Pressure-Pattern Navigation

Perk up your long cross-country flights with a different navigation system. No mysterious black boxes required—only a flair for something new, a rate-time-distance computer and a compass

by BARRY SCHIFF / AOPA 110803

■■ Every once in a while a pilot becomes utterly bored with the prosaic chore of navigating a long cross-country trip. So there he sits, watching for the timely flip-flop of a TO-FROM indicator, or mesmerized by the hypnotic wig-wagging of a LEFT-RIGHT needle. Ho hum!

When this happens, it's time for a change of pace. Perhaps experimenting with a different method of navigation will liven things up a bit.

For the most part, pressure-pattern navigation techniques (aerologation) have been set aside for use by the big boys in their long-range aircraft. But this needn't be so. The same techniques can be applied to cross-country navigation in light aircraft. It's not only a challenging method of navigation, it's also refreshing to learn that expensive, heavy black boxes are not required as part of the deal. All that's needed is a rate-time-distance computer, a compass, and a flair for something new.

Most pilots have heard of a technique allowing deviation from a direct course to take advantage of favorable tail winds or to evade strong head winds. This has become standard procedure on most airline flights of two hours or more. For example, when a high-pressure system sits over the central United States (see Figure 1), eastbound jets fly north of the high, while westbound jets deviate south of it. In both cases the courses, though many miles longer than a direct straight-line course, will take appreciably less time. This off-course flying is called the minimum-time route (MTR). It is a classic example of the goal of pressure-pattern navigation: to make the most of existing pressure and wind conditions.

Euclid, father of modern geometry, may have been right when he said that the shortest distance between two points is a straight line, but he certainly didn't have the pilot in mind. The shortest flying time en route is generally achieved by following along the often curved and devious MTR.

Many pilots attempt to employ this technique although few are successful at it. How far off-course should a pilot go to put the prevailing winds to advantage? Obviously, a pilot should not fly 100 miles off-course during a 200-mile trip even though strong tail winds would be gained. Determining the minimum time route cannot be done through hunches or guesswork. Most of the time, a pilot is better off flying the direct course rather than guessing. The forbidding grid side of an E-6B computer could be used to determine the MTR, but that would be too much like work. There is a far simpler method at hand.

Not too long ago, a Chicago scientist, Dr. John C. Bellamy, devised a rather simple formula that caused a navigational revolution. He stated that no matter what wind conditions exist along a given route, that trip can be flown with a single heading. His formula led to what is now the basis for pressure-pattern navigation. By using the Bellamy formula, a pilot can depart on any flight with one—and only one—wind correction and this correction ultimately will lead the pilot to his destination, despite the wind shifts (speed or direction) encountered en route. And the track established by an aircraft flying a single route heading to the destination later will prove to approximate closely the minimum time route.

The magic key to successful pressure-pattern navigation was expressed by Bellamy as follows:

$$\text{Drift} = \frac{(P_2 - P_1)\ K}{\text{TAS}}$$

In the formula, P_2 is the actual barometric pressure at cruise altitude above the destination airport and P_1 is the actual barometric pressure at that same altitude above the departure airport. These pressure values generally can be obtained from the Weather Bureau prior to departure. Should they be unavailable, destination and departure altimeter settings can be substituted with negligible accuracy loss with cruising altitudes of less than 10,000 feet MSL. If the flight is to be conducted above 10,000 feet, the pilot will require access to a constant pressure chart covering his route of flight.

The TAS (true airspeed) must be expressed in knots. K is a factor dependent upon the average latitude of the trip

FIGURE 1

When a high-pressure system sits over central portion of the United States, eastbound jets fly north of the high; westbound jets deviate south of it.

Illustrations by the author

to be flown and may be determined from the following table:

Latitude Range	K Factor
22°–25°	540
25°–28°	480
28°–31°	440
31°–34°	400
34°–38°	360
38°–43°	330
43°–50°	300
50°–55°	270

Now for a hypothetical problem. A pilot is about to embark on a trip from San Francisco to Los Angeles. The average latitude between SFO and LAX is quickly determined from the aeronautical chart; it's about 36° N. A K factor of 360 will be used, therefore, in the formula. A cruise altitude of 7,500 feet is selected and the pilot determines (from the Weather Bureau) that the barometric pressure at 7,500 feet is 22.75 inches above SFO and 22.95 inches above LAX. The TAS of our Firebang Special is 100 knots. The known values are now plugged into the Bellamy formula to obtain the drift.

$$\text{Drift} = \frac{(2295 - 2275)\ (360)}{100} = 72 \text{ NM}$$

Notice that (1) the decimal points in the pressure values are omitted and (2) the drift is shown in nautical miles. This simply means that if no correction were made for en route winds, the aircraft would have drifted 72 NM off course by the time it should have arrived over LAX, the destination airport.

A question now is raised as to whether the 72 NM drift will be left or right. Think carefully; think of the wind circulation about high- and low-pressure areas. Pilots have to learn this before being licensed; it's basic knowledge for all flyers. Since destination barometric pressure is higher than that of departure, the flight is being made, effectively, out of a low-pressure area into a high. Would the pilot expect left or right drift? Careful now! If you would anticipate a left drift, proceed to the head of the class.

If you're not interested in using logic to determine the direction of drift, just remember these simple rules. When P_2 is larger than P_1 ($P_2 - P_1$ is positive), a left drift can be expected. When P_2 is smaller than P_1 ($P_2 - P_1$ is negative), a right drift can be expected. In the example, P_2 is greater than P_1. The aircraft therefore can be expected to have drifted 72 nautical miles to the left of Los Angeles if no correction for wind were made.

The left drift of 72 nautical miles (83 statute miles), as determined by Bellamy's dandy arithmetical computation, is easily convertible to a drift angle through a simple flick of any time-speed-distance computer. Set up the amount of drift (72 NM) on the outer scale opposite the distance to be traveled on the inner scale. For purposes of this example, the distance from SFO to LAX is approximately 300 NM. Opposite 60 (57.6 for those who want greater accuracy) on the inner scale, read the drift angle of 14° on the outer scale. Since drift is left, the 14° wind correction angle must be added to the true course. The true course from SFO to LAX is about 145° plus a 14° wind correction, which will provide a true heading of 159° to fly the intended route. This is the one and only heading that will correct for all wind conditions between SFO and LAX when the given pressure values exist. The track resulting from flying this heading represents a close approximation of the minimum time route between those two points.

In the example, it was determined that the drift for the intended trip would be 72 NM to the left. This does not mean that only a left drift would be encountered during the trip. The Bellamy formula only states that the net drift at the end of the flight will be 72 NM to the left if no correction for wind is made. Indeed, during the course of the flight, the aircraft may drift both right and left of course, depending upon actual winds encountered. The net result of *all* winds acting upon the aircraft will cause a 72 NM left drift.

At first it may be difficult to believe that this one drift correction will provide for arrival precisely over destination. Although it appears that no compensation has been provided for high-velocity winds which may exist en route, this is not true. The pressure differential between any two points will determine the *net* effect of all winds between them.

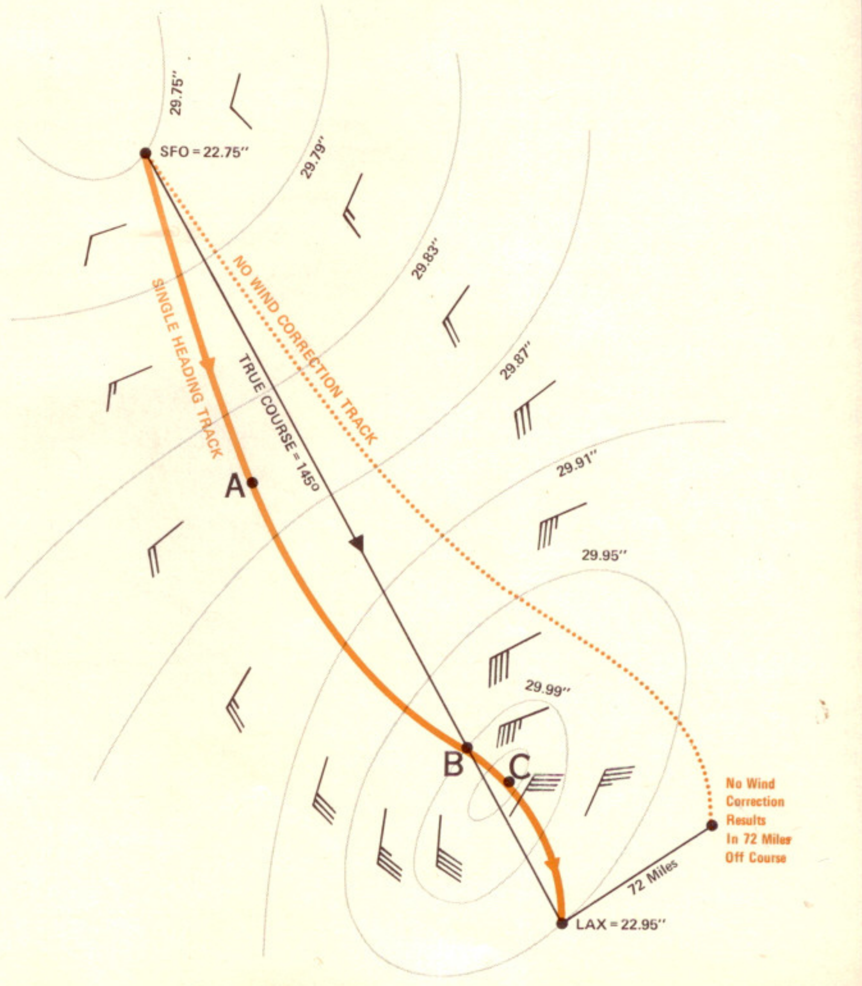
Figure 2 is only one of many possible situations which could exist between SFO and LAX when differential pressure is .20 inches Hg (22.95" − 22.75"). SFO is located under a low-pressure system and a pilot would experience a slight right crosswind as he began his trip. The wind is so weak that the 14° crab would be considered an overcorrection and the aircraft would fly slightly right of course. Upon reaching Point A, the winds have picked up in strength and begin to blow the aircraft back on course (Point B). As the flight progresses toward the high-pressure area, greater drift is encountered and the ship drifts considerably left of course. At Point C, the aircraft is abeam the high and the wind shifts from a right crosswind to a left. Now the aircraft drifts toward the original straight-line course. If everything has gone according to Hoyle (or Bellamy!), the reinterception of the direct route should take place above the LAX airport.

Actually, there are an infinite number of pressure patterns that could exist between SFO and LAX, but as long as the pressure differential between them remains the same, the average crosswind or net drift will also remain the same.

The dotted line in the example repre-

FIGURE 2

One of many possible situations which could exist between San Francisco and Los Angeles when differential pressure is .20 inch Hg.

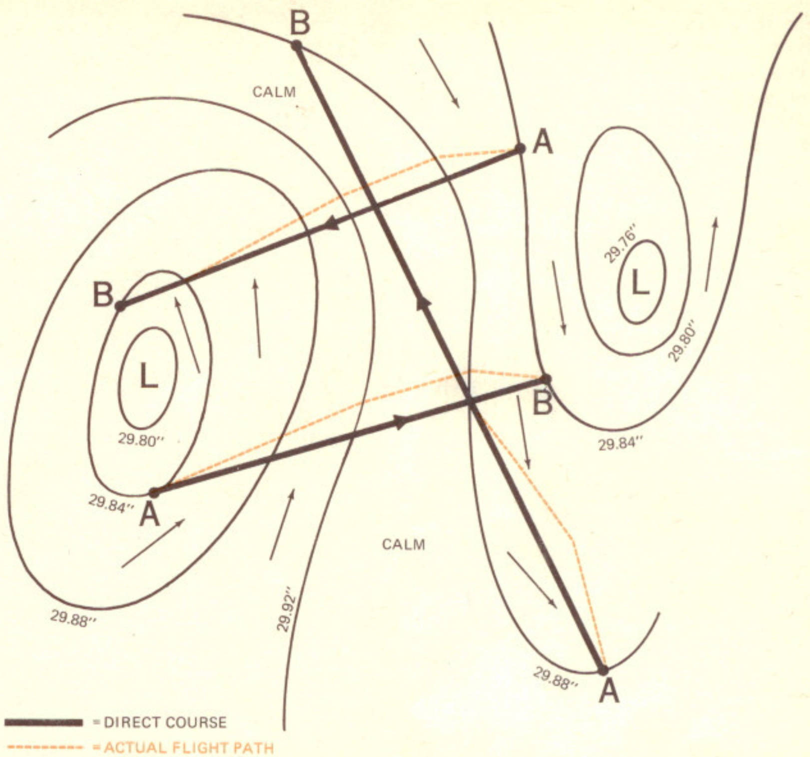


sents the course that would have been followed had no wind correction been made. Note that the aircraft would have arrived 72 NM to the left of LAX, the net effect of all drift encountered en route.

Single-heading flight reduces time en route for a very simple reason. During a normal flight along a fixed course, a pilot may have to crab right or left as he progresses in order to maintain a constant straight-line track. Each time he crabs into the wind, his ground speed will be lessened, increasing the time required for the flight. Using a single heading allows the aircraft to drift right and/or left of course without the loss of ground speed caused by variable crab angles. The actual track flown may be a few miles longer, but it will definitely take less time to fly. It is also easier to execute a flight with one heading than to compute and fly the various headings often required to fly a straight-line course with variable winds aloft.

By a quick glance at Dr. Bellamy's formula, it should be apparent that if the pressure values at the destination and departure airports are the same, then $P_2 - P_1$ will equal zero and the net drift for the entire flight will also be zero. Under these conditions, you could take off with absolutely no wind correction and expect to arrive over your destination in minimal time, despite the winds aloft. You may encounter drift en route, but the net drift effects of all winds encountered will be nil—and you will have flown the minimum time route. This, too, at first may be a bit tough to swallow, but Figure 3 should dispel any confusion. A flight conducted between any two points of equal pressure will encounter as much left drift as it will right. And voila! No wind correction is necessary to fly the MTR.

The main advantage of pressure-pattern navigation is obvious. It provides a method of flying from A to B in minimal time without having to fool around with wind triangles and their resultant and time-consuming crab angles. It's also easier for the Weather Bureau to forecast accurate barometric pressure values than winds aloft.



No wind correction is necessary to fly the minimum time route between any two points of equal pressure. There will be as much drift to the left as to the right.

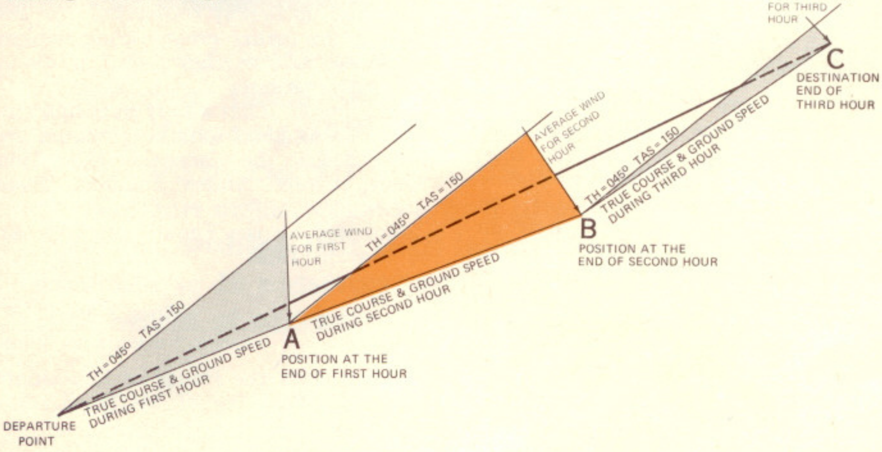
FIGURE 3

But there are some problems. The accuracy of single-heading flight diminishes as the pressure values at the terminal points of the flight change. If they both go up or down, the flight will be unaffected as long as the difference between them remains relatively constant. But if one value should rise while the other drops (not too likely on trips of less than a few hundred miles), then the net drift encountered will change accordingly. The shrewd Magellan-type can counter these barometric pressure changes by determining new wind correction angles with the Bellamy formula as the flight progresses.

Another disadvantage arises when the pilot attempts to plot the MTR on his chart. After all, it's nice to have some checkpoints for reference. Unless an upper-air chart is available, this really isn't too easy. The Weather Bureau might frown on an attempt to plot courses on one of its beautiful charts, so always ask for one of your own. As a last resort, the wind triangles can be plotted on a conventional sectional or WAC chart. First, plot the true course on the chart as in Figure 4. Then draw a line which represents the true heading from the departure point. The angle between the TC and the TH is obviously the single-heading correction angle. Then measure a distance along the TH line that is equal to one hour's worth of TAS and mark an X. This is where the aircraft would wind up under no-wind conditions. From this point draw a wind vector representing the average wind to be encountered during this first segment of the flight. Winds aloft information can be obtained directly from the upper-air chart or from a conventional forecast. The end of the wind line (Point A) represents the expected position of the aircraft at the end of one hour of cruise flight. From Point A, draw a new true heading line and repeat the process over and over until the destination is reached. By connecting all of the "one-hour" positions with a smooth curving line, a close approximation of the MTR will be reached.

FIGURE 4

Plotting true course (TC) and true heading (TH). Angle between TC and TH is the single-heading correction angle.



On the other hand, those less inclined to pencil, plotter, and chart and more prone to adventure might decide to chance it, not really knowing where the winds will blow them until arrival over the destination. Have faith that the single-heading technique will work, but it is advisable to monitor the path of flight with at least a sectional chart. This writer doesn't wish anyone to get lost.

Pressure pattern navigation doesn't lend itself too well to on-the-airway flying. The FAA simply won't cooperate by laying out its route structure according to the daily whims and dictates of the wind. But a modification of the single-heading technique can prove beneficial if VOR to VOR flight is desired. Using the techniques previously described, obtain a plotted MTR. Then select the VOR stations most closely aligned with it and prepare an airway-modified MTR. The results may be surprising. An airway ordinarily considered out of the way might fit pleasantly into the scheme of things.

Determining precisely how long the trip will take also creates problems. The ambitious pilot can continue with the wind triangles to obtain various en route ground speeds. A simpler but not-so-accurate technique involves obtaining an estimated time en route by normal methods and then saying to himself: "Using the MTR, I know it'll take *somewhat* less time." Half the fun is finding out precisely how much time is saved. See how much time can be shaved off the ETA obtained with standard dead-reckoning methods. The results will be surprising.

One further word of caution. Pressure-pattern navigation can be used only when the chosen en route altitude is above the altitude below which wind speed and direction are modified by the frictional effects of the terrain. This takes place generally at 2,000 feet AGL and below. Above 2,000 feet above the terrain the winds are governed almost exclusively by the direction and spacing of the isobars, i.e., winds flow parallel to the isobars and the speed is inversely proportional to the distance between each one.

Pressure-pattern navigation works like a charm on long-distance flights. Its benefits have been known for many years. This technique may never replace VOR navigation for light aircraft but it is sure a lot of fun to play with. And who knows? If you become good enough at it, you may want to look into pressure lines of position, or PLOPS, as they're so ungracefully called. □

THE AUTHOR

Barry Schiff, who began flying when he was 14 years old, has devoted most of his adult life to aviation. Presently a pilot for Trans World Airlines, Schiff is well-known as an aviation writer. Readers of The PILOT will recall two of his recent articles in this magazine: Dial-In Doppler Navigation (June 1967, page 56) and LORAN (November 1967, page 81).
