TECHNICAL DEVELOPMENT REPORT NO. 358

TESTS OF THE HAZELTINE VOR MONITOR AND FIELD DETECTOR

FOR LIMITED DISTRIBUTION

by

Alan L Saunders
Glen Hershberger
Virgil G. Irelan

Electronics Division

August 1958

CIVIL AERONAUTICS ADMINISTRATION
TECHNICAL DEVELOPMENT CENTER
INDIANAPOLIS, INDIANA

U. S. DEPARTMENT OF COMMERCE

Sinclair Weeks, Secretary

CIVIL AERONAUTICS ADMINISTRATION

James T Pyle, Administrator

D. M. Stuart, Director, Technical Development Center

This is a technical information report and does not necessarily represent CAA policy in all respects.

TESTS OF THE
HAZELTINE VOR MONITOR AND FIELD DETECTOR

SUMMARY

This report presents the results of tests conducted at the CAA Technical Development Center to determine the accuracy of ground calibration of a VOR facility when using a Hazeltine monitor and field detector. A simple circuit modification was developed to improve the performance of the monitor. Comparative tests made with other types of monitors and detectors show that ground calibration curves are slightly different for every monitor and detector combination.

INTRODUCTION

The CAA Office of Air Navigation Facilities requested that tests be conducted on the Hazeltine Type CA-1575 VOR monitor to determine its accuracy when used for ground calibration of a VOR. Also, it was requested that the Technical Development Center (TDC) determine the effect on the monitor when it is operated with the Hazeltine field detector Type CA-1575/2 and a portable detector, Type CA-2943.

At the present time, there is no method of establishing a calibration curve of a VOR that is independent of errors caused by monitors or navigation receivers. It is, therefore, impossible to determine exactly what inaccuracy is to be charged to a particular monitor. The approach to this problem was

1. To conduct laboratory tests in which known sources of error can be introduced into the monitor. In the laboratory, these sources of error were examined one at a time and in amounts that could be measured and described.

2. To conduct field tests in which other types of monitors are subjected to the same conditions as the monitor in question. Although this does not provide an exact measure of accuracy, it does provide a means of comparing ground calibration curves obtained with various monitors on the bearing information radiated from a VOR.

The following monitors were selected for comparison with the Hazeltine monitor: Hoffman monitor, Type CA-1277, Memco monitor, Type CA-1485, a monitor developed by TDC[1]; and a modified version of the Hazeltine monitor.

In addition to the field tests conducted with the two detectors as requested by the Office of Air Navigation Facilities, a third detector also was

[1] R. A. Forcier and W. H. Klein, "The Development of an Improved VOR/TVOR Monitor," CAA Technical Development Report No. 271, June 1955.

used. It was a Type CA-2041 field detector modified to reduce some of the inaccuracies that may be introduced into a monitor by the detector.

Tests were made using each of the three detectors with each of the four monitors described above. Tests were conducted to determine the error-producing characteristics of the Hazeltine Type CA-1575/2 field detector as compared to the portable Type CA-2943 field detector and the modified CA-2041 field detector. Also, data were collected on effects of improper physical alignment of the detector dipole with respect to the VOR antenna system.

TESTS

Laboratory Tests.

One of the factors which affect the accuracy of any VOR monitor when it is used to obtain a ground calibration of a VOR station is its ability to discriminate against unwanted audio signals. Controlled levels of normally unwanted audio signals were introduced at the monitor input along with a normal VOR signal. The phase of the interfering signal was adjusted to result in the greatest error in the monitor. Table I shows the results of this test conducted with the Hoffman, Hazeltine, TDC, and Memco monitors. The measured percentages of low-frequency signals obtained at the detector operating at a VOR station and considered to be normal are shown in Table I also. The frequencies, 45 cycles per second (cps) and 75 cps, are not likely to be generated at a VOR facility and, therefore, need not be expected to cause VOR calibration errors.

TABLE I

AUDIO INTERFERENCE TESTS

Frequency of Interfering Signal (cps)	Variation at Monitor in Degrees with Level of Interfering Signal 10 Per Cent of 30-cps Signal Level				Relative Levels Measured at Tilden VOR (per cent)
	Hoffman (deg.) + or -	Hazeltine (deg.) + or -	TDC (deg.) + or -	Memco (deg.) + or -	
30	6.0	5.7	5.5	5.8	100
45	5.5	5.6	0	5.0	0
60	1.9	0.3	0.1	0.15	4.0
75	1.5	0.3	0	0.1	0
90	0.9	0.1	0.6	0.05	0.6
120	0.5	0	0	0	0.4
150	0.3	0	0.4	0	0.5
180	0.1	0	0	0	0

The error caused when 30-cps amplitude modulation occurs on the 9.96-kc subcarrier is shown in Fig. 1 for four different types of monitors. For these tests, the 9.96-kc subcarrier was amplitude-modulated with a variable-phase, 30-cps signal. This simulates the type of modulation that occurs in a VOR field detector when operating at a low radio-frequency (r-f) level. Using the Hazeltine monitor, a large reduction in this type of error was obtained when a multivibrator circuit, developed by the Hazeltine Company, replaced the limiter circuit in the 9.96-kc amplifier channel.

A simple and slightly more effective modification was made to the Hazeltine monitor for the reduction of error caused by 30-cps amplitude modulation on the 9.96-kc subcarrier. This modification consisted primarily of using a 9.96-kc band-pass filter similar to that used in the Collins navigation receiver. The filter first was used at TDC in the grid circuit of an early stage of the 9.96-kc amplifier, but later tests showed that better results could be obtained when the filter was used in parallel with Items R-3090 of the limiter stage V-3090A as shown in Fig. 2. In addition to the filter, the lead to Item C-3040 was removed from pin 8 (cathode) of V-3140A and connected to pin 1 of V-3050A. Pin 8 (cathode) of V-3040A was grounded. The improvement obtained with this modification is shown in Fig. 1.

Figures 3 and 4 show the results of tests made on the Hazeltine and TDC monitors, respectively, when subjected to changes in temperature and humidity. The tests on the Hazeltine unit were made with the added multivibrator circuit.

Field Tests.

Most of the field tests were conducted at the Tilden experimental VOR. Ground calibrations were made using a Hazeltine field detector, Type CA-1575/2, a modified CAA portable field detector, Type CA-2943, and a modified Type CA-2041 field detector. The Type CA-2943 field detector was modified to include a 51-ohm resistor in each antenna element. The Type CA-2041 field detector was modified to include longer antenna elements and an improved detector circuit The schematic diagram of the improved detector circuit is shown in Fig. 5. All detectors were tuned to resonance at the start of each test. The adjustable Faraday shield in the portable field detector Type CA-2943 was used in certain tests to provide low detector levels.

Each calibration curve was obtained by substituting a phase standard signal from a Type CA-1430 test generator for the detector signal, similar to the method described in CAA MANOP IV-B-3-3, Par. 8.4.15, entitled "Standard Ground Check Procedure." All calibrations were made with a reference signal from the tone wheel fed directly to the reference channel of the monitor over a conductor rather than by way of r-f radiation and demodulation. An exception was made, however, when data for Fig. 9 were obtained by the normal process of demodulating and using the 9.96-kc subcarrier thus obtained for a reference signal.

A switching arrangement was provided at each monitor to permit three input signal combinations. The No. 1 switch position connected the variable signal from the detector, and the reference signal from the tone wheel, to the respective variable and reference channels of the monitor. The No. 2 position connected both reference and variable signals from the detector to the normal monitor input, while the No. 3 position connected both signals from the phase standard generator to the monitor.

Figure 6 shows a comparison of calibration curves for the North experimental VOR obtained with the TDC monitor using the Hazeltine and Type CA-2943 portable field detectors. For these tests, each field detector was rotated 180° in the horizontal plane at each test position on the counterpoise. Should there be misalignment between the electrical center of the detector dipole and the physical axis about which it rotates, a uniform difference between the two error curves is apparent at all azimuths. However, the differences between these curves vary considerably, with azimuth indicating that some of the calibration curve error is due to vertical polarization. Examination of the difference between these curves will disclose that the CA-2943 portable field detector produced error curves that differ from one another by only 0.3° while the curves produced by the Hazeltine detector differ by 0.6°. The greater similarity of the curves taken with the Type CA-2943 field detector is attributed to the greater dipole length, which provides a greater ratio of horizontally polarized to vertically polarized signal.

The effects of misalignment between the electrical center of the dipole and a physical axis about which the dipole may be rotated is a fixed error that is the same at all azimuths, plus some error derived from the vertically polarized component and proportional to its intensity at any given azimuth. Curves A and B of Fig. 7 show how similar such curves can be when the dipole is symmetrically balanced, both mechanically and electrically. Data for curves C and D were obtained with the same detector, but with one of the dipole elements shortened 2 7/8 inches to cause a displacement of the electrical center from the supporting mast. The large fixed difference of approximately 1° from the average of curves A and B is evident. Also, some changes in the shape of the curves are believed to be caused by vertically polarized pickup.

The curves in Fig. 8 show the effect on the bearing indicated by the monitor when the detector antenna is not perpendicular to the station radial passing through the center of the dipole. From these data, it will be noted that the modified detector with long dipole elements is more susceptible to this type of misalignment. However, under normal calibration conditions, even the long dipole misalignment will not cause an error greater than 0.05°.

Three calibration curves are presented in Fig. 9 showing the variations caused by three different conditions of monitor and VOR operation. Curve A was obtained by taking the reference signal directly from the station tone wheel by shielded cable to the reference channel of the monitor, with the reference channel disconnected from the detector input but with the reference signal modulating the transmitter. The conditions for curve B were the same except that no reference signal was radiated. Curve C was obtained when both station and monitor were operating normally.

Figure 10 shows a comparison of calibration curves obtained at the North VOR when the Hazeltine monitor Type CA-1575 was operating with the multivibrator circuit and the Type CA-2943 portable field detector. Calibration curve A was obtained when the field detector was adjusted for a maximum direct-current (d-c) output, which was 3.0 volts. Curve B was obtained when the field detector was adjusted to provide a d-c output of 0.5 volt. Curve C was obtained under the same conditions as for curve B except that a 500-microfarad (mfd) capacitor was connected across the field strength meter. The displacement of curve B was caused mainly by the inductive reactance of the field strength meter shifting the phase of the 30-cps variable signal when the monitor input attenuator was changed. This indicates a mismatch in impedances between the detector and monitor. The use of a 500-mfd capacitor connected across the field strength meter partially corrected the error caused by the meter.

The data presented in Fig. 11 demonstrate the improvement made in the normal Hazeltine Type CA-1575 monitor by the TDC circuit modification. The Type CA-2943 portable field detector, operating at a low output level, was used to furnish a signal to the monitor in this test since it was known to cause some amplitude modulation on the 9.96-kc subcarrier. Curve A is a calibration curve obtained from the unmodified Hazeltine Type CA-1575 monitor, while curve B was obtained from the same monitor but with the TDC modifications. For this test, the modification consisted of the filter change in the reference channel, as described in a previous paragraph, and the 500-mfd capacitor in parallel with the field strength meter. A calibration curve, curve C, also was obtained with a Hoffman Type CA-1277 monitor for comparison purposes. The Hoffman monitor was operated from the same detector and under the same conditions as the Hazeltine. It is apparent from the curves that a VOR ground calibration made with an unmodified Hazeltine monitor would be quite different from one made with the TDC-modified Hazeltine or Hoffman monitors.

A 12-mile theodolite-controlled flight check was made on the Tilden experimental VOR. Immediately after the flight, a series of ground checks was made at the counterpoise edge. It was desired to determine which monitor produced calibration data that agreed most closely with the flight check. Also, since it had been noted previously that the use of different detectors resulted in different calibration data from the same monitor, checks were made with different detectors. A comparison of the data obtained from four monitors when using the field detectors, Hazeltine Type CA-1575/2, portable Type CA-2943, and modified Type CA-2041, are shown in Figs. 12, 13, and 14. The flight-check data also are shown on each of the three figures. For easy comparison of the effect of detectors on the calibration, the same information is regrouped so that each figure contains the data from a single monitor obtained with the three different detectors, including the flight-check data. Figures 15, 16, 17, and 18 show the data obtained from the Hazeltine, Memco, Hoffman, and TDC monitors, respectively. None of these ground checks shows close correlation with the flight check, nor do any two of the monitors show complete agreement with one another. The discrepancies between the flight calibration curve and the ground calibration curves are believed to be due to several reflecting objects in the immediate vicinity of the Tilden VOR and, possibly, to measurement errors involving the signal generator and receiver.

DISCUSSION

It is apparent that when different monitors are supplied with identical signals, they do not provide the same calibration data. Furthermore, the signals from different detectors applied to the same monitor provide different calibration data. There is insufficient information available to determine which combination of monitor and detector provides the most accurate calibration curve. In order to resolve the differences obtained between ground-check data using various monitors and detectors and the flight-check data, additional tests must be conducted at a site free of reflecting objects.

CONCLUSIONS

It is concluded that:

1. The error caused by 30-cps amplitude modulation on the 9.96-kc subcarrier in the Hazeltine monitor can be reduced greatly by two simple circuit changes, and the addition of a 9.96-kc filter unit, or by the use of a multivibrator circuit. The 9.96-kc filter modification is superior to the multivibrator circuit because of its inherent simplicity.

2. The addition of a 500-mfd capacitor connected across the field strength meter in the Hazeltine monitor will reduce the error caused by the inductive reactance of the meter.

3. The calibration data obtained with the 9.96-kc reference signal fed directly from the tone wheel to the monitor are more accurate than when the radiated reference signal is used because they eliminate errors due to 30-cps amplitude modulation on the subcarrier.

4. The ground calibration curve of a VOR will vary approximately plus or minus 0.7°, depending upon the type of monitor and detector used.

5. The flight calibration curve will not agree completely with the ground calibration curve due to siting and measurement errors.

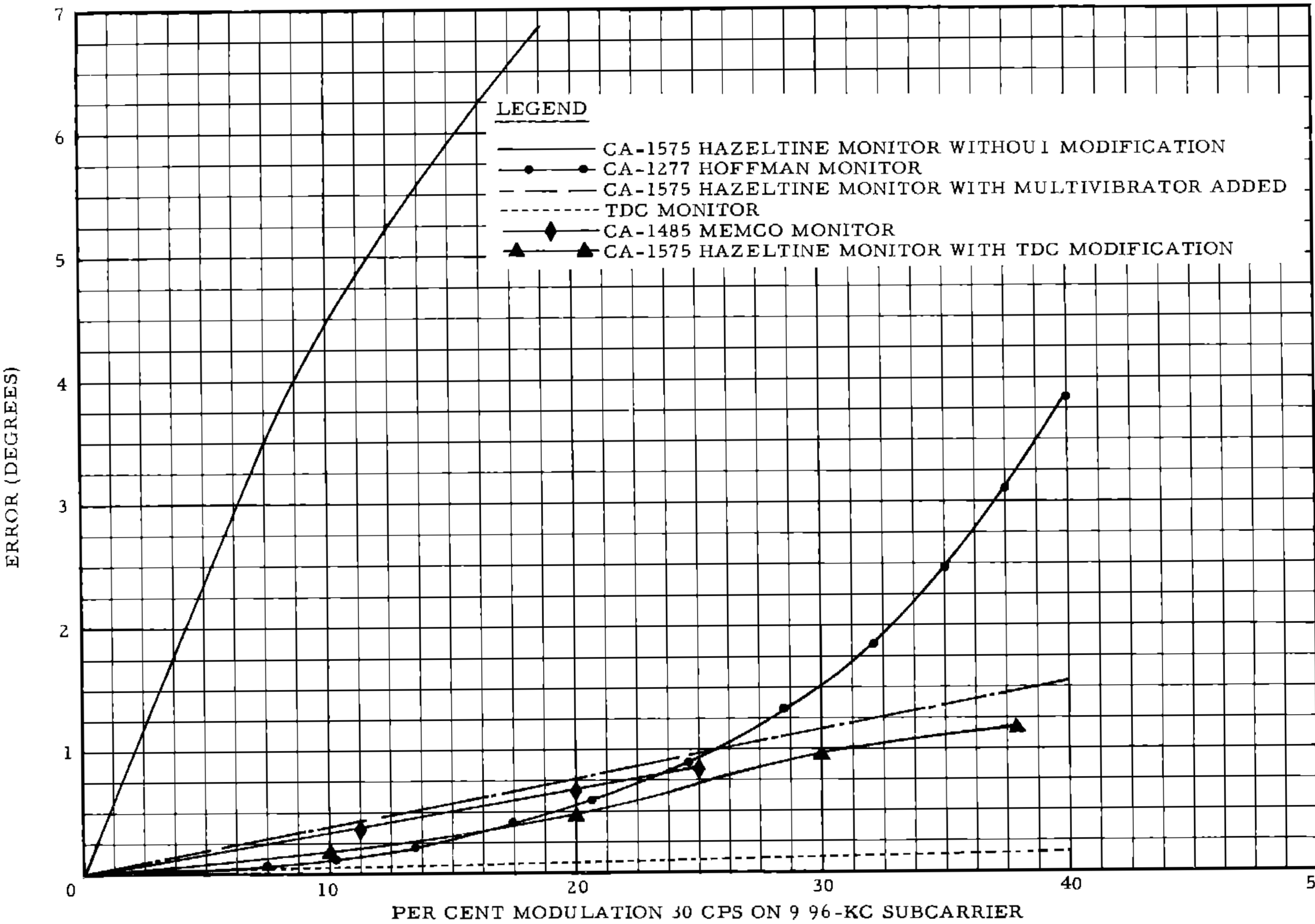

FIG 1 ERROR CAUSED BY 30-CPS AMPLITUDE MODULATION ON 9 96-KC

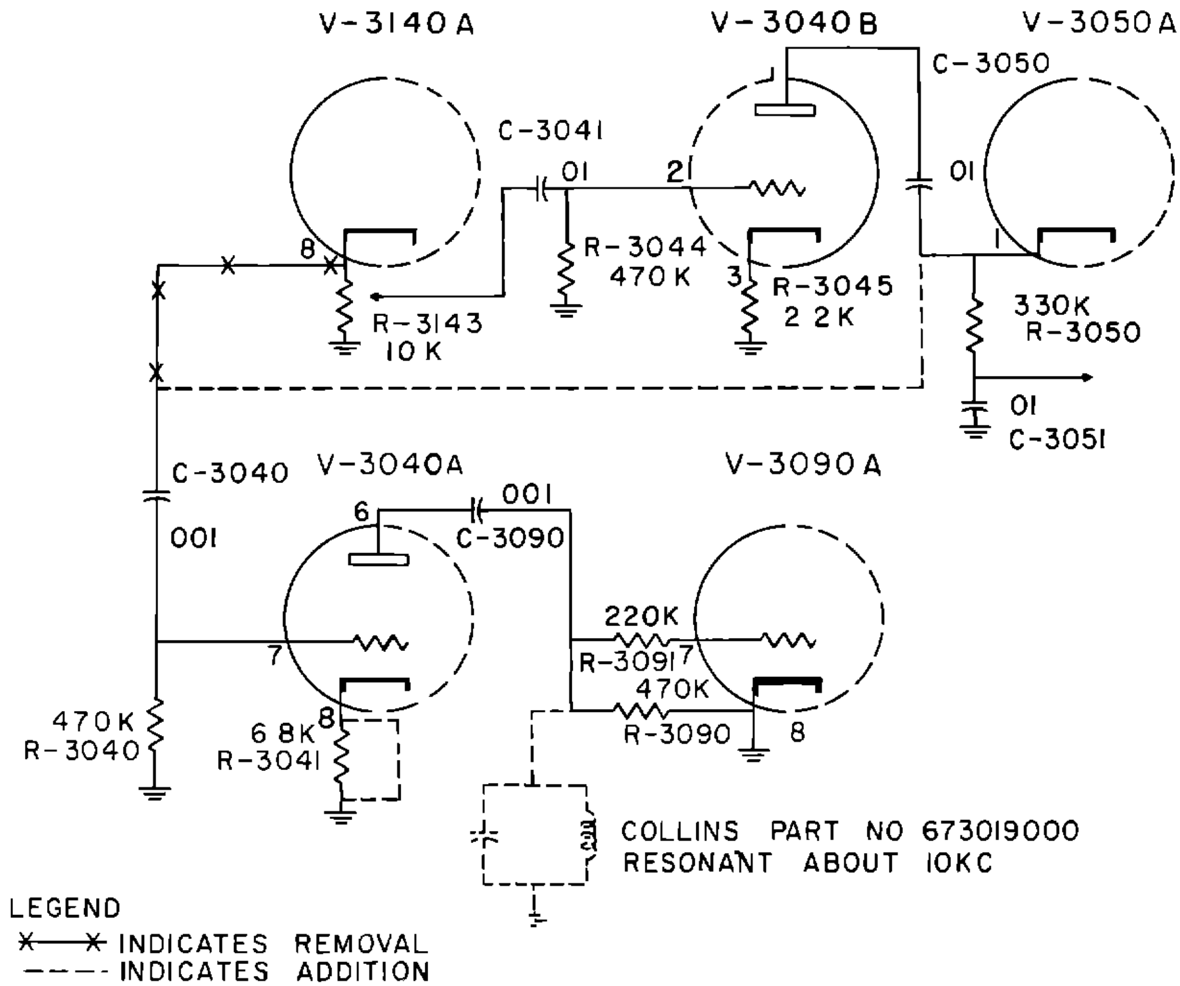

FIG. 2 SCHEMATIC OF TDC MODIFICATION TO CA-1575 HAZELTINE MONITOR

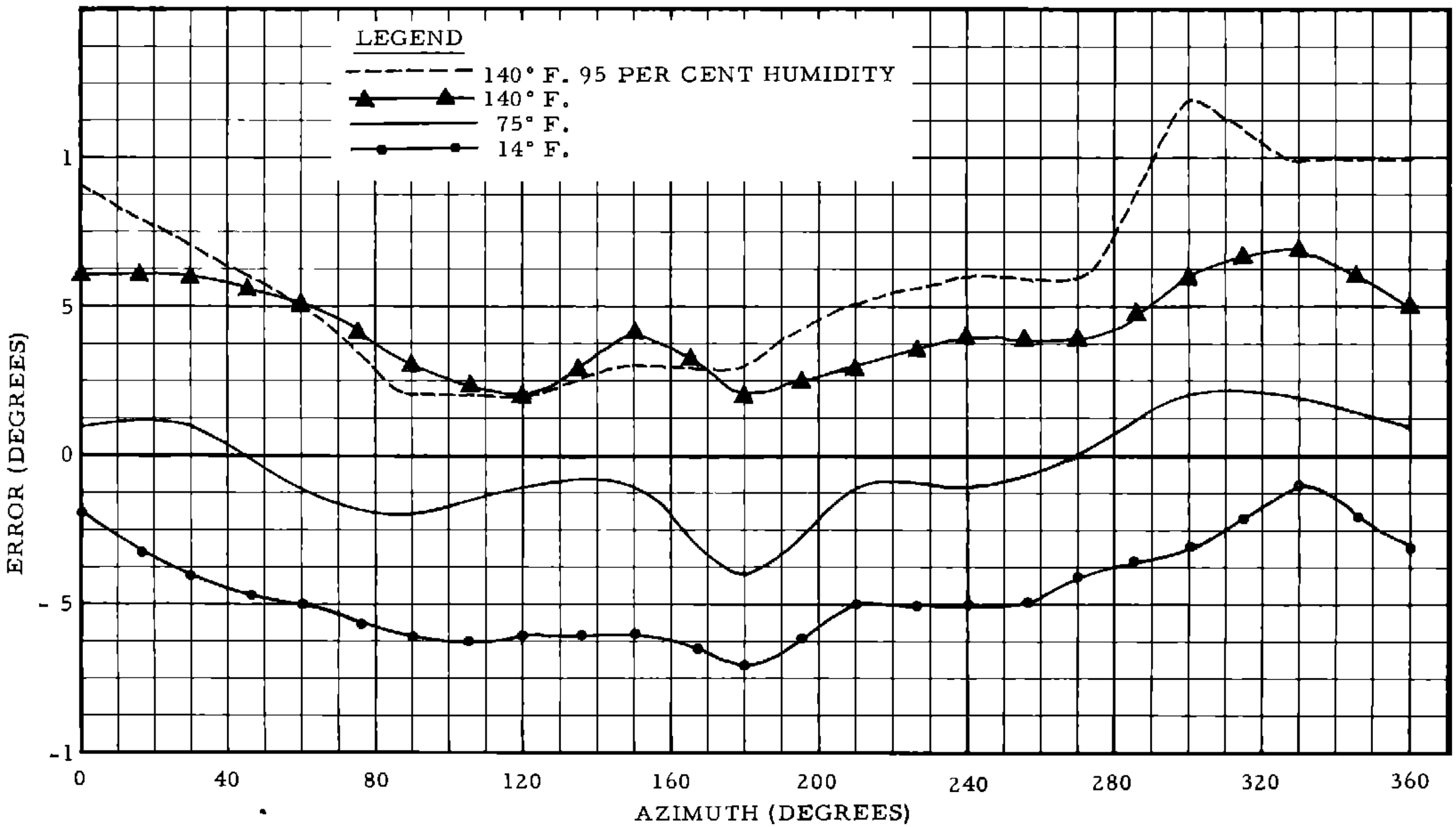

FIG. 3 ERROR CURVES FOR ENVIRONMENTAL TEST OF CA-1575 HAZELTINE MONITOR WITH MULTIVIBRATOR ADDED

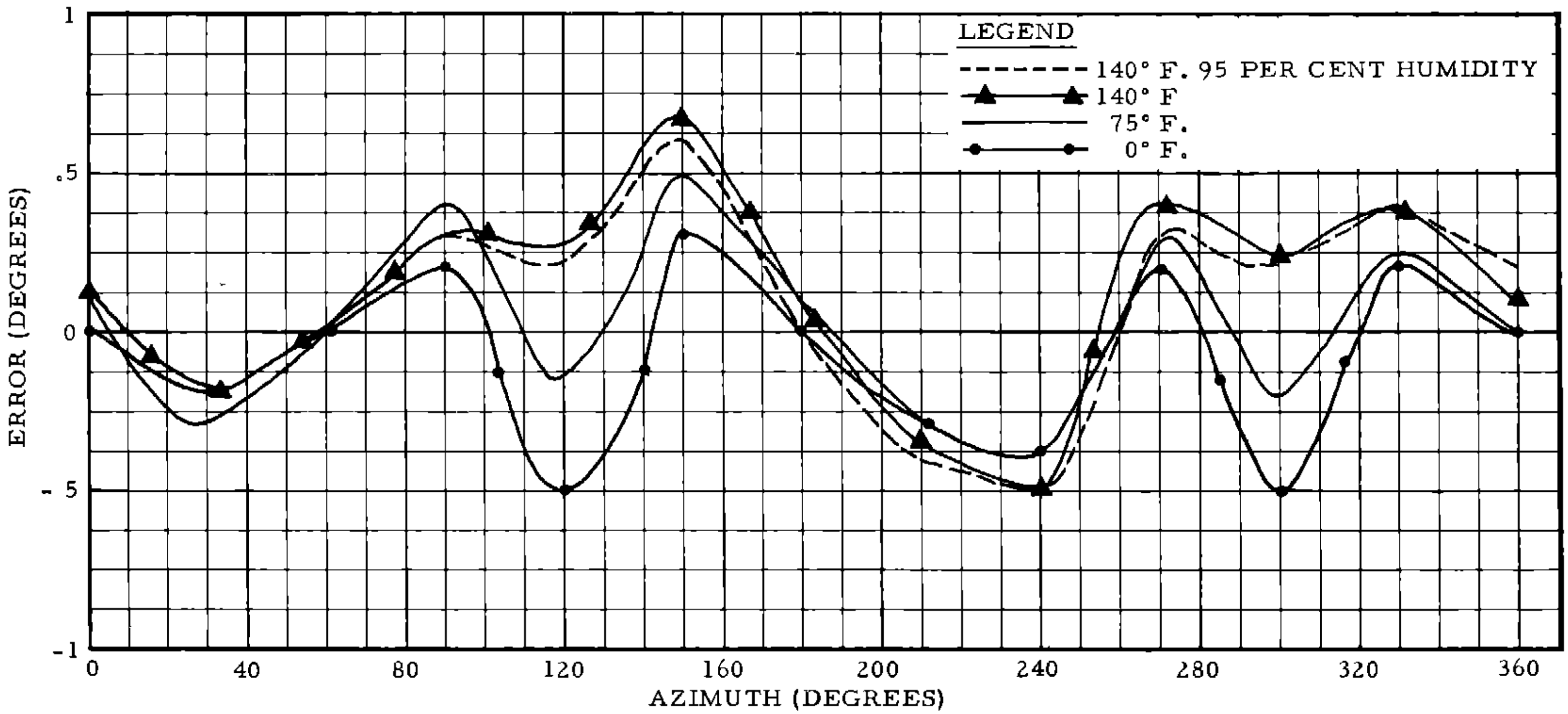

FIG 4 ERROR CURVES FOR ENVIRONMENTAL TEST OF TDC MONITOR

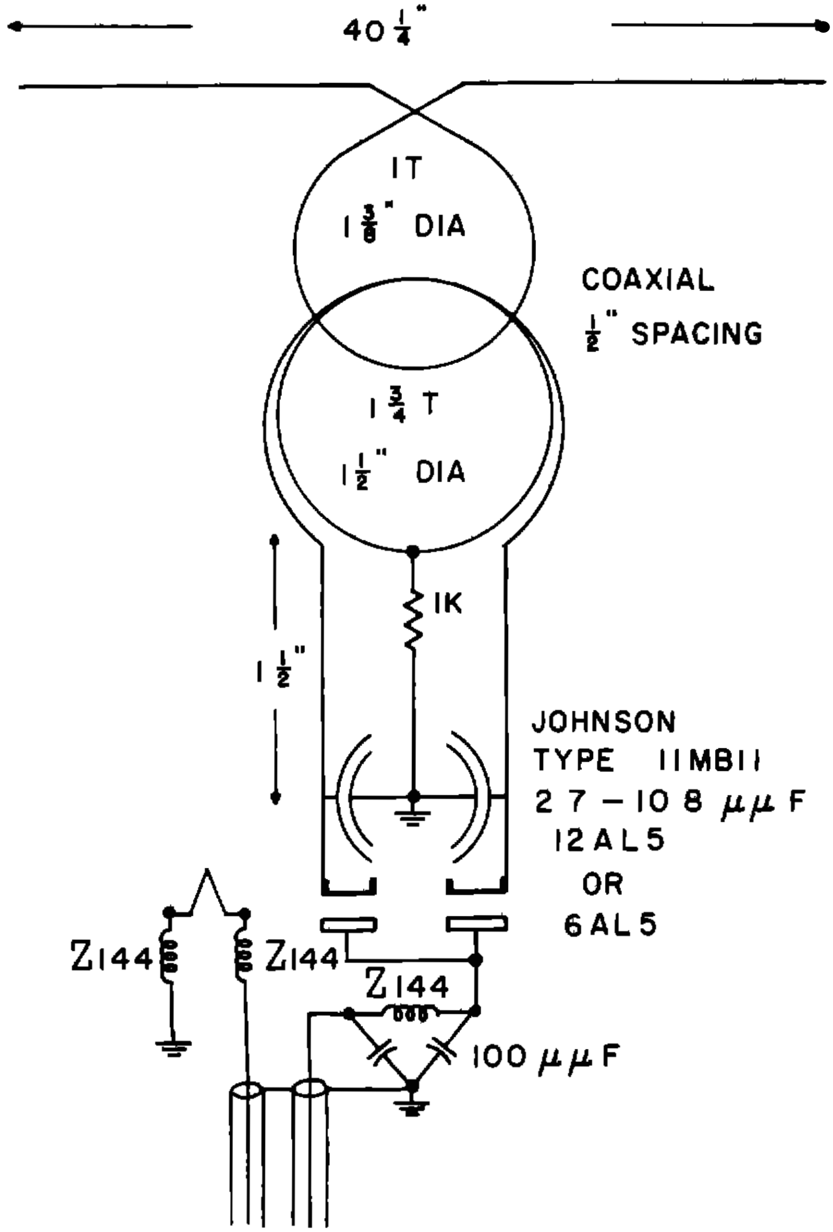

FIG. 5 SCHEMATIC DIAGRAM OF FIELD DETECTOR CA-2041 (MODIFIED)

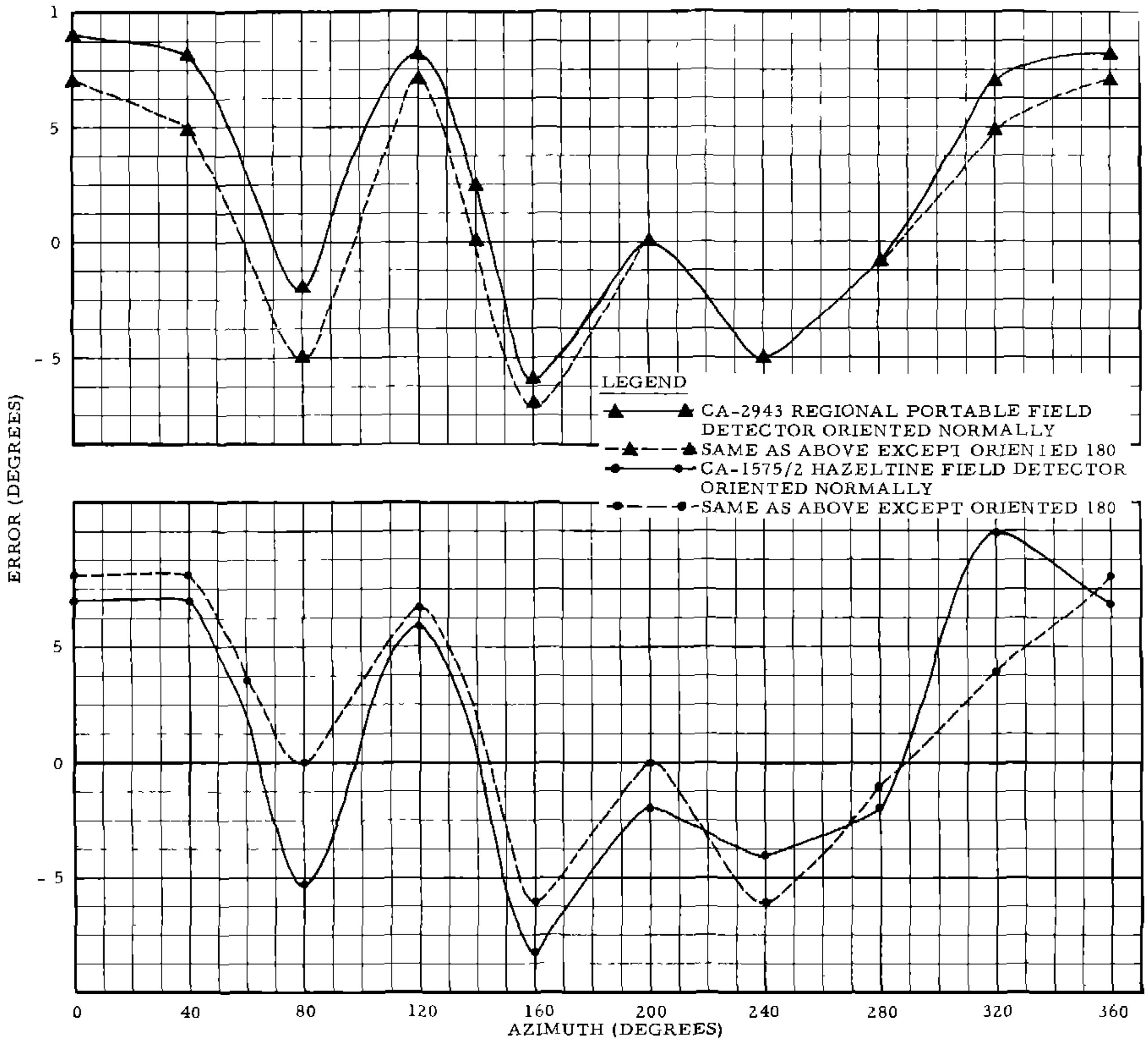

FIG 6 COMPARISON OF CALIBRATION CURVES FOR NORTH VOR USING TDC MONITOR WITH CA-2943 REGIONAL PORTABLE AND CA-1575/2 HAZELTINE FIELD DETECTORS

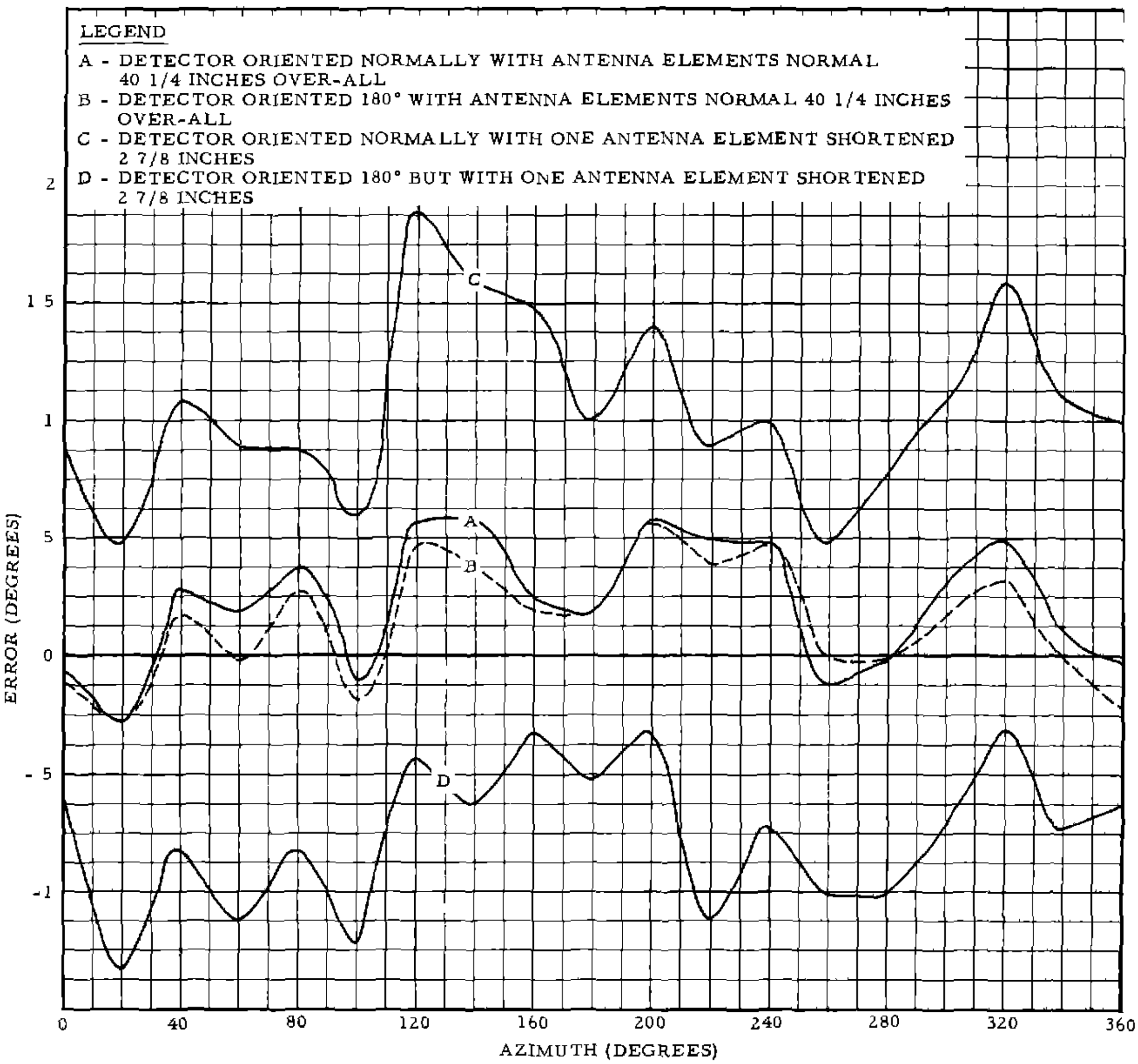

FIG 7 COMPARISON OF CALIBRATION CURVES MADE FOR TILDEN VOR WITH TDC MONITOR AND CA-2041 MODIFIED FIELD DETECTOR TO SHOW EFFECT OF DETECTOR ORIENTATION AND ANTENNA UNBALANCE

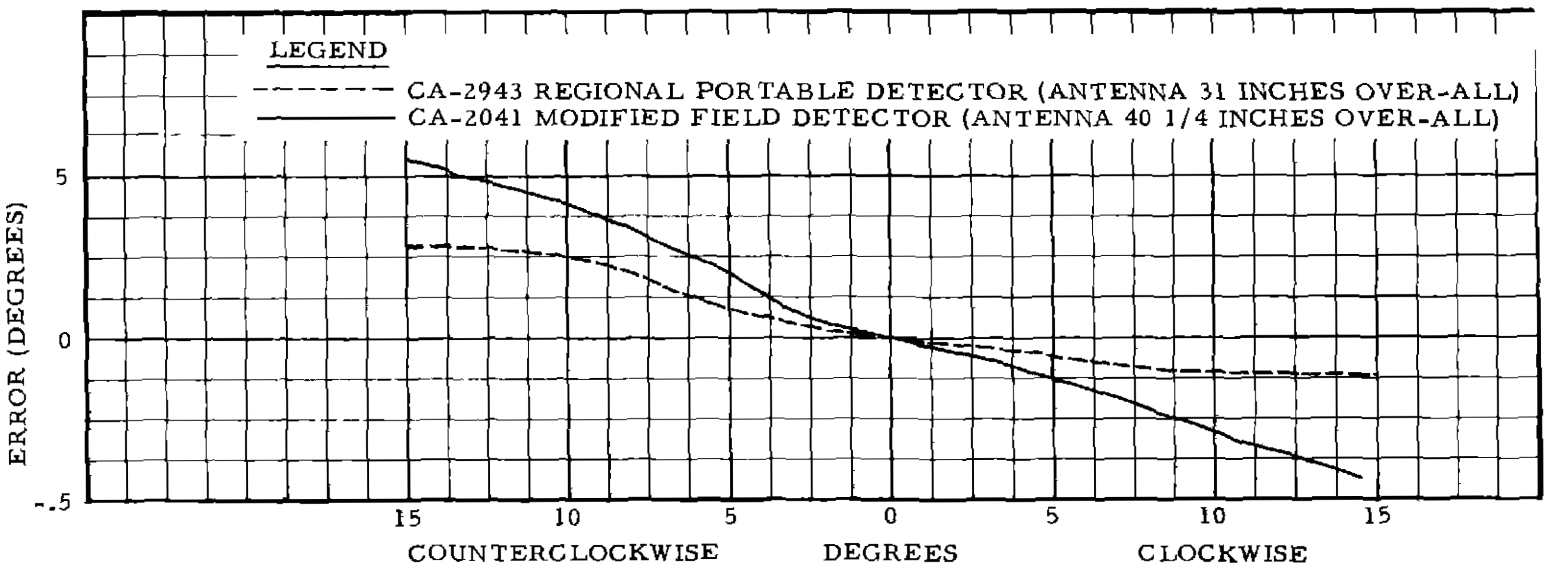

FIG. 8 ERROR AT 120° AZIMUTH RESULTING FROM ORIENTING DETECTORS AS MUCH AS 15° FROM THE NORMAL POSITION TANGENT TO THE COUNTERPOISE EDGE

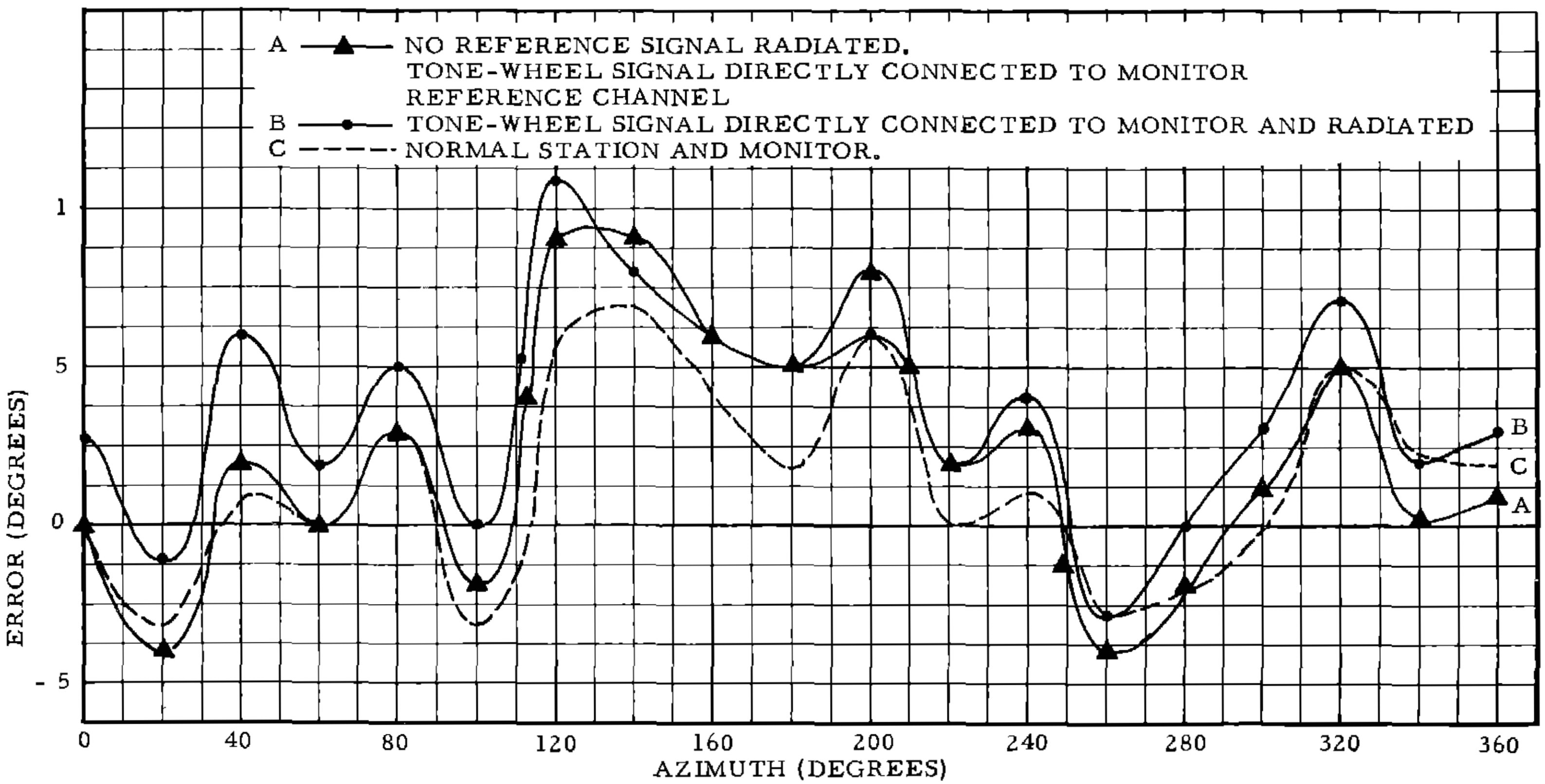

FIG. 9 COMPARISON OF CALIBRATION CURVES FOR TILDEN VOR TAKEN WITH TDC MONITOR AND CA-2041 MODIFIED FIELD DETECTOR WITH THREE DIFFERENT CONDITIONS OF MONITOR AND VOR OPERATION

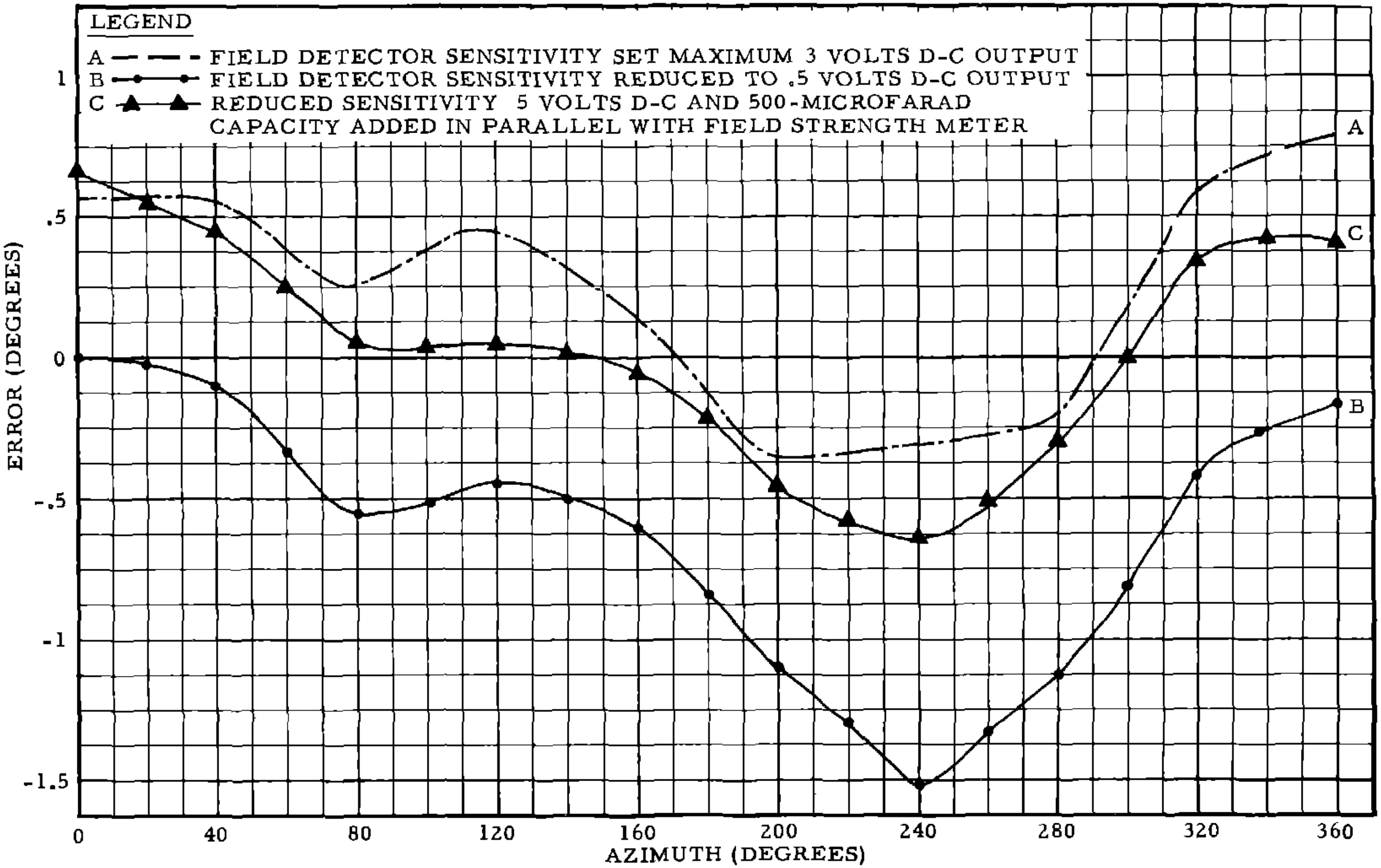

FIG 10 COMPARISON OF CALIBRATION CURVES FOR NORTH VOR TAKEN WITH CA-1575 HAZELTINE MONITOR (WITH MULTIVIBRATOR ADDED) AND CA-2943 REGIONAL PORTABLE DETECTOR DURING TWO DETECTOR SENSITIVITY SETTINGS AND THE ADDITION OF CAPACITY IN PARALLEL WITH THE FIELD STRENGTH METER

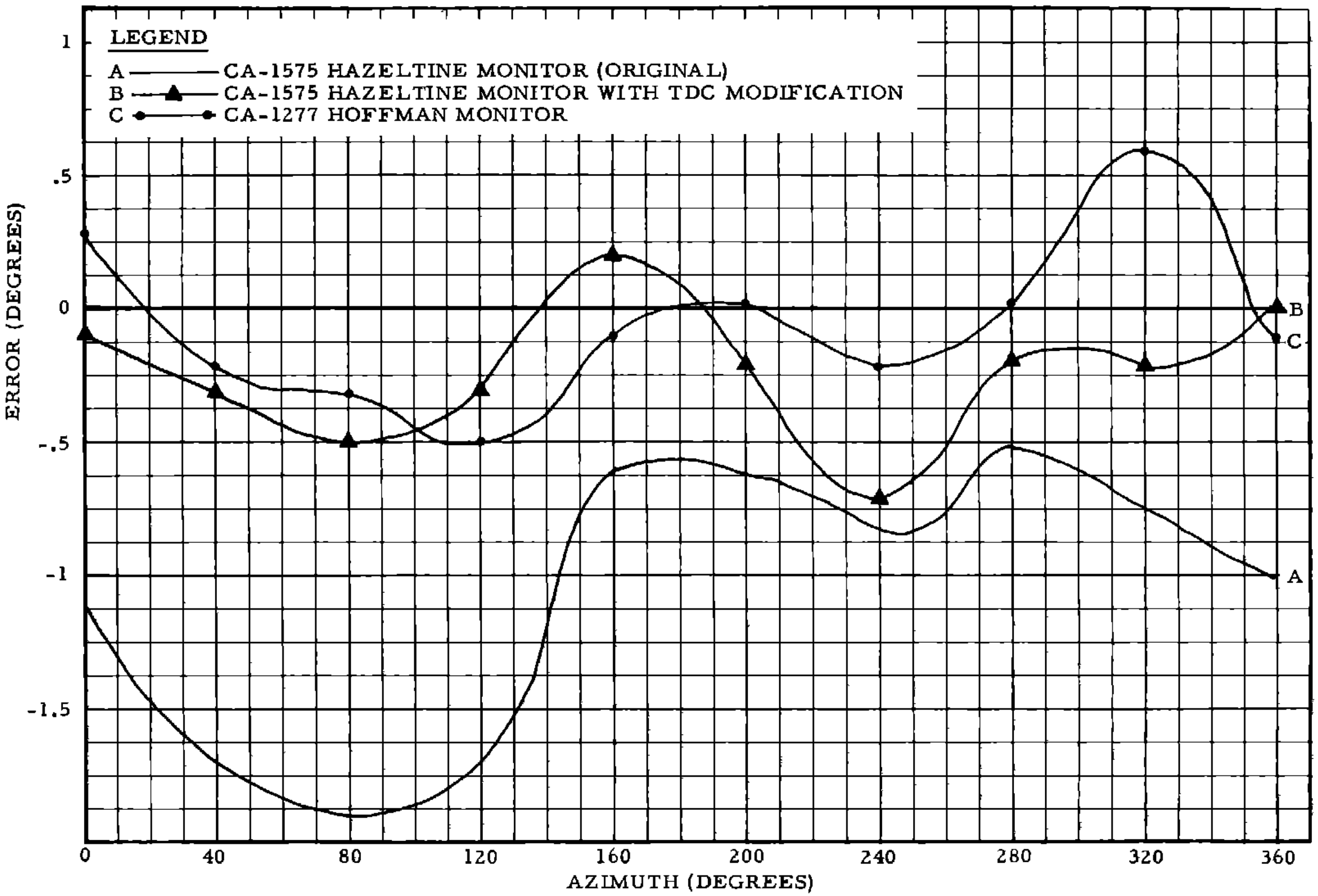

FIG 11 COMPARISON OF CALIBRATION CURVES FOR NORTH RANGE VOR TAKEN BY GROUND CHECK WITH CA-2943 REGIONAL PORTABLE DETECTOR AND WITH HAZELTINE AND HOFFMAN MONITORS

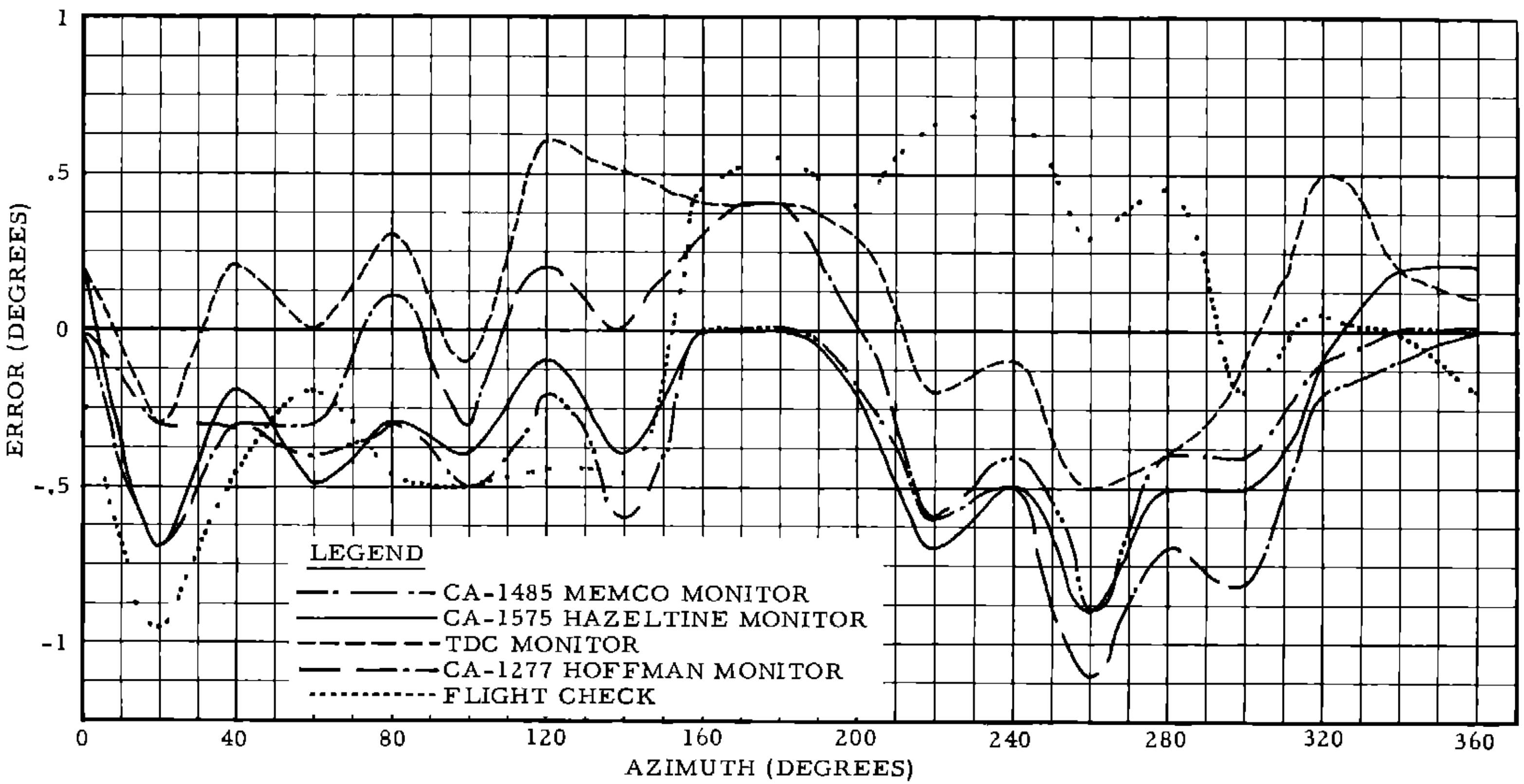

FIG 12 COMPARISON OF CALIBRATION CURVES FOR TILDEN VOR TAKEN BY GROUND CHECKS USING CA-1575/2 HAZELTINE FIELD DETECTOR WITH FOUR MONITORS AND BY FLIGHT CHECK

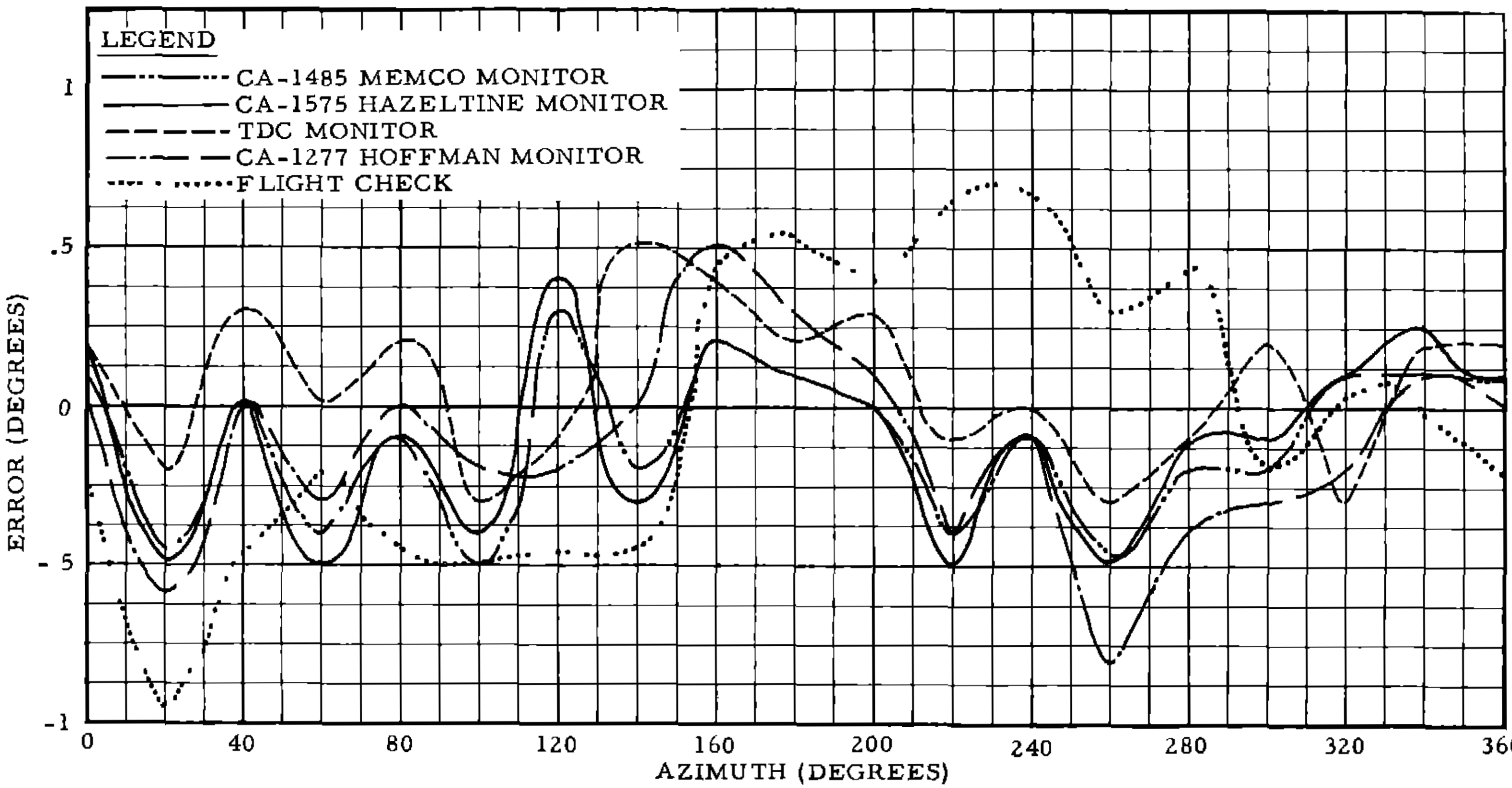

FIG. 13 COMPARISON OF CALIBRATION CURVES FOR TILDEN VOR TAKEN BY GROUND CHECKS USING CA-2943 REGIONAL PORTABLE FIELD DETECTOR WITH FOUR MONITORS AND BY FLIGHT CHECK

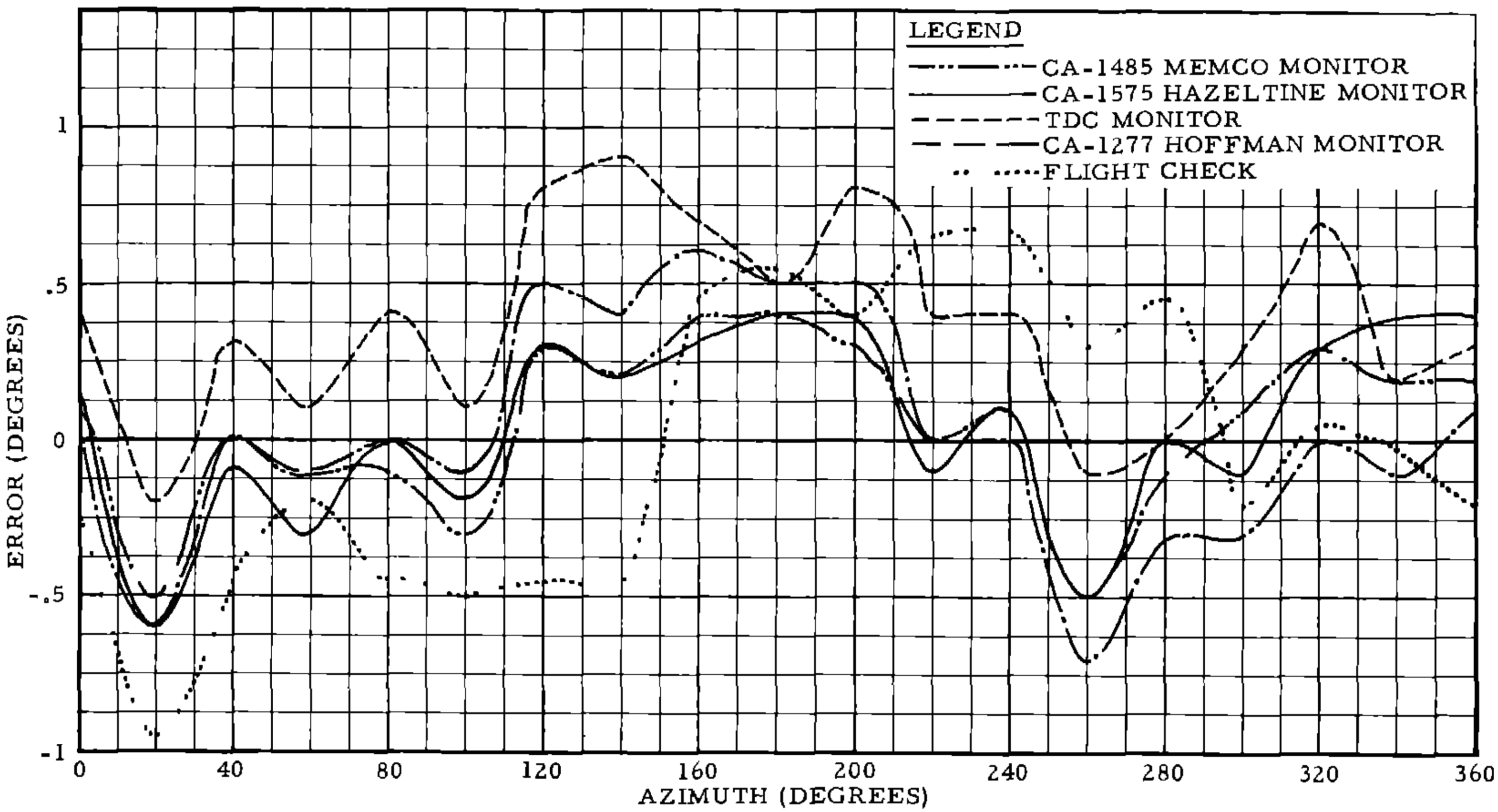

FIG 14 COMPARISON OF CALIBRATION CURVES FOR TILDEN VOR TAKEN BY GROUND CHECKS USING CA-2041 MODIFIED FIELD DETECTOR WITH FOUR MONITORS AND BY FLIGHT CHECK

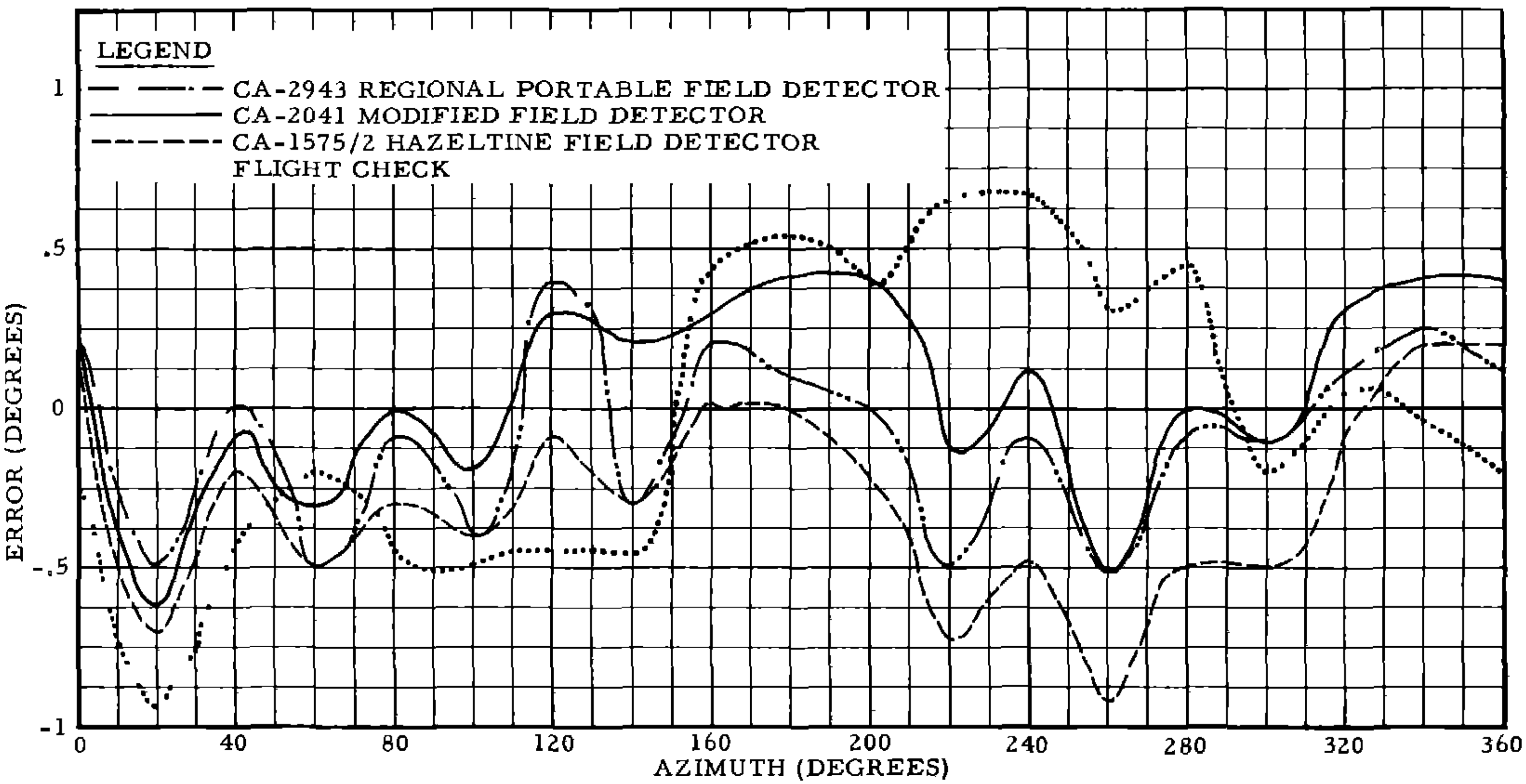

FIG 15 COMPARISON OF CALIBRATION CURVES FOR TILDEN VOR TAKEN BY GROUND CHECKS USING CA-1575 HAZELTINE MONITOR WITH THREE FIELD DETECTORS AND BY FLIGHT CHECK (WITH MULTIVIBRATOR ADDED TO MONITOR)

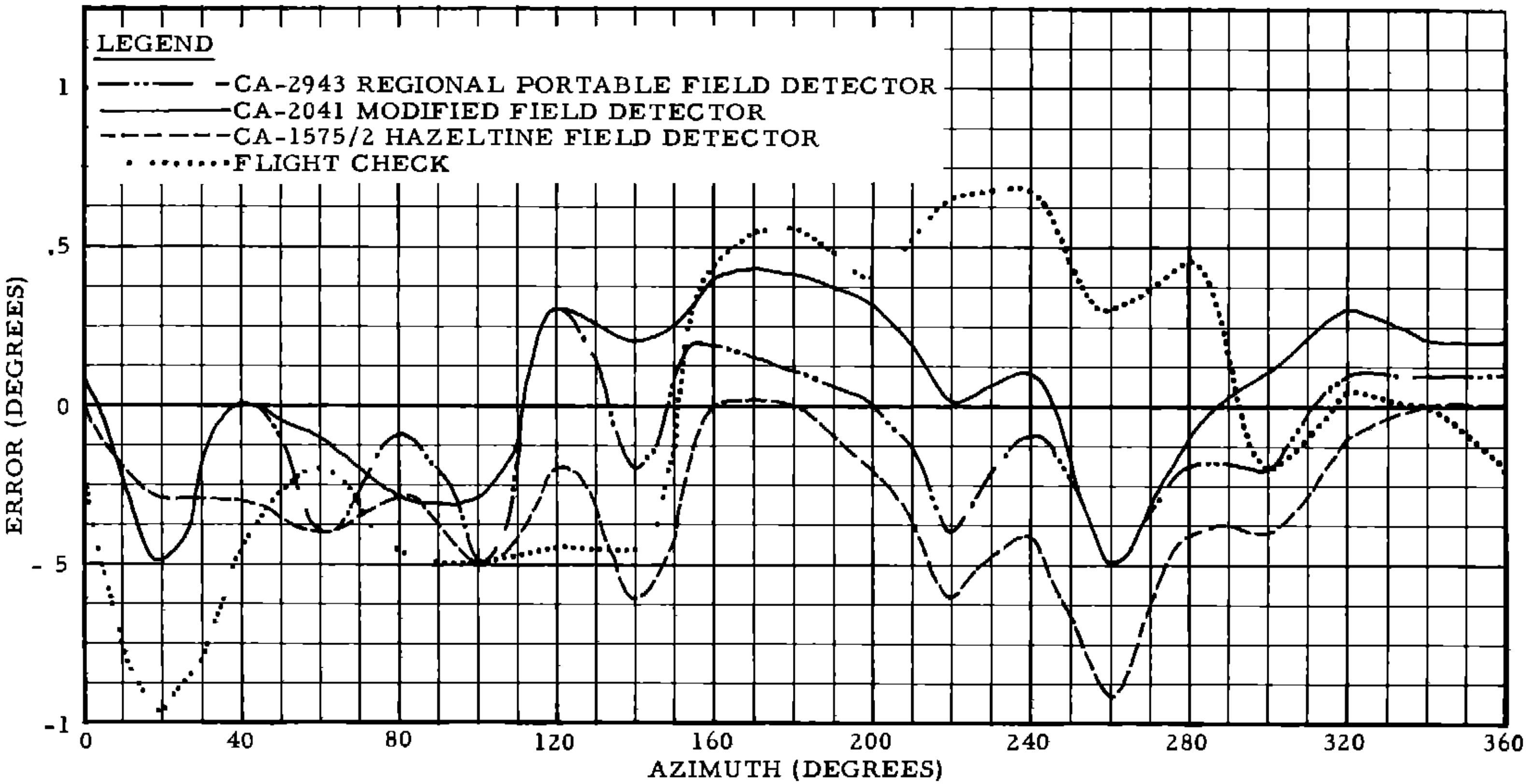

FIG. 16 COMPARISON OF CALIBRATION CURVES FOR TILDEN VOR TAKEN BY GROUND CHECKS USING CA-1485 MEMCO MONITOR WITH THREE FIELD DETECTORS AND BY FLIGHT CHECK

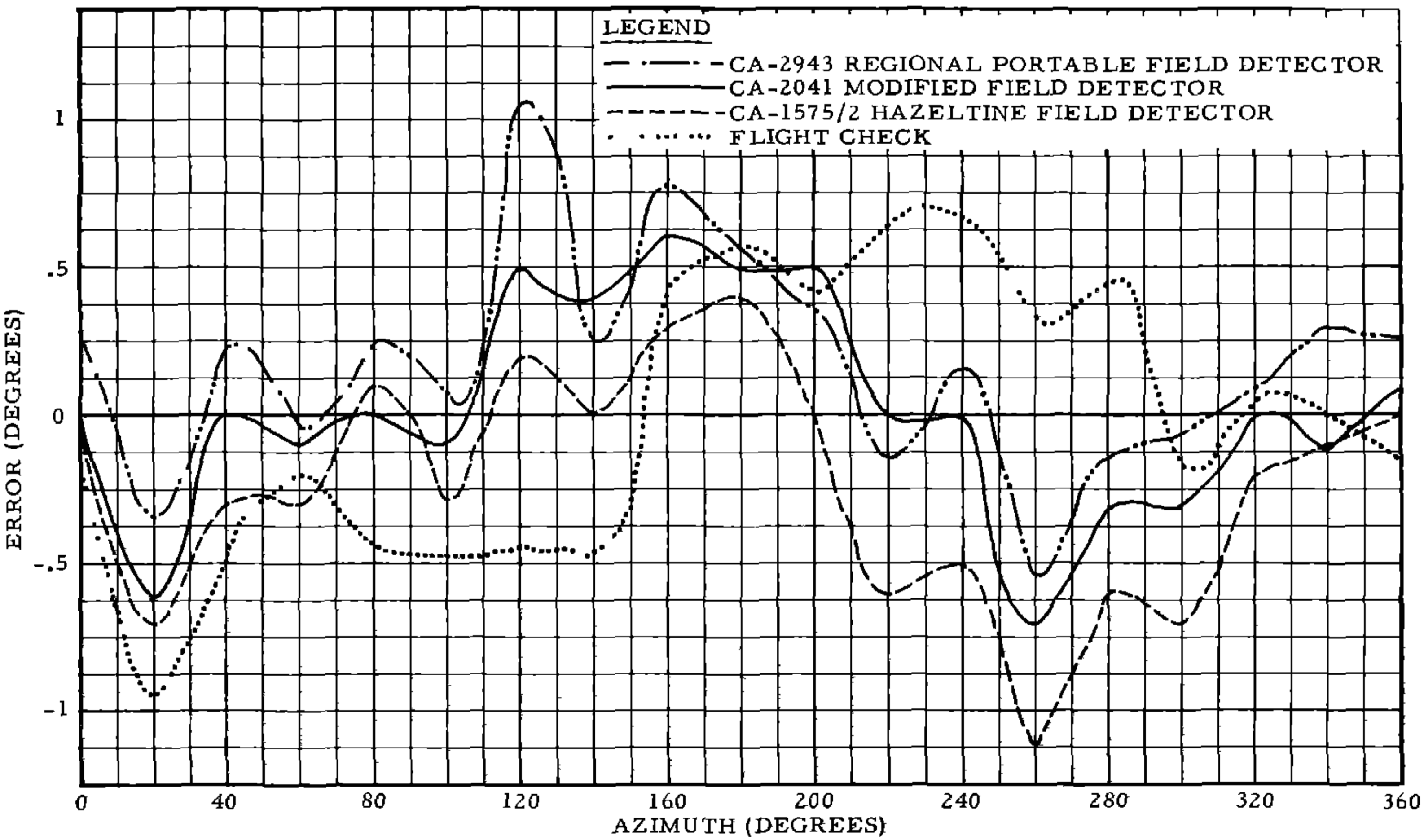

FIG 17 COMPARISON OF CALIBRATION CURVES FOR TILDEN VOR TAKEN BY GROUND CHECKS USING CA-1277 HOFFMAN MONITOR WITH THREE FIELD DETECTORS AND BY FLIGHT CHECK

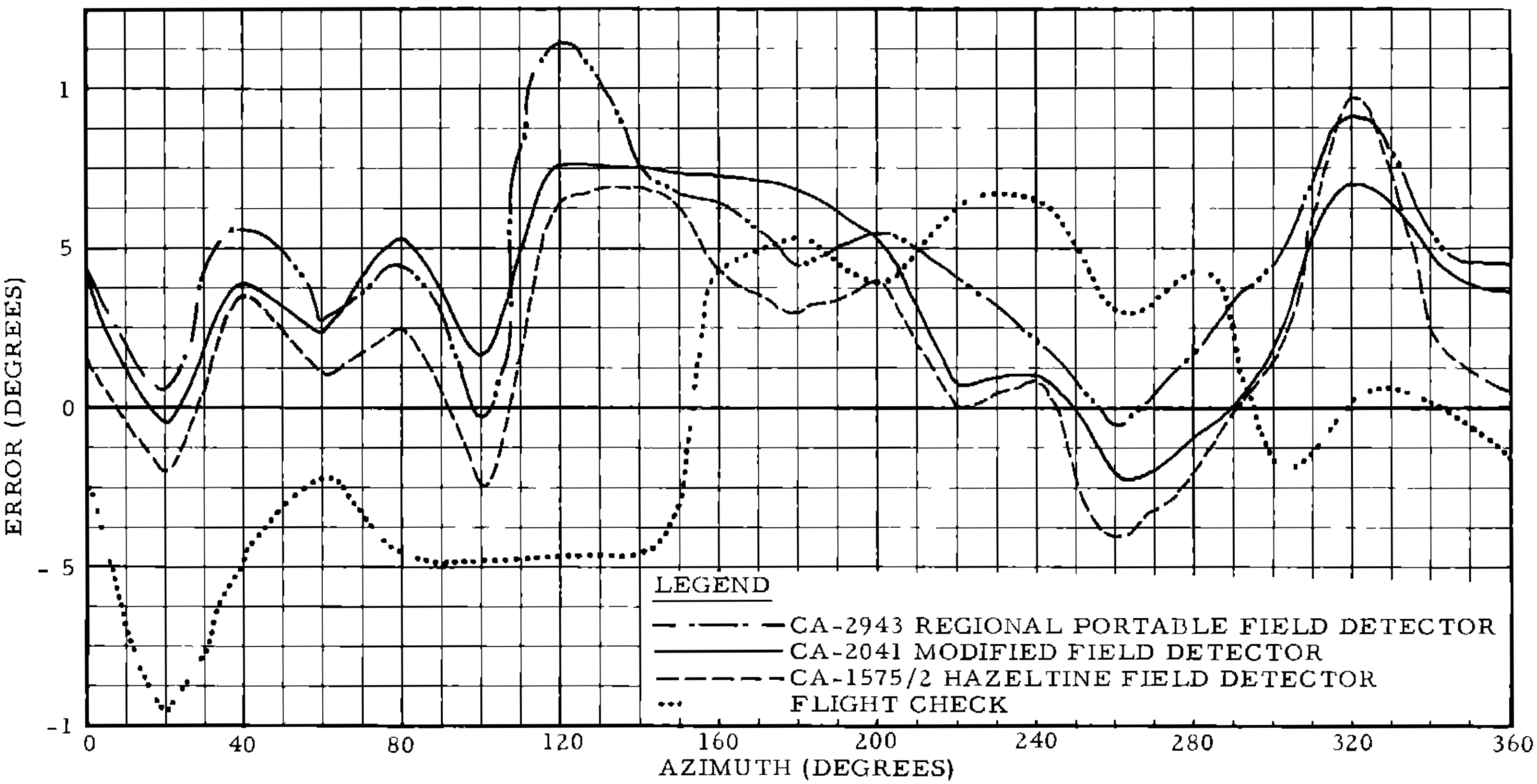

FIG 18 COMPARISON OF CALIBRATION CURVES FOR TILDEN VOR TAKEN BY GROUND CHECKS USING TDC MONITOR WITH THREE FIELD DETECTORS AND BY FLIGHT CHECK