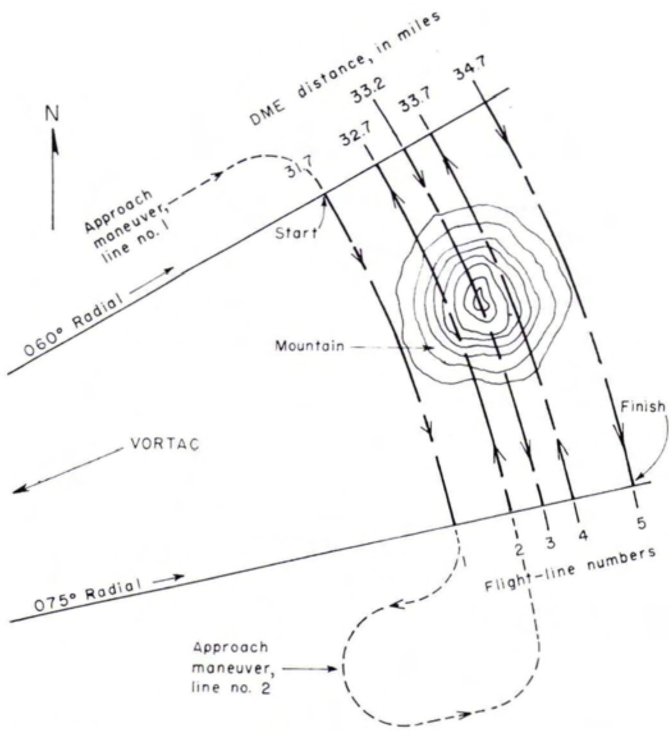

FIG. 1. Configuration of flight lines to survey area of small mountain.

RAY LAFFERTY, JR.*
U. S. Geological Survey
Phoenix, Arizona 85025

Circular Flight Paths Using DME

A quick, accurate, and inexpensive method for continuously determining the aircraft location is through the use of Electronic Distance-Measuring Equipment.

(*Abstract on page 199*)

WITH INCREASING USE of aircraft in collecting hydrologic data by remote-sensing techniques, it is extremely important that the exact aircraft location be known continuously. A quick and inexpensive way—involving hardware readily available—is to use electronic distance-measuring equipment (DME) with digital readout. The readout is in nautical miles and tenths of miles from the tuned TACAN facility. In using such equipment the aircraft location is fixed as accurately—particularly if the flights are at high altitudes—as when using visual reference points. Some kinds of hydrologic data, such as temperature profiles and infrared

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imagery, are collected at night, and the cost (equipment and man-hours) of specially placing visual navigational aids quickly becomes prohibitive. Thus the advantages of using DME equipment are obvious, particularly if the flights are to be over water or wilderness areas (day or night) where distinguishable landmarks are few. One needs only reconcile himself to using circular flight paths rather than the familiar straight-line runs.

Although there are some exceptions, generally speaking any location in the United States is within 70 miles of a TACAN facility. Such a facility is inherent in both the TACAN stations established primarily for military use, and the VORTAC stations established for joint civilian and military use. The term VORTAC signifies a combination facility incorporating the features of the Very High Frequency Omni-Directional Range Station (VOR) with those of the TACAN station. The altitude and nature of the terrain between the aircraft and the station determine the practical limits (high and low) between which flight lines may be successfully flown using that station for positioning. For flights at high altitudes the DME is accurate at distances well over 100 miles from the station, and for altitudes less than 15 percent of the distance from the station the slant range and ground distance are very nearly within 1 percent of each other.

The DME channels are in the ultra-high-frequency range—978 megacycles to 1212 megacycles—and are paired with the VOR channels occupying the 108- to 117-megacycle range. Because of this, reception is limited to line of sight. Although the effective or useful range is determined primarily by the nature of the intervening terrain, other contributing factors are the location and altitude of the ground transmitter, its power output and degree of maintenance, and the maintenance of the aircraft DME unit. Each DME unit contains a complete transmitter, receiver, power supply, and circuits for readout of range, speed, and time-to-station.

FIGURE 1 ILLUSTRATES an area around a mountain peak over which night flights are to be flown to collect certain hydrologic data. Upon checking the appropriate maps, the area is found to lie between the 060- and 075-degree radials of the VORTAC station selected for use. After carefully scaling the distance from the station to the mountain peak (in this case 33.2 miles) the four flight lines shown are drawn. The separation of the lines depends on the flight altitude chosen, the area covered by the scanner device or camera lens, and the desired image overlap. In this example, lines 2, 3, and 4 are placed half a mile apart, and lines 1 and 2, and 4 and 5, are placed one mile apart. Should there be any doubt as to the accuracy of the map, a flight over the mountain peak during the day can be made and the DME distance noted.

The best preparatory procedure involves designing a pattern for the flight similar to a standard-instrument-approach plate, since this device is familiar to most pilots. Assume the first flight line to be run is No. 1 and that it will be flown toward the south. The approach to the desired starting point at the north end of flight line No. 1 is planned from the west, well to the north of the 060-degree radial (Figure 1). Approaching the starting point on a course parallel to this radial (heading 060°), a standard-rate (3 degrees per second) right turn of 90 degrees is started at a distance short of flight line No. 1 equal to 0.006 multiplied by the speed of the airplane in knots. When the 90-degree turn is completed, the aircraft heading is 150°, and it is passing over the starting point on flight line No. 1. If the aircraft speed over the ground is assumed as 150 knots, with a no-wind condition, the turn would be started 0.9 nautical mile (DME) short of the starting point. For convenience, this value is rounded to one

ABSTRACT: *The use of distance-measuring equipment* (DME) *allows the accurate placement of an aircraft within a 150-mile range of Tactical Air Navigation System* (TACAN) *stations. This method of aircraft placement is particularly applicable to remote sensing, which frequently is done at night or through cloud cover. It is also useful for aerial photography where flight paths can be circular arcs having a large radius. The navigational precision made possible by such flight paths makes this, in many cases, the most efficient way to plan and execute the flight.*

mile and, in the example given in Figure 1, the turn is started at a DME reading of 30.7 miles.

If the aircraft is equipped with a Radio Magnetic Indicator (RMI), the specified flight lines and approaches thereto are simple to fly, even if accurate wind corrections are needed. The VOR pointer or needle in the RMI device points toward the tuned VORTAC station (see Figure 2). Thus on a clockwise run, such as that planned for flight line No. 1 (Figure 1), and again assuming a no-wind condition, the VOR needle should point steadily to the fixed reference point on the rim of the RMI instrument 90° clockwise from the index point. In other words, along flight line No. 1 the right wingtip of the aircraft will be oriented to point continuously toward the tuned VORTAC station. All corrections in heading should be relatively small, with the ones *toward* the radio station greater than those *away*, because of the continual curvature (*toward* the station) of the arc being flown. Progressing along the flight line, the magnetic heading will increase at a rate which depends on the speed of the aircraft.

The ground-speed indicator of the DME should read zero along the planned circular flight lines inasmuch as no progress is being made either toward or away from the radio station. With the use of dual VOR receivers, one can be set to indicate the 060-degree radial, which is the northern limit of the planned flight lines (Figure 1), and the other can be set to indicate the 075-degree radial, which is the southern limit.

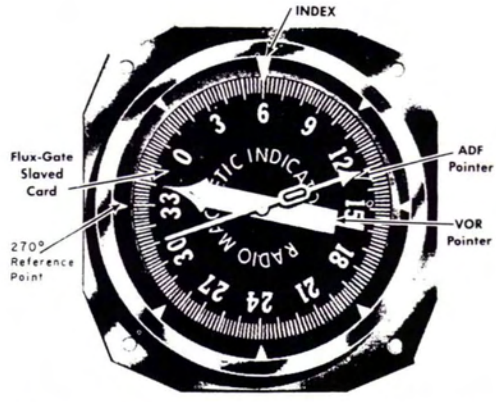

FIG. 2. Radio Magnetic Indicator with rotatable compass card for use in instrument flying to show magnetic heading of the airplane and bearings to navigational station aids. (Through permission of Jeppesen & Co.)

WHEN THE AIRCRAFT reaches the southern end of flight line No. 1, its heading is 165°. At this point, a 90-degree right turn is made toward the radio station and, as soon as the aircraft reaches its new heading of 255°, a 180-degree turn to the left is made (Figure 1). This places the aircraft back on a heading of 075° on a course parallel to, and a little south of, the 075-degree radial. As before, when the DME reading is one mile short of the desired arc denoting flight line No. 2, a standard-rate turn to the left is begun to bring the plane over the starting point for the second run at a heading of 345°.

The second run is much the same as the first, except for reciprocal headings, counter-clockwise direction, and different point from which the approach is made to the desired flight line. Also, along flight line No. 2 the VOR needle points toward the 270-degree fixed reference point (Figure 2) on the rim of the RMI instrument, or 90° counter-clockwise from the index point. If a wind condition exists, the starting point or the rate of turn may be varied to get the desired results.

If the aircraft is equipped with an autopilot that has an omnicoupler, this can be used to control the plane with even greater accuracy than if it is done manually, thus relieving the pilot of a considerable part of the workload. To do this, a pulse generator is added to the DME circuit and paralleled with the count meter into the left-right relay, of the type used in the DME, through a two-position reversing switch labeled right and left orbit. When the desired distance appears on the digital readout, the pulse generator is adjusted so that the left-right meter is centered. The autopilot is then activated and takes over the job of keeping the aircraft on its DME orbit. This system has an inherent accuracy of approximately ±50 feet.

Many other navigational schemes and types of equipment exist, some of which permit flying straight and parallel lines with extreme accuracy. The easy-to-obtain equipment described here, however, can produce desired results at a nominal cost.