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WIND-TUNNEL TESTS OF THE MARK 19 ANTENNA MOUNT WITH THE MARK 28 AND MARK 34 RADAR ANTENNAS

by

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PERSONNEL

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ABSTRACT

The effect of wind loads on the servo-drives of the traverse and elevation mechanisms of the Mark 19 Radar Antenna Mount was investigated in one of the 8- by 10-foot wind tunnels of the David Taylor Model Basin.

When tests showed that the torque outputs of the servo-drives were inadequate to meet normal conditions of service, remedial measures for the balancing and reduction of the imposed aerodynamic forces were devised and tested.

The use of a canvas enclosure around the reflector proved to be the only one of the several means tested that provided satisfactory operation of the antenna drives at the desired maximum wind speed of 70 knots.

INTRODUCTION

The Mark 19 Radar Antenna Mount of the Mark 63 Gun Director System is used to direct the fire of 40mm antiaircraft guns on board ship. In service the antenna mount is attached to the 40mm gun mount so that it may be rotated in train and elevation by the gun drives. The gun must lead the target, however, to allow for the time of flight of the projectile, while the antenna always points toward the actual position of the target. This relative angular displacement of the gun and antenna is accomplished by the traverse and elevation servo-drives of the antenna mount.

The torque required of the servo-drives at various wind speeds was of primary concern in this investigation. Reports from the field indicated unsatisfactory operation of the antenna mounts at wind speeds in excess of 35 knots. A balancing vane was developed aboard the USS PURDY (DD734) which permitted successful operation at wind speeds up to about 40 knots. A vane of this design, designated as the Purdy Balancing Vane, was tested in this investigation.

Wind-tunnel tests of the radar antenna mount were requested by the Bureau of Ships to determine the amount of torque required of the servo-drive at various wind speeds and to study methods of reducing the drive torques (1).*

Personnel from the Naval Research Laboratory conducted electrical tests of the operation of the antenna mount at various wind speeds and assisted in making aerodynamic measurements. The results of the electrical tests were reported separately (2).

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* Numbers in parentheses indicate references on page 17 of this report.

TEST APPARATUS, SETUP, AND PROCEDURE

Tests were conducted in the 8- by 10-foot closed-throat atmospheric Wind Tunnel 1 of the David Taylor Model Basin on a standard Mark 19 Antenna Mount. The antenna mount was fitted for most of the tests with a Mark 28 Radar Antenna, as shown in Figure 1, and for a few later tests with a Mark 34 Radar Antenna, as shown in Figure 2. The Mark 19 Antenna Mount consists essentially of a tubular framework which supports the servo-drive mechanisms

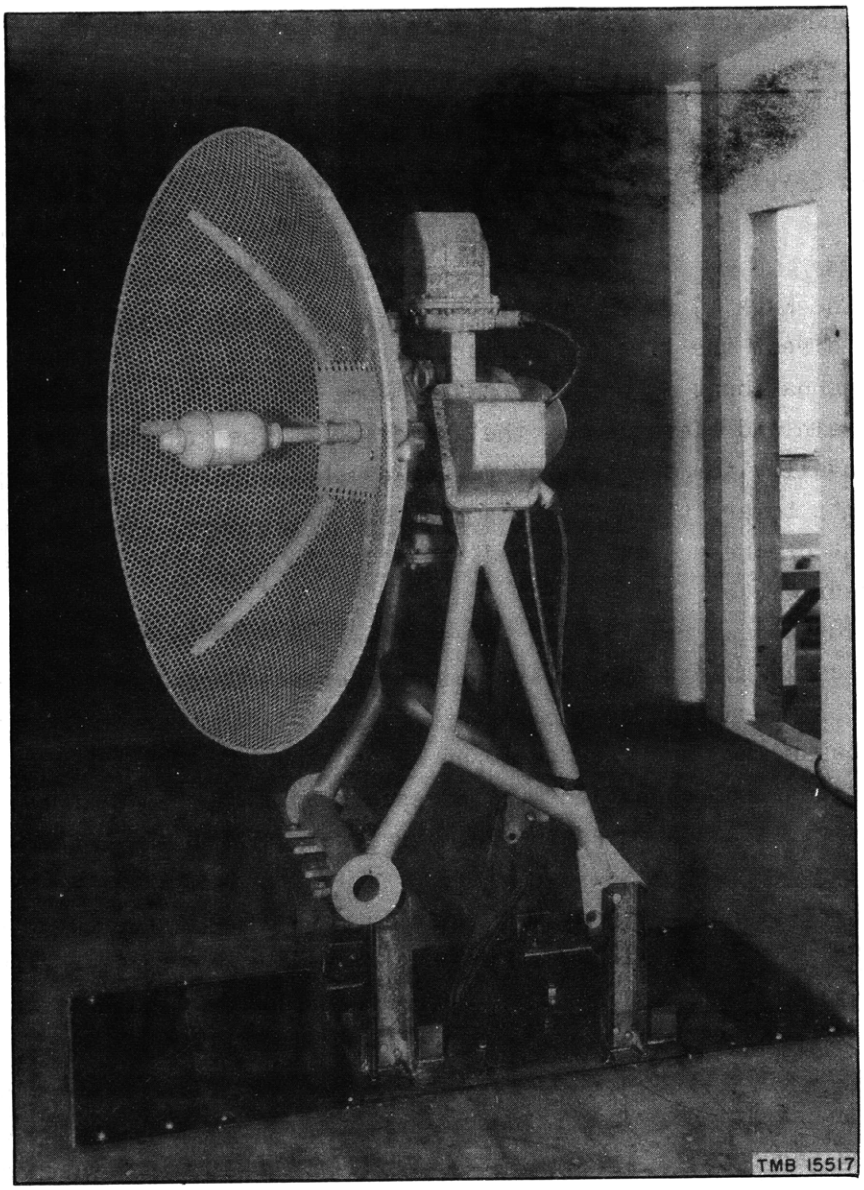

Figure 1 - Mark 28 Radar Antenna on the Mark 19 Antenna Mount Installed in TMB Wind Tunnel 1

The antenna mount is supported by the original test fixture which was used in measuring the aerodynamic forces and moments of the complete assembly.

and a gimbal mounting for the radar antenna. The principal feature of the radar antenna is a parabolic reflector, which is much larger in diameter for the Mark 28 Antenna than for the Mark 34 Antenna.

The first tests were made with the antenna mount installed on the wind-tunnel mounting fixture shown in Figure 1. The forces and moments of the antenna mount with the Mark 28 Antenna were measured. Preliminary determinations of the servo-drive torques were made by transferring the measured forces and moments of the complete assembly to the servo-drive axes and then

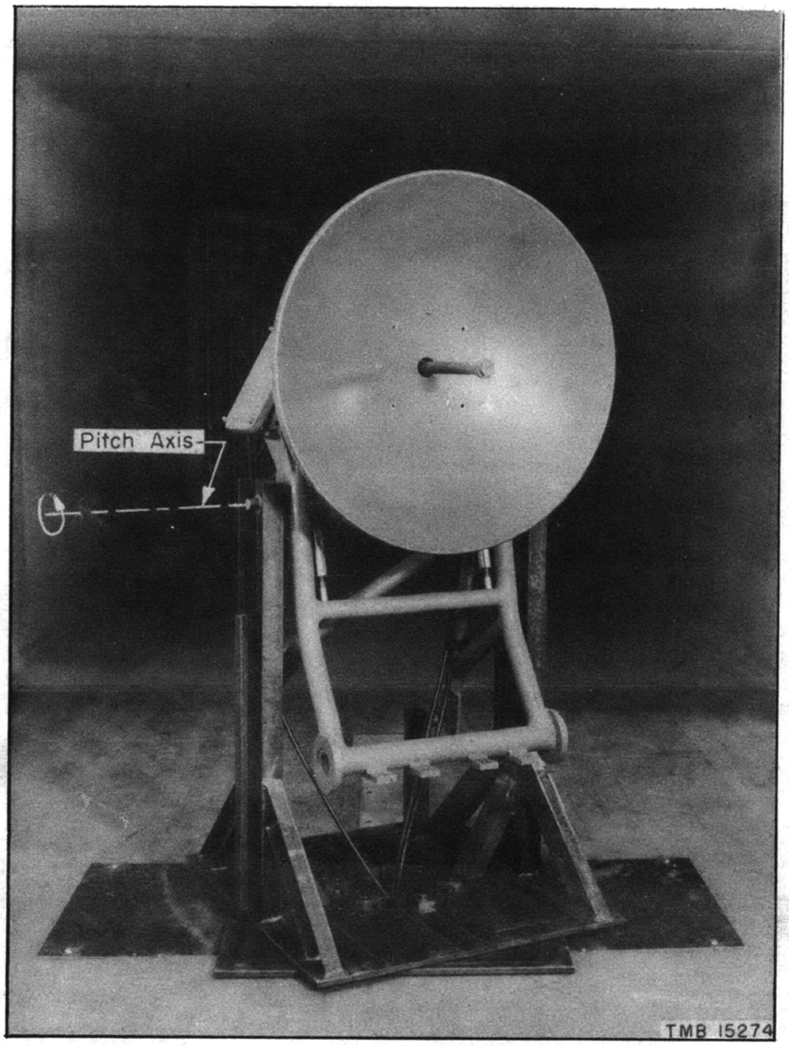

Figure 2 - Mark 34 Radar Antenna on Mark 19 Antenna Mount

An improved test fixture supports the antenna assembly and provides for changes of pitch angle about a transverse steel shaft, one end of which is shown extending through one of the vertical channels at the top of the fixture. The axes of rotation of the antenna mount and the antenna reflector are shown in Figure 7 on pages 8 and 9.

applying approximate corrections for the effect of the antenna mount. Because of the loss of accuracy inherent in the corrections and the time consumed in their application, direct-reading torque indicators were devised and installed in the antenna mount on the elevation and traverse axes of the antenna in place of the servo-drive mechanisms. As shown in Figure 3, the torque indicators consisted essentially of cantilever beams which were clamped rigidly to the elevation and traverse drive shafts at one end and restrained at the other. Metalectric strain gages were mounted on opposite faces of the beams to read tensile and compressive surface strains. The strain-gage readings were related to the torques by deadweight calibration.

A second limitation found in the original setup was the inflexibility of the wind-tunnel mounting fixture which did not permit adjustment of

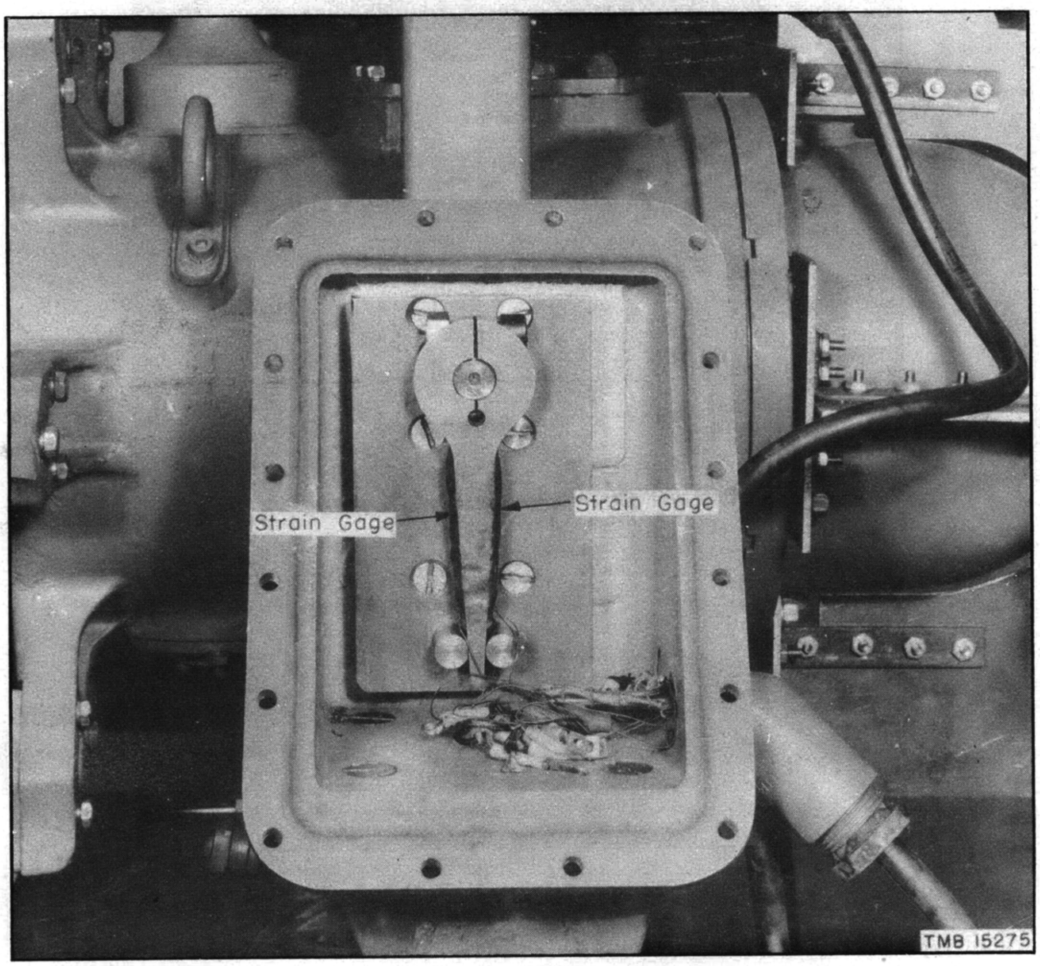

Figure 3 - Cantilever Beam Installed on Elevation Axis

The metalectric strain gages used for indicating the deflection of the tapered vertical beam are attached to opposite faces of the beam.

the model in pitch and which proved inconvenient for setting it in yaw. These difficulties were remedied in the fixture shown in Figure 2, which proved very satisfactory during subsequent tests.

With the improved apparatus, the servo-drive torques were measured for various attitudes of the Mark 28 Antenna to the wind stream. Then a Purdy Balancing Vane was attached to the rear of the antenna, as shown in Figure 4, and tests were conducted to measure its effectiveness.

As might have been expected from its relatively small size and its position behind the antenna, largely shielded from the wind, the Purdy Vane did not substantially reduce the servo-drive torques. A canvas enclosure shown in Figures 5 and 6 was constructed to shield the antenna from the wind.

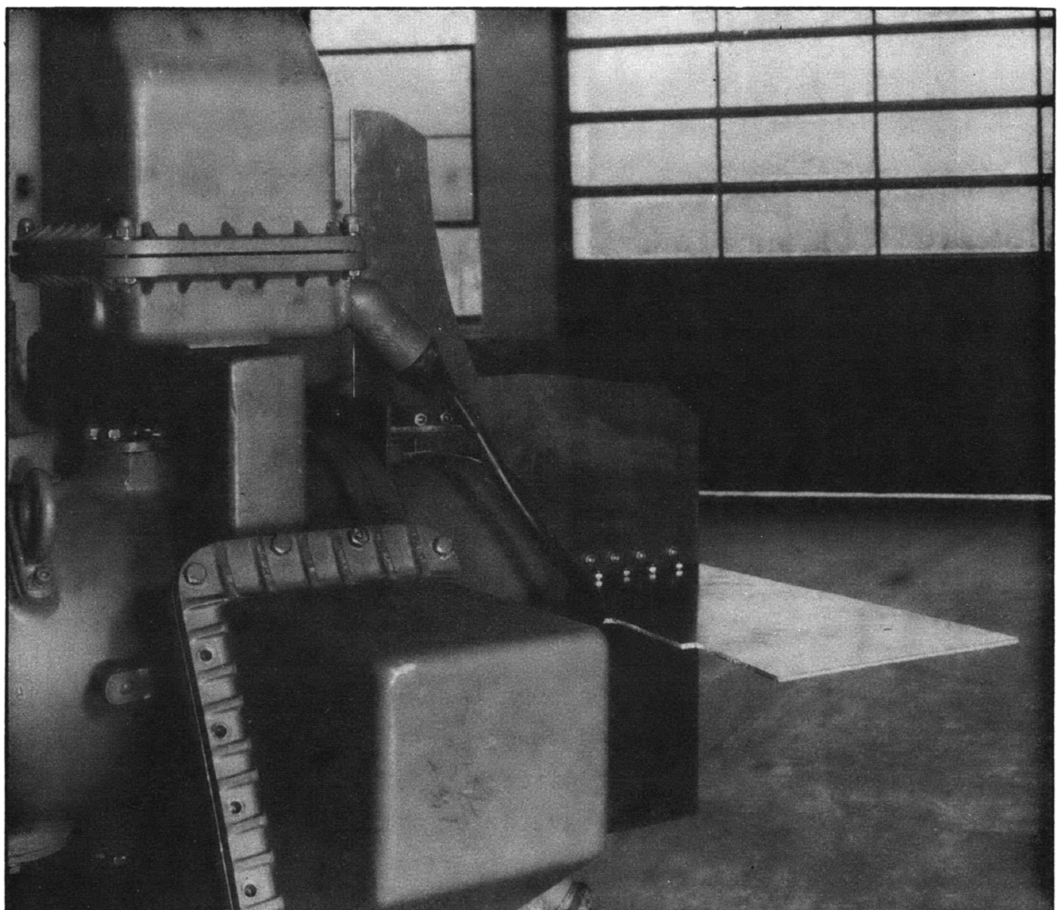

Figure 4 - Purdy Balancing Vane Attached to Rear Portion of Mark 28 Radar Antenna

The irregular shapes of the horizontal and vertical surfaces of the Purdy Vane provided adequate clearance for all lead-angle positions of the antenna under service conditions.

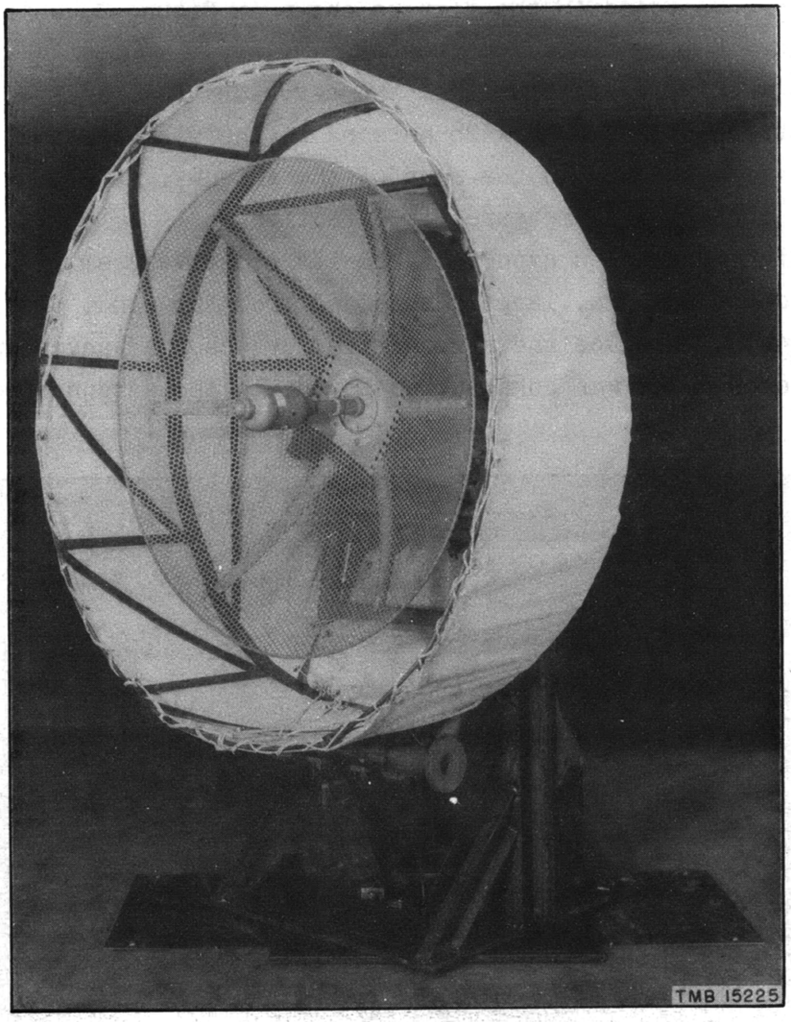

Figure 5 - Three-Quarter Front View of Mark 19 Antenna Mount with Mark 28 Radar Antenna and Canvas Enclosure

The canvas enclosure was made large enough to permit full lead-angle deflections in all directions when attached to the antenna mount. Tests were conducted under various combinations of pitch and yaw angles of the antenna mount, together with elevation and traverse angles of the antenna reflector, to evaluate the maximum values of the servo-drive torques.

The servo-drive torque of the Mark 34 Radar Antenna installed on the Mark 19 Antenna Mount did not exceed allowable limits because of the small diameter of the antenna reflector. Tests of the Mark 34 Radar Antenna with balancing vanes or with an enclosure were consequently considered unnecessary.

Since in preliminary tests the antennas proved to be very nearly symmetrical about their vertical axes as far as aerodynamic characteristics

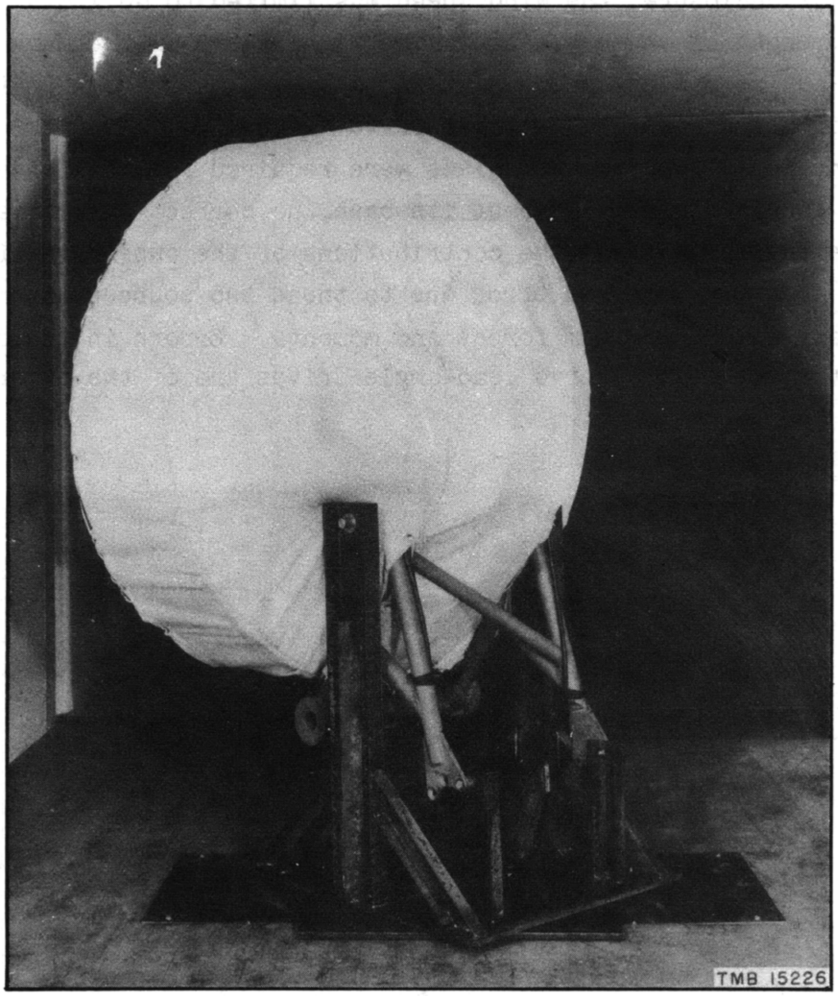

Figure 6 - Three-Quarter Rear View of Mark 19 Antenna Mount
with Mark 28 Radar Antenna and Canvas Enclosure

were concerned, all yaw tests for the antennas at zero traverse lead angle were conducted over the range 0 to 180 degrees. Rotating the antenna to a positive or negative traverse lead angle destroyed this symmetry, and therefore the yaw tests of the antennas with a traverse lead angle required a complete angular range of 360 degrees.

Test wind speeds of 60 and 90 knots were selected for the determination of the forces and moments of the complete antenna throughout its angular range in yaw about its base; 90 knots represented the highest wind speed likely to be encountered in service, and 60 knots were desired for preliminary electrical tests (2) which were conducted simultaneously with the aerodynamic tests. The Purdy Balancing Vane was tested at a wind speed of 60 knots for direct comparison with the prior data on the unmodified antenna. For tests with the canvas enclosure, the wind speed was limited to 40 knots by the structural strength of the enclosure. The final tests on the Mark 34 Antenna were carried out at a wind speed of 70 knots, which was chosen as the maximum wind speed for normal operation of the servo-drives.

Since only approximate values were required for the forces and moments of the complete assembly about its base, no correction was made for the effect of the tunnel walls or the contributions of the supporting fixture. It is estimated that the combined error due to these two sources amounts to less than 5 per cent of the maximum forces and moments. Errors in the determination of the torques of the servo lead-angle drives are of the order of plus or minus 1/2 pound-foot.

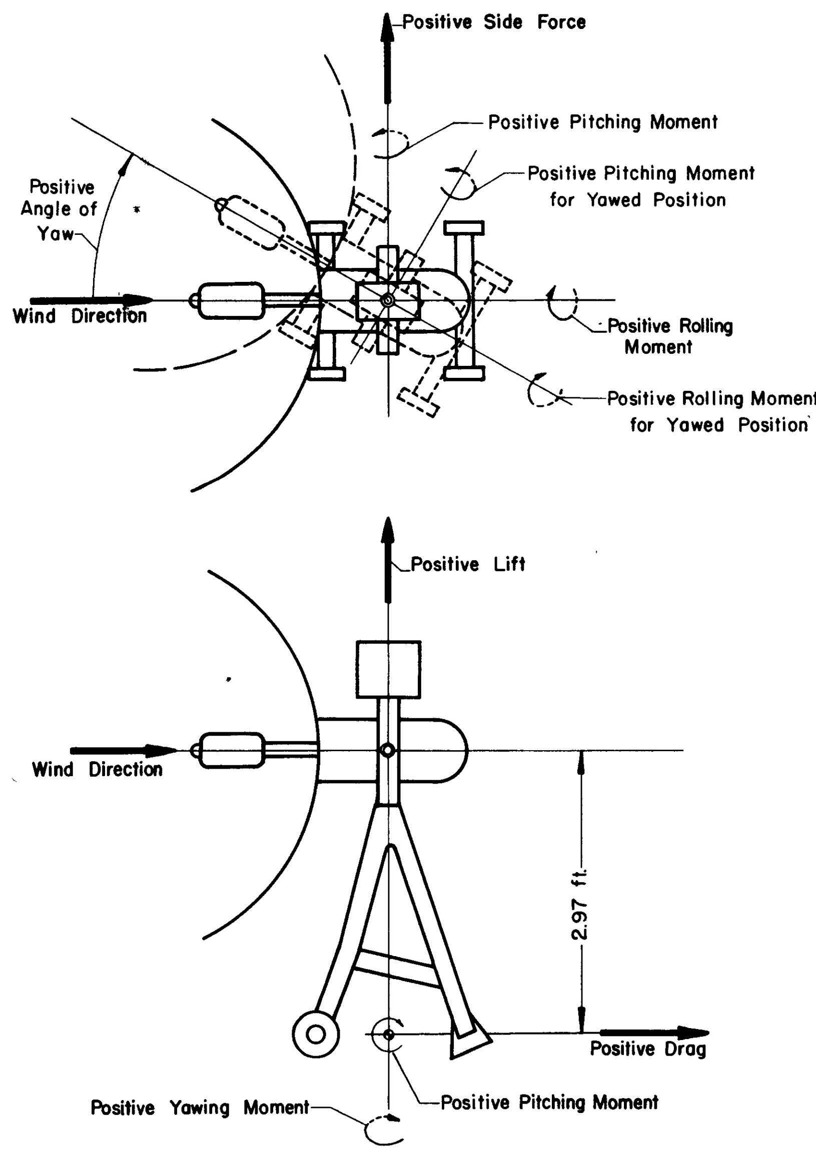

Figure 7a - Positive Directions of Forces and Moments about Axes through the Base of the Antenna Mount

TEST RESULTS

As shown in Figure 7, the positive directions of forces, moments, and angular displacements are in accordance with the usual aeronautical convention. For convenience in the practical use of the forces and moments of the complete antenna, axes have been chosen through the approximate center of the base as dimensioned in Figure 7. It should be noted that the axes of rolling and pitching moment rotate with the antenna as the antenna is turned to different yaw angles. The axes for the drive torques are taken along the centerlines of the elevation and traverse lead-angle shafts.

The results of the wind-tunnel tests are presented in the form of curves of forces and moments plotted on a basis of angle of yaw to the wind

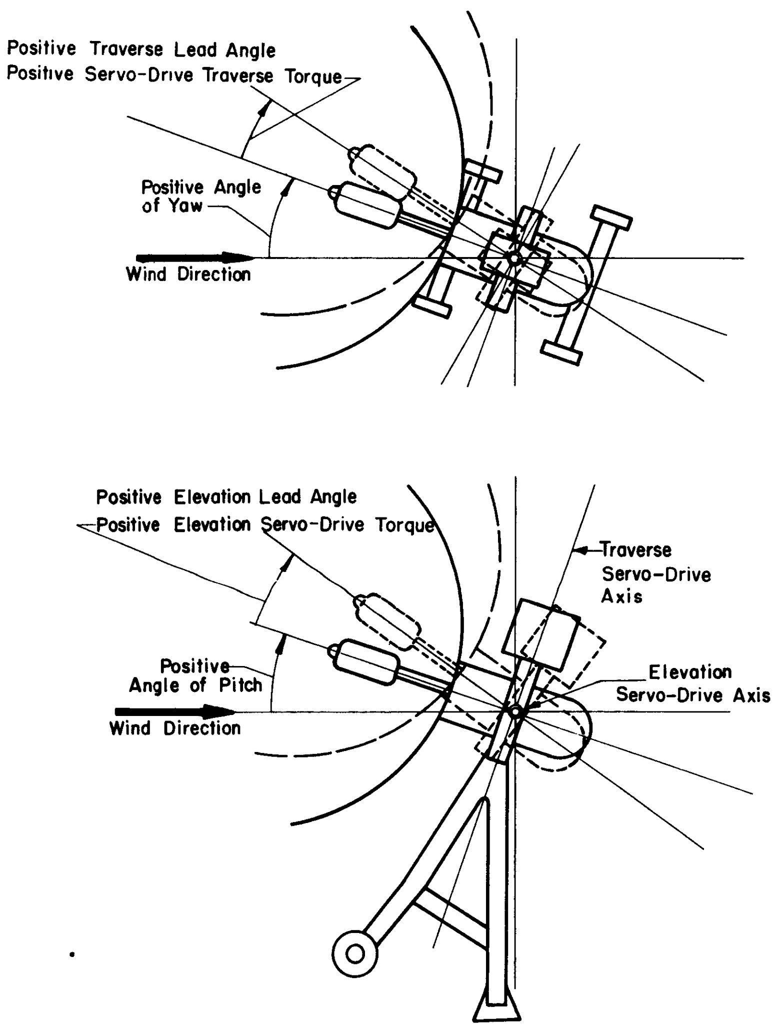

Figure 7b - Positive Directions of Lead-Angle Deflections and Servo-Drive Torques

Figure 7 - Sketch of Antenna Assembly Showing Position of Reference Axes and Positive Directions of Forces and Moments

stream for various configurations of the Mark 19 Antenna Mount with the Mark 28 and Mark 34 Radar Antennas.

The forces and moments transmitted by the Mark 19 Antenna Mount fitted with the Mark 28 Radar Antenna to its supports are shown in Figure 8. The servo-drive torques required for the Mark 28 Radar Antenna on the Mark 19 Antenna Mount are presented in Figure 9 for the unbalanced condition, in Figure 10 for the assembly with the Purdy Balancing Vane, and in Figures 11 through 13 for the assembly with the canvas enclosure.

The servo-drive torques required for the Mark 34 Radar Antenna on the Mark 19 Antenna Mount for various lead-angle deflections are presented in Figures 14 and 15.

DISCUSSION OF RESULTS

The aerodynamic forces and moments measured with respect to axes through the base of the Mark 19 Antenna Mount with the Mark 28 Radar Antenna, Figure 8, add substantially to the torque requirements of the gun-training mechanism. It may be noted, in particular, that the maximum pitching moment transmitted to the gun mount during a 90-knot wind exceeds 1000 pound-feet, as shown in Figure 8d.

For the Mark 28 Radar Antenna on the Mark 19 Antenna Mount, the maximum elevation-servo-drive torque of approximately 90 pound-feet occurs between 0 and 30 degrees and near 180 degrees of yaw angle, as indicated in Figure 9a, for a wind speed of 60 knots. For conversion to other wind speeds, torque may be considered to vary with the square of the wind speed.

The maximum traverse-servo-drive torque of the Mark 19 Antenna Mount with the Mark 28 Radar Antenna occurs at an angle of yaw of 90 degrees, as shown in Figure 9b. For a 75-degree angle of pitch of the complete assembly, the maximum torque reaches 108.5 pound-feet for 60-knot operation. While the upper limit of wind speed likely to be encountered in service was not definitely established, it was felt by Naval Research Laboratory personnel that the gun director should operate satisfactorily up to a wind speed of 70 knots. For this wind speed a maximum operating torque of $108.5 \times \frac{(70)^2}{(60)^2} =$ 147.7 pound-feet would be required. Since the elevation and traverse servo-drives are made interchangeable, a torque output of at least 150 pound-feet is necessary for each drive. The Conrad and Moser Servo-Drive Mechanisms, Serial 56, mounted on the antenna as tested developed approximately 20 pound-feet of torque.

A comparison of the data of Figure 10b for the antenna with a Purdy Balancing Vane with the data of Figure 9b for the antenna alone shows that a

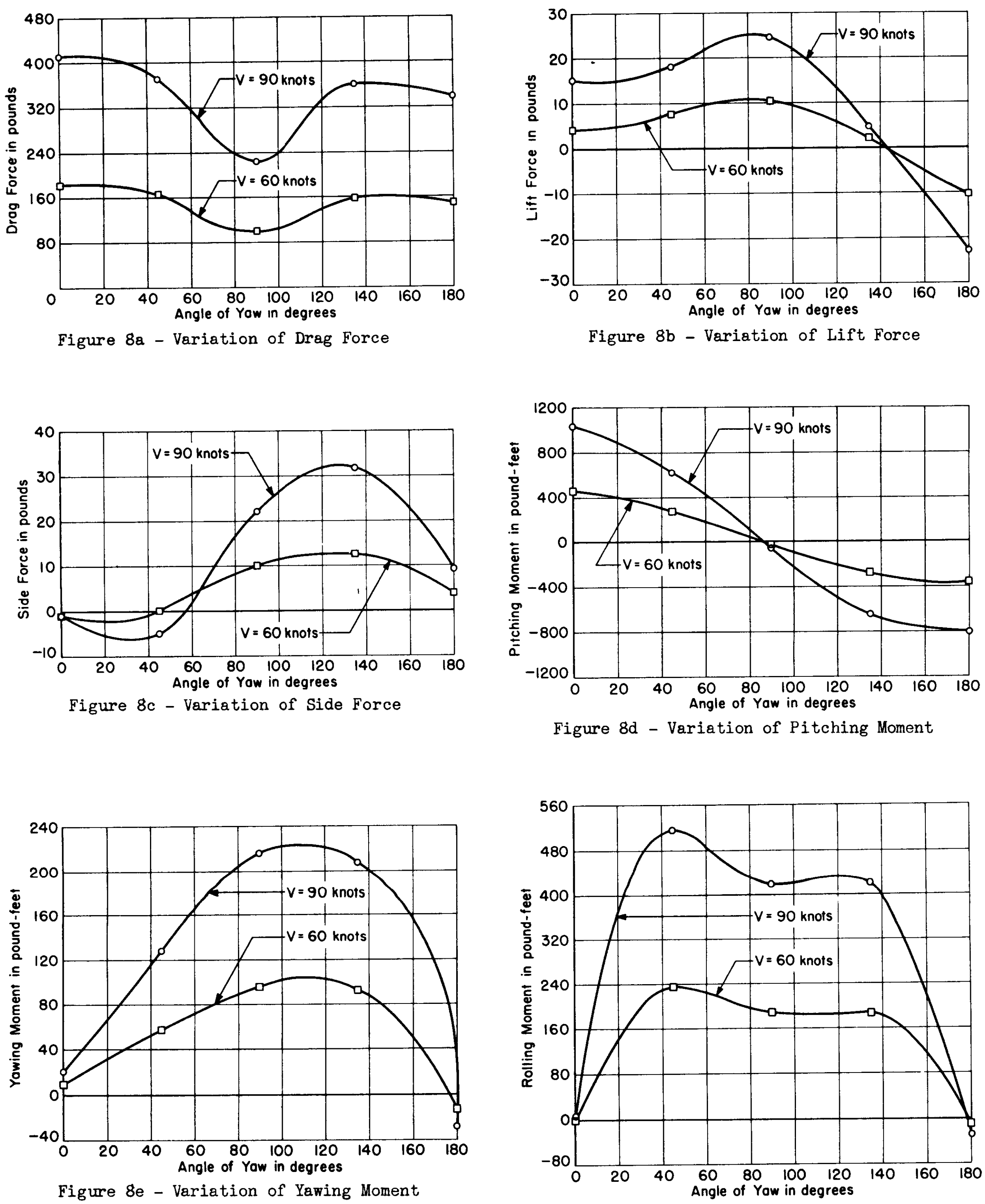

Figure 8a - Variation of Drag Force

Figure 8b - Variation of Lift Force

Figure 8c - Variation of Side Force

Figure 8d - Variation of Pitching Moment

Figure 8e - Variation of Yawing Moment

Figure 8f - Variation of Rolling Moment

Figure 8 - Aerodynamic Forces and Moments Plotted on a Basis of Angle of Yaw at Two Wind Speeds for Mark 28 Radar Antenna on Mark 19 Antenna Mount

The angle of pitch was 0 degree.

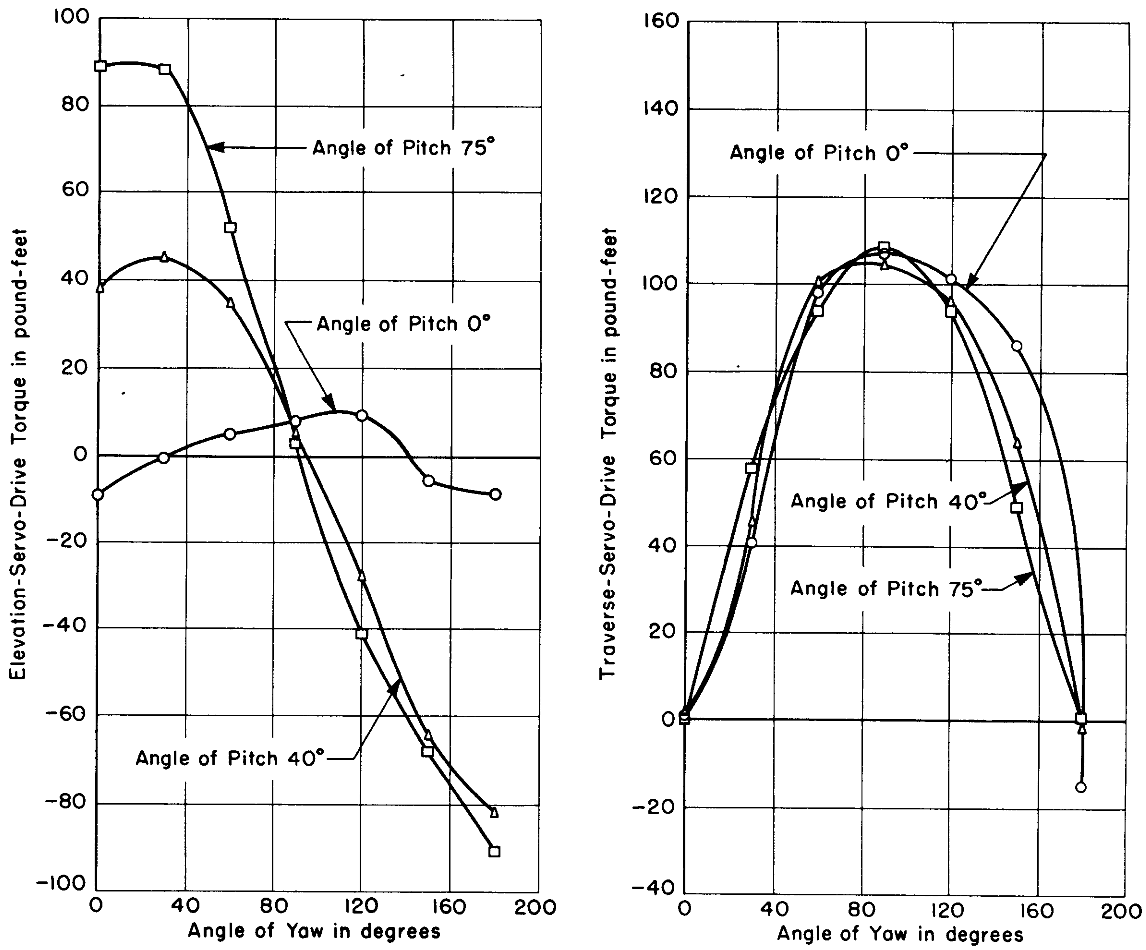

Figure 9a - Variation of Elevation-Servo-Drive Torque

Figure 9b - Variation of Traverse-Servo-Drive Torque

Figure 9 - Elevation- and Traverse-Servo-Drive Torques Plotted on a Basis of Angle of Yaw for Three Angles of Pitch of Mark 28 Radar Antenna on Mark 19 Antenna Mount

The wind speed was 60 knots. The angular deflections of the antenna reflector in elevation and in traverse were 0 degree.

reduction of only about 10 per cent in the maximum aerodynamic torque may be effected through the use of a Purdy Vane.

The antenna servo-drive torques were considerably reduced by the action of the canvas enclosure in shielding the antenna from the wind stream. As shown in Figures 11 through 13, the torques are well within the operating limits of the drives at 40 knots; extrapolation to 70 knots shows that the torques remain within the allowable limit at this operating speed, except

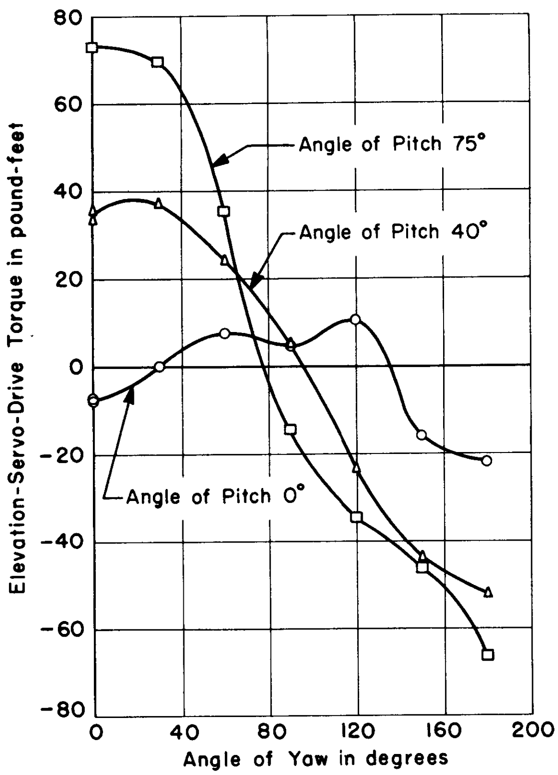

Figure 10a - Variation of Elevation-Servo-Drive Torque

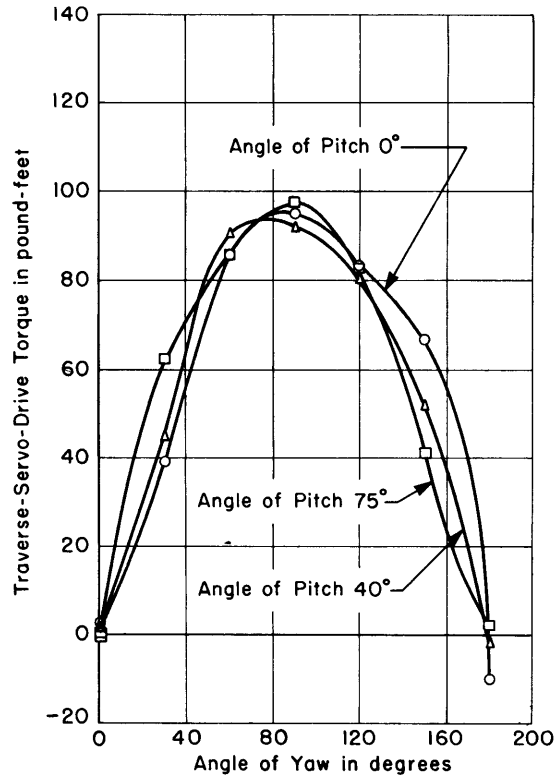

Figure 10b - Variation of Traverse-Servo-Drive Torque

Figure 10 - Elevation- and Traverse-Servo-Drive Torques Plotted on a Basis of Angle of Yaw for Three Angles of Pitch for Mark 28 Radar Antenna on Mark 19 Antenna Mount with Purdy Balancing Vane

The wind speed was 60 knots. The angular deflections of the antenna reflector in elevation and in traverse were 0 degree.

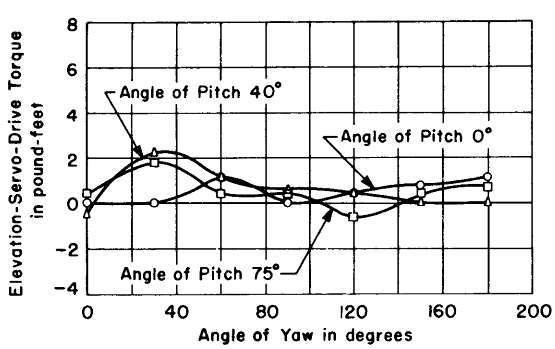

Figure 11a - Variation of Elevation-Servo-Drive Torque

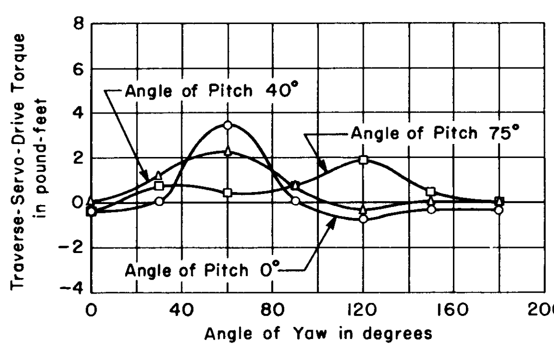

Figure 11b - Variation of Traverse-Servo-Drive Torque

Figure 11 - Elevation- and Traverse-Servo-Drive Torques Plotted on a Basis of Angle of Yaw for Three Angles of Pitch of Mark 28 Radar Antenna on Mark 19 Antenna Mount with Canvas Enclosure

The wind speed was 40 knots. The angular deflections of the antenna reflector in elevation and in traverse were 0 degree.

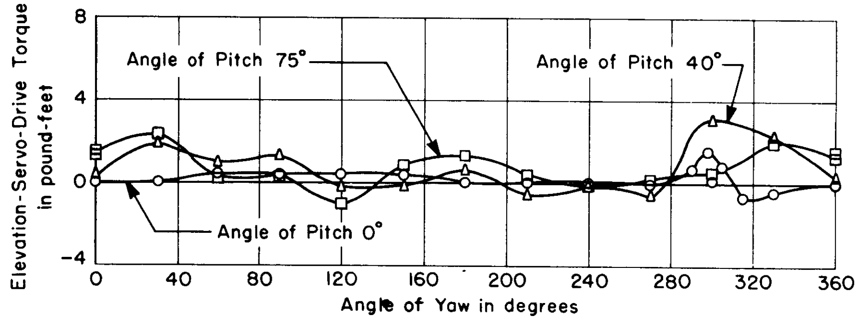

Figure 12a - Variation of Elevation-Servo-Drive Torque

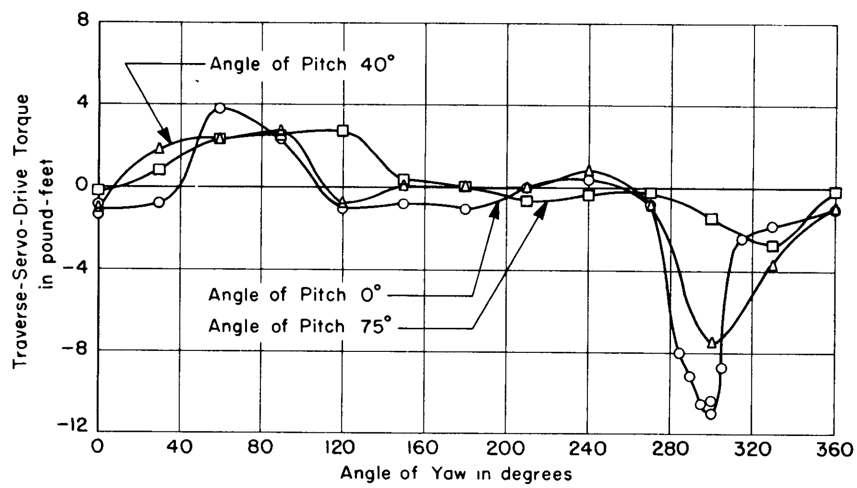

Figure 12b - Variation of Traverse-Servo-Drive Torque

Figure 12 - Elevation- and Traverse-Servo-Drive Torques Plotted on a Basis of Angle of Yaw for Three Angles of Pitch of Mark 28 Radar Antenna on Mark 19 Antenna Mount with Canvas Enclosure

The wind speed was 40 knots. The angular deflection of the antenna reflector in elevation was 0 degree; the angular deflection in traverse was +20 degrees.

around 300 degrees of yaw angle. The maximum torque reaches $11 \times \frac{(70)^2}{(40)^2} = 33.7$ pound-feet at a 300-degree angle of yaw, 0-degree angle of pitch, and maximum lead angle of the antenna of 20 degrees, as shown in Figure 12b.

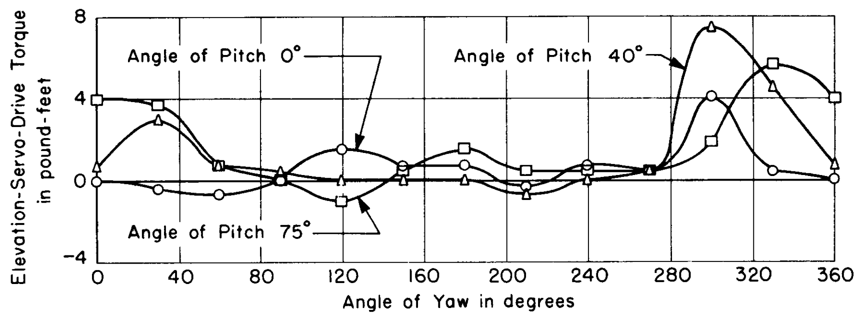

Figure 13a - Variation of Elevation-Servo-Drive Torque

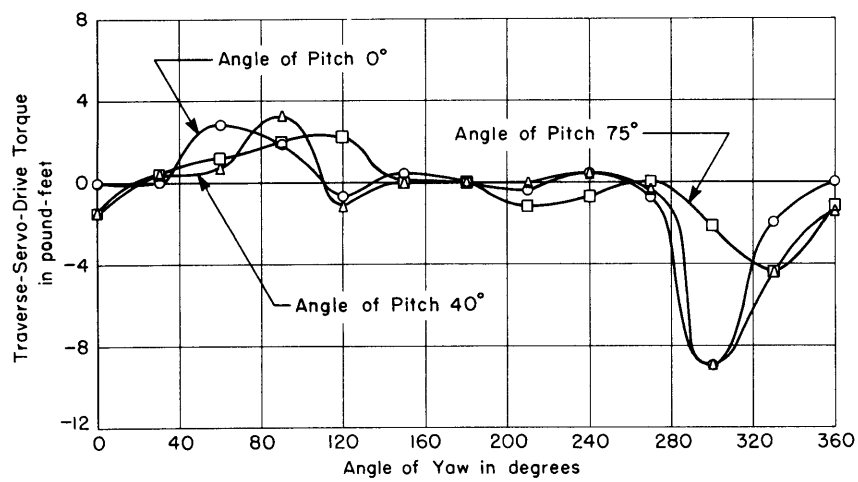

Figure 13b - Variation of Traverse-Servo-Drive Torque

Figure 13 - Elevation- and Traverse-Servo-Drive Torques Plotted on a Basis of Angle of Yaw for Three Angles of Pitch of Mark 28 Radar Antenna on Mark 19 Antenna Mount with Canvas Enclosure

The wind speed was 40 knots. The angular deflection of the antenna reflector in elevation was -20 degrees; the angular deflection in traverse was +20 degrees.

The torques of the Mark 34 Radar Antenna on the Mark 19 Antenna Mount were much lower than those of the larger Mark 28 Radar Antenna but exceeded the capacity of the available drives over a considerable angular range at 70 knots, as shown in Figures 14 and 15.

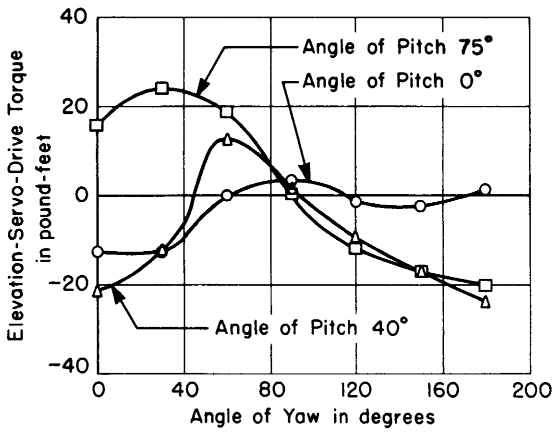

Figure 14a - Variation of Elevation-Servo-Drive Torque

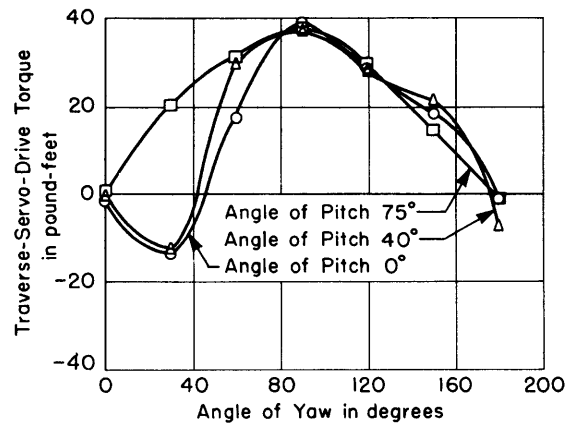

Figure 14b - Variation of Traverse-Servo-Drive Torque

Figure 14 - Elevation- and Traverse-Servo-Drive Torques Plotted on a Basis of Angle of Yaw for Three Angles of Pitch of Mark 34 Radar Antenna on Mark 19 Antenna Mount

The wind speed was 70 knots. The angular deflections of the antenna reflector in elevation and in traverse were 0 degree.

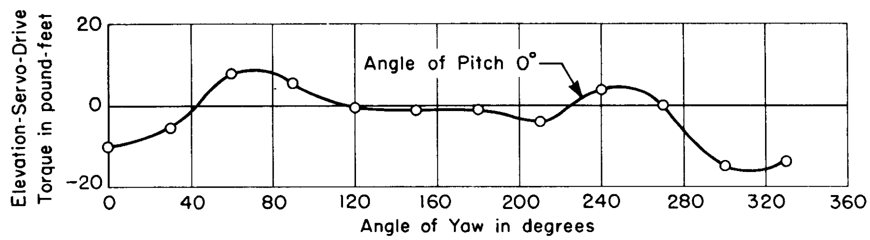

Figure 15a - Variation of Elevation-Servo-Drive Torque

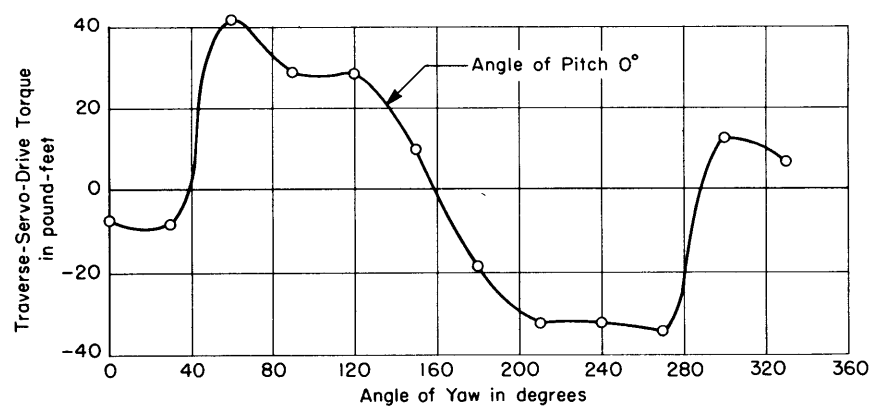

Figure 15b - Variation of Traverse-Servo-Drive Torque

Figure 15 - Elevation- and Traverse-Servo-Drive Torques Plotted on a Basis of Angle of Yaw for an Angle of Pitch of Zero Degree for Mark 34 Radar Antenna on Mark 19 Antenna Mount

The wind speed was 70 knots. The angular deflection of the antenna reflector in elevation was 0 degree; the angular deflection in traverse was +20 degrees.

CONCLUSIONS

1. The maximum servo-drive torque requirement of the Mark 28 Radar Antenna on the Mark 19 Antenna Mount in a 70-knot wind is approximately 150 pound-feet.

2. The Conrad and Moser Servo-Drives, Serial 56, are capable of supplying less than 15 per cent of the maximum torque requirements of the Mark 28 Radar Antenna on the Mark 19 Antenna Mount at a wind speed of 70 knots.

3. The Purdy Balancing Vane provides a reduction of only about 10 per cent in the maximum torque required of the servo-drive motors.

4. The canvas enclosure reduced the wind loads on the Mark 28 Radar Antenna sufficiently to permit operation with the present servo-drives up to 70 knots, under all service conditions except for a very few combinations of yaw, pitch, and lead angles.

5. The servo-drives of the Mark 19 Antenna Mount supply only about 50 per cent of the torque required to operate the small Mark 34 Radar Antenna at all positions relative to a 70-knot wind.

RECOMMENDATIONS

1. It is recommended that the effect of the forces and moments imposed on the 40mm gun by the Mark 19 Antenna Mount be investigated in relation to the accuracy and sensitivity of the gun-train and gun-elevation system.

2. It is recommended that more powerful servo-drives be designed to meet a maximum operating torque of 150 pound-feet at 70 knots with a reasonable margin of safety, provided that effective operation of the Mark 19 Antenna Mount with the Mark 28 Radar Antenna is desired without the use of an enclosure.

REFERENCES

(1) BuShips CONFIDENTIAL letter Equipt. 3-2, Radar-9(332) of 19 March 1945 to TMB.

(2) NRL CONFIDENTIAL letter C-S71-3(395B:SLR), C-395-228/45 of 8 May 1945 to BuOrd.

Note: This project has been downgraded to RESTRICTED by BuShips ltr Equipt. 3-2, Radar-9(330c) of 14 January 1947.