U.S. ARMY AIR CORPS AERIAL DEAD RECKONING COMPUTER TYPE E-6B

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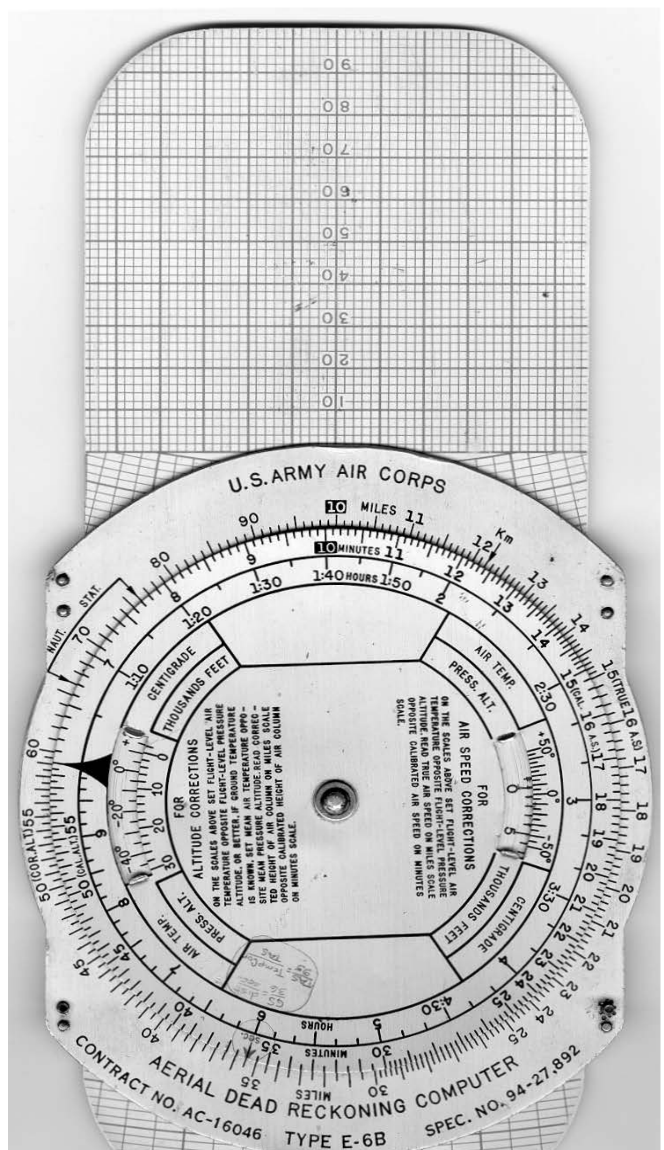
A good many years ago, I acquired a U.S. Army Air Corps, Type E-6B, "Aerial Dead Reckoning Computer." My mother bought it for me at a household auction for 25 cents! The rule is in what appears to be an original leather case, but has no instruction manual. There is no date of manufacture on the rule, but it has a 1935 copyright, and must date between then and 1947 when the Army Air Corps became the Air Force. The rule was manufactured by Keuffel & Esser Co. of New York, and is marked copyright 1935, P. Dalton, and patent no. 2,097,116. Further specification numbers and assembly drawing numbers are also given on the rule.

The patent referenced on the rule was filed in June of 1936, and issued to Philip Dalton of Washington, D.C., in October of 1937. It is titled "Plotting and Computing Device," and covers only the rather neat device for graphically solving various aerial navigation problems that constitutes the reverse side of the rule.

Schwartz [1] has recently described a similar rule produced at a later date by the Weems Division of Jeppesen & Company. The Weems rule is marked "Dalton Dead Reckoning Computer," and bears the same patent number but a slightly later copyright date (1938). Schwartz dates it to circa 1950. The sturdy aluminum construction of the two rules is quite similar, although the diameter of the rotating portion of the Air Corps rule is 110 mm, and the overall diameter is 122 mm, making it somewhat larger than the 105 mm given by Schwartz for the Weems rule. As Schwartz has indicated, the manufacture of this basic rule has continued to the present. I have a plastic version produced by Sanderson Films, Inc., copyrighted 1963, that I purchased new in 1965. (Sanderson, incidently, is also now a part of Jeppesen.) The same basic rule is currently produced by several suppliers, in aluminum or plastic, full or pocket-sized, and sold under such names as the "Sporty's Pilot Shop E-6B Computer" or the "ASA E-6B." Interestingly, the functions of the rule have also been incorporated into an electronic, hand-held calculator, yet it is still called an "E-6B"!

As Schwartz indicated, the E-6B is basically a classical circular slide rule with single-cycle logarithmic scales. The fixed outer scale is labeled "MILES," while the moveable inner scale is labeled "MINUTES." Both these scales range from 10 to 100 instead of the common 1 to 10. I assume that this is to make the numerical entries and results agree more readily with the range of values normally encountered in use. These scales provide for the basic time-distance and fuel-consumption calculations needed for navigation and flight planning. There is another scale printed on the moveable piece that is labeled "HOURS." It is basically a Minutes/60 scale to provide ready time conversion. An oversized pointer mark runs through the 1 on the HOURS scale and the 60 on the MINUTES scale.

The Front of the E-6B



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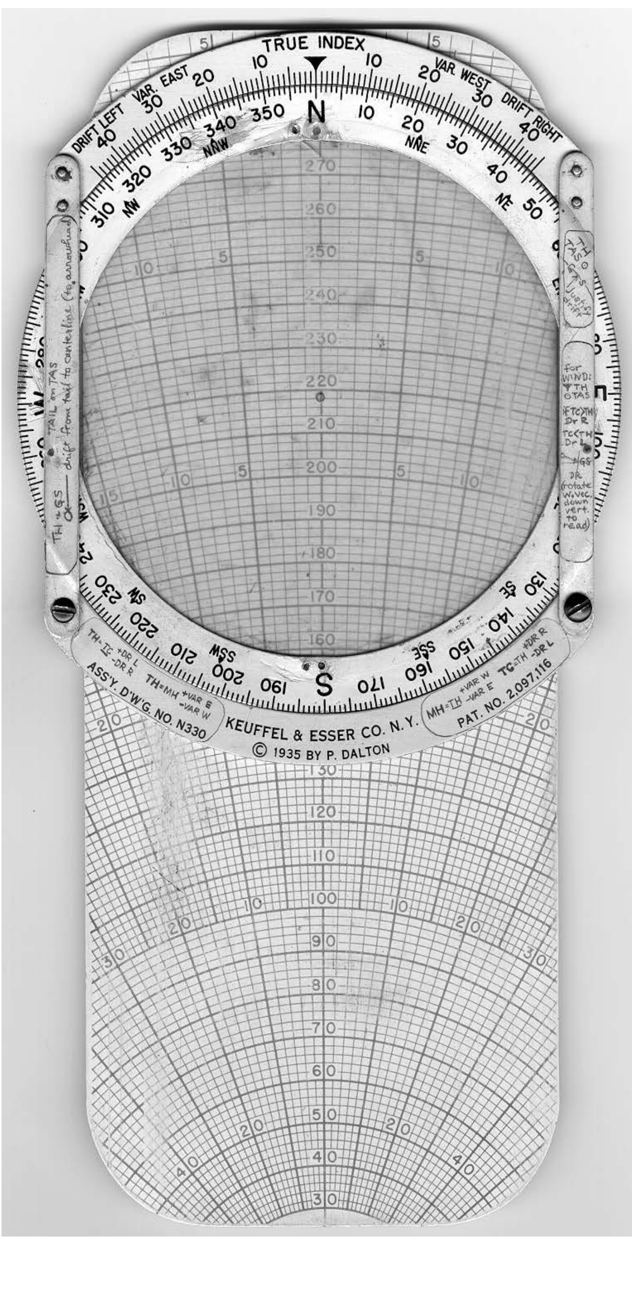
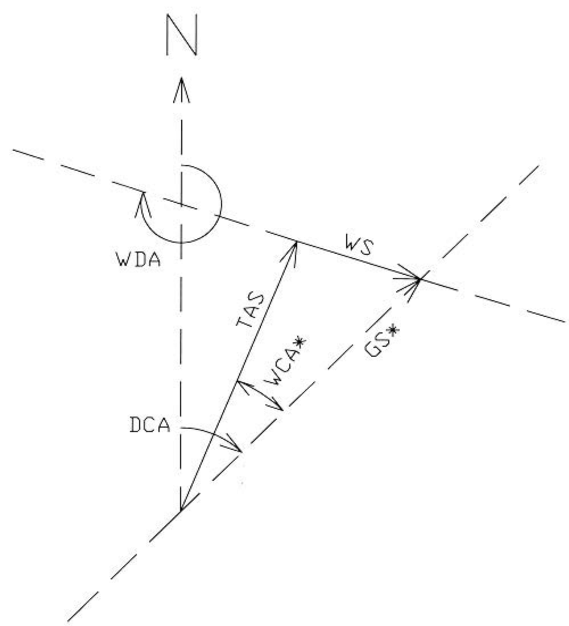
[1] JOS, Vol. 6, No. 1, March 1997

The front of the rule also provides for several ancillary calculations. Marks are provided along the stationary scale to allow ready conversion between statute and nautical miles, and between miles and kilometers. Two windows are located in the moveable part to provide for two other flight-related calculations. One provides a correction to the indicated pressure altitude (Note 1), and the other provides a correction to the indicated air speed (Note 2). Over the years the terminology used on the rules has changed somewhat, and what is shown as "COR. ALT." (corrected altitude) on the Air Corps rule, has become "TRUE ALT." on later rules. Additionally, the newer rules also include more ancillary conversions, including Fahrenheit to Celsius conversions, conversions between US and Imperial gallons, and conversions of fuel and oil quantities to weights.

The Reverse Side of the E-6B



The reverse side of the rule is Dalton's invention for the graphical solution to an interesting trigonometric problem. In making a particular flight, the desired course is known, and the speed of the plane through the air is given by the air speed indicator. The problem is to adjust the actual heading of the airplane to compensate for the winds aloft so that it tracks the desired course along the ground. The magnitude and direction of the winds aloft are known (or forecast), the direction of the desired track is known, and so is the magnitude (but not direction) of the plane's velocity. What needs to be found is the wind correction angle (the angle away from the desired course that the airplane must be pointed into the wind so that the ground track is along the desired course), and the resulting ground speed made good along that course. Fundamentally it is a vector addition problem, except that in this case the magnitude and direction of only one of the vectors is known, while only the magnitude of the other, along with the angle of the solution, are also known. A more complete demonstration of the problem is shown below:



Vector diagram of wind problem
* indicates quantities to be determined.

Suffice it to say for the moment that Dalton's combination of sliding plastic piece for magnitudes (high speeds on one side, low speeds on the other), and the rotating ring for angles, allows for a quick and simple solution to this problem. As Dalton noted in his patent, navigation and calculation tasks to be performed by a pilot require a device that can be operated with one hand - the other is needed to fly the airplane. Dalton's invention and a circular slide rule both fill this need nicely.

The availability of electronic navigation aids has lessened the need for dead reckoning navigation. The skills are still taught in pilot training, however, and are needed for careful flight planning, and as a back-up in case of electrical failure in the aircraft. Incidently, I have recently seen it claimed that the "dead" portion of dead reckoning is not correct. The claim was that it originally was "d'ed reckoning," for "deduced reckoning," but "dead" was obviously well established by 1935.

One of the interesting features of my particular Air Corps rule is the addition of several formulae and instructions by a previous owner. The formulae for conversion between magnetic and true headings, which involves the local magnetic variation (east or west, depending on present position), are included, as are the similar formulae for conversion between true course and true heading, which involves the wind correction angle. Added instructions also explain how to use the reverse side of the rule to solve the wind correction problem. These notes have been added in pencil directly on the aluminum portions of the rule, and then covered by a clear, plastic overlay. On the later Sanderson rule, all of these additions are now included as part of the basic rule. Given the nature of the formulae and the care with which they were added, I'd hazard a guess that these additions were done as part of formal flight training, and not independently by a previous owner of this particular rule.

In practice, the rule was used in planning the flight, and then in updating the plan as actual flight conditions changed. Based on forecast winds aloft and the performance characteristics for the plane, the pilot would calculate the estimated ground speeds for the various legs of the flight with the Dalton portion of the rule. Once the ground speeds are known, the flight times for the legs could be computed using the circular slide rule portion, based on the charted distances. And from those times and the performance charts, fuel consumption and weights could also be computed. In flight, the speed acheived over a leg, the actual wind correction angle required, and the aircraft's true airspeed could be used to determine the true winds aloft. And with all this information, the entire flight plan could be updated as necessary.

There are several variations of similar flight computers on display in the U.S. Air Force Museum in Dayton, Ohio. The most basic is the "TYPE D-4, TIME-DISTANCE COMPUTER." This rule is essentially the circular slide rule portion of an E-6B-type rule. (It doesn't have the Dalton navigation computer part.) It retains the altitude corrections window on the front, and the air speed corrections window on the back. The D-4 is about 4 inches in diameter, and is black anodized with white lettering. The one on display was manufactured by G. Felsenthal & Sons, and is marked MFR'S PART NO. FAA-11. The display label says: "Used in B-17 in England in WWII by donator."

There were also two of the Dalton-type rules on display. They were both manufactured by G. Felsenthal & Sons. One is in a WWII display and looks very much like my Air Corp rule, but is marked "Computer, Air Navigation, Dead Reckoning, Type MB-6B." It is also marked "MFRS PART NO FAA-46C." This is the same model rule used to illustrate the 1959 edition of the Air Force Manual on Air Navigation. The other rule is in a Korean War display and is the black anodized style instead of bare aluminum. It is marked "COMPUTER, DEAD RECKONING, AN-5835-1," and "MFGR PART NO. FAA-8." The sequence of manufacturer's part numbers in the display items is confusing, with the FAA-11 D-4 and the FAA-46C coming from WWII, with the FAA-8 coming from the Korean War.

I have not been able to find any reference to a G. Felsenthal & Sons in my search of current business directories, and they may well no longer be in business. I have also not seen any other references to Philip Dalton. I would appreciate hearing from any readers who can provide me with any further information.

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Note 1. The altimeter actually measures the pressure difference between a datum value (29.92" Hg) and that at the plane's position, adjusted for the current sea-level pressure (manually in the Kollsman window). This pressure difference is displayed as altitude, but the conversion makes the assumption that the air column below the plane follows the Standard Atmosphere. If the temperature variation with altitude of the air column is not "Standard," then the density of the air, and hence the pressure of the air column, is not standard, and the conversion from pressure to altitude is not accurate. By using the temperature of the air column at the plane's locations, or better yet, the mean temperature of the ground temperature and that at the plane's location, the indicated altitude can be appropriately adjusted.

Note 2. The indicated air speed depends on the difference between the "ram" and static pressures sensed as the plane moves through the air. Since the air may be more or less dense than "standard" at a particular altitude, the indicated air speed will be inaccurate. So, in a manner similar to correcting the altitude, the indicated air speed can be corrected for non-standard air densities.