FLIGHT CALIBRATION OF VHF OMNIRANGE SYSTEM

By

Thomas S Wonnell

Radio Development Division

Technical Development Report No 69

CIVIL AERONAUTICS ADMINISTRATION

TECHNICAL DEVELOPMENT

INDIANAPOLIS, INDIANA

June 1949

TABLE OF CONTENTS

Manuscript received, July 1947

FLIGHT CALIBRATION OF VHF OMNIRANGE SYSTEM

SUMMARY

This report describes a method of ascertaining the accuracy of an omnirange system by means of flight calibration.

In the process a series of exact differences between indicated and magnetic bearings is obtained through the 360° around a range station, and these differences are plotted as a calibration or measured error curve.

The process described is equally applicable to low or very high frequency omnirange systems.

INTRODUCTION

The technique of calibrating an omnirange station has been in the process of development by engineers of the Office of Technical Development for a number of years, and the procedure to be described here represents the most straightforward and precise method yet devised.

PROCEDURE

The actual function of calibration consists of recording the movement of the course deviation indicator in an airplane as it circles the omnirange station at any radius from 7 to 15 miles The omnibearing selector is advanced in 10° steps to keep the course deviation indicator on scale and to present, at center scale, the indicated magnetic bearing from the omnistation. This indicated bearing is compared with magnetic bearing from the station as measured by a theodolite operated on the ground at the omnirange station.

A. Theodolite Operation

The instrument used to measure the magnetic bearing of the airplane is a standard Weather Bureau theodolite.

The theodolite is located about 15 feet beneath the antenna counterpoise and directly below the antenna array. The instrument is orientated during the preliminary set-up procedure so that the zero point is aligned with a previously surveyed magnetic north point. Very careful attention must be given to this original placement of the theodolite.

The operation of the theodolite consists of tracking an airplane which is circling the range. Once the proper azimuth and elevation of the airplane are located, the instrument is advanced 5° ahead of the plane, and the operator waits until the plane enters and travels across the field of vision to the center cross-hair position. At this point, the operator presses a control button which automatically marks the recording in the aircraft. The theodolite is advanced another 5° and the operator waits for the plane to enter the field of vision again, repeating the process in 5° steps through 360°.

The prerequisite on the part of the airplane pilot for satisfactory tracking by the theodolite operator is that he fly the plane at a constant altitude and maintain a constant radius throughout the circle. The altitude control is no problem but maintaining a fixed radius requires the constant attention of the pilot. A variation in circle radius calls for a change in theodolite elevation which must be anticipated and a correction made as changes are noticed. If serious variations in radius are noted, aural instructions to the pilot will enable him to remedy the situation

Constant communication with the plane during calibration is an absolute necessity. Transmission from the ground is made over the voice channel of the omnirange while transmissions from the plane are received via VHF channels.

The control button which the theodolite operator presses as the plane crosses each 5° magnetic point actuates an audio amplifier circuit at the range station which will modulate the voice channel with 1020 cps tone signal.

B Recording

The calibration recording which contains all the data of the entire flight is made in an airplane as it circles the VHF omnirange station. The following equipment is required in the aircraft·

1. VHF omnireceiver
2. DC amplifier

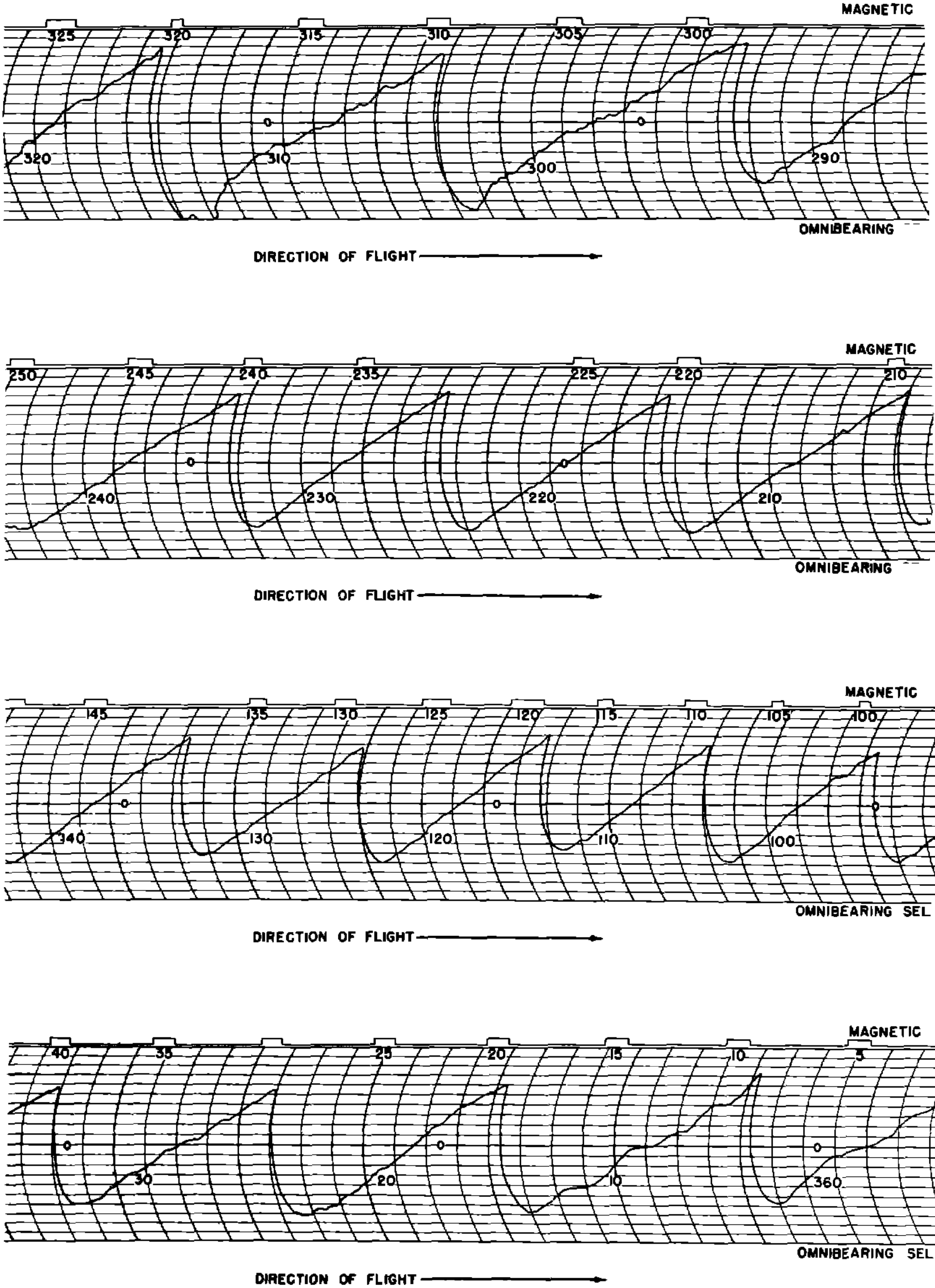
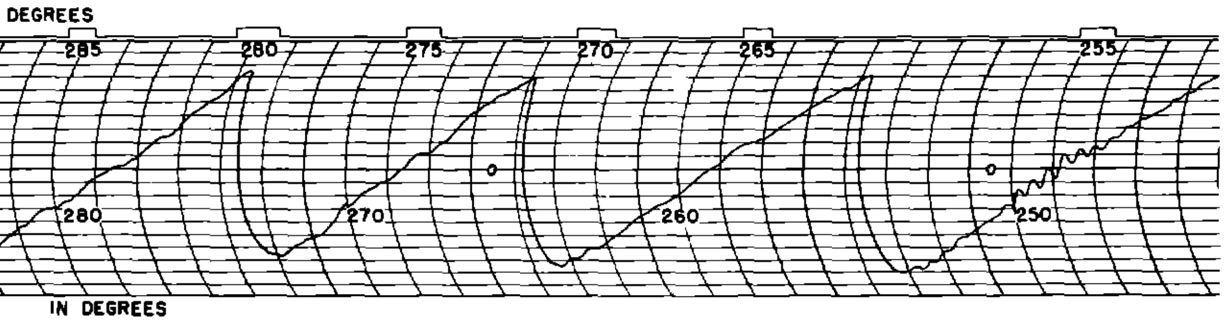
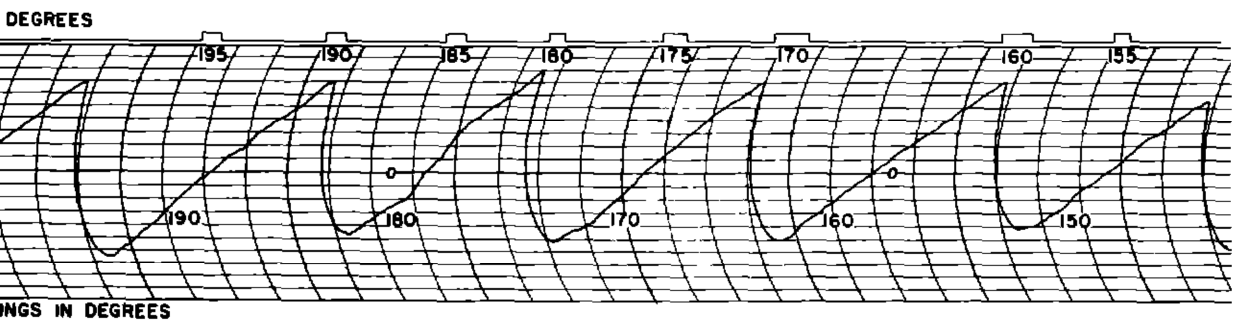
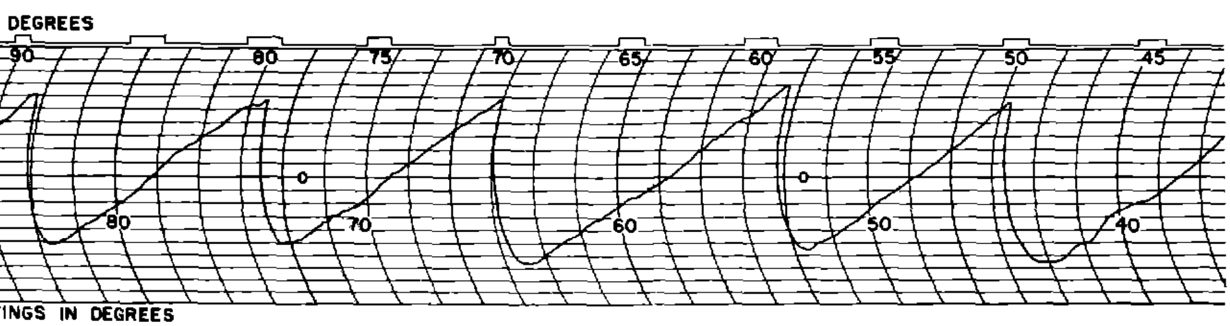
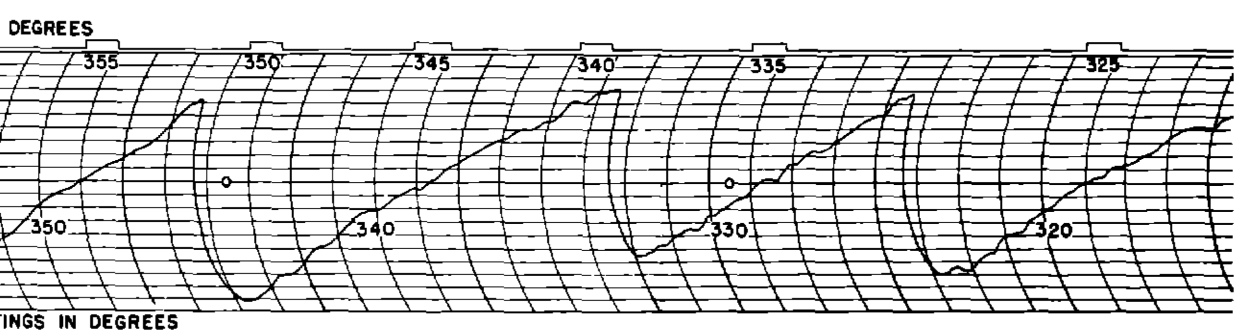

MAGNETIC
325 320 315 310 305 300
320 310 300 290
OMNIBEARING
DIRECTION OF FLIGHT
MAGNETIC
250 245 240 235 225 220 210
240 230 220 210
OMNIBEARING
DIRECTION OF FLIGHT
MAGNETIC
145 135 130 125 120 115 110 105 100
340 130 120 110 100
OMNIBEARING SEL
DIRECTION OF FLIGHT
MAGNETIC
40 35 25 20 15 10 5
30 20 10 360
OMNIBEARING SEL
DIRECTION OF FLIGHT

Fig 5 Flight









on Recording

3. Marking amplifier
4. Graphic recording instrument

A block diagram of this equipment is shown in Fig 1

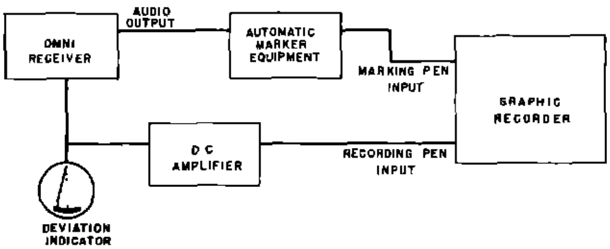


Fig 1 Recording and Marking Equipment

The direct voltage across the deviation indicator is amplified and used to produce a permanent record of the deviation indicator movements. A marker pen at the edge of the recording is operated by a tone amplifier whenever the theodolite operator presses the 1020 cps tone control button.

A block diagram of the automatic marker is shown in Fig. 2

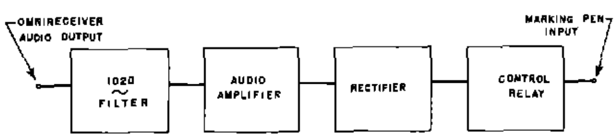


Fig 2 Automatic Marker Equipment

On take-off for an actual recording flight the airplane should first be flown directly over the range station which is to be calibrated, in order to avoid confusion of the ground crew as to identification of the proper plane. This will enable the theodolite operator to start tracking the plane and also allow him to direct the plane as to the proper circle radius This will be governed largely by conditions such as haze, mist, smoke, and low scud.

One operator is required in the aircraft. His duties during the flight are to adjust the gain of the dc amplifier to provide approximately three-quarters of full scale deflection on the recording paper for a 10° variation of the bearing selector, to advance the omnibearing selector in 10° steps either clockwise or counterclockwise as previously agreed upon, and to note on the recording the setting of the bearing selector and the magnetic bearings as reported by the theodolite operator.

As the plane turns off the radial flight over the station to start the circle (we shall assume a counterclockwise circle), the operator in the plane decreases the bearing selector 10°. As the plane proceeds around the circle, the deviation indicator will swing from full right indication to full left indication. Sometime before the deviation indicator reaches full left deflection, the bearing selector is decreased 10° more. This must be done at a time when the change will not cause the indicator to read off-scale or fail to cross the center position. A little trial and error on the first and second points is usually sufficient practice This procedure is then repeated through 360°.

During the flight around the station, the automatic marker will mark the edge of the recording each time the theodolite operator presses his control switch. At the same time, he will call out the bearing of the next point to be marked.

C. Interpretation of Recording

The interpretation of the recording is explained with reference to the sample recording shown in Fig. 3.

The various points of significance are identified with capital letters and an arrow indicates the exact point under consideration.

The line across the top of the recording, with the periodic deflection, contains the information as to the exact magnetic bearing of the airplane with respect to the range station The leading edge of the deflection is the point to be considered. At point A, the plane had a magnetic bearing of 190° from the omnistation, at point D, 185°, point F, 180°, etc. This line and these deflections constitute the calibration base line.

The omnibearing selector settings are shown at the lower part of the trace and in this sample are 190°, 180° and 170°.

Starting our interpretation of the sample recording from the left, it is seen that with an omnibearing selector setting of 190°, at the point B which is center scale, the plane has an indicated bearing of 190° Point B is extended to the same relative position on the base line which we will call point C The airplane actually had a magnetic bearing of

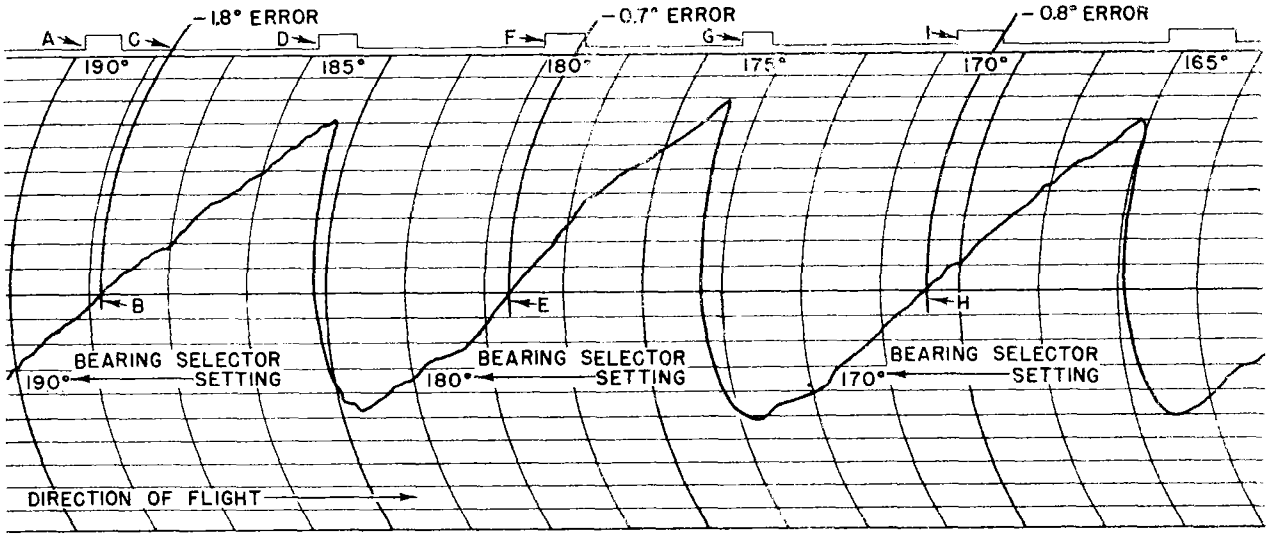


Fig. 3 Sample Recording

190° from the range station at point A as reported by the theodolite operator, and not at point C as indicated; therefore, the range system is in error. The extent of this error is calculated by simple proportion. The distance AD equals 5°, therefore, the error in degrees equals the fractional distance that AC is of the total 5° distance AD, or in this case 1.8°. Since the indicated bearing of 190° was recorded after the actual magnetic bearing of 190°, the error is negative. The errors for the indicated bearings of 180° and 170° on the sample are figured in a like manner.

A simple mechanical device may be used to speed the reading of error from a calibration recording. This instrument is known commercially as a proportional computer or more commonly as a ratio divider. The proportional computer in use at the Experimental Station is a unit manufactured by the KLB Instrument Company of San Antonio, Texas and illustrated in Fig. 4B. A ratio divider which may easily be constructed to do the same job is shown in Fig. 4A. A

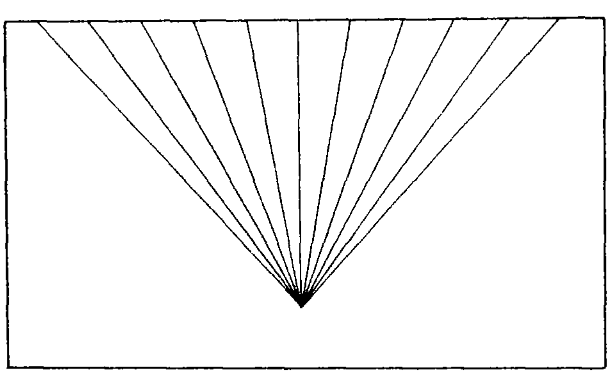


Fig. 4A Ratio Divider

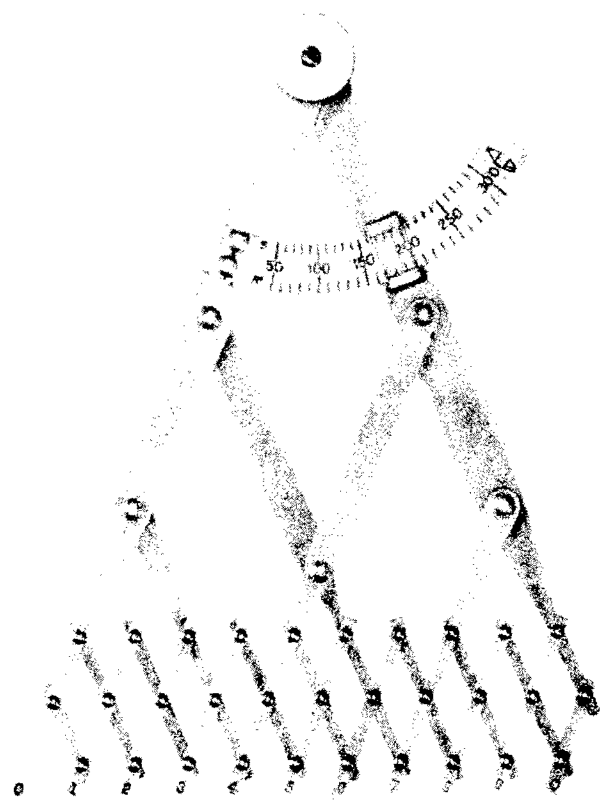


Fig. 4B Proportional Computer

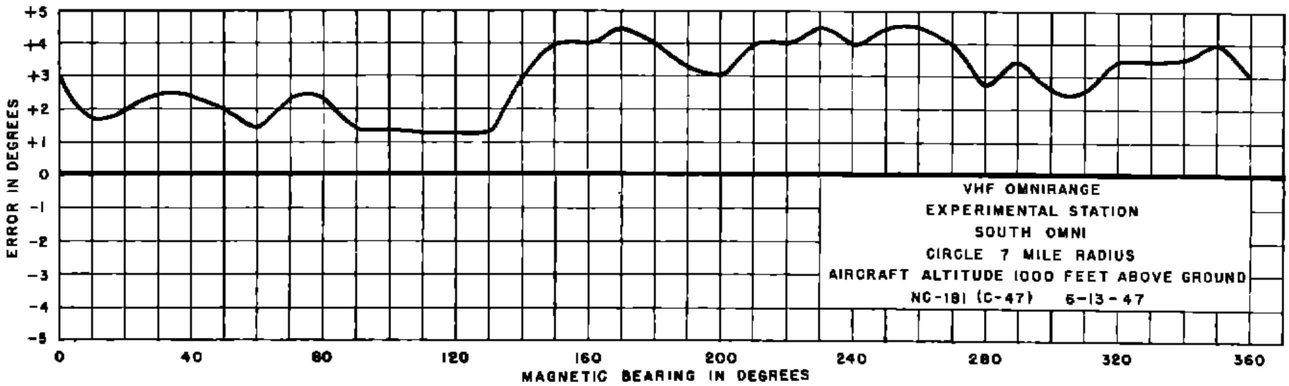


Fig 6 Measured Error Curve

piece of transparent plastic material, such as lucite, is lined so as to produce ten equally proportional lines. This device is placed on the recording in such a manner that the two outside lines touch two adjacent magnetic bearing marks on the base line. If these bearings are 10° apart, the ratio divider measures the space between them on 1° steps. If the bearings are 5° apart, one-half degree steps are positioned. Since the center scale position or indicated bearing is extended to the same relative position on the base line for each omnibearing selector setting, the ratio divider enables the operator to read the error directly in degrees.

If two persons are available in the plane during the calibration flight, one of them can plot the results of the calibration and have the error curve at hand a few minutes after the completion of the circle. This makes it possible to report results to the ground crew and conduct further tests while in the air rather than to land and conduct these tests sometime in the future when different conditions might possibly exist.

Fig. 5 is a reproduction of a typical VHF omnirange system calibration recording. Fig. 6 is the measured error curve plotted from the data contained in Fig. 5. From this error curve, it can be seen that the receiver omnibearing selector should be moved 3° counterclockwise to place it at the average error position A diagram (originally prepared by engineers of the Third Regional Office) which presents, in condensed form, the interpretation of flight calibration readings and showing the corrective action necessary at the omnirange station, is shown in Fig 7

CONCLUSIONS

The omnirange calibration method described has been in use for some time at the Civil Aeronautics Administration, Experimental Station at Indianapolis, Indiana, and has provided an excellent method of determining the over-all accuracy of such a range system

The advantages of this type of calibration over previous methods are speed and accuracy

The time required for a calibration is relatively short since a flight may be completed in approximately an hour, including a second circle about the station to provide overlapping points as an additional check

Accuracy is much improved over earlier methods because the human element is largely eliminated Error curves taken from successive circles flown about the station usually coincide within plus or minus one-half degree

Validity of such tests is high since a flight calibration approaches the conditions under which the system is actually used

In such a calibration it should be pointed out that the error curve thus derived shows the over-all error of the entire system and not merely that of the range station Before the calibration is undertaken, the receiver error must be determined by suitable tests and this taken into consideration when calculating the error of the range station

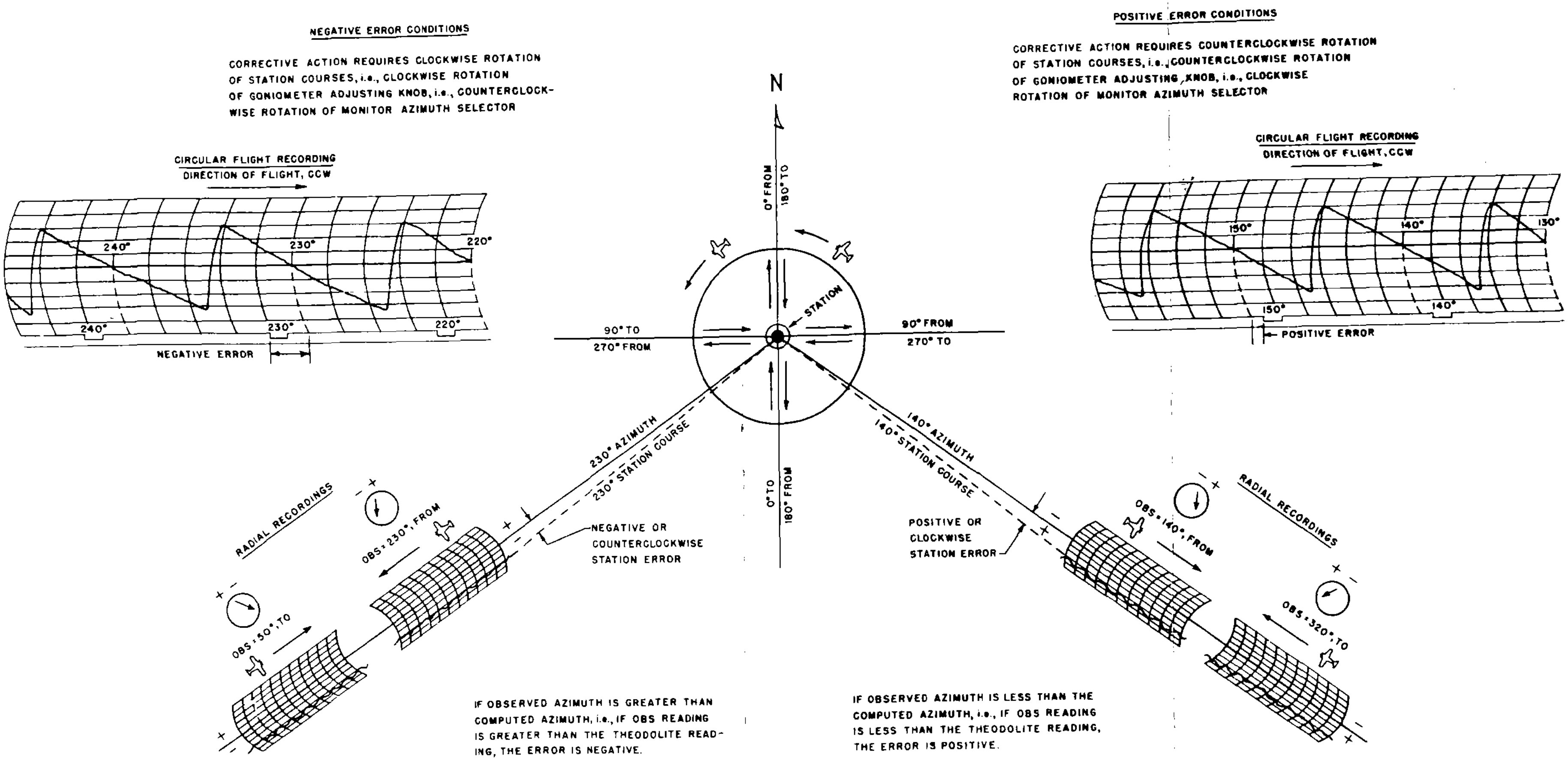


Fig. 7 Typical Recording Data