## ONE-OFF Jerry Tremblay

The Altitude Correction Computer is a single-purpose device for calculating the true altitude of an airplane above a surface. Atmospheric pressure decreases with altitude. An airplane's altimeter is a barometer that indicates the altitudes above mean sea level corresponding to the pressures in a defined "standard atmosphere," as I will explain below. Although the atmospheric conditions are usually not standard, pilots can rely on the indicated altitude safely. However if the true altitude above a surface must be known for some reason--for example in aerial photography or bombing—then it must be calculated.

In February, 1946, G. H. Purcell of Dayton, Ohio, was granted US Patent No. 2,294,563 for his "Altitude Correction Computer." The two figures from the Purcell patent are shown below.

FIG. 1.

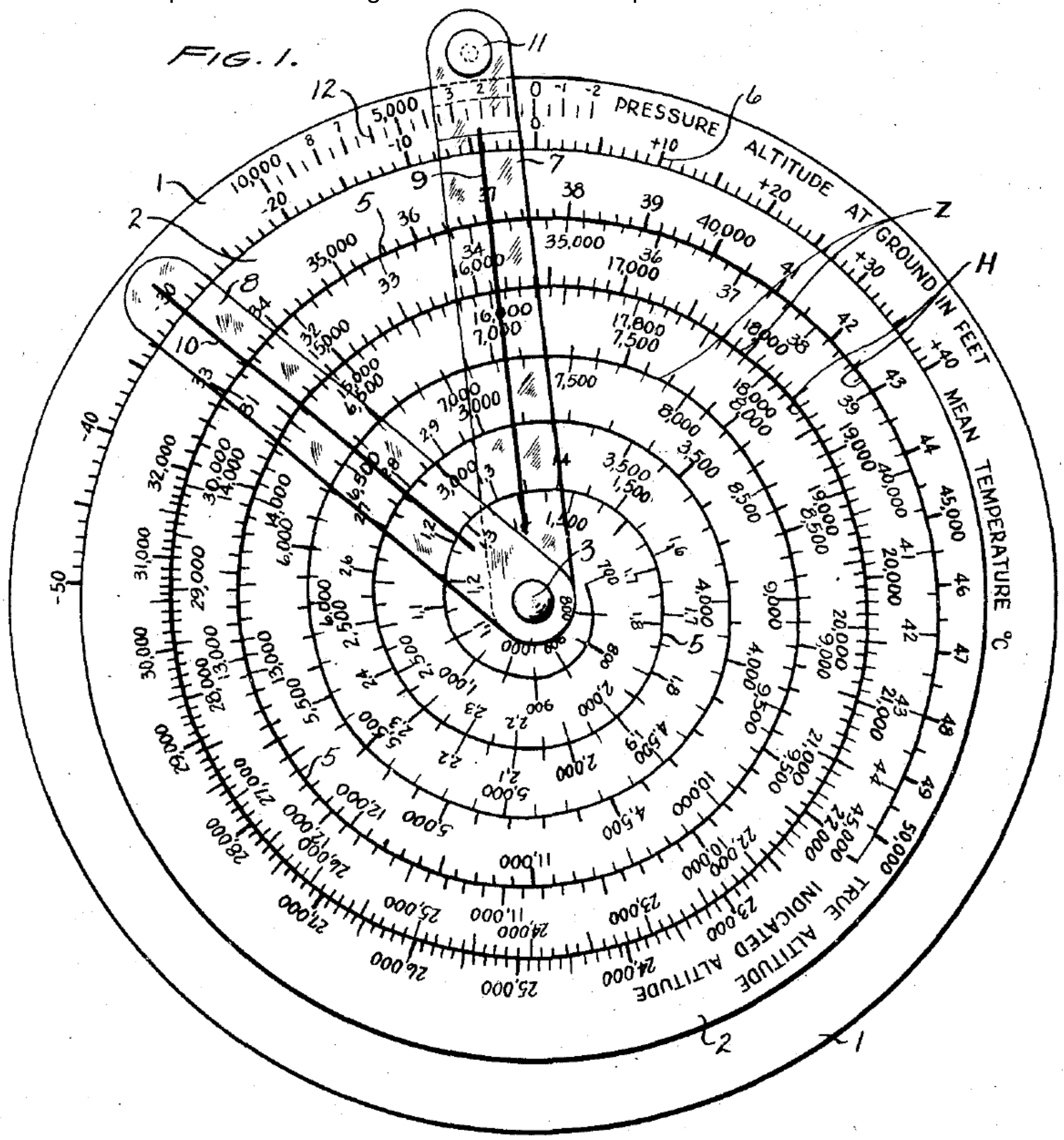
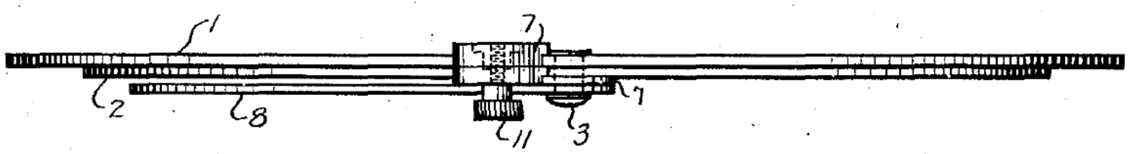
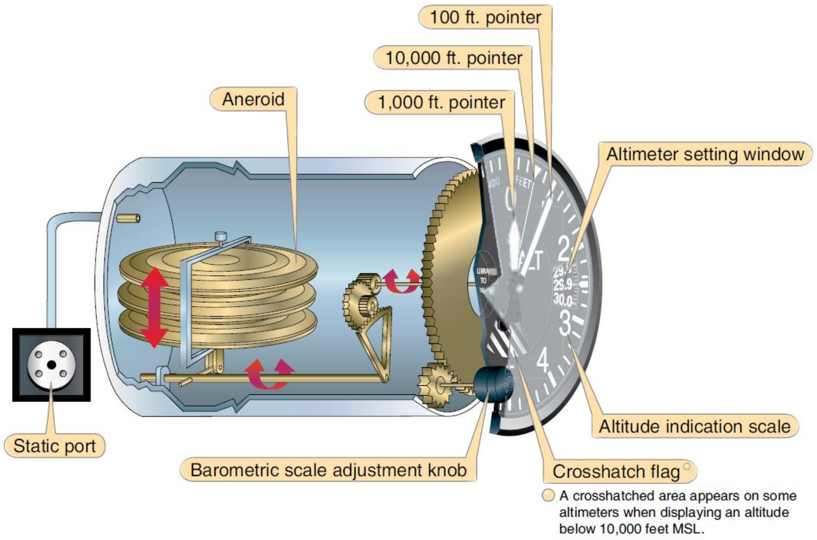



FIG. 2.



The device was manufactured under military contract by various manufacturers.[1] It is commonly called the AN-5837-1 Altitude Correction Computer, but an identical-appearing one made by the J. B. Carroll Company is labeled AN-C-91.
An airplane's altimeter is a sensitive, adjustable, aneroid barometer with hands that indicate the altitude. Images of the altimeter and its face are shown below.[2] The altimeter hands can be adjusted by turning a knob to the local atmospheric pressure setting, which is indicated in the small window on the right side of the instrument's face. The altimeter's scale is read like a clock with three hands. The long, thick hand indicates units of 100 feet or meters, a short, thick hand indicates 1000's, and small triangle on a long, thin hand is for 10,000's.



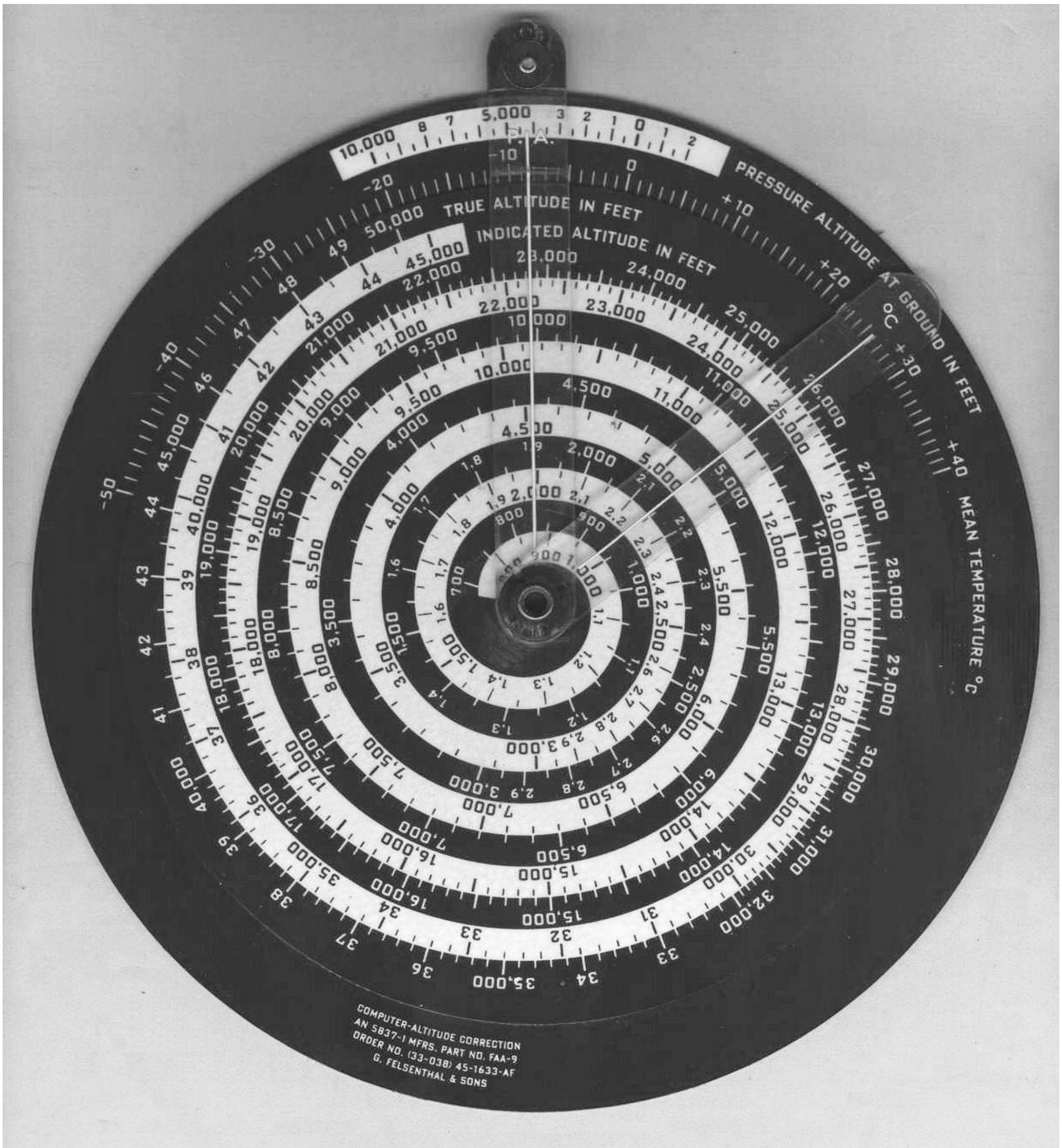


The altimeter is designed so that, when properly set to the current barometric pressure, it indicates the airplane's altitude above mean sea level (MSL). However, it indicates *true* altitude above MSL only in a defined "standard atmosphere."[3] The temperature of this standard atmosphere decreases with altitude 1.98 °C per 1000 feet (6.5 °C/km), which is called the standard temperature "lapse rate." The standard atmosphere is defined by international agreements as an atmosphere with a standard temperature lapse rate and a pressure of 1013.25 hPa or millibar (equal to 29.92 inches of mercury, in. Hg) and temperature 15 °C at mean sea level.
If an airplane's altimeter is set to 1013.25 hPa or 29.92 in. Hg, the altimeter will indicate what is called the "pressure altitude." Pressure altitude is the airplane's height above the standard barometric pressure plane (isobar). The pressure altitude equals the true altitude only in a standard atmosphere. Pressure altitude is used for several calculations in aviation, but its main use is as an altitude reference for fast, high-altitude airplanes. Instead of setting the current barometric pressure on the altimeter, pilots of high-altitude airplanes are required to set their altimeters to 29.92 in. Hg (1013.25 hPa) when they are at or above 18,000 feet MSL in the United States and in many other countries. The local barometric pressure changes too often for fast, high altitude jets flying long distances. Frequent resetting of the altimeter is not practical, so these airplanes use the 29.92 in. Hg isobar reference plane as their "zero" altitude reference. Although the actual height above or below sea level of the 29.92 pressure surface changes with air temperature, at high altitudes the airplanes are less concerned about ground obstructions. The main concern is vertical separation of airplanes flying high altitude jet routes. When the 29.92 altimeter setting is used, the altitudes are called "flight levels", and 18,000 feet is designated FL180. Other countries may use 18,000 as the transition to 29.92 setting and flight levels, or they may use a lower altitude.
Because temperature affects air density, variations in temperature will affect the indications of the altimeter. "Corrected" (approximately true) altitude can be determined using the airplane's outside air temperature. Corrected altitude is only approximately true because the outside air temperature does

[1] G. Felsenthal & sons, Chicago, Illinois. (Mfr's Part No. FAA-9), Cruver Manufacturing Co. (Mfr's Part No. C1920) and by the J.B. Carroll Company of Chicago (Mfr's Part No. 101) in the early 1940's.
[2] Images of the altimeter are from the *Instrument Flying Handbook*, Federal Aviation Administration. US government publications are not subject to copyright restrictions.
[3] http://en.wikipedia.org/wiki/International_Standard_Atmosphere

not necessarily reflect the average temperature of the column of air between the airplane and the surface.
In summary, to compute the corrected altitude, you at least need to know the temperature at your indicated altitude. Or better, if you know the average temperature between the reference location an your present altitude, you can calculate true altitude above the reference with fair accuracy.

The figures below are from Purcell's patent[4] and below them are a photograph of the front face of the device and the instructions on the back. There are 4 scales. Three scales are logarithmic and 1 is linear. The device consists of two plastic disks (labeled 1 and 2 in the patent drawing below) and two transparent cursors (7,8). The disks and cursors are independently rotatable about a common center to which each is held by a rivet (3). The overall diameter of the larger disk (1) is 20 cm. The cursor (7) labeled P.A. (for pressure altitude) is longer than the other cursor (8), which is labeled °C. Each cursor has a hairline in the middle (9, 10). The longer P.A. cursor (7) can be held at a desired pressure altitude reference setting by tightening the nut (11) on a small screw through its outer end.




4 http://www.google.com/patents/US2394563

Two logarithmic inner scales (5) spiral from the center of the inner disk (2). The outer spiral scale (H) is labeled “True Altitude in Feet,” and it the numerals are light-colored on a black background. The numerals range from 700 feet on the inside of the spiral to 50,000 feet on the outside of it. A light-colored spiral scale (Z) with black numerals is labeled “Indicated Altitude in Feet,” and it lies inside the true altitude spiral. It ranges from 800 to 45,000 feet and is shifted with respect to the true altitude spiral. Each of the spiral scales is graduated in 50 foot increments at the lower end and 500 foot increments at the higher end of the scales.
On the outer circumference of the larger disk (1) are two scales, the outer one (12) is linear, about 8 cm long, and is labeled “Pressure Altitude At Ground in Feet.” It ranges from -2000 (on the right) to +10,000 feet in 500 foot increments. Just inside the pressure altitude scale is a logarithmic temperature scale (6), about 22 cm long, labeled “Mean Temperature °C,” ranging from +40 (on the right) to -50 on the left in increments of 1 °C.

**To determine the true altitude of the airplane above a location on the ground:**

1. The pressure altitude and temperature of the reference location must be known. The reference location may be sea level, the takeoff airport, or a bombing or photography target.
2. Rotate the long, P.A. cursor over the pressure altitude of the reference location and tighten the locking screw to hold the cursor in place.
3. Rotate the inner disk so that the altitude indicated on the airplane’s altimeter (the black numerals on the inner spiral) are under the P.A. cursor line.
4. Rotate the shorter °C cursor to the mean temperature between the reference location and the airplane’s current altitude.
5. Read the airplane’s true altitude above the reference location under the cursor line of the °C cursor.

The patent explains the mathematical basis of the computation. Briefly, the logarithm of the mean temperature is added to the logarithm of indicated altitude to provide true altitude. Because the P.A. cursor is set at the reference location on the ground, the °C cursor will indicate the true height above the reference location. If one, by chance, happens to be in a standard atmosphere, then the indicated and true altitude will be the same. This can be demonstrated if one places the P.A. cursor line (9) over the zero on the outer pressure altitude scale (12) to represent mean sea level on a standard day. The temperature at 10,000 feet should be -5 °C (1.98 °C / 1000 feet, the standard temperature lapse rate, therefore a 20 °C decrease from standard temperature at sea level—15 °C—is 15 – 20 = -5 °C). The mean of the ground and outside temperate at 10,000 should, in a standard atmosphere, therefore be the mean of -5 and 15, which is +5 °C. If the °C is set at +5 °C the indicated and true altitude are the same. That is because the airplane’s altimeter is designed to indicated the true altitude in a standard atmosphere, and the example above assumed standard temperature and pressure at sea level and a standard temperature lapse rate. The altitude correction computer corrects the indicated altitude (Z) to the true altitude (H) by multiplying Z by the difference between the actual temperature lapse rate and the standard lapse rate.

A circular aviation slide rule like the E6B can be used to compute a “corrected” altitude, but not a true altitude because it is based on outside air temperature only, not the mean change in the temperature from the ground. My electronic flight computer has no altitude correction function at all. True altitude is not commonly needed, and existing cockpit tools do not provide a very precise result. Some GPS navigation devices provide accurate altimetry, but only if they are augmented by ground-based correction signals and the airplane’s GPS is equipped to receive them. Radar altimetry is available only in some modern airliners. The majority of airplanes rely on simple, reliable, and reasonably accurate barometric altimeters. The altitude correction computer described here provides true altitude with reasonable precision, but it is probably rarely used now. Fortunately, most pilots need not be concerned that their altimeter’s indicated altitude may not be the true altitude.