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EVALUATION OF THE COLLINS TVOR

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SUMMARY

This report describes the evaluation of TVOR equipment manufactured by the Collins Radio Company. The evaluation was conducted at the Technical Development Center of the Civil Aeronautics Administration, Indianapolis, Indiana.

During the early part of the evaluation, bearing errors varied between ±0.5° and ±2.4°. Loose bolts in the antenna assembly caused this bearing instability. After all loose bolts were secured, the bearing-error measurements did not exceed ±0.65°, and no further bearing instability was noted.

A maximum polarization error of ±1.29° was measured with ground equipment, whereas a maximum error of ±0.5° was observed in flight.

The "cone" (region directly above the station) was well defined except for erratic excursions of the course-deviation indicator in the region of the 22° and 55° nulls of the vertical plane-radiation pattern. The elevation angle of the cone was 22°. The TO-FROM indication was satisfactory as the aircraft passed over the station.

The counterpoise diameter was extended from 12 to 35 feet in an effort to improve the cone characteristics. The large counterpoise eliminated the null at 22° and changed the elevation angle of the cone to 55°. This was a desired improvement in cone characteristics, but the polarization and bearing errors increased. An increase in the height of the antenna cylinder was effective in reducing the polarization error at 112.9 and 117.7 megacycles (Mc), but caused an increase in the error at 108.0 Mc. No further attempts were made to improve the bearing accuracy.

INTRODUCTION

A preliminary flight test of the Collins TVOR installed at Cedar Rapids, Iowa, was conducted during 1954.[1] At the request of the CAA Office

[1] Thomas S. Wonnell, Robert B. Flint, and Arthur E. Frederick, "Preliminary Evaluation of the Collins TVOR," CAA Technical Development Report No. 256, November 1954.

of Air Navigation Facilities, a more extensive evaluation of the Collins terminal VHF omnirange (TVOR) was conducted at the Technical Development Center from April 1955 to April 1956. Measurements of bearing accuracy, polarization error, and cone characteristics were made during the first 3 months of the evaluation. During the following 9 months, measurements were made to determine the effect of extending the counterpoise from 12 to 35 feet in diameter on cone characteristics and polarization error. Modifications also were made to the antenna in an effort to reduce the polarization error which was higher with the larger counterpoise. This report describes the tests conducted at the Technical Development Center (TDC).

DESCRIPTION

The Collins TVOR is a packaged equipment consisting of an antenna, counterpoise, equipment shelter, transmitter and associated apparatus, and a monitor. The antenna consists of a rotating dipole enclosed within a slotted metal cylinder 3 feet, 10 1/2 inches in diameter and 9 feet, 5 inches high. The cylinder has 12 vertical slot radiators fed in phase to radiate the carrier. The spinning dipole supplies the rotating figure-of-eight sideband pattern. The antenna is placed at the center of a 12-foot-diameter counterpoise. Extending radially from the counterpoise periphery are 32 equally spaced rods which can be adjusted in length to minimize polarization error. A mechanism also is included for turning the antenna.

The equipment shelter consists of a corrugated steel cylinder 10 feet in diameter and 8 feet high which supports the counterpoise. Figure 1 is a view of the equipment shelter and antenna. The wooden structure shown in Fig. 1 supported the counterpoise when it was extended from 12 to 35 feet in diameter.

Figure 2 is a view of the rack-mounted TVOR equipment. From top to bottom the units contained in the rack are modulation eliminator, monitor, local control, transmitter, and transmitter power supply and modulator. The transmitter, using a 4X150A radial-beam tetrode, delivers 50 watts of radio-frequency (rf) power. Included in the local control unit is an automatic voice-identification system employing a magnetic drum. The remainder of the rack-mounted TVOR equipment, with the exception of the monitor, is of conventional design.

The monitor circuits are an adaptation of the Collins navigation-receiver circuits. The resolver (azimuth selector) is replaced by a step-type resistance-capacity (RC) phase shifter which provides 8 courses at 45° intervals. An azimuth-increment dial provides a vernier adjustment of ±2.0°. The monitor-alarm circuits use Sensitrol relays shunted with fixed resistors and factory-adjusted to obtain sensitivities in accordance with ICAO standards. The monitor employs a remote Collins VOR aircraft receiving antenna connected by coaxial cable to the detector circuit contained within the monitor proper.

GROUND MEASUREMENTS

The bearing accuracy of the Collins TVOR was determined by the ground calibration method developed at TDC.[2] A Type CA-2943 VOR portable field detector positioned at 20° intervals at a radius of 100 feet from the TVOR, a Type CA-1277 VOR monitor, and a Type CA-1430 VOR reference and variable test generator were used for bearing-error measurements.

The magnitude of bearing errors measured during the first two months of operation of the TVOR varied from ±0.5° to ±2.4°. The erratic operation was caused by loose bolts in the antenna cylinder. The curves in Fig. 3 illustrate the maximum and minimum errors obtained during the period of erratic operation, demonstrating the effect on bearing stability of loose bolts in the antenna cylinder. After all of the bolts had been tightened the operation was stable, and the maximum bearing error of the station was ±0.65°. See Fig. 4.

After bearing stability had been achieved, the station was modified in an effort to improve the cone characteristics. The first modification consisted of extending the counterpoise from 12 to 35 feet in diameter. Two later modifications consisted of decreasing the height of the antenna by 19 inches and of increasing the height of the antenna 5 inches over the original height. The bearing-error measurements obtained after modifications to the counterpoise and antenna are listed in Table I.

Ground measurements of the polarization error were made with a mobile polariscope.[3] The antenna for this series of measurements differed from the original antenna used on the portable polariscope, inasmuch as the two dipoles mounted at 90° to each other in the same vertical plane were placed 19 inches in front of a square aluminum-sheet reflector. The antenna and reflector were mounted on the side of a truck, making the unit completely mobile.

[2]Robert B. Flint and William L. Wright, "Ground Calibration of the VOR," CAA Technical Development Report No. 227, October 1955.

[3]Sterling R. Anderson and Wendell A. Law, "The Measurement of VOR Polarization Errors," CAA Technical Development Report No. 202, May 1953.

Polarization measurements were made at a radius of 500 feet from the TVOR and at intervals of 20° throughout the 360° of azimuth. The maximum polarization error measured was ±1.29°. The extended counterpoise caused an increase in the polarization error. Efforts to minimize the polarization error by varying the height of the antenna were successful at 112.9 and 117.7 megacycles (Mc). Table I contains the maximum polarization error measured under the various conditions.

TABLE I

BEARING- AND POLARIZATION-ERROR MEASUREMENTS
OBTAINED BY GROUND CHECK

Antenna Condition	Frequency (megacycles)	Maximum Errors (degrees)	
		Bearing	Polarization
Original antenna with 12-foot-diameter counterpoise	112.9	±0.65	±1.29
Original antenna with 35-foot-diameter counterpoise	108.0	±1.15	±2.0
	112.9	±0.9	±1.4
	117.7	±0.55	±2.0
Antenna height decreased 19 inches, 35-foot-diameter counterpoise	108.0	±1.2	±3.6
	117.7	±1.55	±3.0
Antenna height increased 5 inches over original, 35-foot-diameter counterpoise	108.0	-	±2.7
	112.9	-	±1.36
	117.7	-	±1.15

MONITOR OPERATION

The evaluation of the TVOR monitor equipment included the following tests: effect of rf pickup by the monitor antenna transmission line, scalloping produced by the monitor antenna, and the effect on the monitor indication of vehicles near the TVOR.

To determine the effect of rf pickup by the coaxial cable connecting the monitor to the antenna, the coaxial cable was placed on the surface of the ground between the monitor antenna and the TVOR. Any movement of the cable horizontally or vertically caused variations up to ±.75° in the indicated course. Moving the cable inside the TVOR shelter caused up to ±.25° shift in the indicated monitor course. These shifts in the indicated monitor course are believed to have been caused by rf currents flowing on the outer conductor of the coaxial cable. Because the monitor antenna cable generally is buried underground, the maximum shift in the indicated monitor course caused by movement of the cable or other cables near it in the TVOR building would not exceed ±.25°.

Tests to measure course scalloping caused by the monitor antenna were made by moving the monitor antenna through an arc of 180° at constant radii of 75, 100, and 125 feet, while recording the course deviation indicator (CDI) current at a distance of 700 feet from the TVOR. The CDI current was recorded using a Collins 51R3 navigation receiver and Esterline Angus recorder. The course recorded at an azimuth of 0° and at a distance of 700 feet was 0° when the monitor antenna was removed. Table II shows the magnitude of the scalloping with the monitor antenna at various distances from the TVOR. When the monitor antenna was 10 feet high and 75 feet from the TVOR, the required output level was obtained. At greater distances the output was considerably below the required level. The CAA Type CA-1278 VOR field detector and the CAA Type CA-3410 counterpoise detector used for monitoring commissioned VOR facilities cause less than ±0.2° course scalloping. Mounting the Collins monitor antenna at a distance from the TVOR so that the course scalloping was below ±0.2° resulted in insufficient output for proper monitor operation.

The Collins Type 37J-3 aircraft antenna used for the monitor antenna has very shallow nulls in the figure-of-eight horizontal-plane pattern. This characteristic of the antenna causes it to be susceptible to reflections from vehicles passing near the antenna, especially in the vicinity of the nulls. The reflected energy from the vehicle will contain course information which is out of phase with the information received directly from the TVOR. This results in a shift in the indicated course by the monitor. A vehicle passing or stopping within 20 to 40 feet of the monitor antenna caused sufficient course shift (more than 1.0°) to actuate the monitor-alarm circuits. This characteristic of the Type 37J-3 antenna is undesirable because maintenance vehicles, mowing machines, or similar equipment frequently may be near the TVOR, and they could cause operation of the monitor-alarm circuits.

TABLE II

GROUND MEASUREMENTS OF COURSE SCALLOPING WITH MONITOR ANTENNA 10 FEET HIGH

Distance (feet)	Scalloping (Variation of Course from 0°) (degrees)
75	±0.23
100	±0.2
125	±0.135

FLIGHT TESTS

Flight tests of the Collins TVOR with 12- and 35-foot-diameter counterpoises were conducted to determine polarization errors, cone characteristics, and distance range. Polarization-error flight checks were conducted at an altitude of 1000 feet and at a distance of 10 miles north of the station. While recording the CDI current, the aircraft was flown on 8 different headings, crossing a ground checkpoint at every 45° heading to determine heading effects. The course recording was marked each time the airplane passed over the checkpoint, and the indicated bearing then was compared with the magnetic bearing. The zero-reference point in each case was taken as the heading toward the station. The wing-rock test was made as the aircraft banked ±30.0°, the nose of the airplane being held "on point" during the maneuver. The CDI current then was converted to degrees of course displacement. The results of these tests are listed in Table III.

Cone characteristics were determined by radial flights with theodolite guidance over the station at 5000 feet above ground. The vertical-plane field pattern plotted in Fig. 5 is indicative of the receiver-input voltage variation with elevation angle for a constant distance from the TVOR antenna. A recording of the CDI current is shown in Fig. 7. It will be observed that the nulls in the vertical-plane field pattern at elevation angles of 22° and 55° caused considerable disturbance to the CDI. The cone of a VOR is defined as beginning when the CDI deviates beyond 2.0°. The cone elevation angle of the Collins TVOR was 22.0°. The recording of the TO-FROM indicator current shown in Fig. 9 revealed one rapid movement of the indicator from the TO position to the FROM position, providing a precise check as to when the aircraft was directly over the station.

TABLE III

FLIGHT TESTS OF POLARIZATION ERROR AND CONE ANGLES

Antenna Condition	Frequency of Operation (megacycles)	Polarization Errors Wing Rock (degrees)	Polarization Errors 8 Ways Over Point (degrees)	Cone Elevation Angle (degrees)
Original antenna with 12-foot-diameter counterpoise	112.9	±0.25	±0.5	22
Original antenna with 35-foot-diameter counterpoise	108.0	±0.25	-	-
	112.9	±0.75	±1.8	55
	117.7	±1.4	-	-
Antenna height decreased 19 inches, 35-foot-diameter counterpoise	108.0	±1.1	±1.5	55
Antenna height increased 5 inches over original length, 35-foot-diameter counterpoise	108.0	-	-	-
	112.9	±1.4	-	55
	117.7	-	-	-

The counterpoise diameter of the TVOR was extended from 12 to 35 feet to determine the effect on cone characteristics. There was no null in the vertical-plane field pattern at the 22° elevation angle, but a shallow null appeared at 15° elevation as illustrated in Fig. 6. The CDI recording was improved considerably inasmuch as there were no course disturbances until an elevation angle of 55° was reached as shown in Fig. 8. The TO-FROM indicator recording shown in Fig. 10 still provided a precise check when the aircraft passed over the station, although there was some roughness at elevation angles above 55°.

The distance range of a TVOR is defined as the distance in statute miles from the station at which the course width in degrees becomes double the course width measured at 10 miles. This test was conducted at an altitude of 1000 feet above ground. Circumstances did not permit a distance range of the TVOR to be made while operating on the 12-foot-diameter counterpoise; however, a previous flight check of a Collins TVOR indicated a distance range of 70 miles. This distance range is considerably greater than the distance range generally obtained from a VOR. This indicates that unusual VHF propagation conditions existed at the time the distance-range tests were conducted. The distance range of the TVOR with the 35-foot-diameter counterpoise was 56 miles.

CONCLUSIONS

It is concluded that:

1. The bearing accuracy of ±0.65° obtained with the Collins TVOR is comparable to bearing accuracies of ±0.6° to ±0.9° obtained at Federal Airways facilities.

2. The cone-elevation angle is increased from 22° to 55° by using a 35-foot-diameter counterpoise.

3. The polarization error was acceptable although the value is somewhat greater than the maximum polarization error of ±1.0° measured on the four-loop VOR.

4. The monitor performance was unsatisfactory because of the monitor antenna pattern and the location of the detector within the monitor equipment mounted in the transmitter rack.

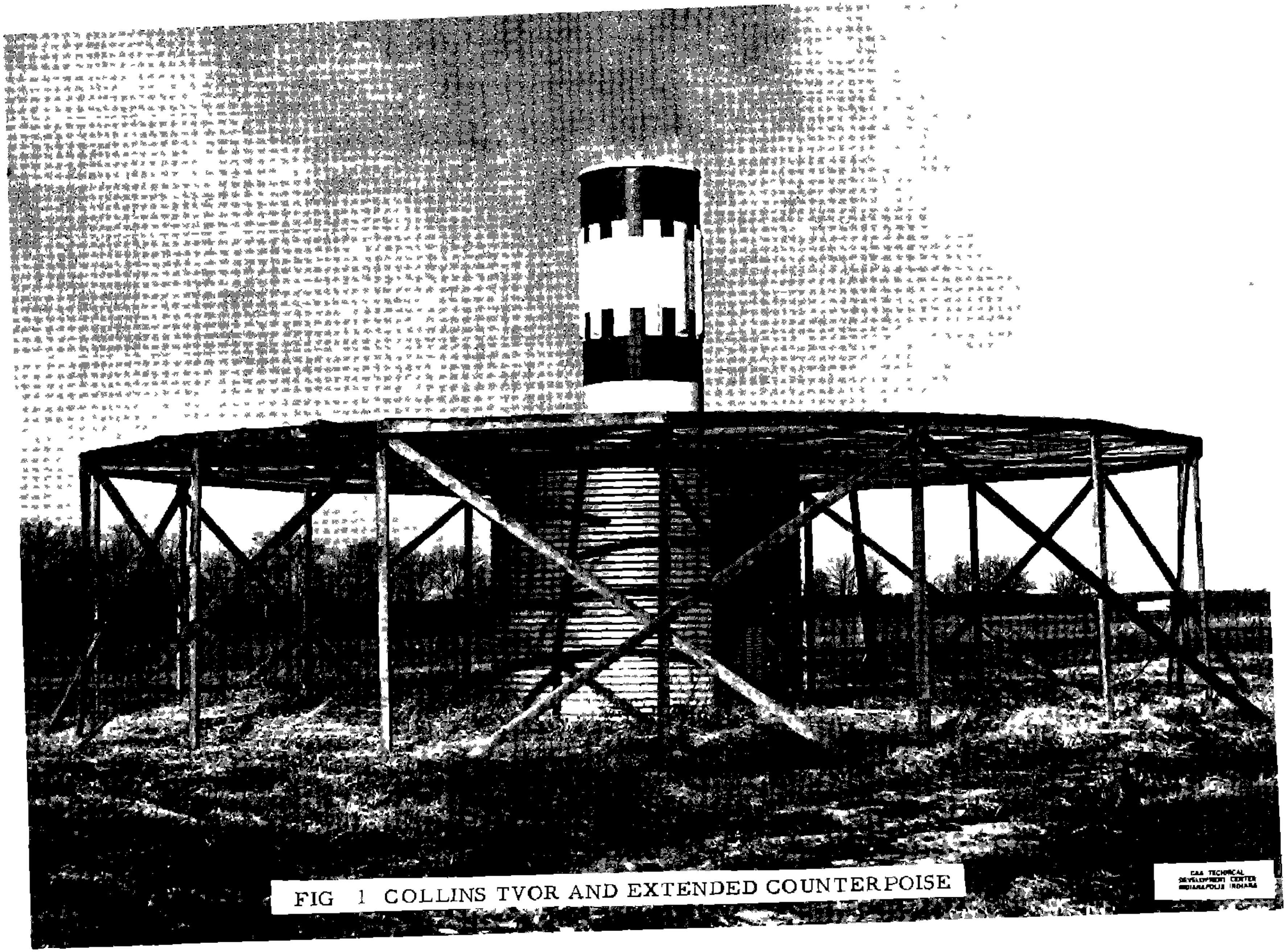

FIG 1 COLLINS TVOR AND EXTENDED COUNTERPOISE

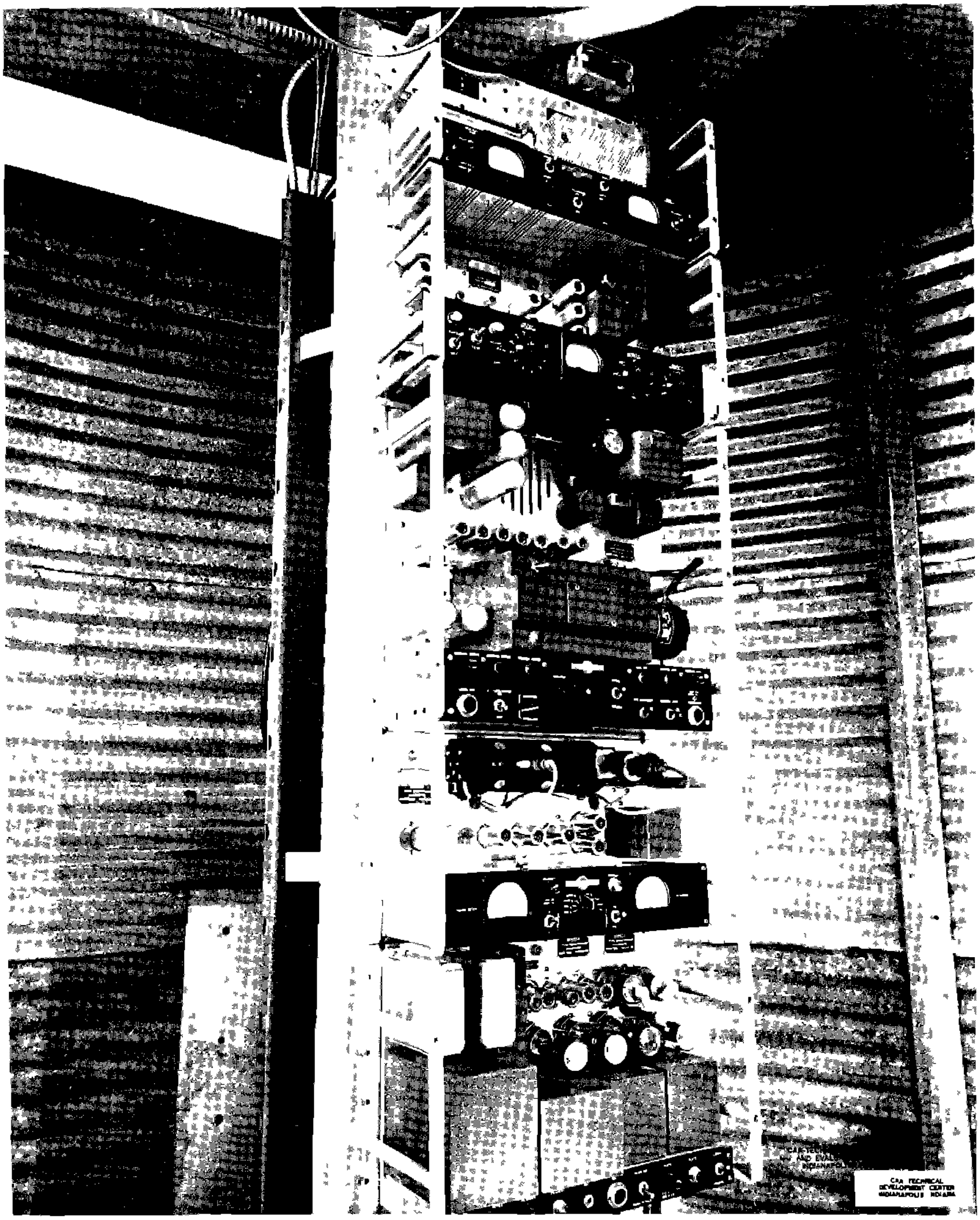

FIG 2 COLLINS TVOR TRANSMITTING EQUIPMENT

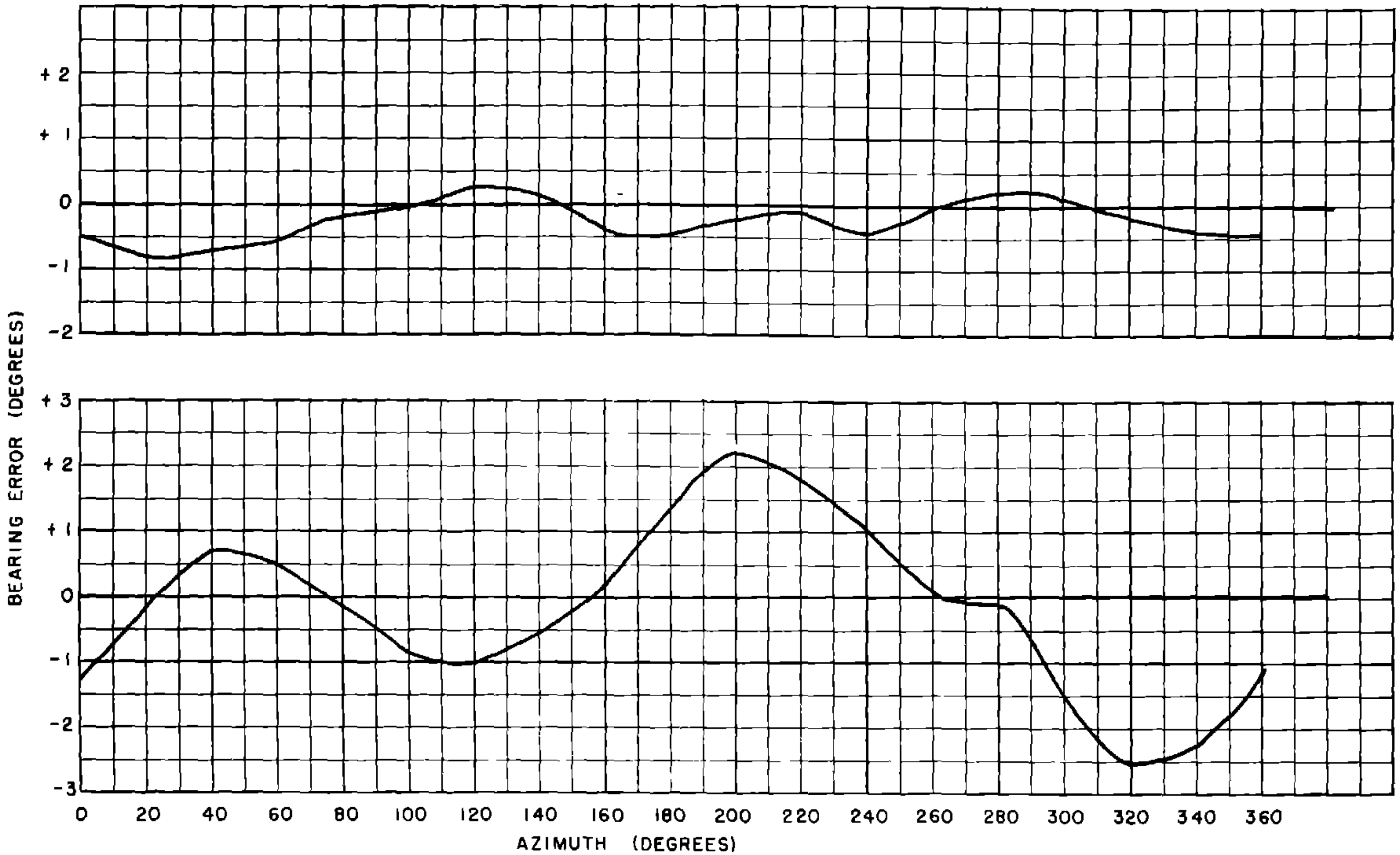

FIG 3 BEARING ERROR CURVES OF COLLINS TVOR DEMONSTRATING EFFECT OF LOOSE BOLTS IN ANTENNA ASSEMBLY ON BEARING STABILITY

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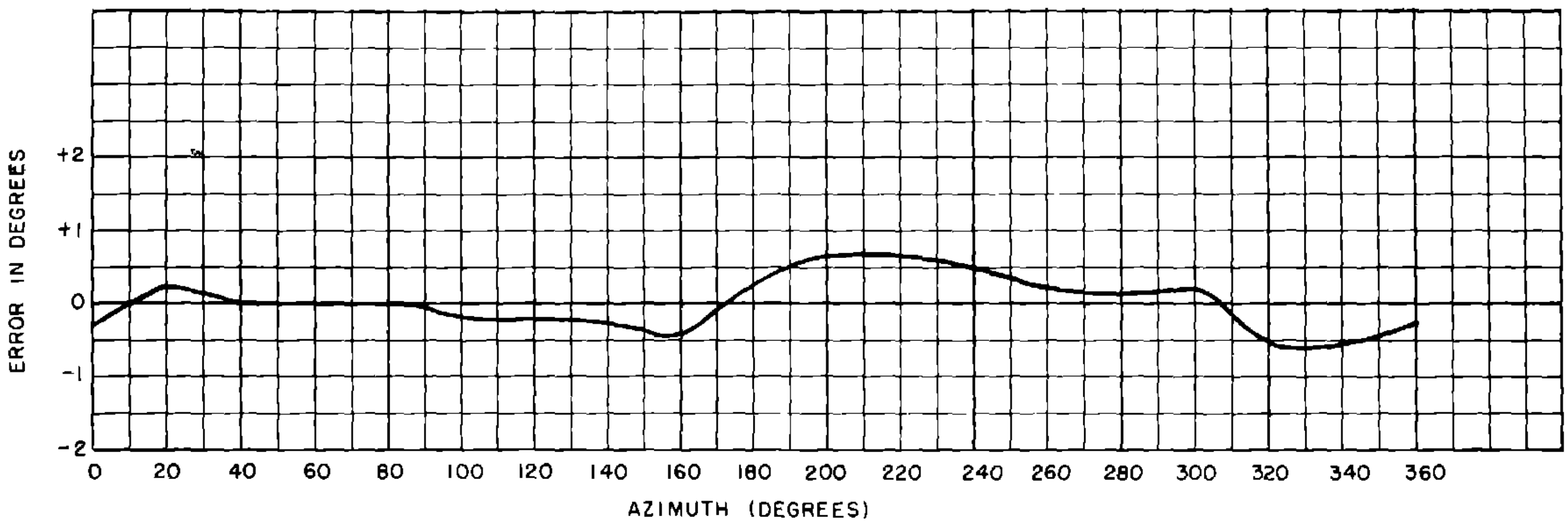

FIG 4 BEARING ERROR CURVE OF COLLINS TVOR

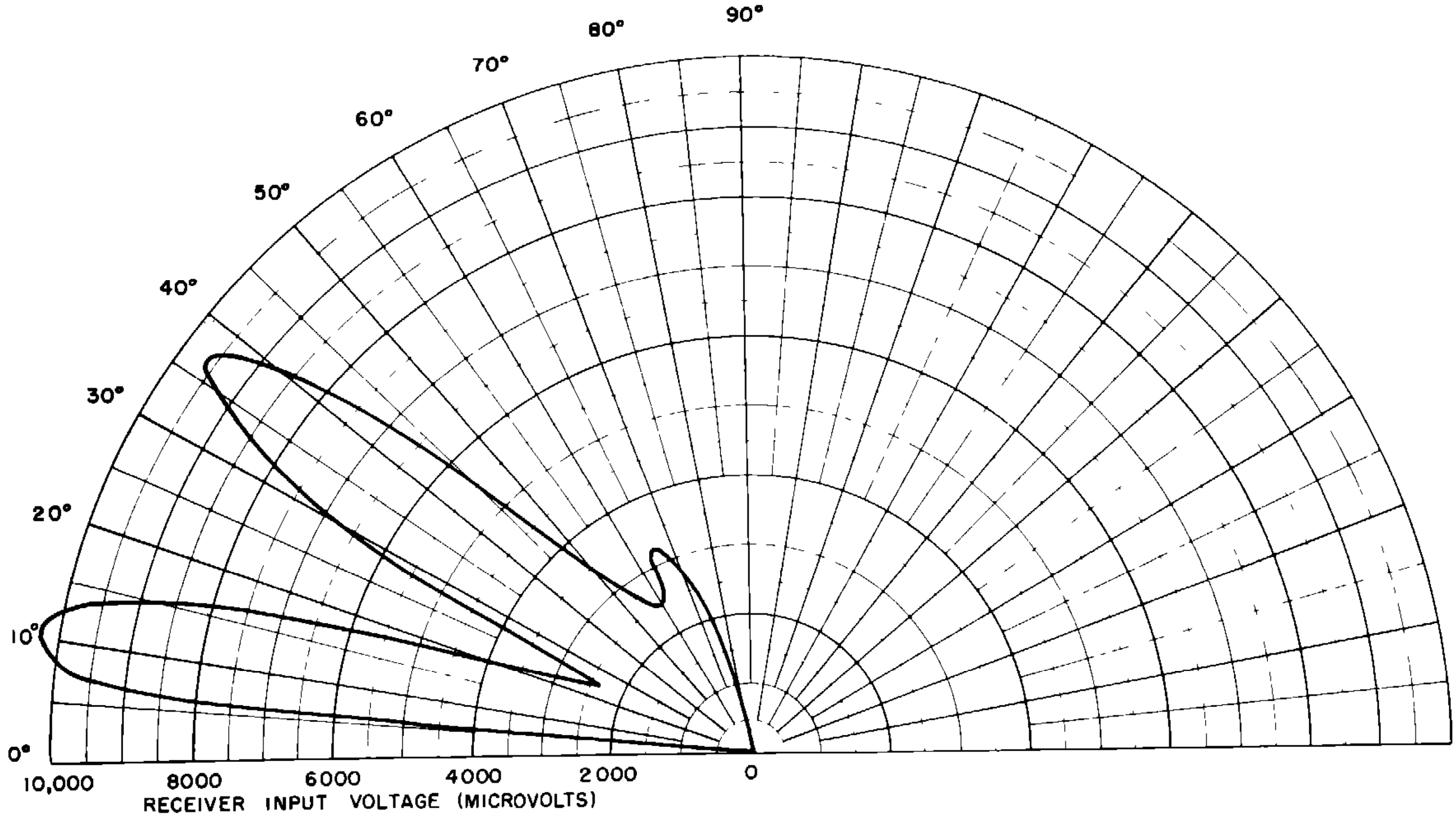

FIG 5 COLLINS TVOR VERTICAL PLANE FIELD PATTERN—12 FOOT DIAMETER COUNTERPOISE

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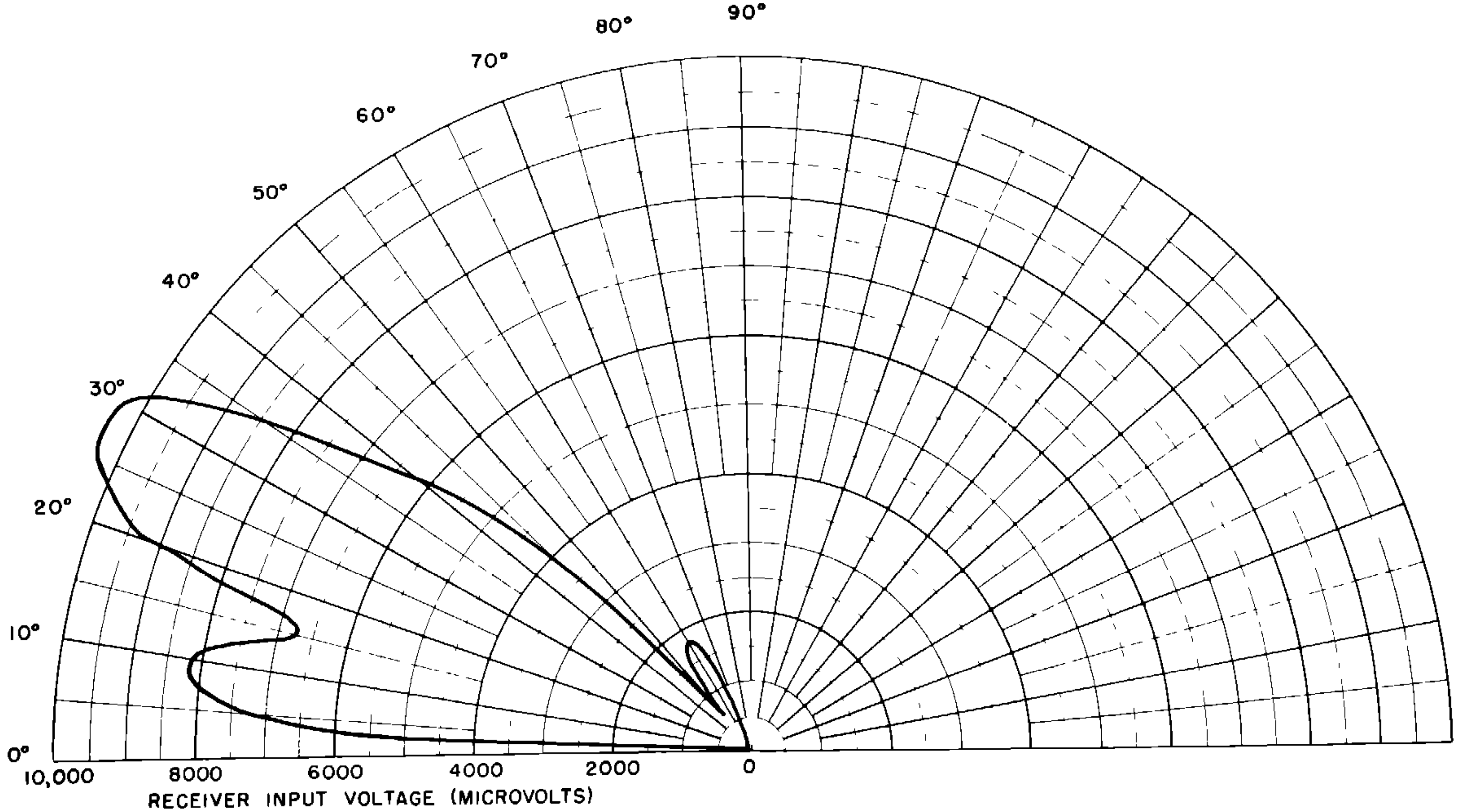

FIG 6 COLLINS TVOR VERTICAL PLANE FIELD PATTERN—35 FOOT DIAMETER COUNTERPOISE

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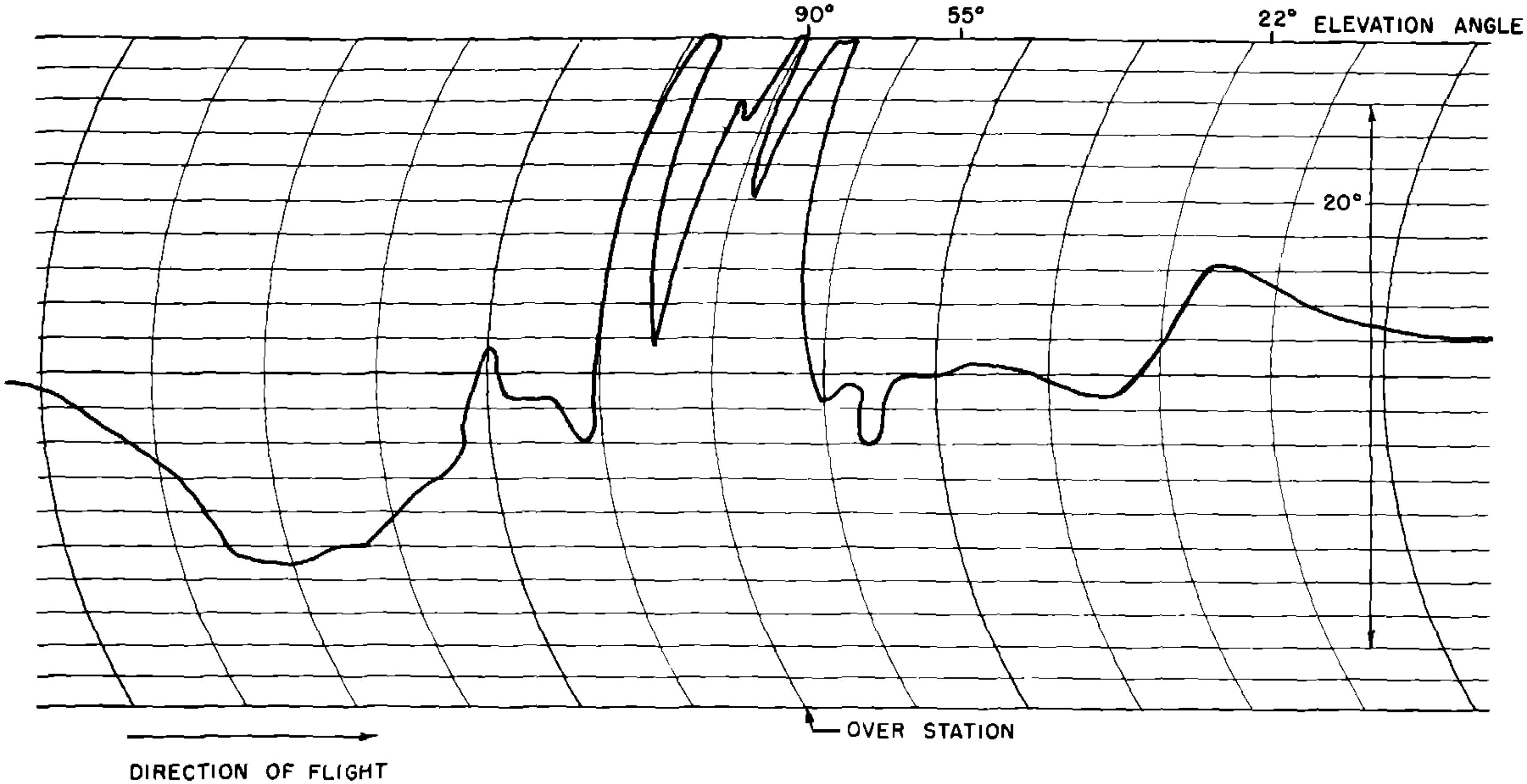

FIG 7 COURSE-DEVIATION-INDICATOR RECORDING FLIGHT DIRECTLY OVER TVOR- 12 FOOT DIAMETER COUNTERPOISE

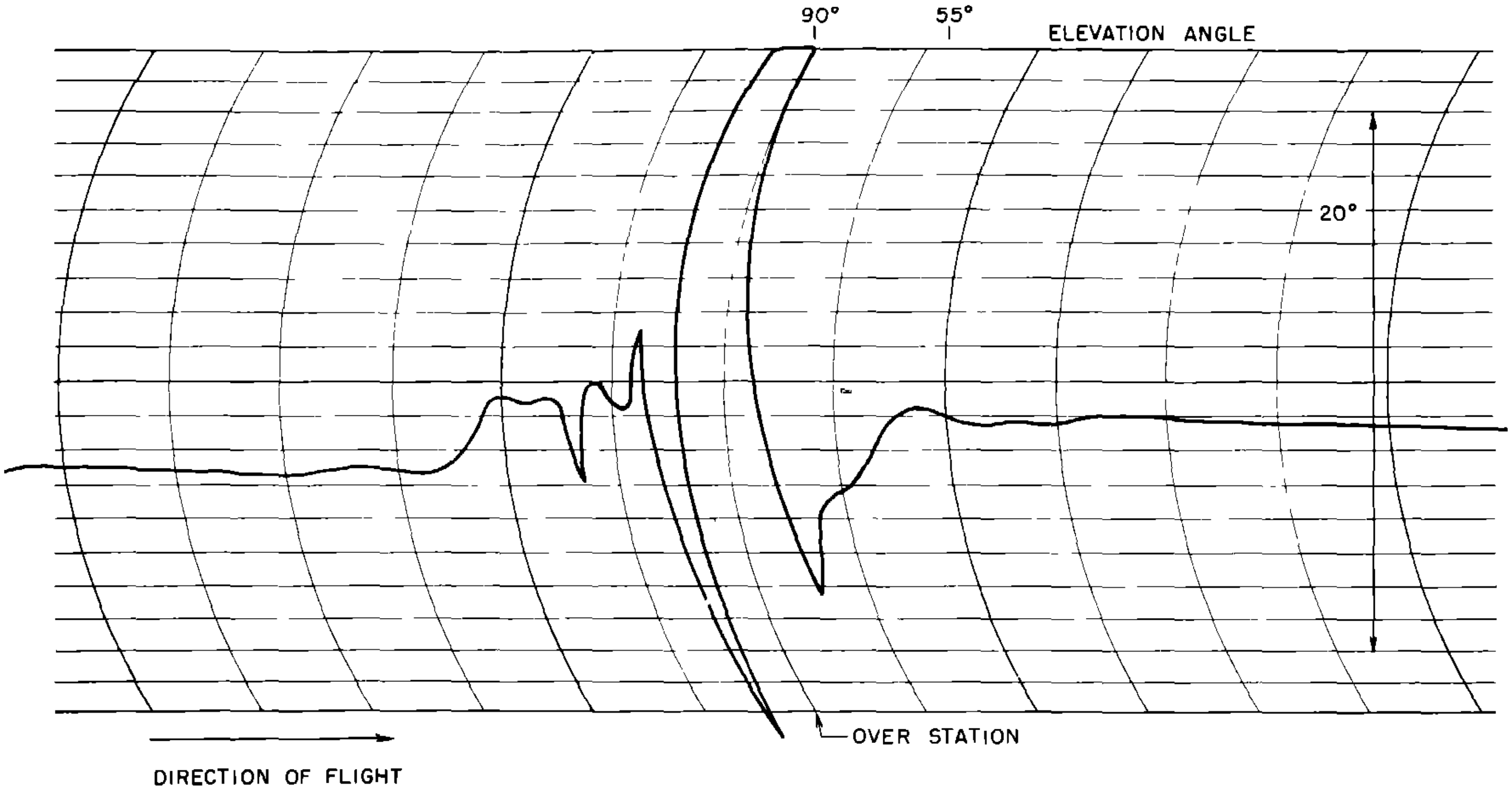

FIG 8 COURSE-DEVIATION-INDICATOR RECORDING FLIGHT DIRECTLY OVER TVOR-35 FOOT DIAMETER COUNTERPOISE

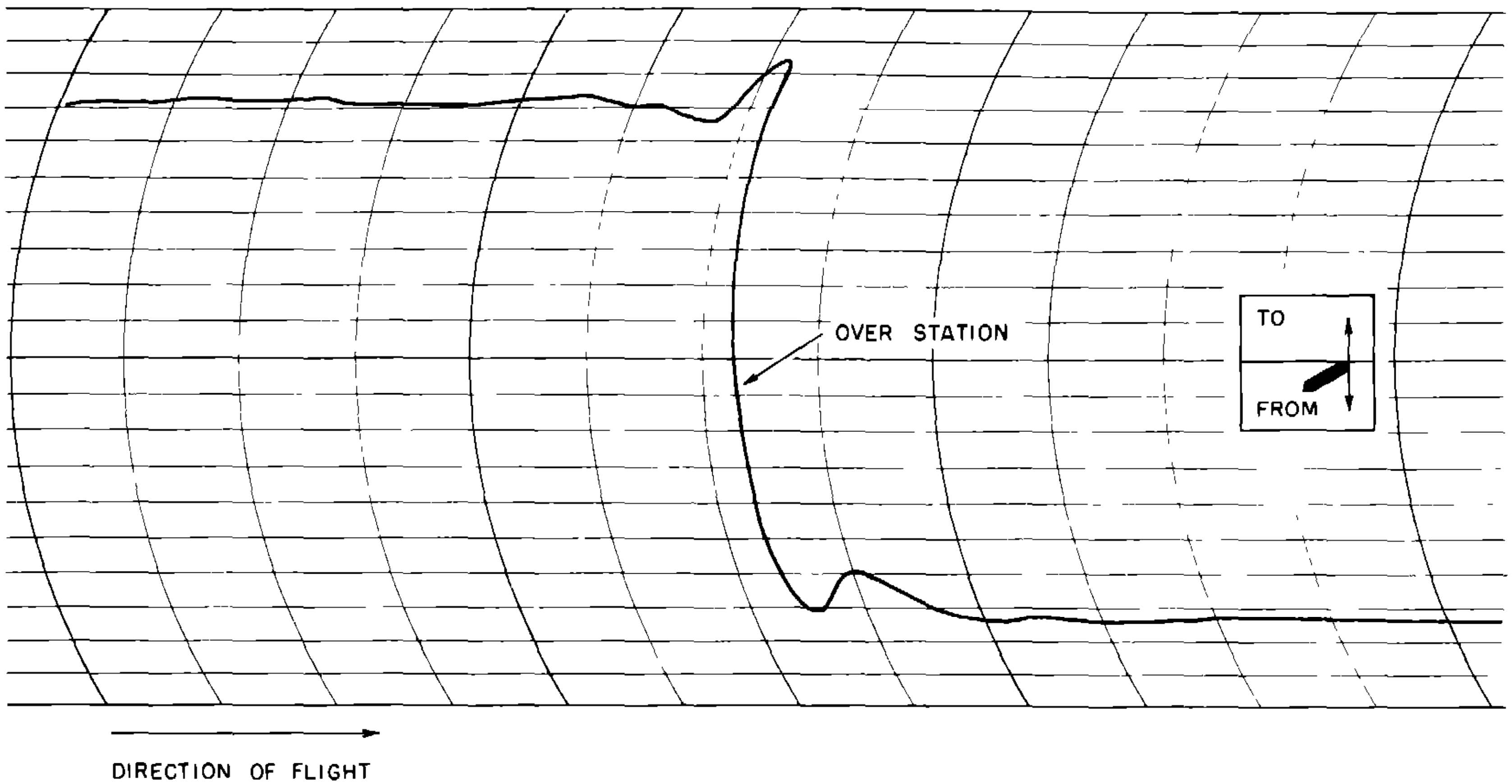

FIG 9 TO-FROM INDICATOR RECORDING FLIGHT DIRECTLY OVER TVOR—12 FOOT DIAMETER COUTERPOISE

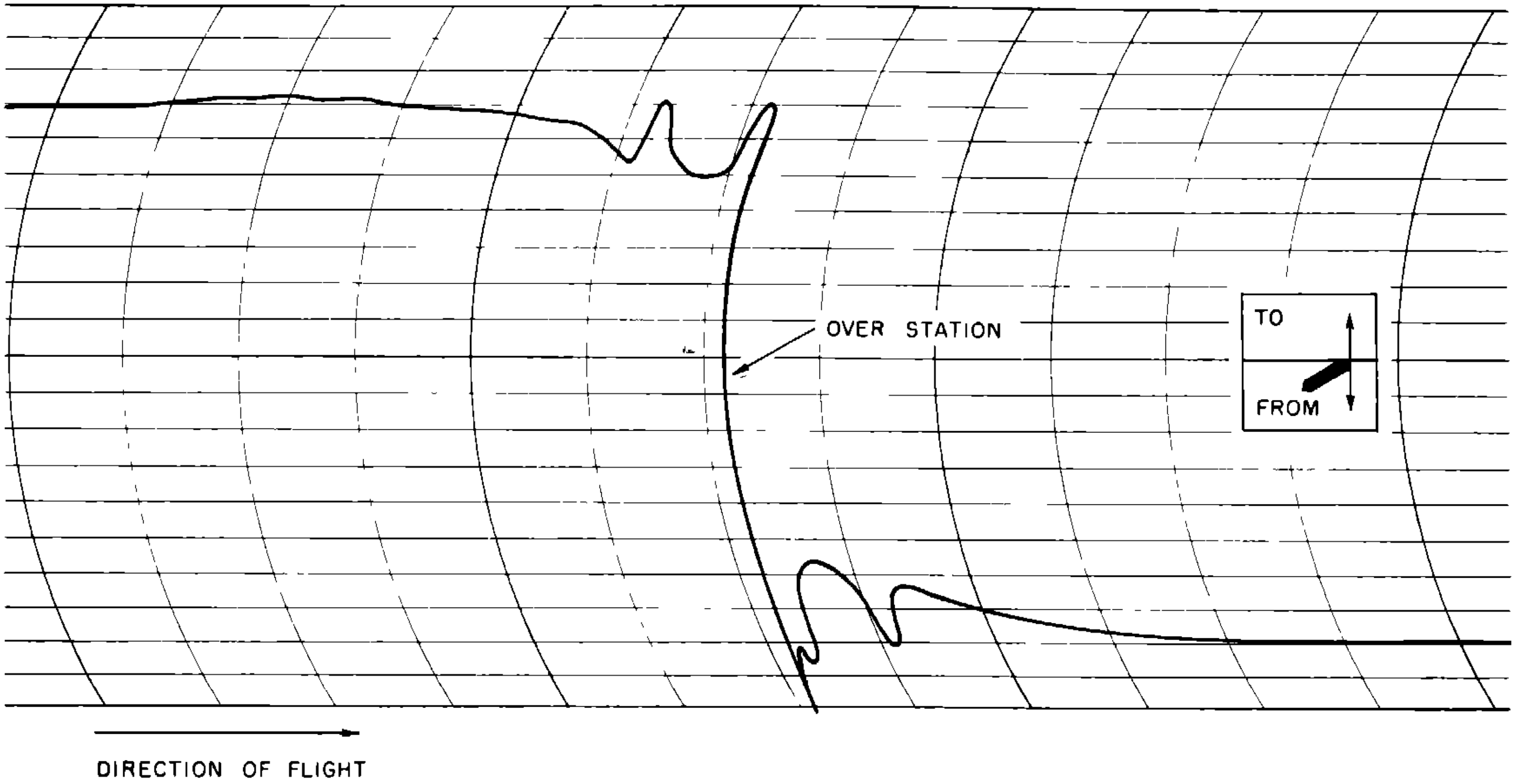

FIG 10 TO-FROM INDICATOR RECORDING FLIGHT DIRECTLY OVER TVOR—35 FOOT DIAMETER COUNTERPOISE