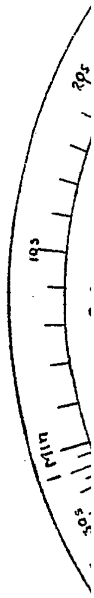


FIG. 2



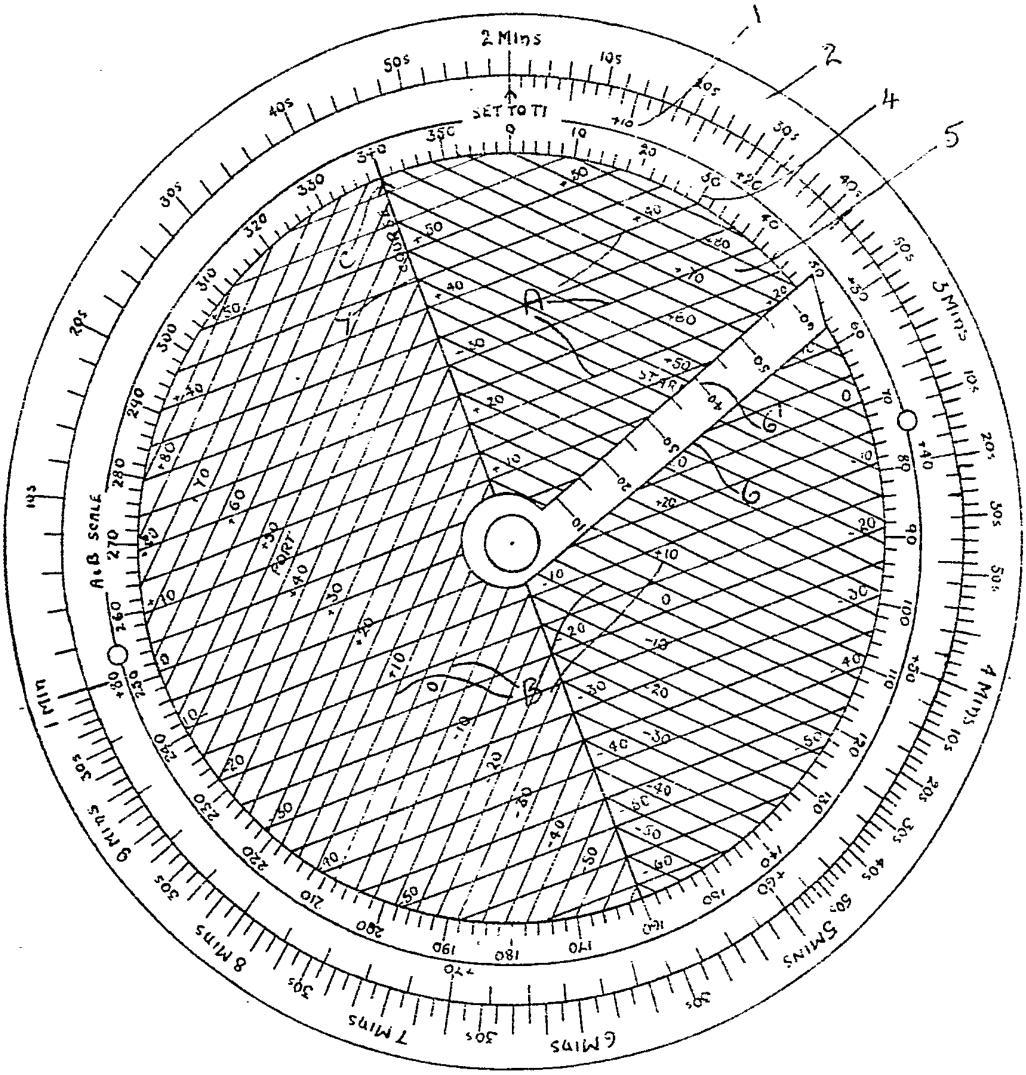

2 Mins
SET TO T1
3 Mins
4 Mins
5 Mins
6 Mins
7 Mins
8 Mins
9 Mins
1 Min
A&B SCALE
COURSE
PORT
STAR
1
2
4
5
6
6'
A
B
C

FIG. 3

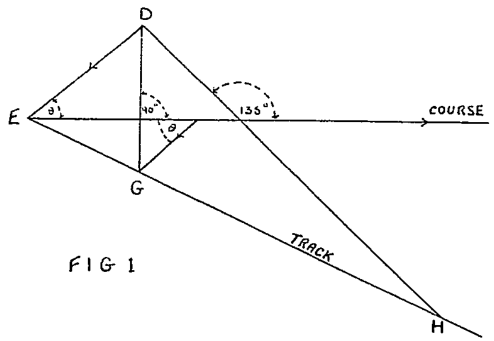


FIG 1

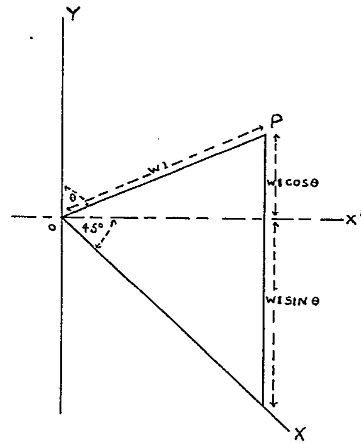


FIG. 2

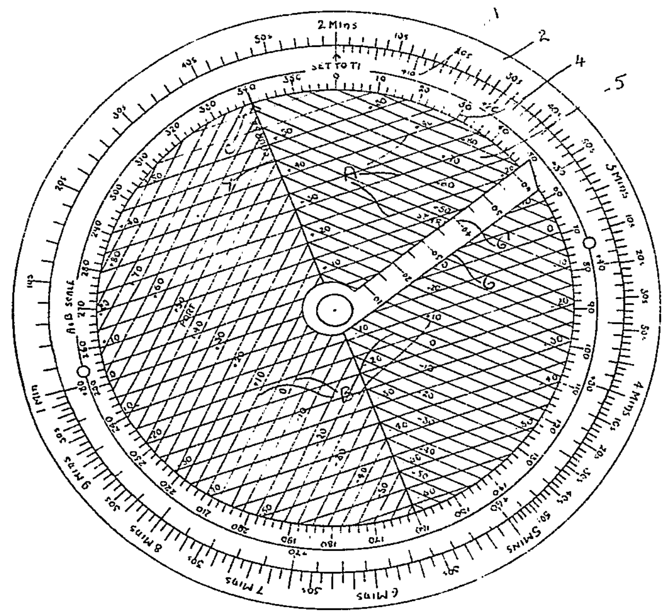


FIG. 3