# DEVELOPMENT AND FLIGHT TESTS OF THE CAA TYPE VI COURSE LINE COMPUTER

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## SUMMARY

This report presents the results of flight tests made with the CAA Type VI Course Line Computer, which was designed and constructed in accordance with a CAA specification. The computer differs in design from previous computers in that sine-cosine resolvers are used in its computing circuits, the size and weight have been reduced and the controls have been made more accessible. The flight tests described herein were performed at the CAA Technical Development and Evaluation Center. The computer had an average off-track error of 0.7 mile and an average distance-to-waypoint error of 0.17 mile. A further saving in size, weight and cost is possible through simplification of the data presentation. The computer is designed for ease of maintenance, and the tests indicate that a high degree of reliability may be expected.

## INTRODUCTION

The CAA Type VI Course Line Computer was designed and built in accordance with a specification for an improved computer. The features desired in the new computer were accuracy comparable with previous large experimental types, a reduction in size and weight, increased accessibility of controls to the pilot and increased reliability. The specification was made to conform with the conclusions and recommendations of Radio Technical Commission for Aeronautics Special Committee SC-49 which studied the performance objectives of course line computers. It was recognized that this computer would contain features whose desirability would depend on the operational use of the computer in air navigation and the manner of designating parallel airways. The elimination of some of these features in a production model would effect a further saving in size, weight and cost. The computer was constructed by the Collins Radio Co., Cedar Rapids, Iowa.

## SOME CONSIDERATIONS IN THE DESIGN OF COMPUTERS

Computer designs differ in the way bearing and distance information are utilized in the computing circuits. The navigation triangle formed by the location of the aircraft, the omnibearing-distance station and the waypoint is represented either by vector voltages of a polar system of co-ordinates or by voltages referred to a rectangular system of co-ordinates. To provide vector voltages, phase shifters are employed. The rotor of a phase shifter provides a voltage of constant magnitude whose phase varies with shaft rotation. Bearing information is introduced as shaft rotation and distance information is provided by modifying the magnitude of the rotor voltage. When so modified, the voltage represents both bearing and distance. The addition of such voltages is analogous to the graphical addition of map vectors representing bearing and distance. The resulting voltage will have a phase angle equivalent to the bearing, and a magnitude proportional to the distance of the vector sum of the map vectors. This type of computer is difficult to maintain because reliable and precise phase angle indicators are not readily available.

In other computer designs, sine-cosine resolvers are employed. Two windings 90 electrical degrees apart are provided on the stator. With a voltage impressed on the rotor, the magnitude of one stator-winding voltage will vary with the sine of the angle of shaft rotation while the magnitude of the other stator-winding voltage will vary with the cosine of the angle of shaft rotation. A constant phase angle of 90° is maintained between the stator-winding voltages. In these computers, the treatment of bearing and distance information can be considered as being on the basis of rectangular co-ordinates. A voltage representing a vector quantity is impressed on the rotor of a sine-cosine resolver, the magnitude of the voltage being made proportional to distance, and the shaft rotation in degrees being made equivalent to the bearing. On the stator windings will appear voltages proportional to the product of the magnitude of the rotor voltage and the sine and cosine of the angle of shaft rotation. Thus, the stator windings provide components of a vector voltage with reference to a set of rectangular co-ordinates. The addition of vector quantities is accomplished by the algebraic addition of their components along the respective axes.

## DESCRIPTION OF THE CAA TYPE VI COMPUTER

The components comprising the CAA Type VI Computer are shown in Fig. 1.

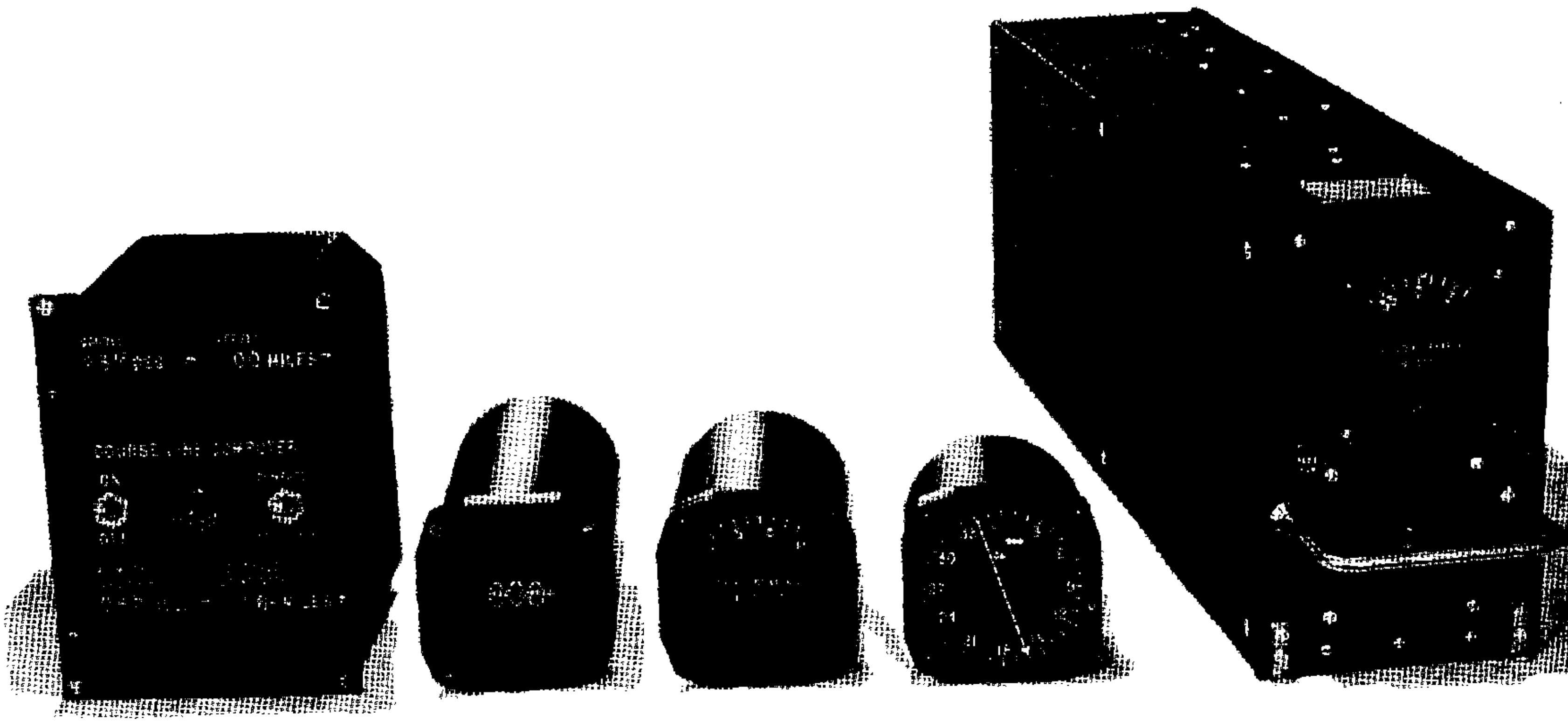



Fig. 1 The CAA Type VI Course Line Computer

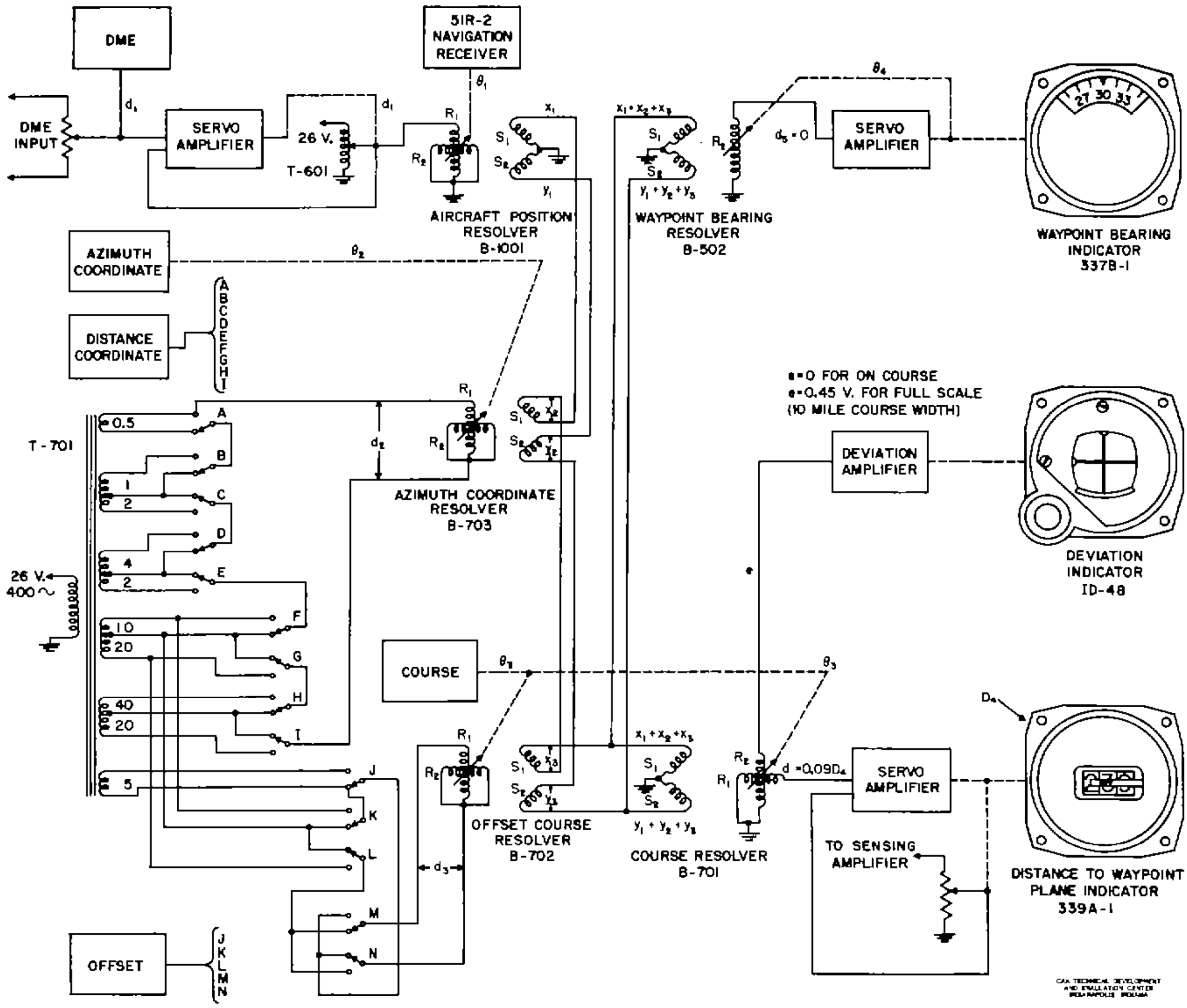


Fig. 2 Functional Wiring Diagram, CAA Type VI Course Line Computer

Sine-cosine resolvers are utilized in the computing circuits, because they have been found easy to service, and voltage magnitudes can be determined with a high impedance voltmeter. Strip amplifiers are used, three of which are identical. These contribute materially to the ease of maintenance. The distance-to-waypoint information provided is the distance from the aircraft to a line through the waypoint and perpendicular to the course. This is known as aircraft-to-waypoint plane distance or "projected distance," and is equivalent to the distance from the aircraft to the waypoint only when the aircraft is on course. The computer may, by a simple redesign, be changed to provide aircraft-to-waypoint distance or "radial distance," i.e., the distance to the waypoint regardless of the aircraft position. A schematic diagram of the computer is shown in Fig. 2.

In order to fly to a waypoint along a specific course line, three settings are made on the computer control panel:

1. Magnetic bearing from omnirange station to waypoint.
2. Distance from omnirange station to waypoint.
3. Magnetic course along which the aircraft is to approach the waypoint.

These settings are map data and may be scaled from any map showing the locations of the omnibearing distance station, the waypoint and magnetic north. Courses parallel to, but offset from the selected course may be flown by setting a fourth control knob to the offset or perpendicular distance between the reference course and the desired offset course.

Left and right indications are provided by the computer to the course deviation indicator, enabling the pilot to fly the aircraft along the course. The radio magnetic indicator (RMI) also may be connected to indicate the magnetic bearing to the omnirange or the waypoint (or both, if both pointers of the RMI are utilized). Supplied with the computer is an additional instrument, the "course bearing indicator," which indicates the course which is set on the computer control panel. It was thought that such an instrument might prove desirable if the control panel is not located on the pilot's instrument panel. In the case with the course bearing indicator is the TO-FROM meter, which indicates whether the course selected on the control head is toward or away from the waypoint line. A switch on the computer control panel provides for connecting the course deviation indicator to the omnireceiver when the flying of omnirange courses is desired.

The weight of the computer and its associated components is 33 pounds. The weight of the computer rack unit is 21 pounds. Photographic views of the computer installed in a TDEC Douglas C-47A aircraft are shown in Figs. 3 and 4.

## FLIGHT TESTS

Four computer courses were selected which formed a square about the Indianapolis omnibearing-distance station. Each side of the square was approximately 60 miles in length. With the station in the center, the perpendicular offset from the station to each course was approximately 30 miles. A total of 51 check points was selected along the four courses. With the co-ordinates of each course properly set on the computer control panel, the aircraft was flown visually over the courses. Over each check point the indicated omnibearing to the station, the distance to the station, the indicated distance to waypoint and the course deviation indicator deflection were recorded. The omnibearing error, the DME error and the over-all distance-to-waypoint error were determined by comparing the indicated values with correct values obtained from special maps of the area prepared by the U. S. Coast and Geodetic Survey. The contributions of the omnibearing error and the DME error to the over-all off-track error and to the over-all distance-to-waypoint error were calculated using equations derived for that purpose.[1] The values obtained from the equations were subtracted from the over-all errors to determine the contribution of the computer to the off-track error and distance-to-waypoint error. The results of a typical test flight together with the calculated values are shown in Table I. The computer off-track error varied between -2.56 and +1.56 miles. The average off-track error was -0.7 mile. The computer distance-to-waypoint error varied between -1.26 and +1.50 miles. The average error was +0.17 mile. When the courses were retraced with the aircraft flown so as to keep the deviation indicator centered, the track of the aircraft was recorded, and is shown in Fig. 5.

To investigate the performance of the computer when used to fly offset courses, a reference course was selected with parallel offset courses ten miles to the right and ten miles to the left. The tracks of the aircraft when flying the course deviation indicator with the reference course set in and the offset course knob set to Left 10, 0, and Right 10 are shown in Fig. 6. These courses are approximately 90 nautical miles in length.

To investigate the performance of the computer over a course of considerable length, which would include a transition from one omnirange-distance station to another, courses were flown on the Indianapolis station and the Dayton station. A line connecting the two stations has a magnetic bearing of 83.5° from the Indianapolis station and a magnetic bearing of 265.5° from the Dayton station. Courses parallel to the line, but offset ten miles to either side, were flown. The track of the aircraft is shown in Fig. 7.

At the conclusion of the tests, the equipment had been flown approximately 100 hours. No tubes or major components had failed. One germanium rectifier in the ambiguity indicator circuit was replaced.

To determine the average length of time necessary to set the required information on the control panel in the transition from one course to another, ten pilots were timed in their operation of a bench set-up. The courses selected required the maximum rotation of the control knobs from their previous settings. Four courses were required to be set by each pilot. Three pilots were familiar with the control head; seven were not. The average length of time required was 25 seconds.

[1]Francis J. Gross and Hugh A. Kay, "Initial Flight Tests and Theory of an Experimental Parallel Course Computer," Technical Development Report No. 83, September 1948.

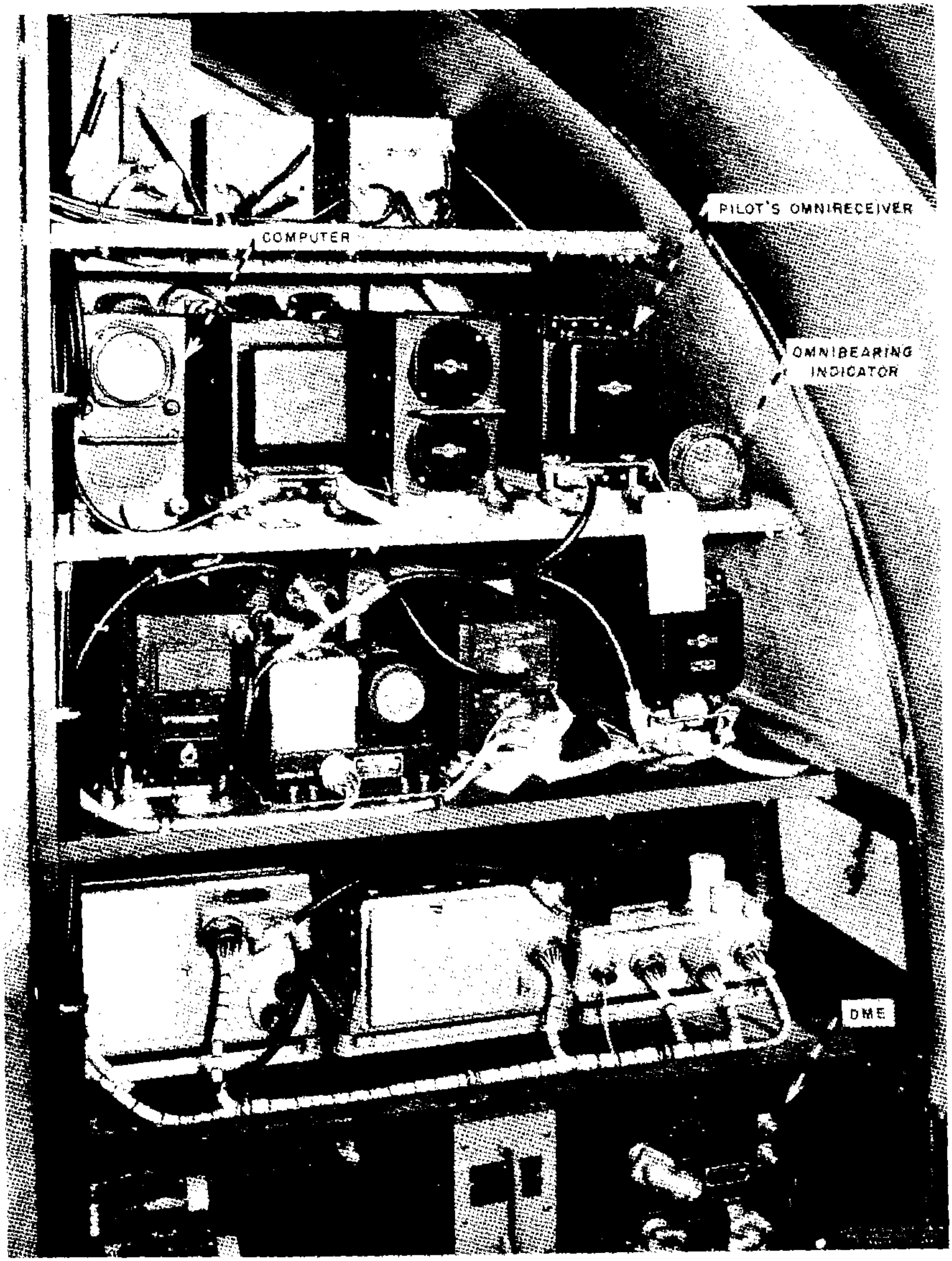


Fig. 3 Aircraft Equipment Rack

## TABLE I

Results Of Four Computer Courses
Forming A Square About The Station

Omni Error — +1.4° to -3.7° Average = -1.08°

DME Error — -0.2 to -1.1 Average = -0.74 Mile

Computer — Off-Track Error, -2.56 to +1.55 Average = -0.7 Mil Dist.-To-Waypt. Error, -1.26 to +1.50 Average = +0.17 Mile

| Check Point | Magnetic Bearing Degs. | Modified OBI Degs. | Bearing Error Degs. | True Dist. Nautical Miles | Indicated Dist. Nautical Miles | Dist. Error Nautical Miles | True Dist.-To-Waypt. Nautical Miles | Indicated Dist.-To-Waypt. Nautical Miles | Dist.-To-Waypt. Error Nautical Miles | Dist.-To-Waypt. Error From Omni & DME Nautical Miles | Computer Dist.-To-Waypt. Error Nautical Miles | Crosspointer Deflection Microamps | Over-All Off-Track Error Nautical Miles | Off-Track Error From Omni & DME Nautical Miles | Computer Off-Track Error Nautical Miles |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 308.4 | 308.0 | -0.4 | 42.3 | 41.5 | -0.8 | 57.7 | 55.7 | -2.0 | -0.74 | -1.26 | 25L | +0.83 | +0.43 | +0.40 |
| 2 | 302.9 | 301.0 | -1.9 | 39.4 | 38.5 | -0.9 | 52.9 | 50.9 | -2.0 | -1.55 | -0.45 | 13L | +0.43 | +0.04 | +0.39 |
| 3 | 295.6 | 294.5 | -1.1 | 36.5 | 35.5 | -1.0 | 47.2 | 45.5 | -1.7 | -1.05 | -0.65 | 9R | -0.30 | +0.59 | -0.89 |
| 4 | 288.0 | 286.5 | -1.5 | 34.5 | 33.5 | -1.0 | 42.1 | 41.0 | -1.1 | -1.15 | +0.05 | 14R | -0.47 | +0.66 | -1.13 |
| 5 | 280.0 | 278.5 | -1.5 | 33.2 | 32.2 | -1.0 | 37.3 | 36.0 | -1.3 | -1.01 | -0.29 | 19R | -0.63 | +0.82 | -1.45 |
| 6 | 271.9 | 270.5 | -1.4 | 32.5 | 31.5 | -1.0 | 32.5 | 31.5 | -1.0 | -0.81 | -0.19 | 11L | +0.37 | +0.96 | -0.59 |
| 7 | 264.2 | 262.5 | -1.7 | 32.6 | 31.5 | -1.1 | 28.2 | 27.0 | -1.2 | -1.86 | +0.66 | 3R | -0.10 | +1.02 | -1.12 |
| 8 | 255.1 | 254.5 | -0.6 | 33.4 | 32.5 | -0.9 | 22.9 | 22.5 | -0.4 | -0.53 | +0.13 | 1L | +0.03 | +0.80 | -0.77 |
| 9 | 249.5 | 248.0 | -1.5 | 34.4 | 33.5 | -0.9 | 19.4 | 18.0 | -1.4 | -1.12 | -0.28 | 9L | +0.30 | +0.56 | -0.26 |
| 10 | 244.3 | 243.0 | -1.3 | 35.7 | 35.0 | -0.7 | 16.0 | 14.5 | -1.5 | -1.02 | -0.48 | 5L | +0.17 | +0.30 | -0.13 |
| 11 | 238.3 | 236.5 | -1.8 | 37.7 | 37.0 | -0.7 | 11.6 | 10.0 | -1.6 | -1.35 | -0.25 | 3R | -0.10 | +0.02 | -0.12 |
| 12 | 232.8 | 231.5 | -1.3 | 40.1 | 39.0 | -1.1 | 7.2 | 6.0 | -1.2 | -1.38 | +0.18 | 9R | -0.30 | +0.36 | -0.66 |
| 13 | 229.2 | 227.0 | -2.2 | 42.2 | 41.5 | -0.7 | 3.9 | 2.0 | -1.9 | -1.66 | -0.36 | 21R | -0.70 | -0.47 | -0.23 |
| 14 | 225.4 | 223.5 | -1.9 | 44.7 | 44.0 | -0.7 | 0.0 | -1.5 | -1.5 | -1.53 | +0.03 | 10R | -0.33 | -0.50 | +0.17 |
| 15 | 219.9 | 218.0 | -1.9 | 41.3 | 41.0 | -0.3 | 54.6 | 55.0 | +0.4 | -1.22 | +1.26 | 20L | +0.67 | -0.66 | +1.33 |
| 16 | 212.7 | 210.5 | -2.2 | 37.5 | 37.0 | -0.5 | 48.5 | 47.5 | -1.0 | -1.44 | +0.44 | 30L | +1.00 | -0.36 | +1.36 |
| 17 | 204.2 | 203.0 | -1.2 | 34.5 | 33.5 | -1.0 | 42.4 | 42.5 | +0.1 | -1.07 | +1.17 | 10L | +0.33 | +0.61 | -0.28 |
| 18 | 195.9 | 193.5 | -2.4 | 32.6 | 32.0 | -0.6 | 37.2 | 36.0 | -1.2 | -1.48 | +0.28 | 9L | +0.30 | +0.18 | +0.12 |
| 19 | 187.4 | 187.5 | +0.1 | 31.6 | 31.0 | -0.6 | 32.4 | 31.5 | -0.9 | -0.03 | -0.87 | 5L | +0.17 | +0.60 | -0.43 |
| 20 | 176.9 | 176.0 | -0.9 | 31.2 | 30.5 | -0.7 | 26.8 | 26.5 | -0.3 | -0.52 | +0.22 | 8L | +0.27 | +0.68 | -0.41 |
| 21 | 169.4 | 170.0 | +0.6 | 31.6 | 31.0 | -0.6 | 22.6 | 22.5 | -0.1 | +0.20 | -0.30 | 4R | -0.13 | +0.64 | -0.77 |
| 22 | 162.8 | 163.0 | +0.2 | 32.4 | 31.5 | -0.9 | 18.9 | 18.5 | -0.4 | -0.19 | -0.21 | 3R | -0.10 | +0.89 | -0.99 |
| 23 | 155.2 | 155.0 | +0.3 | 34.1 | 33.0 | -1.1 | 14.2 | 14.5 | +0.3 | -0.32 | +0.62 | 3L | +0.10 | +1.07 | -0.97 |
| 24 | 149.6 | 150.0 | +0.4 | 35.8 | 35.0 | -0.8 | 10.4 | 10.0 | -0.4 | -0.18 | -0.22 | 2L | +0.07 | +0.82 | -0.75 |
| 25 | 141.6 | 142.0 | +0.4 | 39.3 | 38.5 | -0.8 | 4.2 | 4.0 | -0.2 | -0.27 | +0.07 | 15L | +0.50 | +0.80 | -0.30 |
| 26 | 137.1 | 137.0 | -0.1 | 41.9 | 41.0 | -0.9 | 0.0 | 0.0 | 0.0 | -0.66 | +0.66 | 34L | +1.13 | +0.61 | +0.52 |
| 27 | 131.5 | 130.5 | -1.0 | 39.6 | 39.0 | -0.6 | 54.9 | 55.5 | +0.6 | -0.90 | +1.50 | 28L | +0.93 | +0.40 | +0.53 |
| 28 | 127.1 | 128.5 | +1.4 | 37.2 | 37.0 | -0.2 | 51.1 | 52.0 | +0.9 | +0.58 | +0.32 | 38L | +1.27 | +0.70 | +0.57 |
| 29 | 119.9 | 118.5 | -1.9 | 34.1 | 33.5 | -0.6 | 45.7 | 45.0 | -0.7 | -1.26 | +0.56 | 19R | -0.63 | +0.05 | -0.68 |
| 30 | 112.6 | 111.0 | -1.6 | 31.9 | 31.5 | -0.4 | 41.0 | 40.5 | -0.5 | -0.97 | +0.47 | 22R | -0.73 | +0.01 | -0.74 |
| 31 | 102.0 | 110.0 | -2.0 | 30.1 | 29.5 | -0.6 | 34.9 | 34.5 | -0.9 | -1.14 | +0.24 | 21R | -0.67 | +0.35 | -1.02 |
| 32 | 92.8 | 91.5 | -1.3 | 29.4 | 29.0 | -0.4 | 30.2 | 29.5 | -0.7 | -0.70 | 0.0 | 29R | -0.97 | +0.36 | -1.33 |
| 33 | 82.5 | 81.5 | -1.0 | 29.6 | 29.0 | -0.6 | 24.9 | 24.5 | -0.4 | -0.56 | +0.16 | 40R | -1.33 | +0.55 | -1.88 |
| 34 | 75.4 | 74.0 | -1.4 | 30.2 | 29.5 | -0.7 | 21.2 | 20.5 | -0.7 | -0.85 | +0.15 | 43R | -1.43 | +0.51 | -1.94 |
| 35 | 68.0 | 67.0 | -1.0 | 31.5 | 30.5 | -1.0 | 17.0 | 16.5 | -0.5 | -0.84 | +0.34 | 41R | -1.37 | +0.75 | -2.12 |
| 36 | 62.4 | 62.0 | -0.4 | 32.9 | 32.0 | -0.9 | 13.6 | 13.5 | -0.1 | -0.60 | +0.50 | 36R | -1.20 | +0.71 | -1.91 |
| 37 | 55.5 | 55.5 | 0.0 | 35.3 | 34.5 | -0.8 | 8.8 | 8.5 | -0.3 | -0.44 | +0.14 | 28R | -0.93 | +0.67 | -1.60 |
| 38 | 49.6 | 49.5 | -0.1 | 38.1 | 37.5 | -0.6 | 4.2 | 4.5 | +0.3 | -0.46 | +0.76 | 26R | -0.87 | +0.42 | -1.29 |
| 39 | 45.1 | 43.0 | -2.1 | 40.8 | 40.5 | -0.3 | 0.0 | -0.5 | -0.5 | -1.29 | +0.79 | 38R | -1.27 | -0.82 | -0.45 |
| 40 | 43.6 | 41.0 | -2.5 | 40.6 | 40.0 | -0.6 | 60.2 | 59.5 | -0.7 | -1.67 | +0.97 | 10L | +0.30 | -0.81 | +1.11 |
| 41 | 37.7 | 34.0 | -3.7 | 37.0 | 36.0 | -1.0 | 54.9 | 53.0 | -1.9 | -2.45 | +0.55 | 26L | +0.87 | -0.68 | +1.55 |
| 42 | 30.3 | 28.0 | -1.7 | 33.9 | 33.5 | -0.4 | 49.4 | 48.5 | -0.9 | -0.97 | +0.07 | 11R | -0.37 | -0.18 | -0.19 |
| 43 | 19.9 | 20.0 | +0.1 | 31.0 | 30.5 | -0.5 | 42.8 | 42.5 | -0.3 | -0.12 | -0.18 | 20R | -0.67 | +0.49 | -1.16 |
| 44 | 12.0 | 12.0 | 0.0 | 29.7 | 29.0 | -0.7 | 38.5 | 38.5 | 0.0 | -0.16 | +0.16 | 31R | -1.03 | +0.68 | -1.71 |
| 45 | 4.0 | 3.0 | -1.0 | 29.0 | 28.0 | -1.0 | 34.3 | 34.0 | -0.3 | -0.56 | +0.26 | 30R | -1.00 | +0.95 | -1.95 |
| 46 | 354.0 | 352.5 | -1.5 | 29.0 | 28.0 | -1.0 | 29.2 | 29.0 | -0.2 | -0.63 | +0.43 | 42R | -1.40 | +0.93 | -2.33 |
| 47 | 343.4 | 342.5 | -0.9 | 30.0 | 29.5 | -0.5 | 23.8 | 23.5 | -0.3 | -0.32 | +0.02 | 36R | -1.20 | +0.36 | -1.56 |
| 48 | 333.0 | 332.0 | -1.0 | 32.1 | 31.0 | -1.1 | 17.7 | 18.0 | +0.3 | +0.01 | +0.29 | 54R | -1.80 | +0.76 | -2.56 |
| 49 | 322.7 | 321.5 | -1.2 | 35.8 | 35.0 | -0.8 | 10.7 | 10.5 | -0.2 | -0.10 | -0.10 | 38R | -1.27 | +0.23 | -1.50 |
| 50 | 315.0 | 313.9 | -1.1 | 40.1 | 39.5 | -0.5 | 4.0 | 4.0 | 0.0 | -0.19 | +0.19 | 43R | -1.43 | -0.16 | -1.27 |
| 51 | 311.1 | 310.0 | -1.1 | 43.0 | 42.5 | -0.5 | 0.0 | 0.0 | 0.0 | -0.17 | +0.17 | 36R | -1.20 | +0.95 | -2.05 |

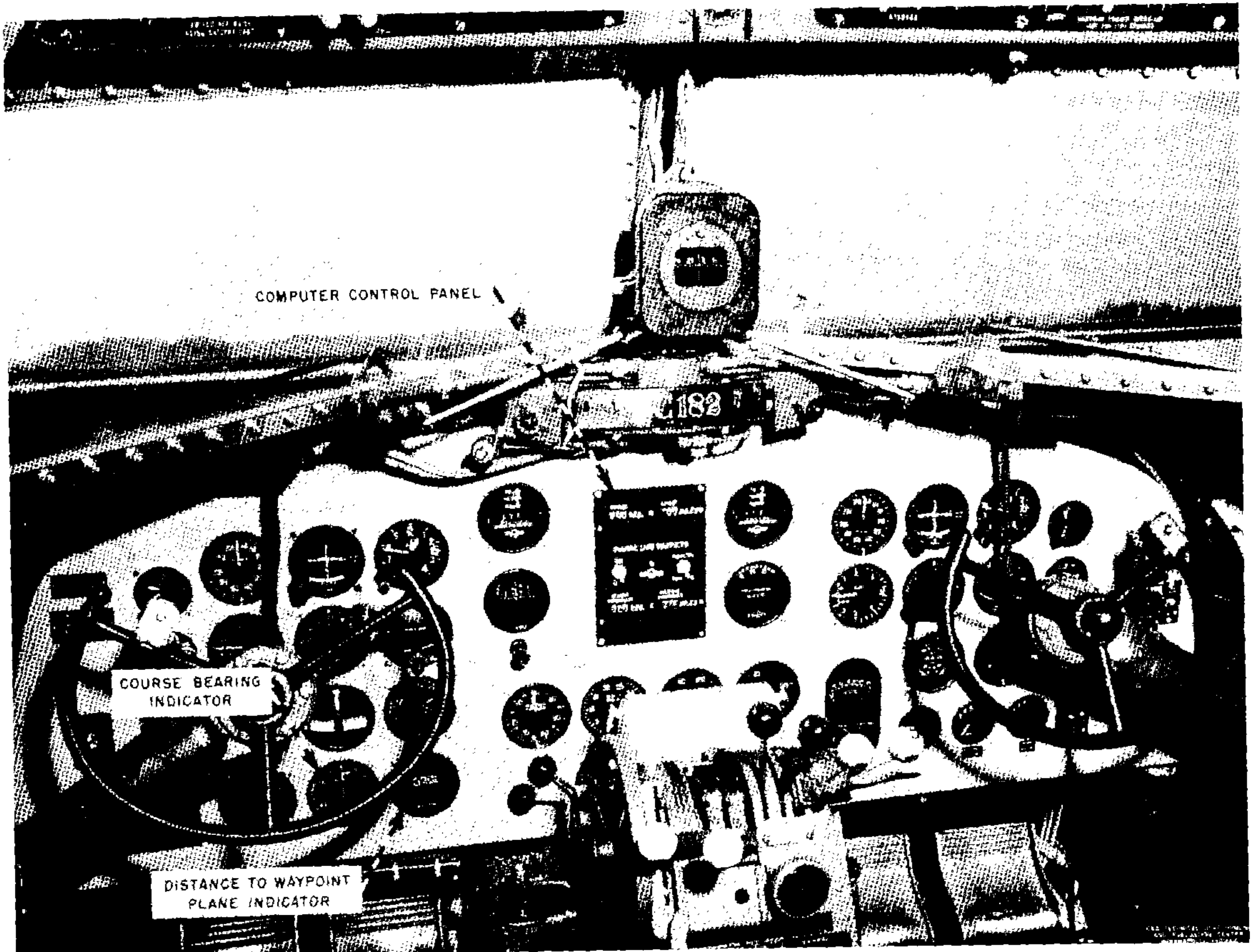


Fig. 4 Aircraft Instrument Panel

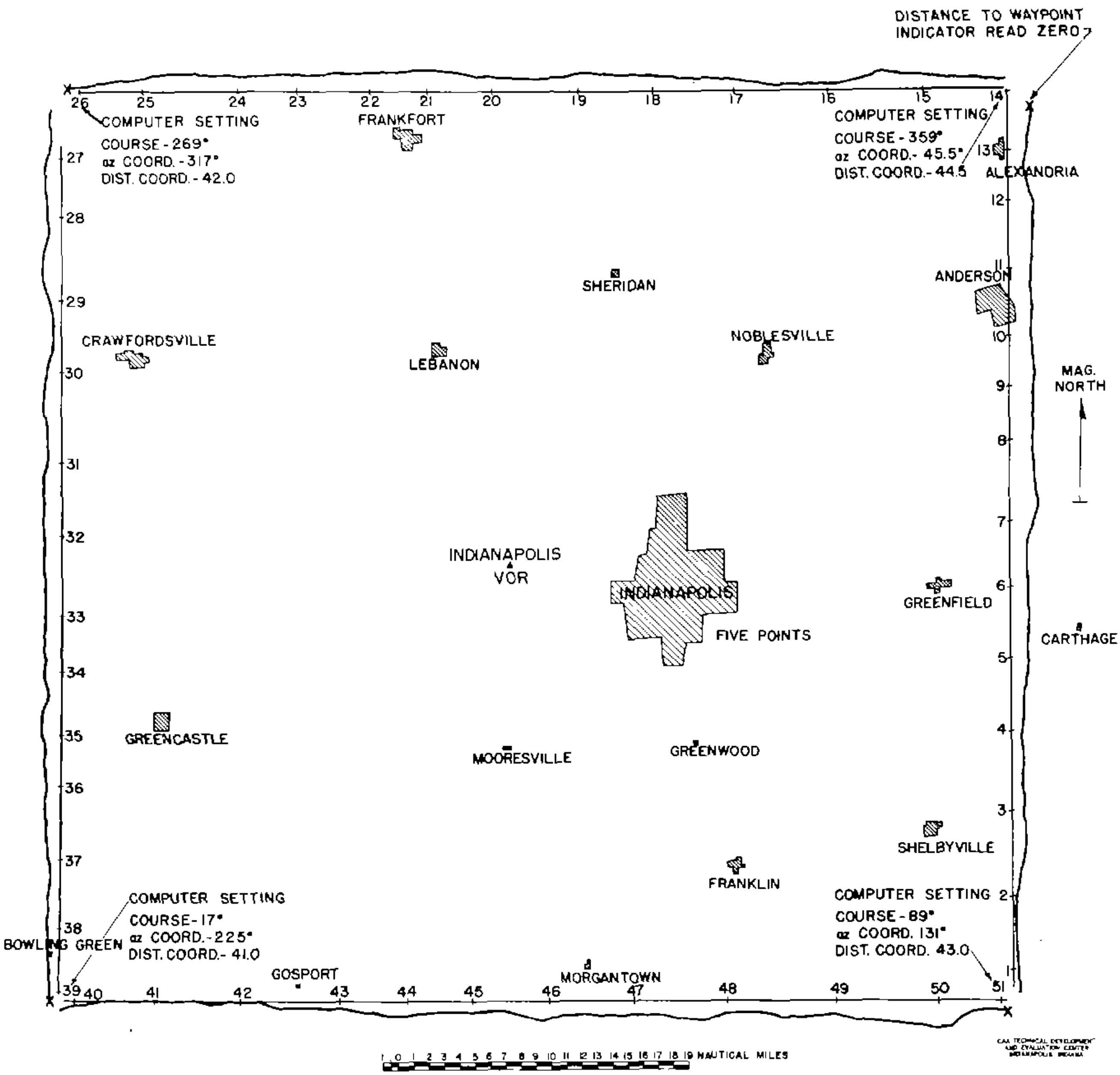


Fig. 5 Tracks Flown Forming a Square About the Omnidistance Station

## CONCLUSIONS

The CAA Type VI Course Line Computer tested at TDEC had an average off-track error of -0.7 mile and an average distance-to-waypoint error of 0.17 mile. At the conclusion of these tests the equipment had been flown approximately 100 hours. No tubes or major components had failed. The equipment is well constructed and is designed for ease of maintenance. The weight of the computer is 33 pounds.

The transition from one computer course to another involves the operation of from one to four knobs on the control panel to set up the new course. Tests revealed an average time of 25 seconds was necessary for settings requiring the maximum rotation of controls. It is believed that in most cases the time would be considerably less, and in any event the time is not considered excessive when compared with the time required for standard rate turns to new headings.

Some of the functions performed by the computer could be omitted with a consequent saving of weight, size and cost of the equip-

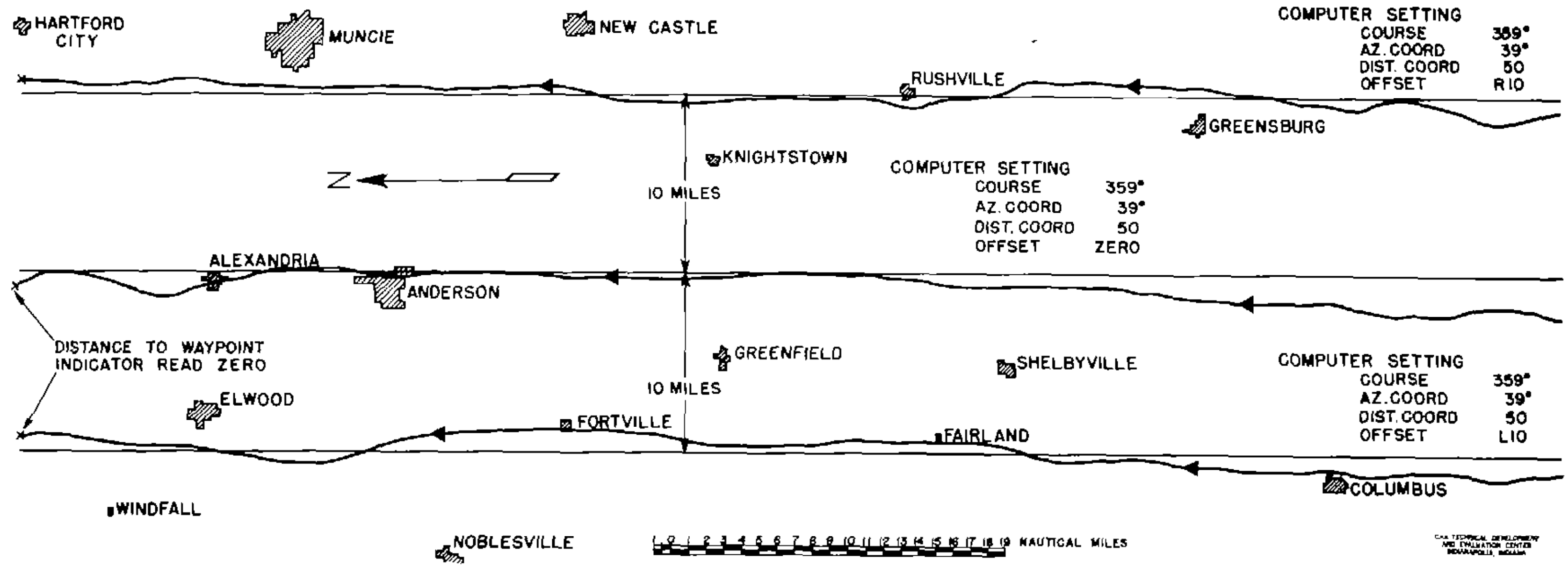


Fig. 6 Parallel Tracks Flown Using Offset Control

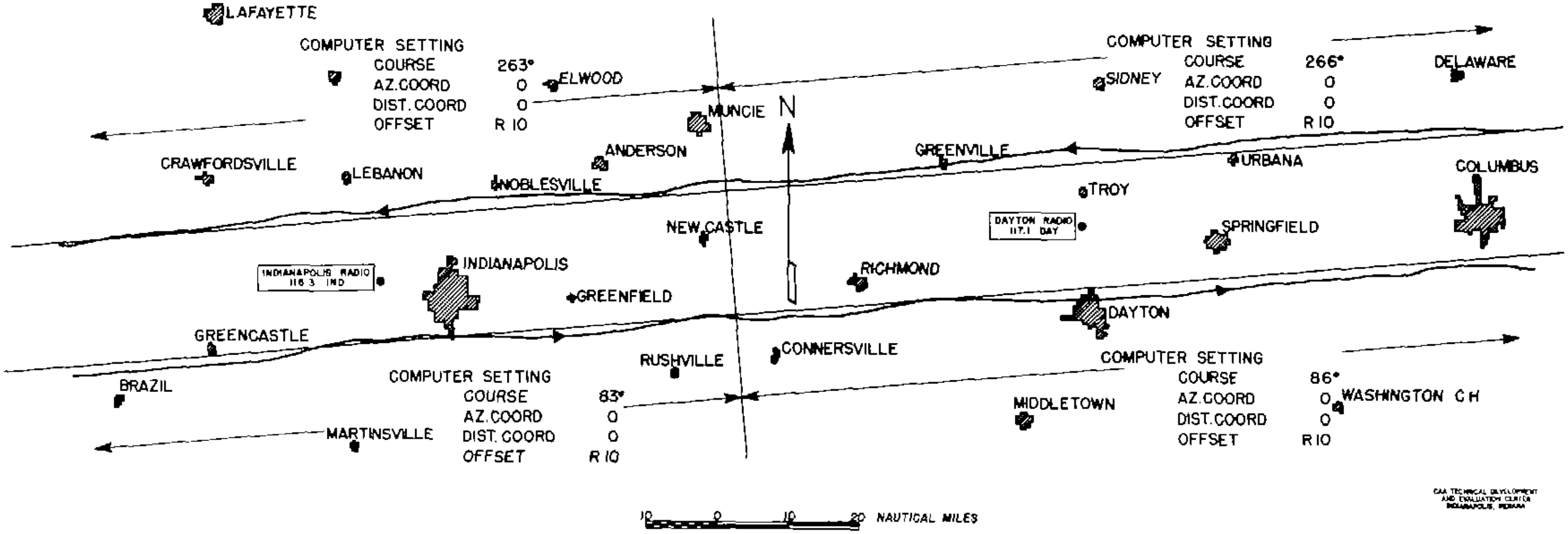


Fig. 7 Tracks Flown on Indianapolis and Dayton Omnidistance Stations

ment and should improve the reliability. The offset control knob on the control panel does provide, however, a very convenient means of flying parallel offset courses. Some possible variations in data presentation follow:

1. Elimination of RMI presentation.

Eliminates: Waypoint bearing indicator which includes differential transformer, waypoint resolver and servo-motor.

Servo amplifier.

Offset resolver in control head.

2. Elimination of Offset Course Selection.

Eliminates: Offset resolver in control panel.

Simplifies control panel.

3. Elimination of Course Bearing Indicator.

Eliminates: Course bearing indicator.

Simplifies control panel.

(Note: TO-FROM indicator must be relocated.)

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