Radius of Action to the Same Base

Crew members are constantly working to secure the maximum performance of an aircraft while on tactical duty. When flying on scouting and patrol missions, the navigator must determine how to cover the greatest ground distance in a specified time. One problem of this nature is determination of *Radius of Action*. The radius of action of an aircraft is the greatest ground distance it can fly outward from a given point on a given course before returning to the same or another point within a limited time. In solving this type of problem, the navigator must determine the heading to be flown on the trip out, when and where to make the turn, and the heading to be flown on the return leg.

The radius of action may be plotted or computed before take-off, but once in the air, dead reckoning methods, supplemented by radio and other navigational aids must be used to make good the pre-computed courses and distances.

Various factors enter into the determination of the radius of action of an aircraft. Each factor, singly or in combination with other factors, is important in determining the distance an aircraft may fly under known conditions. The resultant of certain factors may aid or hinder the aircraft while in flight; therefore, the navigator must have a thorough understanding of the values of each factor, the relation one bears to another, and the correct application of each to the problem under consideration.

There are three basic factors dealt with in working radius of action problems, namely wind, time, and airspeed.

Wind has a pronounced effect on the time required to fly a given distance. For a two-way trip, wind is always a hindrance, unless it changes so that there is a tail wind for both legs. The maximum radius of action results when the wind is at right angles to the course. The minimum radius of action results when the wind is parallel to the course. If the aircraft has been flying with a tail wind and has used half of the gas load, it can never expect to get back to its starting point unless the wind changes.

R/A CAN BE COMPUTED BEFORE TAKE-OFF — THEN CHECKED IN FLIGHT

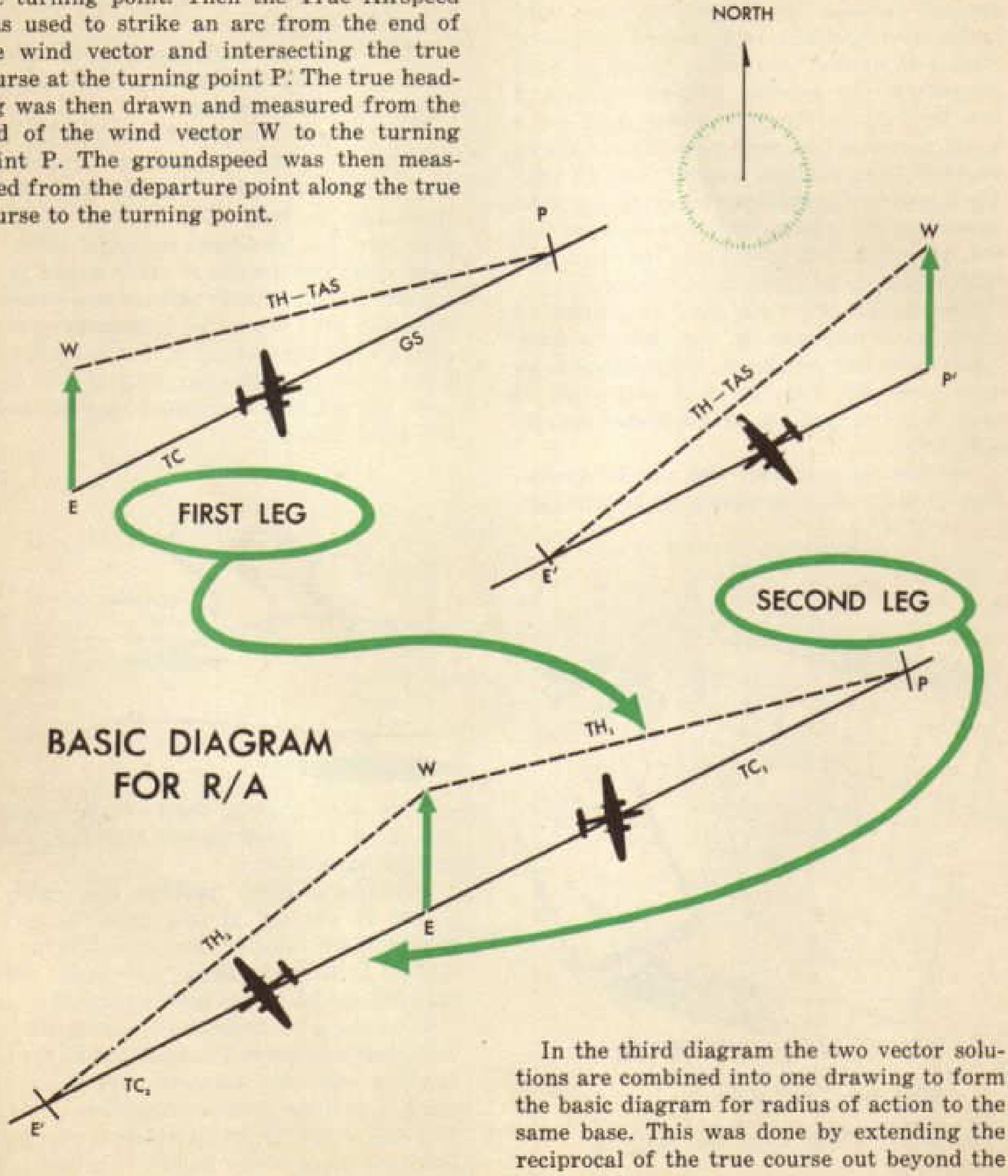
Time is affected by the wind, fuel supply, rate of fuel consumption, and fuel safety margin allowance.

A radius of action problem may easily be solved by the use of two wind vector diagrams. These diagrams are used in a manner similar to that explained previously, except that two modifications are introduced.

First the wind is drawn from the point of departure instead of from the end of the true heading and true airspeed vector. Second, the two graphic solutions used are combined into one vector diagram, which is considered the basic diagram for radius of action to the same base.

The two diagrams below picture a plane flying from departure point E, to turning point P, and return. Just prior to departing the navigator had calculated the true airspeed, the true course to be made good, and the prevailing wind speed and direction. In the first diagram the true course was drawn from the departure point in the direction of the turning point. Then the True Airspeed was used to strike an arc from the end of the wind vector and intersecting the true course at the turning point P. The true heading was then drawn and measured from the end of the wind vector W to the turning point P. The groundspeed was then measured from the departure point along the true course to the turning point.

The second diagram is just the reverse of the first and shows the return trip from turning point P to the departure point E. Notice that the turning point P has become the plane's departure point and that the original departure point E has become the destination.



BASIC DIAGRAM FOR R/A

In the third diagram the two vector solutions are combined into one drawing to form the basic diagram for radius of action to the same base. This was done by extending the reciprocal of the true course out beyond the point of departure.

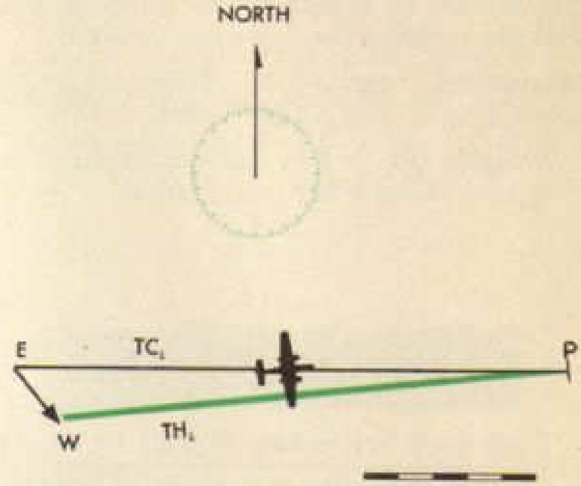
There are definite reasons for drawing the wind from the point of departure. In the first place, the point of departure is always known and the wind force and direction can usually be found.

Also the true airspeed and true course are usually known; therefore, it is a very simple matter to determine the groundspeed by drawing the wind from the point of departure and using the true airspeed to strike an arc on the true course.

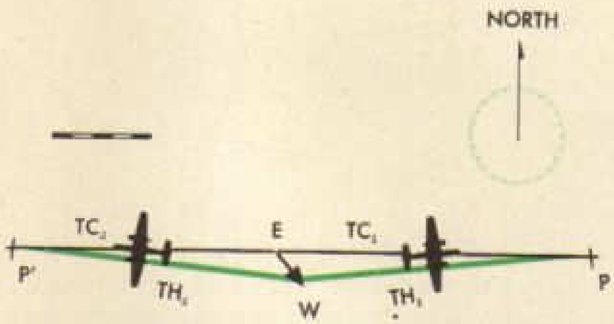
Now consider an actual example of radius of action to the same base. The aircraft is ordered to depart at 1200 and to scout a true course of 090 to a maximum distance and return in three hours. A true airspeed of 150 knots is to be maintained with a wind from 320 degrees at 20 knots.

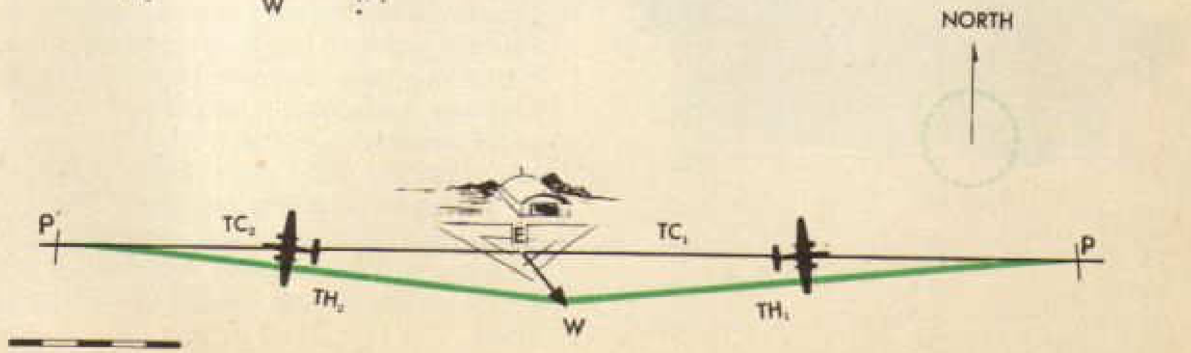
The navigator must calculate the true heading to be flown on both legs and the time to turn at the end of the first leg. The first step is to construct the basic wind vector diagram for radius of action to the same base. It is also necessary to make some distinction between the headings, courses, and speeds. This distinction is made by designating all data pertinent to the trip out as TH_1, TC_1 and GS_1. All data used on the return trip is distinguished by TH_2, TC_2 and GS_2. The wind and the true airspeed remain constant.

The navigator takes the following steps in constructing the basic wind vector diagram for radius of action to the same base. 1. The course (TC_1) is drawn from departure in the direction to be flown on the first leg. 2. The wind vector is drawn downwind from the departure point.



3. The true airspeed (150 knots) is used to strike an arc from the end of the wind vector to the point of intersection with the true course out. 4. The true heading out (TH_1) is measured and found to be 084. 5. The groundspeed out (GS_1) is found to be 162 knots when measured along the TC_1. 6. The course for the return trip (TC_2) is drawn as the reciprocal of 090 or 270 from the point of departure. 7. The True airspeed (150 knots) is used to strike an arc from the end of the wind vector to the point of intersection with the true course back (TC_2). 8. The true heading back (TH_2) is found to be 276, and the groundspeed back (GS_2) is 136 knots.





Up to this point the radius of action problem has been merely a wind vector graphic solution to determine headings and groundspeeds. There remains the problem of finding the number of minutes to be flown on the first leg. Knowing the estimated groundspeed for both legs, and the total time allowed for the flight, the navigator can find the number of minutes to be flown on the first leg by using the following formula:

$$\text{Minutes on First Leg} = \frac{180 \times 136}{162 + 136} = \frac{24480}{298} = 82 \text{ min.}$$

Multiply $GS_1 \times t$ to obtain R/A distance
$R/A = 162 \times 1^h22^m = 221$ miles.

TIME ON 1ST LEG =

$$\frac{\text{(TOTAL FLT TIME IN MIN)} \times \text{(SPEED OF RETURN)}}{\text{(SPEED OF DEPARTURE)} + \text{(SPEED OF RETURN)}}$$

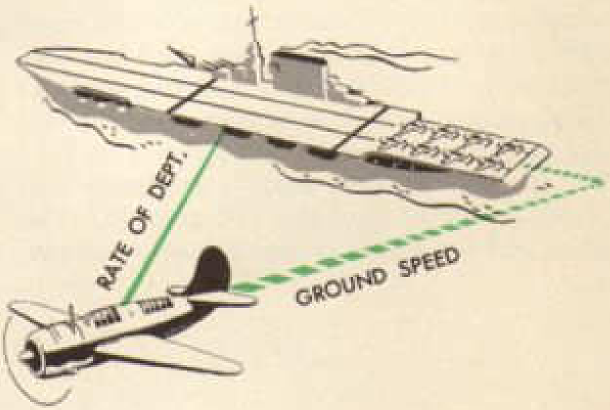
$$t = \frac{T \times GS_2}{GS_1 + GS_2}$$

T = TOTAL TIME MINUS RESERVE

t = TIME ON 1st LEG

Radius of Action to an Alternate Base

In the preceding section it was found that radius of action to the same base implied the greatest ground distance that an aircraft may travel from a departure base along a given course and still return to the same base in a specified time. Radius of action to an alternate base presents a more difficult problem. The alternate base may be either a moving carrier or a stationary base. In either case it may be thought of as a point moving along a straight line from the departure point to the position of the alternate base. It will be seen that groundspeed ceases to be the rate of departure or return when the base is moving. Thus, in addition to GS, the rate of departure and rate of return must be determined.

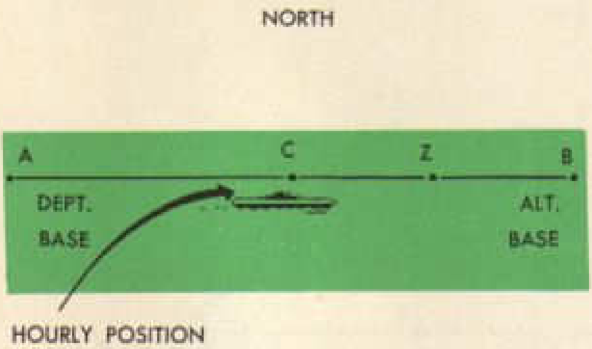


The range of an aircraft is limited by time, fuel, and weather. Completing a mission with the maximum distance covered involves careful calculation of length of flight before turning toward the alternate base. The problem becomes increasingly important when adverse weather conditions make it necessary to change the flight plan during the mission, returning to an emergency base. The ability to calculate accurately and complete the mission as well as possible within the safety limits of fuel supply cannot be over-emphasized.

In order to understand better the problem of radius of action to an alternate base, a short review of the simpler problem, radius of action to the same base, should be helpful.

In radius of action to the same base, the groundspeed out (GS_1) is the rate at which the aircraft is leaving the departure point. Upon turning and heading back, the groundspeed back (GS_2) becomes the rate at which it is converging on the departure point. The departure point does not move and the aircraft flies directly away and then returns on a reciprocal course directly toward the base; therefore, the bearing between the aircraft and the departure point remains constant.

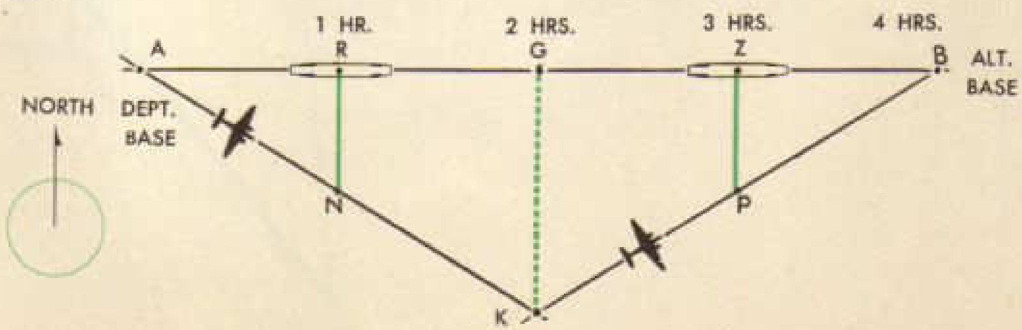
On the other hand, in radius of action to an alternate base, the point which the aircraft is leaving and converging on is a moving point; therefore, GS_1 may not be the rate of departure and GS_2 may not be the rate at which the aircraft is converging on this moving point. Below is a diagram showing the location of the moving point at various times.



Suppose that the moving point has two hours to get from base A to base B. Then, at an even rate of speed, it will be exactly half way between A and B at the end of one hour. Likewise, after one and a half hours have elapsed, it will be three-fourths of the way (point Z). At the end of two hours this moving point has traced a straight line from A to B. Thus, the total allowable time (T) was two hours; therefore, since the radius of action will be worked on the hourly basis, the moving point will be exactly half way between A and B at the end of one hour or at point C.

An aircraft may be ordered to leave a land base and patrol a certain course and return to a different land base after a given time, or it may be ordered to leave on patrol from a moving base, such as an aircraft carrier, and return to the carrier after a given time. In either case the radius of action problem may be worked in a similar manner.

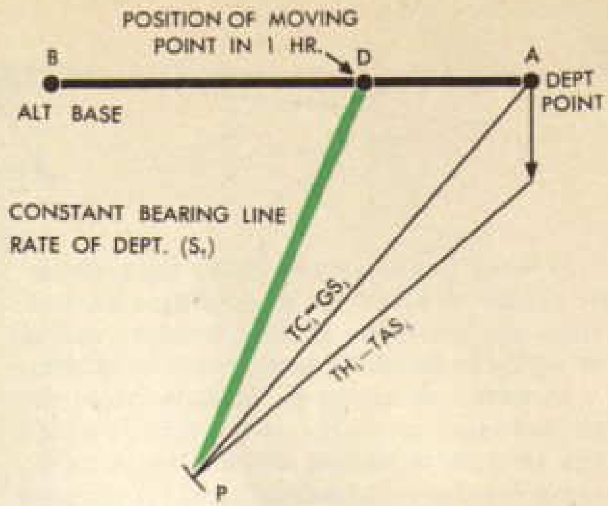
In order to explain better the moving point concept, take the case of an aircraft which takes off from a carrier and patrols at a uniform speed on a southeast course and then returns to the carrier at a uniform speed on a northeast course at the end of four hours. The carrier continues at a uniform speed on a course of due East between the time of take off and return of the aircraft. A no-wind condition is assumed.



The carrier and the aircraft will move apart at a uniform rate and the bearing of a line joining them at any time will be constant provided each maintains a uniform course and distance. In one hour this *rate of departure* is represented by the *constant bearing line RN*. At the end of two hours the length of this constant bearing line has been doubled and appears as line GK in the diagram. At this time the aircraft changes course and begins flying toward the carrier. On the return trip the aircraft and the carrier will move toward each other at a constant rate if each maintains a uniform course and speed. This is called the *rate of closure* and is represented by the constant bearing line ZP which joins the aircraft and carrier at the end of three hours.

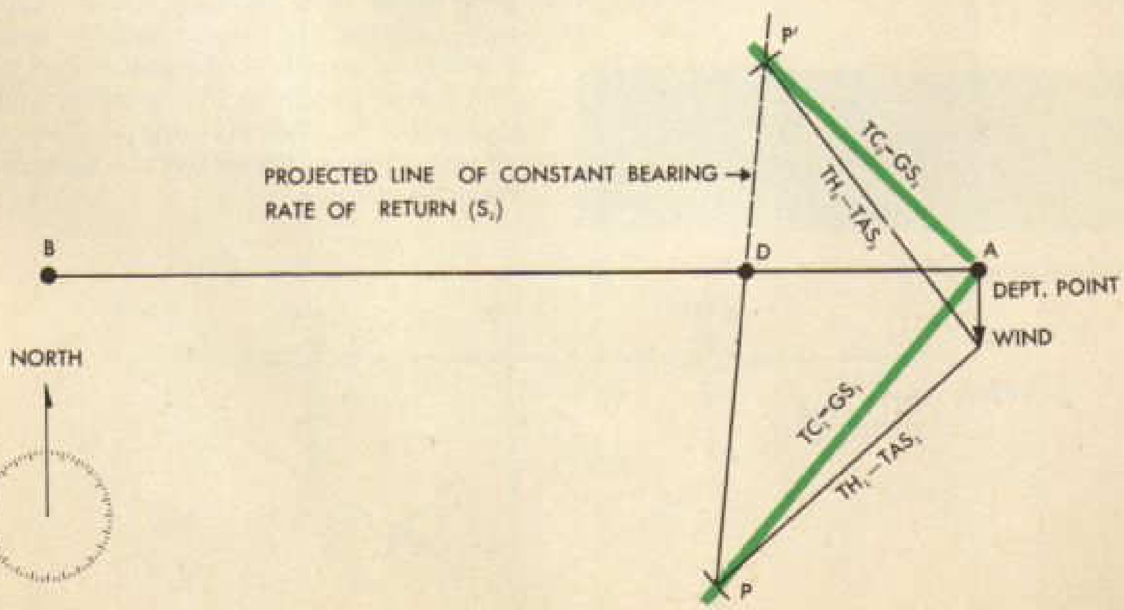
In this case the rate of closure ZP is equal to the rate of departure RN, only because the aircraft is not being affected by a wind. In four hours the aircraft should return to the carrier at the point B.

The radius of action to an alternate base can be solved by using a wind vector diagram similar in appearance and construction to the basic diagram used for R/A to the same base. However, it is necessary to introduce several variations in solving R/A to an alternate base. One difference is the use of a *constant bearing line* to join the aircraft's position and the position of the moving base at exactly one hour after departure time. Also



instead of drawing TC_2 as the reciprocal of TC_1, as is the case in solving R/A to the same base, a different procedure is used. TC_2 is drawn from the departure base to a point where it intersects the constant bearing line projected through and beyond the moving point's hourly position. However, before TC_2 can be drawn, its point of intersection with the extended constant bearing line must be located. This point is located by using the TAS, to scale, to swing an arc from the end of the wind vector and intersecting the extended constant bearing line.

The solution of an actual problem of R/A to an alternate base is shown in the diagram below.



An aircraft with a true airspeed of 140 knots was ordered to patrol a true course of 220 from departure base A and return within four hours to an alternate base B, which is 300 nautical miles on a bearing of 270 from departure base A. The wind is from 000 degrees at 25 knots.

The navigator must find the true headings to be flown on the courses out and back, and when and where to make the turn to come back.

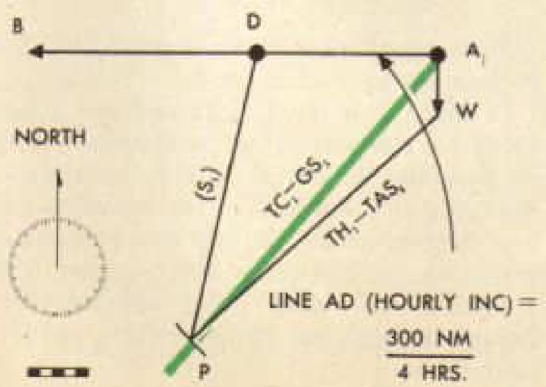
Upon taking off to patrol course AP, the departure base A is imagined to begin moving at a uniform rate on a straight line toward the alternate base B. Since the total allowable time is four hours, the moving base will be at the alternate position B at the end of that time. If the R/A is worked correctly, the aircraft will be at alternate base B when T, the total allowable time, is used up. Then the navigator must determine the R/A in order to get the turning point and direction of the true course back (TC_2) to the alternate base's T position, B. The effect of the wind on the plane must be considered; therefore, the wind is drawn in from the departure point A just as in R/A to the same base. From the end of the wind vector W the TAS, which is constant, is measured to P where it cuts the true course out (TC_1). Now the navigator has completed one vector diagram from which the TH_1, and GS_1 can be determined. However the navigator does not know the rate at which the aircraft has been leaving the departure base. Remember that the departure base has been moving at a uniform speed along a straight line toward the alternate base B.

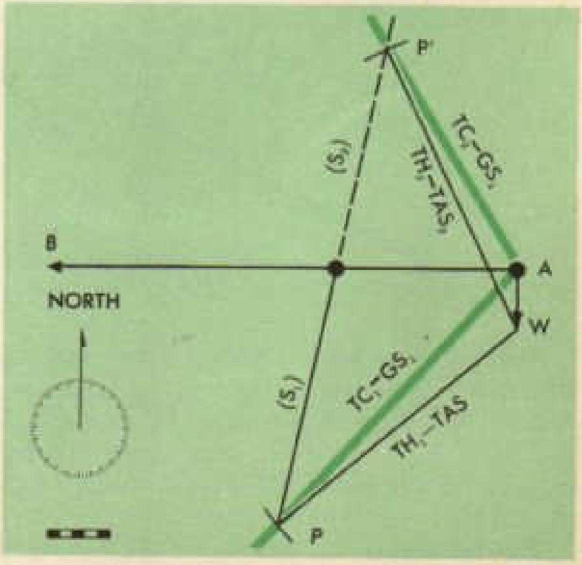
Notice that the vector diagram is worked for one hour and the navigator can locate the aircraft at point P at the end of that time. Also, the moving base would be at D on the line joining AB at that time. The rate of movement of the base, sometimes called the hourly increment (HI), was found by dividing the total distance between bases (300 nautical miles) by the total allowable time (T), four hours. Then to find the rate of departure of the aircraft (S_1) a constant bearing line is drawn and measured from P to D.

Before the navigator can complete the problem, the rate at which the aircraft will converge upon the moving base after the turn is made must be determined. Knowing the rate of departure (S_1) and the rate of return (S_2) the navigator obtains the time of turning to intercept, by substituting in the familiar formula,

$$t = \frac{T \times S_2}{S_1 + S_2}$$

In order to find the aircraft's rate of return, or S_2, the navigator projects the constant bearing line PD indefinitely to the opposite side of the AB line. Then with a center at the end of wind vector W and radius the aircraft's TAS, to scale, an arc is drawn cutting the extended PD line at point P′. Then AP′ must be the TC_2 (course to fly after the turn) and the GS_2 is scaled along this line. The TH_2 is then drawn and measured from the end of the wind vector W to intersection point P′.





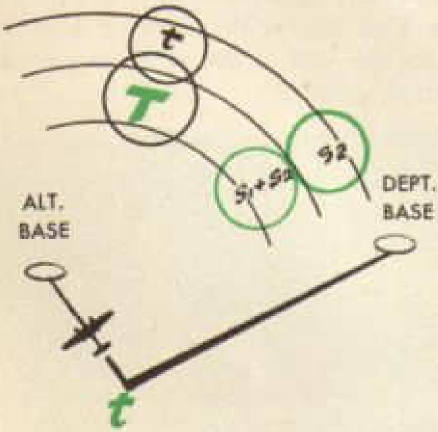
Knowing the time (little t) that can be spent on TC_1 and the GS_1 on that course, the navigator can determine the turning point. This is the aircraft's radius of action or the point at which the flyer changes course from TC_1 to TC_2 in order to arrive at the alternate base B at the exact instant the total allowable time has been used.

$$t = \frac{T \times S_2}{S_1 + S_2}$$

Now by substituting in the radius of action formula, the time of turning (t) to intercept is found to be 1 hour and 50½ minutes:

$$t = \frac{T \times S_2}{S_1 + S_2} = \frac{240 \times 107}{125 + 107} = 110\tfrac{1}{2} \text{ min. or } 1^h\,50\tfrac{1}{2}^m$$

The time to turn can be found by using the computer to solve the above formula. Read (little t) in minutes on the outer scale above (big T) on the inner scale after placing S_2 on the outer scale above the sum of S_1 and S_2 on the inner scale.



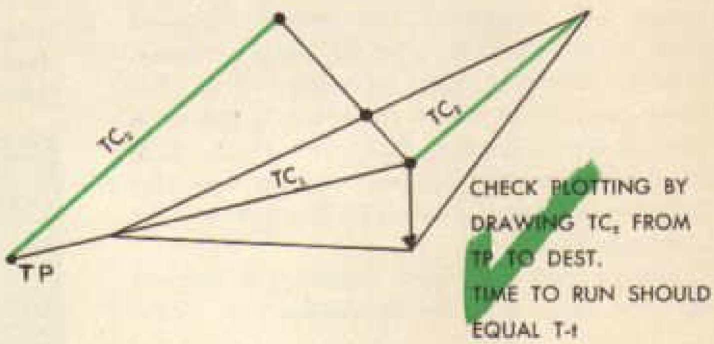
Radius of action logbook procedure is essentially the same as the D.R. logbook procedure described previously. In keeping a record of R/A to an alternate base, the log entries are similar to those used for DR dog-leg flights.

The importance of keeping a log on every flight cannot be overemphasized. While on R/A missions, entries such as T, HI, S_1, S_2, t, and R/A need to be added to the usual log entries. These items are listed one under the other in the proper column of the logbook.

Most training missions require the navigator to take a double drift on each leg of the R/A. This is allowed for in the total time given for the flight. Accordingly T will be two minutes *less* than this total time. Therefore, when the ETA to turn is figured it will be one minute greater than t.

When the turning point is reached, a position report is made in the usual manner and a double line is drawn across the log. The position, time, and other D.R. entries, are set down, and the new TC and TH are entered and worked across to MH and CH. The distance from turning point to destination is entered in the Distance to Run column. The T minus t *plus* one minute (for a double drift) is entered in the Time to Run column.

The ETA to destination should then correspond with starting time plus total air time. A check on your plotting can be made by drawing TC_2 from turning point on the Mercator, and measuring out this line a distance equal to T minus t times GS_2. The point now arrived at should, of course, fall on (or very near) destination.



If such a check is made, it should be shown in your log as well as on the Mercator.

If there is a wind shift and the groundspeed on the second leg is changed, it may be possible to control this groundspeed by changing the airspeed in the opposite direction to compensate. In this way you can still arrive at destination on your original ETA.

Should the wind shift severely early enough in flight, the entire problem should be reworked.

RADIUS OF ACTION TO AN ALTERNATE BASE ON E-6B COMPUTER

Before working R/A to an alternate base on the computer, the distance between the bases and the bearing of base B from base A must be determined.

The student should already know the method of solution on a Mercator by vector diagram.

If distances are too great to be drawn on a computer, all distances may be halved. The answers must be doubled before being used in the formula.

THE FORMULAE:

$$t = \frac{T \times S_2}{S_1 + S_2} \text{ or } \frac{t}{T} = \frac{S_2}{S_1 + S_2}$$

$$R/A = t \times GS_1$$

ILLUSTRATIVE PROBLEM:

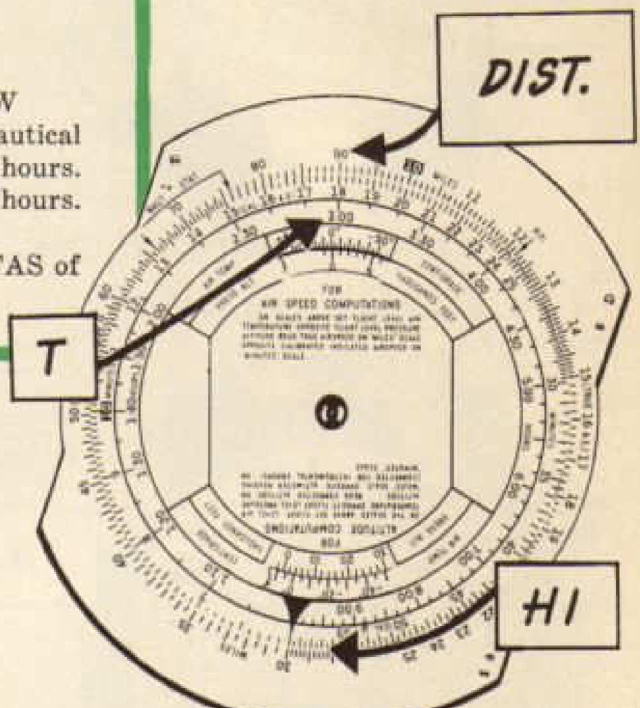
Departure is at 29°21′N-99°09′W

Alternate base is at 30°51′N-99°09′W

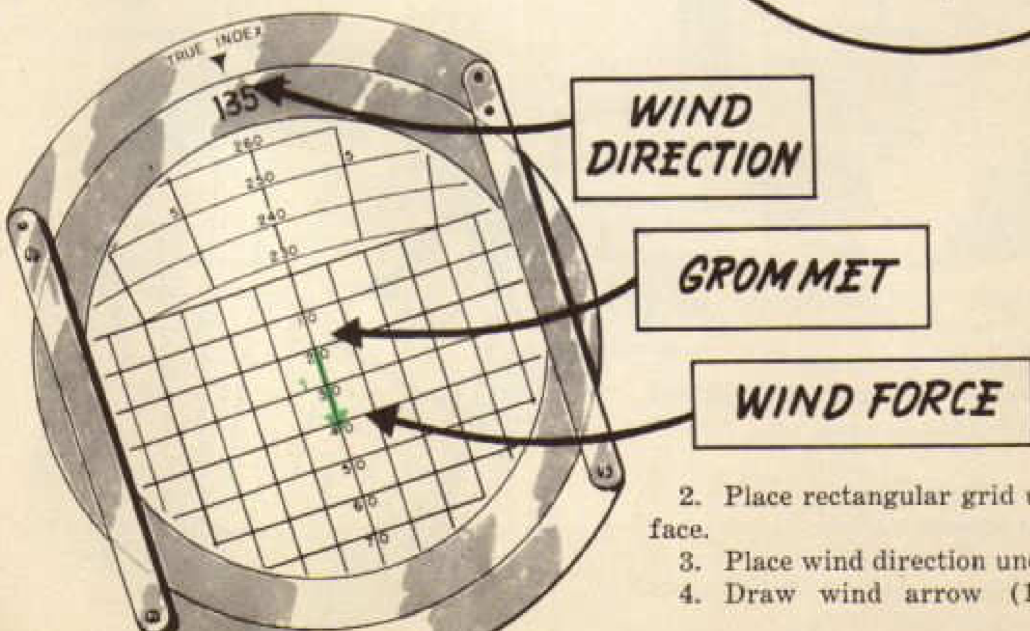
Alternate base bears 360° and 90 nautical miles from departure. Total Time = 4 hours. Allowing 25% reserve, we get T = 3 hours.

Wind is from 135° at 20 K.

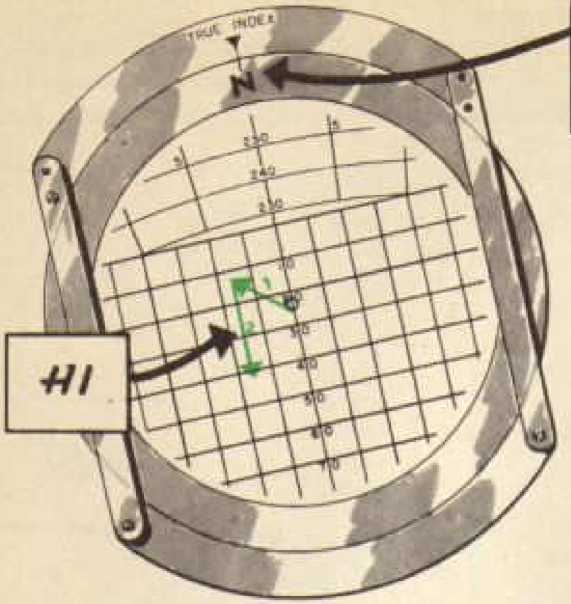
Plane is to patrol a TC of 270° at TAS of 150 K.



1. Set distance over time (T) and read hourly increment at arrow.



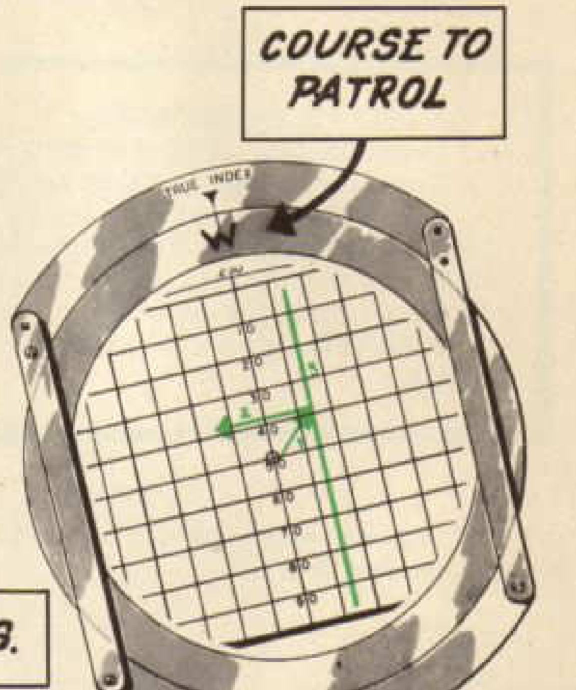
2. Place rectangular grid under computer face.
3. Place wind direction under True Index.
4. Draw wind arrow (1) down from



grommet.

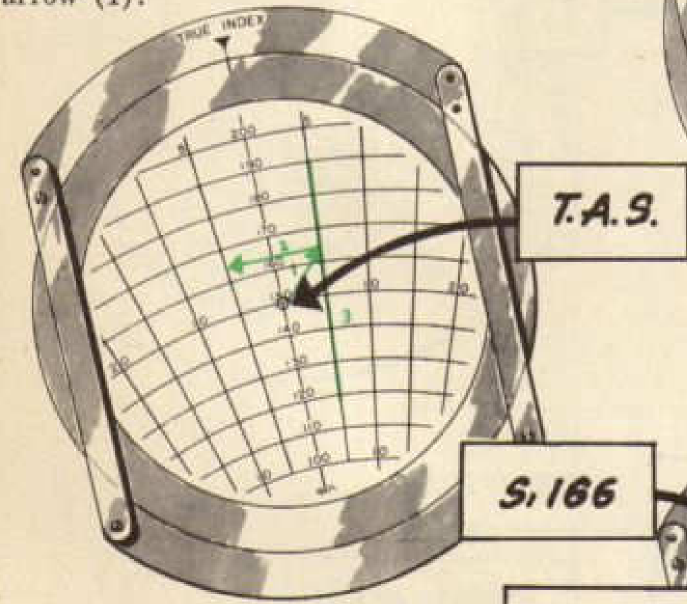
5. Place bearing of alternate base under True Index.

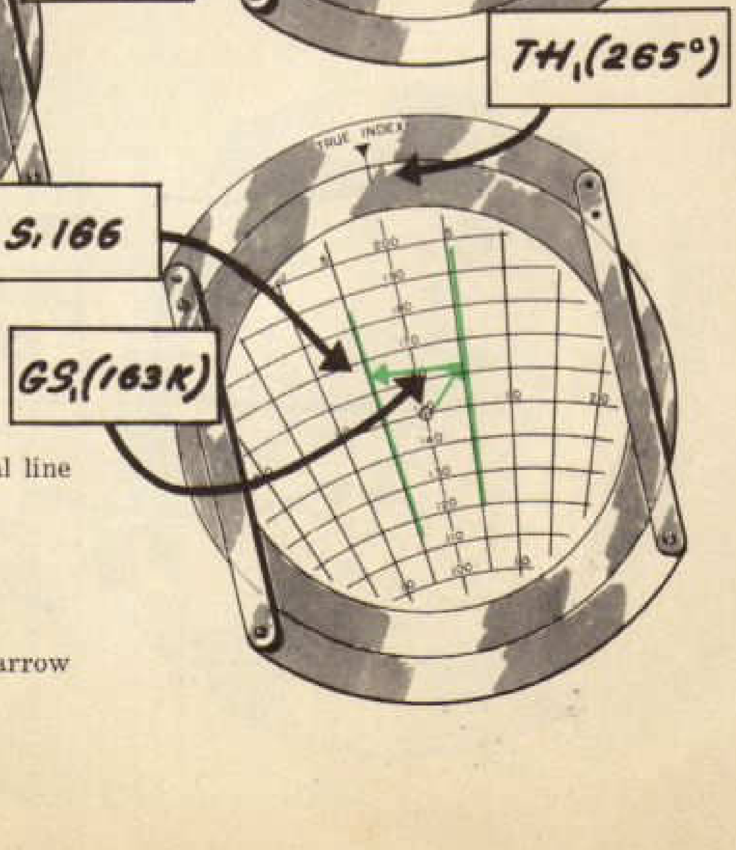
6. Draw HI arrow (2) down from end of wind arrow.



7. Place course to patrol under True Index.

8. Draw vertical line (3) at end of wind arrow (1).





9. Place circular grid under computer face.

10. Place TAS under grommet.

11. Shift computer face until vertical line (3) parallels drift lines on card.

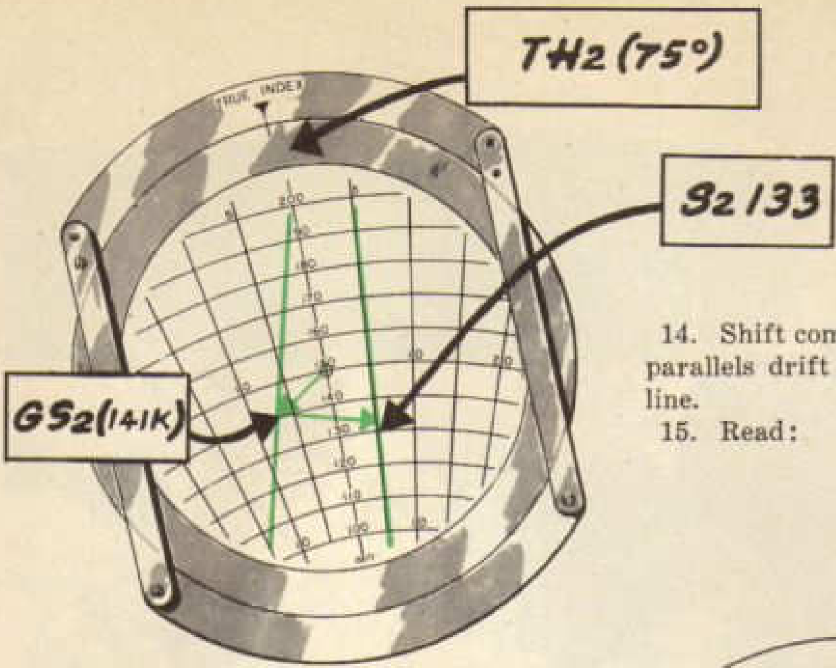
12. Read:

TH_1 under True Index.

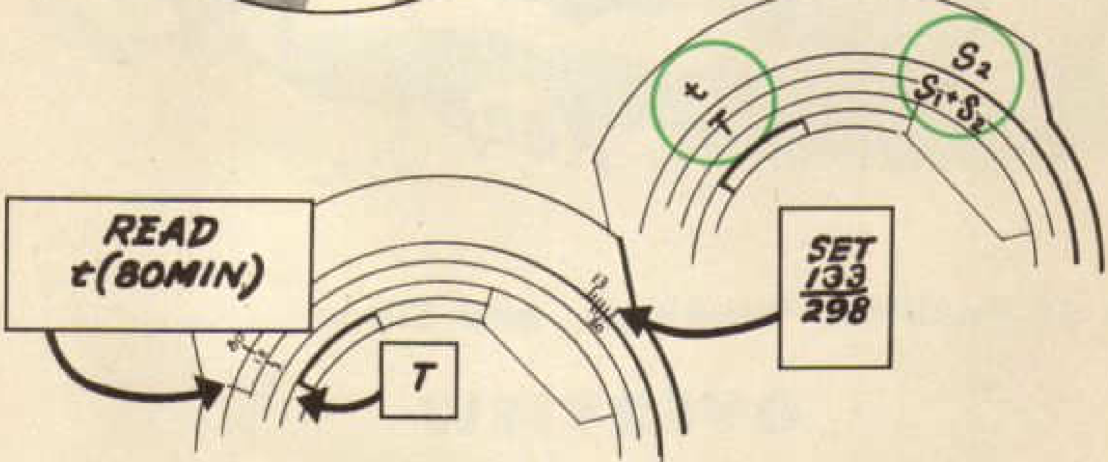
GS_1 at end of wind arrow (1).

S_1 at end of HI arrow (2).

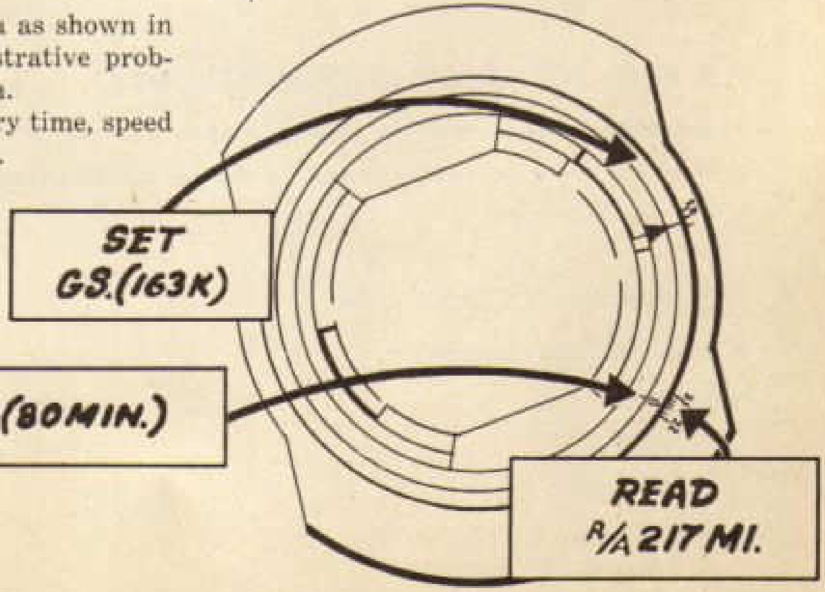
13. Draw in line (4) at end of HI arrow (2), paralleling drift lines on card.



14. Shift computer face until drift line (4) parallels drift lines on opposite side of TH line.
15. Read:



16. To find t, set up formula as shown in upper diagram. Values in illustrative problem are shown in lower diagram.
17. To find R/A set up ordinary time, speed and distance problem as shown.



ANSWERS:

Hourly Increment = 30 mi.
TH_1 = 265°
TH_2 = 75°
TC_2 = 67½°
GS_1 = 163 K
GS_2 = 141 K
S_1 = 166
S_2 = 133
t = $1^h\,20^m$
R/A = 217 naut. mi.