air navigation

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FOREWORD

1. **Purpose.** This Manual provides information on all phases of air navigation for navigators, aircraft observers (bombardment), radar bombardiers, and students being trained in these specialties.

2. **Contents.** This Manual develops the art of navigation from its simplest concepts to the most advanced procedures and techniques. Procedures for instrument calibration of navigational instruments are established in this Manual.

3. **Recommendations.** Recommendations or suggestions for the improvement of navigational techniques and or procedures prescribed in this Manual are encouraged. Comments may be forwarded to the Director of Training, Headquarters USAF, Washington 25, D. C.

BY ORDER OF THE SECRETARY OF THE AIR FORCE:

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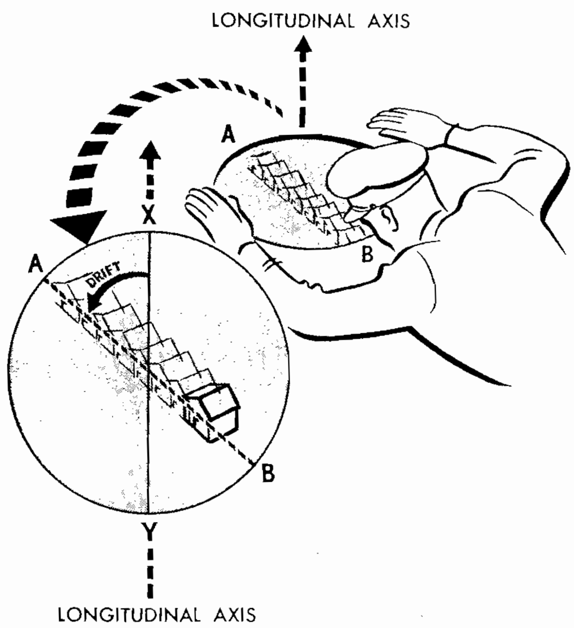
THE DRIFTMETER

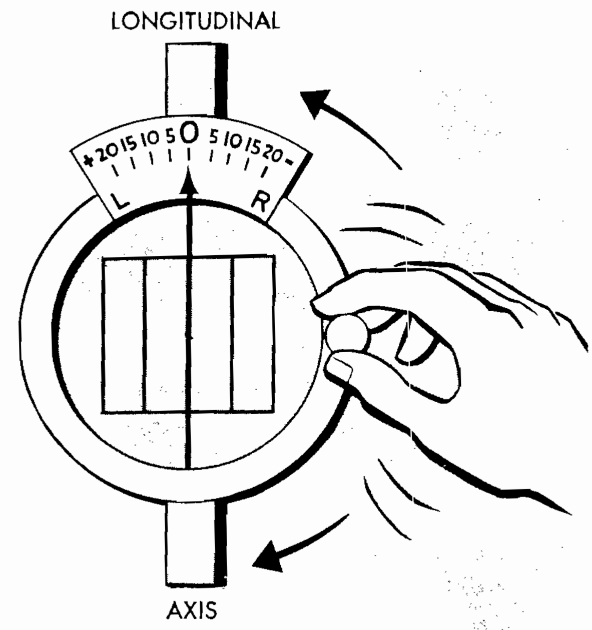
Several methods of wind finding depend on your knowledge of the drift angle—the angle between TH and TR. When the earth's surface (land or sea) is visible, you can measure this angle directly with an instrument known as a **driftmeter.**

PRINCIPLE OF THE DRIFTMETER

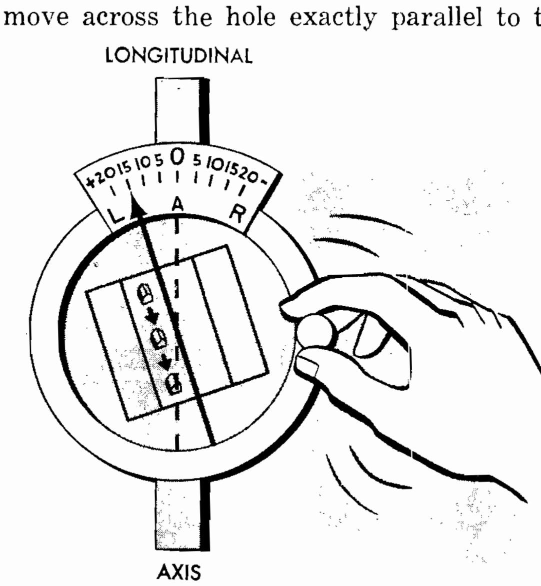
The principle of the driftmeter is very simple. Suppose that you watch the ground through a hole in the floor of an airplane. As the airplane flies in the direction of its TR, objects on the ground appear to move across the hole in the direction exactly opposite to the TR. Thus, in the diagram, if the airplane's TR is in the direction of the line BA, a house appears to move across the hole from A to B. Suppose now that you stretch a wire across the hole parallel to the airplane's longitudinal axis. This wire YX represents the airplane's TH. Since BA is the TR and YX is the TH, the drift angle is the angle AOX.



The driftmeter measures this angle AOX. A simple driftmeter might be built as shown in the figure. Over a hole in the floor of the airplane is placed a glass plate which may be rotated by means of the handle on the right. On the glass are drawn parallel **drift lines.** The drift lines, together with the two or three cross lines usually present in a drift meter, are called the **reticle.** The center drif line extends to the edge of the plate as a pointer. On the floor ahead of the hole is a drift scale, which shows the position of the drift lines with relation to the longitudina axis of the airplane. Thus, when the pointe is on 0°, the drift lines are parallel to the axis; and, when the pointer is on 10°R, the drift lines make a 10° angle to the right of the axis.



To use this simple driftmeter, you turn the glass plate so that objects on the ground move across the hole exactly parallel to the



drift lines. Then the drift lines are parallel to the airplane's TR. You read the drift scale opposite the pointer. If the pointer indicates 15°L, the airplane is drifting 15° to the left. Then if the TH is 090°, the TR is 075°. It's as simple as that.

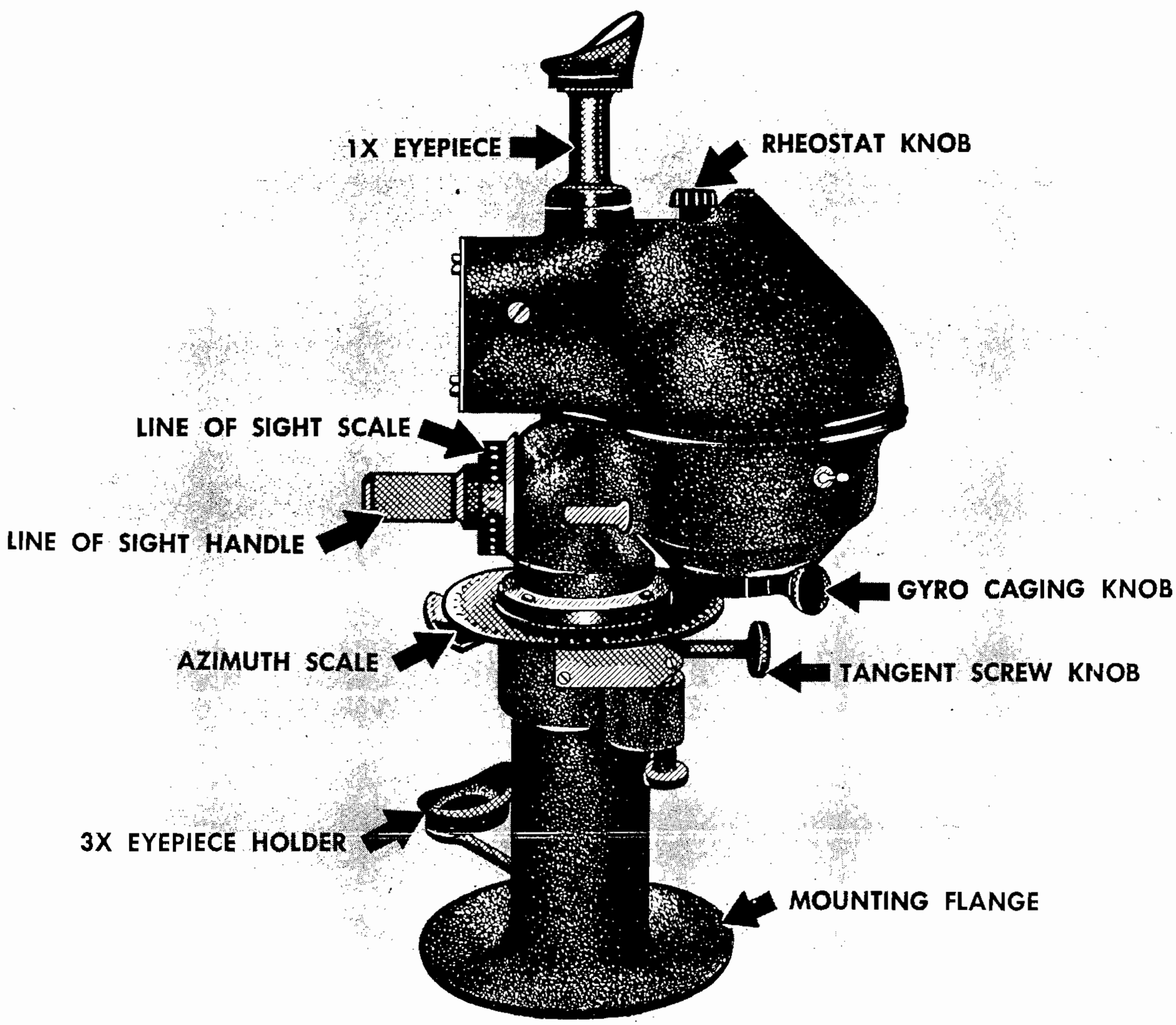
On every driftmeter, the drift scale is marked with the words "right" and "left" or "port" and "starboard," or with the letters "R" and "L." These words *always* refer to the *drift* and not to the drift correction. In addition, every AAF driftmeter has a plus and a minus sign on the scale. These give the sign of the *drift correction.*

THE B-3 DRIFTMETER

The driftmeters used in AAF airplanes are basically the same as the simple instrument described above; but they have many refinements. The B-3, especially, is a driftmeter de luxe. As you will see, it can be used for purposes other than reading drift.

For reading drift, the most important distinctive feature of the B-3 is the gyroscope, which keeps the reticle horizontal. A driftmeter without a gyro is difficult to use in rough air.

You may vary the line of sight of the B-3 driftmeter so as to see surrounding areas as well as the ground beneath the airplane. The **line of sight control handle** turns a prism at the bottom of the driftmeter tube and directs your line of sight away from the vertical. When the azimuth pointer is at 180° on the azimuth scale, the line of sight can be turned through an arc from 17° before to 87° behind the vertical. The angle between the line of



sight and the vertical is the **trail angle.** Since you can turn the driftmeter through 360°, you can see at a trail angle of 87° in any direction from the airplane.

The B-3 driftmeter, a delicate instrument, requires careful treatment. Read carefully the following operating procedure:

1. Before take-off, clean the window at the bottom of the driftmeter tube. To remove grit, brush lightly to avoid scratching the glass.

2. See that the azimuth pointer is at zero drift during take-off and landing, to prevent breakage of the glass by stones.

3. When the engines are started, turn on the inverter switch. After making sure that the gyro caging knob is in the caged position, turn on the gyro by means of the toggl switch.

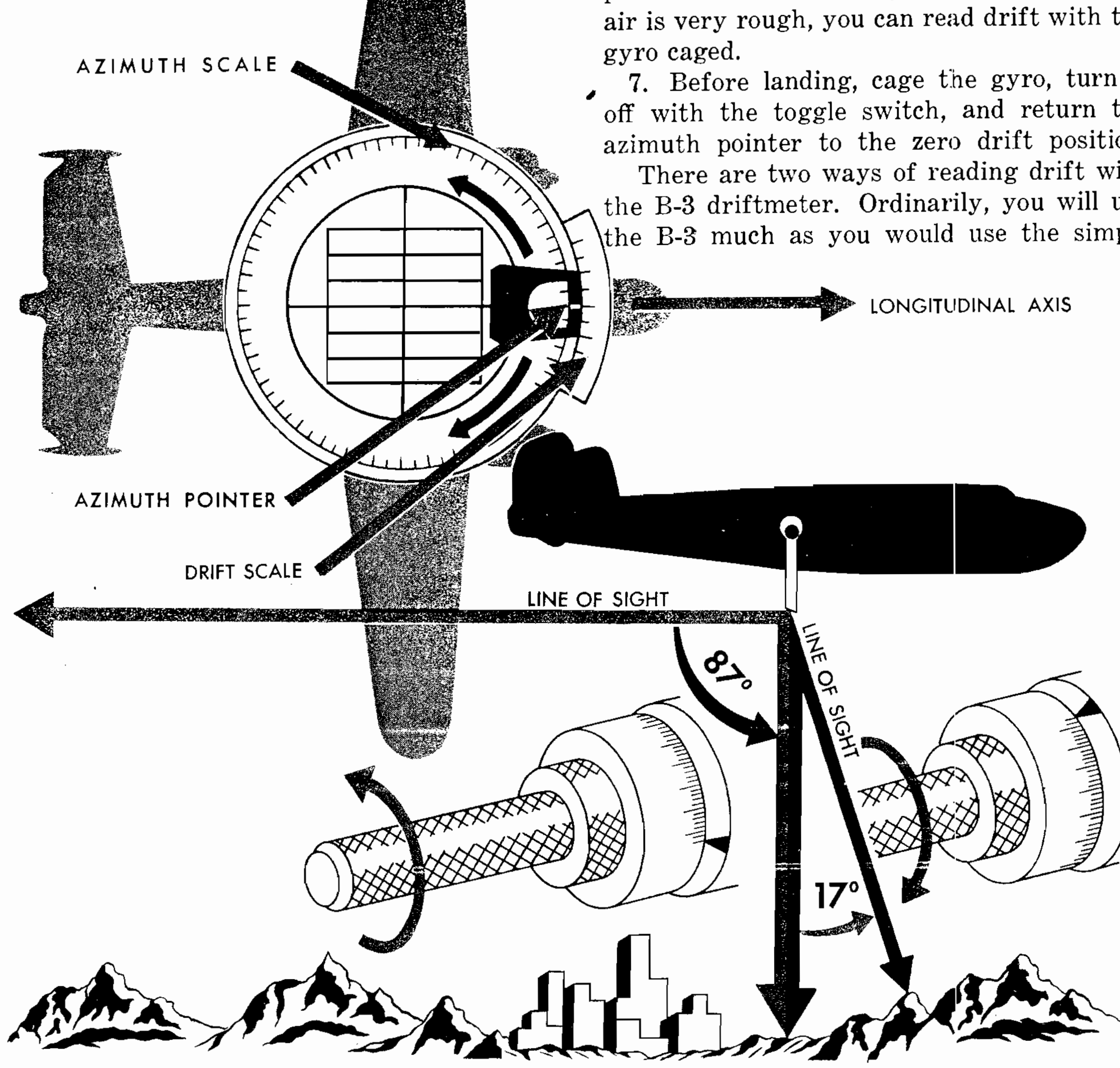
4. After leveling off, uncage the gyro. B sure that the line of sight control is at zer so that you see the ground directly belov the airplane. Adjust the focus of the eyepiece Adjust the illumination of the reticle b means of the rheostat knob.

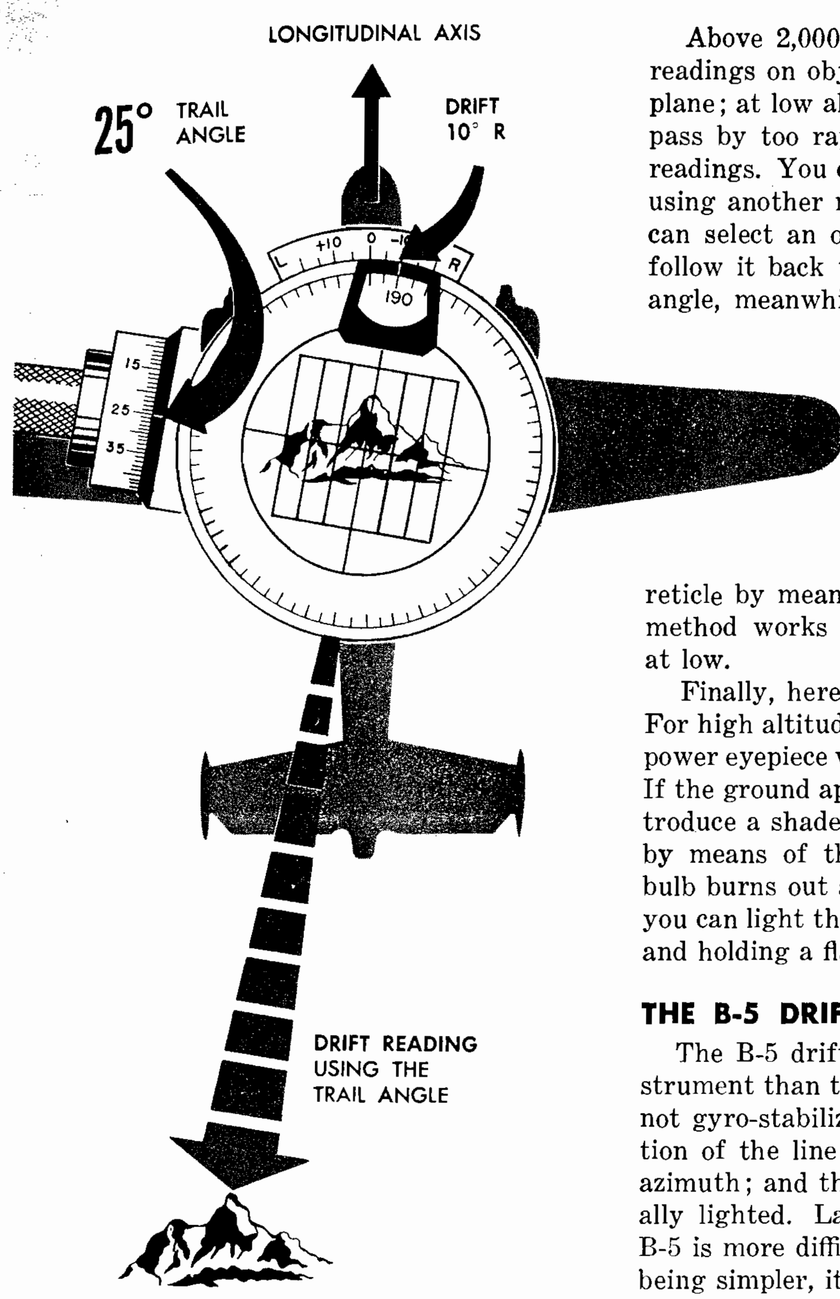
5. In level flight, leave the gyro uncaged If you expect the airplane to bank more thai 15°, gently cage the gyro until level fligh is resumed; otherwise the gyro may tumble If the gyro does tumble, cage it only when th airplane is level; then allow 10 minutes fo the gyro to erect.

6. If the gyro becomes inoperative o tumbles frequently, cage it. Remember to re port the trouble when you land. Unless th air is very rough, you can read drift with th gyro caged.

7. Before landing, cage the gyro, turn i off with the toggle switch, and return th azimuth pointer to the zero drift position

There are two ways of reading drift witl the B-3 driftmeter. Ordinarily, you will us the B-3 much as you would use the simpl





Above 2,000 ft. you can make good drift readings on objects directly beneath the airplane; at low altitudes, however, objects may pass by too rapidly for you to get accurate readings. You can overcome this difficulty by using another method of reading drift. You can select an object under the airplane and follow it back to about 25° or more of trail angle, meanwhile keeping it centered in the reticle by means of the azimuth drive. This method works at high altitudes as well as at low.

Finally, here are some miscellaneous tips. For high altitude, you should replace the one-power eyepiece with the three-power eyepiece. If the ground appears too bright, you may introduce a shade glass into the optical system by means of the shade glass lever. If the bulb burns out and you do not have another, you can light the reticle by removing the bulb and holding a flashlight against the hole.

driftmeter already described. Turn the azimuth drive until the drift lines are parallel with the path of each object across the field of vision. Read drift on the drift scale opposite the azimuth pointer.

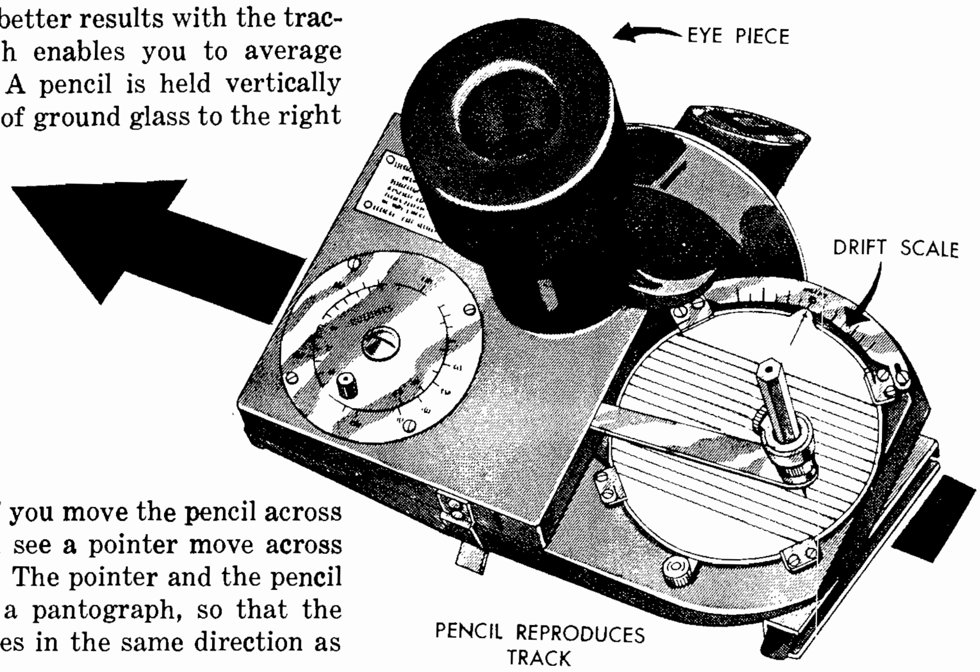
After reading drift, turn the pointer several degrees away from your drift reading. Then, when you read drift again, you will be taking an independent reading. Otherwise, you can easily be influenced by the previous reading.

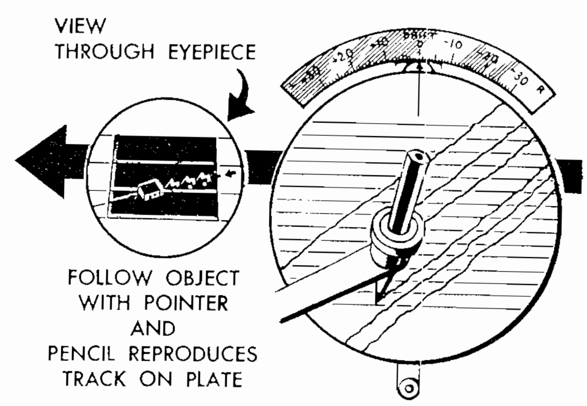
THE B-5 DRIFTMETER

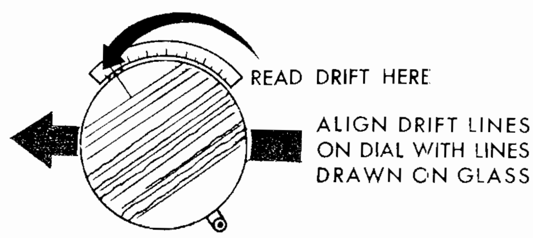
The B-5 driftmeter is a much simpler instrument than the B-3. The optical system is not gyro-stabilized and doesn't permit variation of the line of sight in trail angle or in azimuth; and the drift lines are not electrically lighted. Lacking these advantages, the B-5 is more difficult to use than the B-3; but being simpler, it is less likely to malfunction. Since the B-5 is a driftmeter frequently installed in tactical airplanes, you should take pains to learn to use it correctly.

Looking through the eyepiece, you see the ground a little to one side of the airplane. Also you see a set of drift lines, which you can turn parallel with the paths of objects moving across the field—much as in the B-3. Then you can read drift opposite the pointer on the drift scale.

This method of reading drift works well so long as the airplane remains level and moves at a constant velocity. But ordinarily you can get much better results with the tracing method, which enables you to average several readings. A pencil is held vertically on a circular plate of ground glass to the right of the eyepiece. If you move the pencil across the glass, you can see a pointer move across the field of vision. The pointer and the pencil are connected by a pantograph, so that the pencil always moves in the same direction as the pointer.







To use the tracing method, you keep the pointer on an object as it moves across the field of vision. Since you move the pointer by means of the pencil, you can draw a line on the ground glass at the same time. This line is parallel to the path of the object across the field of vision. Therefore it is parallel to the TR of the airplane. To read drift, then, it is necessary only to find the angle between this line and the TH or 0° drift line.

Under the glass is a dial bearing a set of drift lines. This dial is linked to the reticle in the field of vision so that however the two are turned, the drift lines on the card stay parallel with the drift lines of the reticle. When the card is turned so that its drift lines are parallel to the line you have drawn on the glass, then the drift lines of the reticle are parallel with the path of the object across the field. Therefore, to read drift, you align the drift lines of the card with the line you have drawn on the glass; then you read the drift scale opposite the pointer.

The advantage of the tracing method is that you can take an average of several readings. Don't rely on a single tracing. Make enough tracings so that you can see some consistency among them. Make some tracings on each side of the center; otherwise there is a slight error.

With the B-5 driftmeter you should use a soft pencil. It is preferable to clean the glass with a damp rag. If you use an eraser, the fragments will tend to clog the instrument.

THE BOMBSIGHT

A bombsight makes an excellent driftmeter. It gives accurate results even at high altitudes.

WIND FINDING

You should obtain wind information from the weather office before every flight. This infomation usually is very helpful, but occasionally it is greatly in error. For this reason, you should continually find the wind during flights.

There are several methods by which you can find the wind. Since each method requires certain data which are not always available, you will not necessarily have your choice of methods. Therefore, you should know all methods.

You have already seen that you can find the wind velocity by solving the wind triangle, if you know the TH-TAS vector and the TR-GS vector. You can find the TH-TAS vector by reading your flight instruments, and there are several ways of finding the TR-GS vector. You may be able to find it by locating the airplane's position; you will learn this method under "MAP READING," Section 3. Frequently, however, you may find it impossible to establish your position. If you don't know your exact position there are two methods of finding the TR-GS vector with the aid of the driftmeter.

Finally, you may find the wind by direct observation, without knowing the TR-GS vector or your position.

The methods of wind finding, when the airplane's position is not precisely known, are discussed on the following pages under these three topics: (1) drift on multiple headings, (2) groundspeed by timing, and (3) wind pilotage.

DRIFT ON MULTIPLE HEADINGS

If you can read drift on two or more headings, you can find the wind. You do this by means of a vector diagram which combines two or more wind triangles.

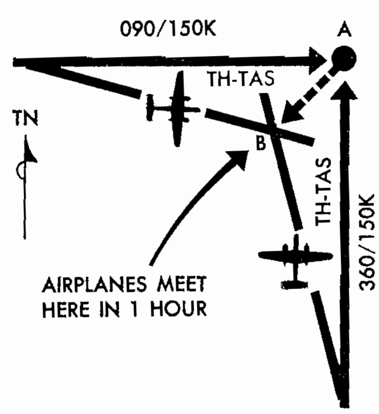
Suppose two airplanes are each 150 n.m. from point A, one west and the other south. The first flies a TH of 090° and the second a TH of 360°, each with a TAS of 150K. If there is no wind, the two airplanes meet at point A after one hour.

If there *is* a wind, it carries both airplanes the same distance downwind in an hour. Therefore, at the end of the hour the two airplanes meet at some point B, downwind from point A. The line AB shows the distance and direction that the wind carries the airplanes in one hour. Therefore AB represents the wind velocity.

If this diagram is drawn to scale, you can find the wind velocity by measuring AB. For example, the first airplane, flying 090° at 150K, drifts 15°R; and the second, flying 360° at 150K, drifts 15°L. The wind velocity, found by measuring AB, is 45°/45K.

If a single airplane, flying on the same two headings, drifts 15°R on the TH of 090° and 15°L on the TH of 360°, you can find the wind by exactly the same diagram. Note, however, that the diagram does not represent the path of the single airplane over the earth.

To find the wind by drift on two headings, you may draw a vector diagram on your chart. Usually, however, you will use the vector face of your computer. The following sample problem is solved by both methods.



TO FIND WIND VELOCITY WHEN DRIFT ON TWO OR MORE HEADINGS IS KNOWN

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Chart Solution

Construct the triangle:

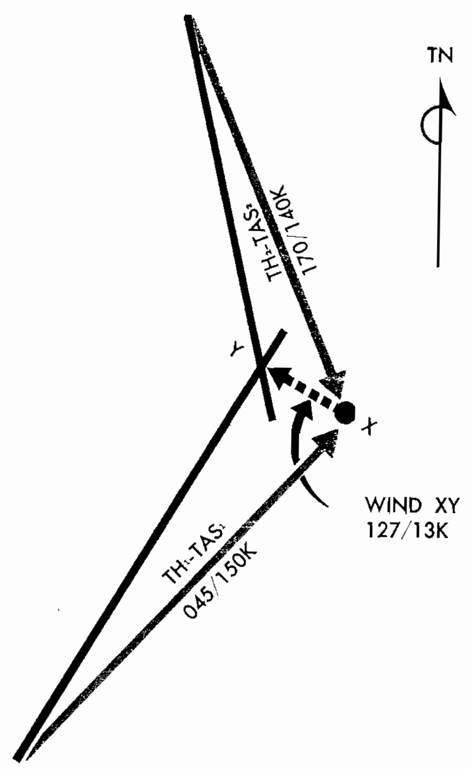
1. *To* any point X, draw the first TH-TAS vector in the direction of TH_1 (045°) and to the length representing TAS_1 (150K) in any convenient scale.
2. Apply $drift_1$ (5°L) to TH_1 (045°) to obtain TR_1 (40°). From the tail of the first TH-TAS vector, draw a line in the direction of TR_1 (40°) and of indefinite length, since you don't know GS_1.
3. To point X, draw the second TH-TAS vector in the direction of TH_2 (170°) and to the length showing TAS_2 (140K) in the scale used in step 1.
4. Apply $drift_2$ (4°R) to TH_2 (170°) to obtain TR_2 (174°). From the tail of the second TH-TAS vector, draw a line in the direction of TR_2 (174°) and extend it to intersect the first TR line at some point Y.
5. Draw the line XY.

This line is the wind vector. Its head is at the intersection of the first TR-GS vector and the second TR-GS vector. Thus you have drawn two wind triangles with a wind vector in common.

Now read the answers:

6. To determine WD (127°), measure the direction of the wind vector XY. Remember again that WD is the direction *from* which the wind blows.
7. To determine WS (13K), measure the length of the wind vector, using the same scale as before.
8. To determine GS_1 (149K) and GS_2 (131K), measure the length of the first and second TR-GS vectors, using the same scale as before.

If you know the drift on another heading, you can draw in another TH-TAS vector and another TR line. If your work has been perfect and if the wind has not changed between drift readings, this new TR line should pass through point Y. Usually, however, it will form a small triangle with the first and second TR lines. You will then call the center of the triangle point Y and proceed as before.



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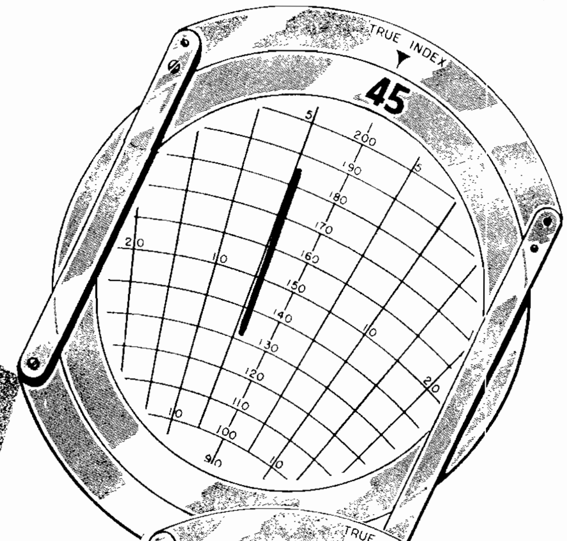
Computer Solution

Set in the data:

1. Set TH_1 (045°) under the true index and TAS_1 (150K) under the grommet.

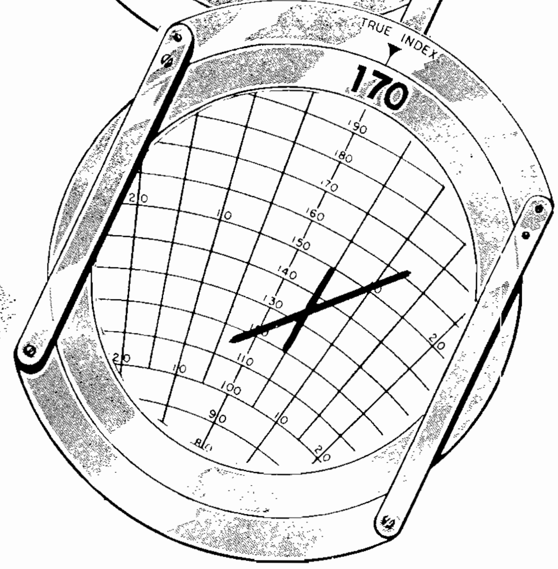
2. On the transparent circular plate rule a line over the track line (5° left of center) representing TR_1. Remember that the TR is the same number of degrees right or left of the center line that drift is right or left. If drift is 10°R, you use the track line 10° right of the center line.

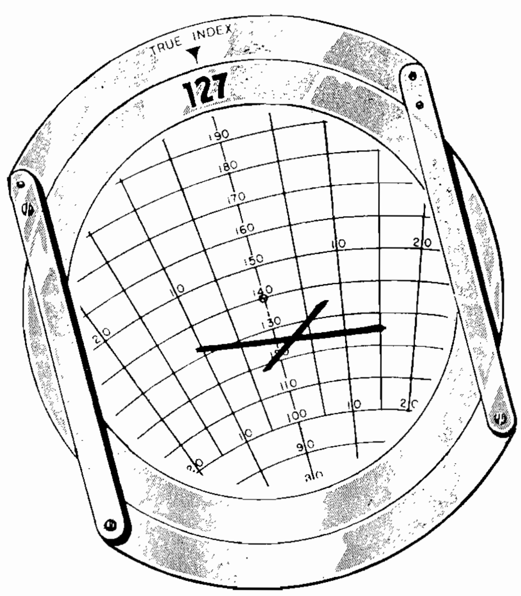


3. Set TH_2 (170°) under the true index and TAS_2 (140K) under the grommet.

4. Rule a line over the track line (4° right of center) representing TR_2.

The intersection of the two lines which you have drawn is the head of the wind vector; and, *for any TH*, this intersection is the head of the TR-GS vector.





Now read the answers:

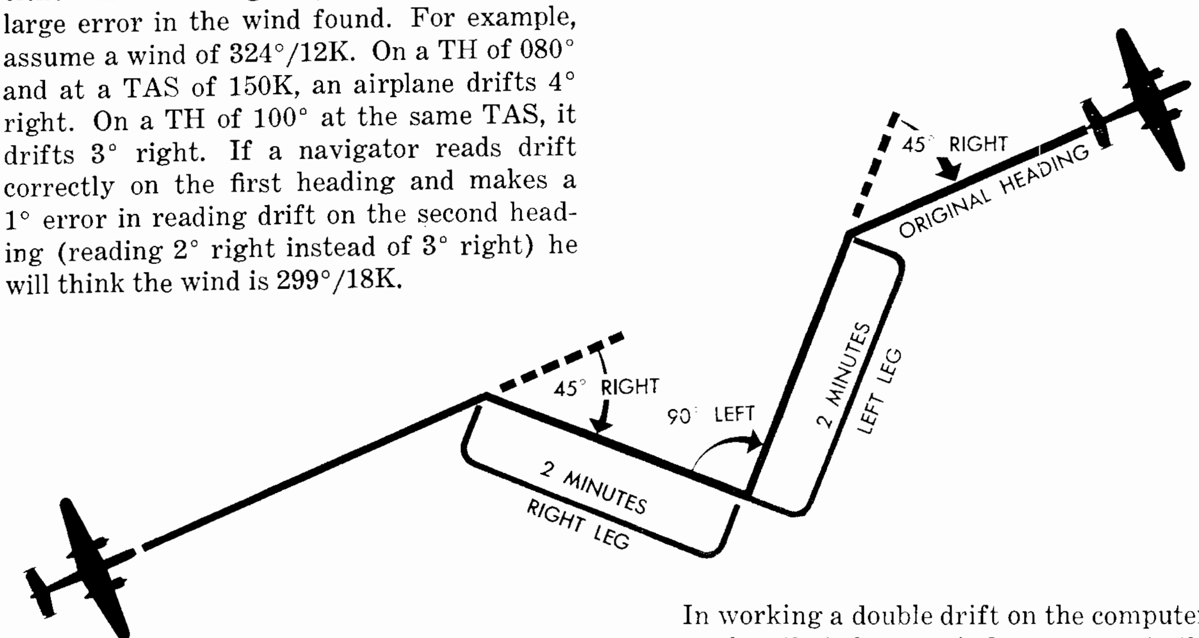
5. Leaving TH_2 under the true index and TAS_2 under the grommet, read GS_2 (131K) on the speed circle passing through the head of the wind vector.

6. Rotate the compass rose until the head of the wind vector is on the center line below the grommet. Now read WD (127°) under the true index, and WS (13K) from the grommet to the head of the wind vector.

7. If you want GS_1, put TH_1 (045°) under the true index and TAS (150K) under the grommet. Read GS_1 (148K) on the speed circle passing through the head of the wind vector.

If you know the drift on another heading, you can rule in another track line on the computer. If the three lines intersect at a point, you use that point as the head of the wind vector. If they form a triangle, you use the center of the triangle.

You can and should find the wind by drift on two headings whenever course is altered more than about 30°. If the change of heading is much less than 30°, a small error in either drift reading may cause a relatively large error in the wind found. For example, assume a wind of 324°/12K. On a TH of 080° and at a TAS of 150K, an airplane drifts 4° right. On a TH of 100° at the same TAS, it drifts 3° right. If a navigator reads drift correctly on the first heading and makes a 1° error in reading drift on the second heading (reading 2° right instead of 3° right) he will think the wind is 299°/18K.



DOUBLE DRIFT

Sometimes your flight plan will call for no alteration of course great enough for you to find the wind by drift on two headings. At other times you may wish to find a wind soon after departing on a mission and before you alter course. In either situation, you may turn away from your correct TH long enough to make drift readings on two other headings and then return to the correct TH. This procedure is known as flying a **double drift (DD).**

The double drift is flown according to a definite, standardized pattern. First you change headings 45° to the right and fly a **right leg** for 2 minutes. Then you change headings 90° to the left and fly a **left leg** for 2 minutes. Finally you change headings 45° to the right, thus turning back onto the original TH, though usually not quite onto the extension of the original TR.

Reading drift on the right leg, on the left leg, and on course, you can find the wind by drift on three headings. You can use either the chart solution or the computer solution, just as in the preceding example. Since you will usually work out the double drift solution on your computer, an example of the computer solution will be given.

In working a double drift on the computer, remember that the true index represents the TH of the airplane, and that you turn the compass rose relative to the TH instead of turning the TH relative to the compass rose. This makes it seem natural to turn the compass rose in the *wrong* direction. To change to a TH 45° to the right, you could hold the compass rose and turn the computer frame 45° to the right. Instead, you rotate the compass rose 45° to the *left*. The result is the same. For example, suppose that you turn 45° right from a TH of 060°. Your new TH would be 105°. To get 105° under the true index, you must turn the compass rose 45° to the *left*.

Note that the drift scale on the computer frame extends 45° to each side of the true index. This scale is useful in working out a double drift. To change to a TH 45° to the *right*, turn the compass rose until the on-course TH is under the 45° mark to the *left* of the true index.

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Computer Solution of Double Drift

[redacted]

Set in the data:

1. Set on-course TH (060°) under the true index and TAS (130K) under the grommet.

2. On the transparent plate, rule a line over the track line (5° left of center) representing on-course TR. Remember that TR is the same number of degrees right or left of the center line that drift is right or left.

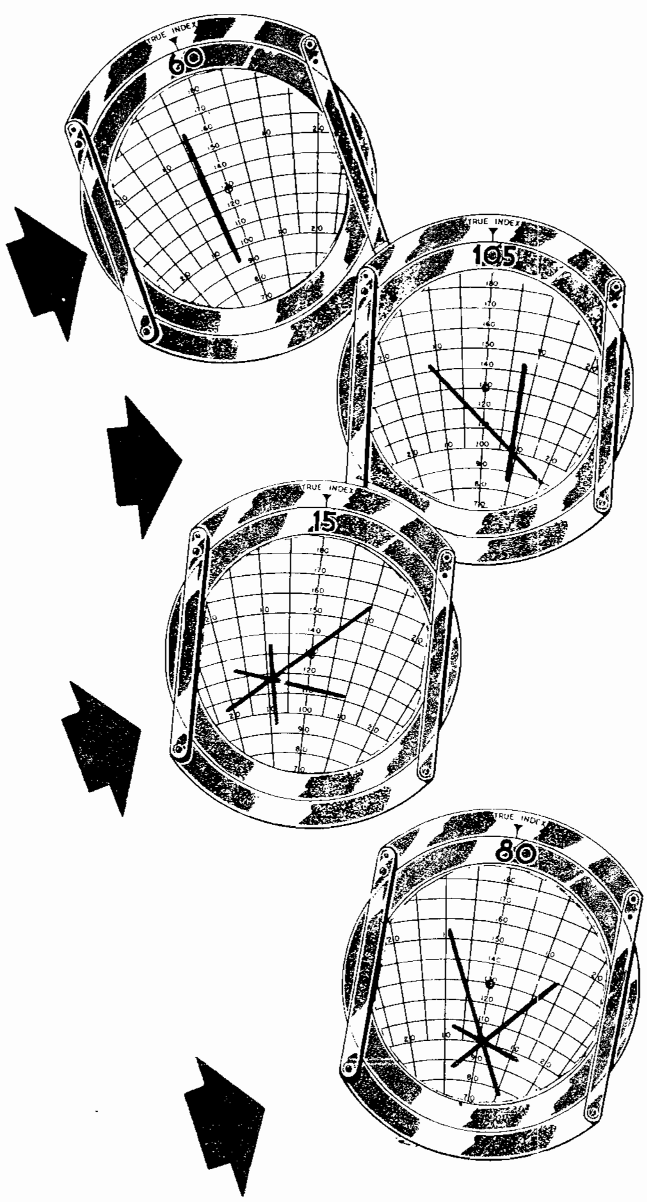
3. Rotate the compass rose 45° left, that is, until the on-course TH (060°) is under the 45°-left-drift mark. Then the right-leg TH (105°) is under the true index.

4. Rule a line over the track line (6° right of center) representing the right-leg TR.

5. Rotate the compass rose 90° right, that is, until the on-course TH (060°) is under the 45°-right-drift mark. Then the left-leg TH (015°) is under the true index.

6. Rule a line over the track line (11° left of center) representing the left-leg TR.

If the three track lines intersect at one point, use that point as the head of the wind vector. If they form a triangle, use the center of the triangle.



Now read the answers:

7. Set on-course TH (060°) under the true index. Read on-course GS (106K) at the speed circle passing through the head of the wind vector.

8. Rotate the compass rose until the head of the wind vector is on the center line below the grommet. Now read WD (080°) under the true index, and read WS (26K) from the grommet to the head of the wind vector.