NAVY DEPARTMENT

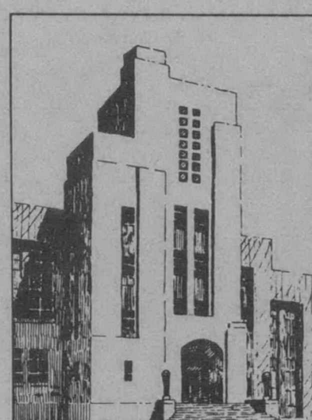
THE DAVID W. TAYLOR MODEL BASIN

WASHINGTON 7, D.C.

INVESTIGATIONS OF SPEED EFFECTS AND INTERACTIONS ON A THRUST-TORSION METER OF A 5000 POUND, 1000 POUND-FOOT TRANSMISSION DYNAMOMETER

by

G.J. Norman



January 1952

Report 803

INITIAL DISTRIBUTION

Copies	
6	Chief, Bureau of Ships, Project Records (324) 5 Project Records 1 Code 554
2	Commander, U.S. Naval Ordnance Laboratory, White Oak, Silver Spring 19, Md.
2	Director, U.S. Naval Research Laboratory, Washington 20, D.C.
1	Director, National Bureau of Standards, Connecticut and Van Ness Sts., N.W., Washington 25, D.C.

20740

TABLE OF CONTENTS

INVESTIGATIONS OF SPEED EFFECTS AND INTERACTIONS ON A THRUST-TORSION METER OF A 5000 POUND, 1000 POUND-FOOT TRANSMISSION DYNAMOMETER

by

G.J. Norman

ABSTRACT

A thrust-torsion meter designed to measure the thrust and torque in a rotating shaft has been dynamically tested to determine speed effects and interactions between the thrust and torque units of the meter. Information obtained from this test is to be used to determine the calibrating procedure for this and similar meters.

The results of the tests presented in Figures 9 and 10 show that if tare or 'no-load' dynamometer readings can be obtained at the various test speeds, then the use of a static calibration of this instrument will give accurate results in dynamic tests.

INTRODUCTION

The thrust-torsion meter illustrated in Figure 1 was originally developed by the David Taylor Model Basin engineering staff for use in the transmission dynamometer of a proposed twenty-four inch water tunnel. The proposed water tunnel was not constructed. The compact design of the thrust-torsion meter, however, suggested its possible use as a transmission dynamometer for various surface and sub-surface powered bodies. Consequently, it was decided to perform dynamic tests to determine the effects of speed and thrust-torque interactions on the dynamometer. It was hoped that the results of the tests would indicate whether static calibrations of similar elements would suffice, or whether it would be necessary to carry out dynamic calibrations in future work.

The dynamic and interaction effects studied are as follows:

1. Effect of variations in speed on thrust deflection.
2. Effect of variations in speed on torque deflection.
3. Effect of changes in torque on thrust deflection.
4. Effect of changes in thrust on torque deflection.

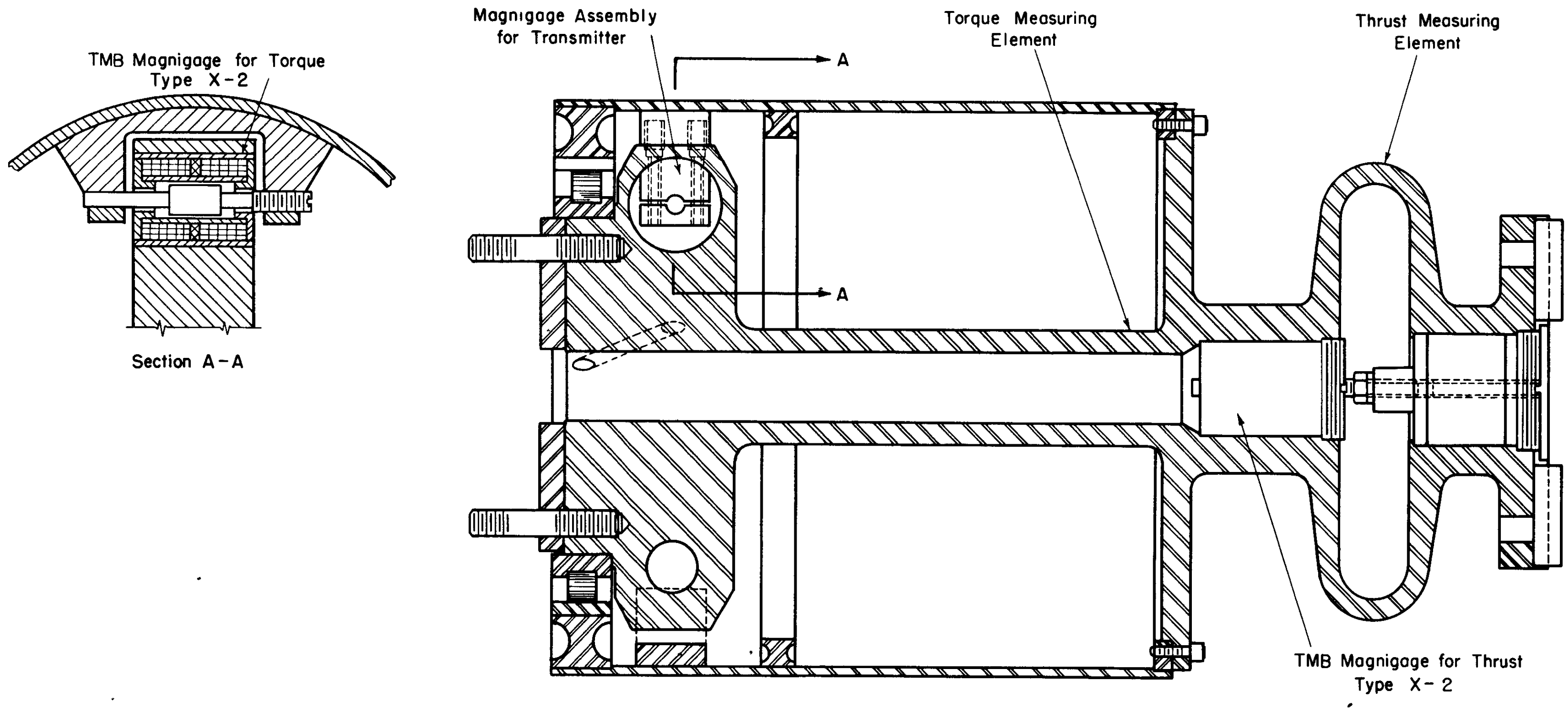


Figure 1 - Transmission Dynamometer Development, Thrust-Torsion Meter, Internal Shaft Element Assembly

DESCRIPTION OF APPARATUS [3]

The apparatus used in this test can be divided into three parts:

1. Dead-weight testing machine located at the National Bureau of Standards. This machine was used for static calibration of the thrust unit of the thrust-torsion meter and for static calibration of the 10,000-pound proving ring in tension and compression.

2. Dead-weight, beam balance, torsion-testing machine located at the National Bureau of Standards. This machine was used for static calibration of the torque unit of the thrust-torsion meter.

3. Dynamic testing apparatus as shown in Figures 2, 3, 4, and 5. This apparatus was set up at the National Bureau of Standards in the Dynamometer Testing Laboratory.

The 200-hp east dynamometer was used as the driving motor, and the torque delivered by this dynamometer was indicated by Toledo scales. The 150-hp west dynamometer was used as the absorption dynamometer, and the torque was indicated by Toledo scales.

Thrust was applied to the thrust-torque meter by loading the proving ring by means of jack nuts. The thrust on the proving ring was transmitted to the thrust-torque meter through a floating thrust block.

The telemetering units for the thrust-torsion meter were TMB Type X-2 Magnigages which were mounted in the thrust-torsion meter and rotated with the meter. Signals from these magnigages were taken from the rotating shaft by means of slip rings. The indicating unit for thrust was TMB Magnetic Micrometer Number 7, and for torque TMB Magnetic Micrometer Number 11. Values of thrust applied to the proving ring were telemetered by means of SR-4 strain gages cemented to the proving ring, and a Baldwin Southwark SR-4 Strain Indicator, TMB Number 350134, was used for indicating these values.

PROCEDURE

The sequence followed in conducting the tests was as follows:

1. Static calibration of proving ring on dead-weight testing machine.

2. Static calibration of thrust unit of the thrust-torsion meter for compression and tension loadings.

3. Static calibration of torque unit of thrust-torsion meter. Torque was calibrated in the counterclockwise sense only because the torque testing machine could be loaded in this direction only.

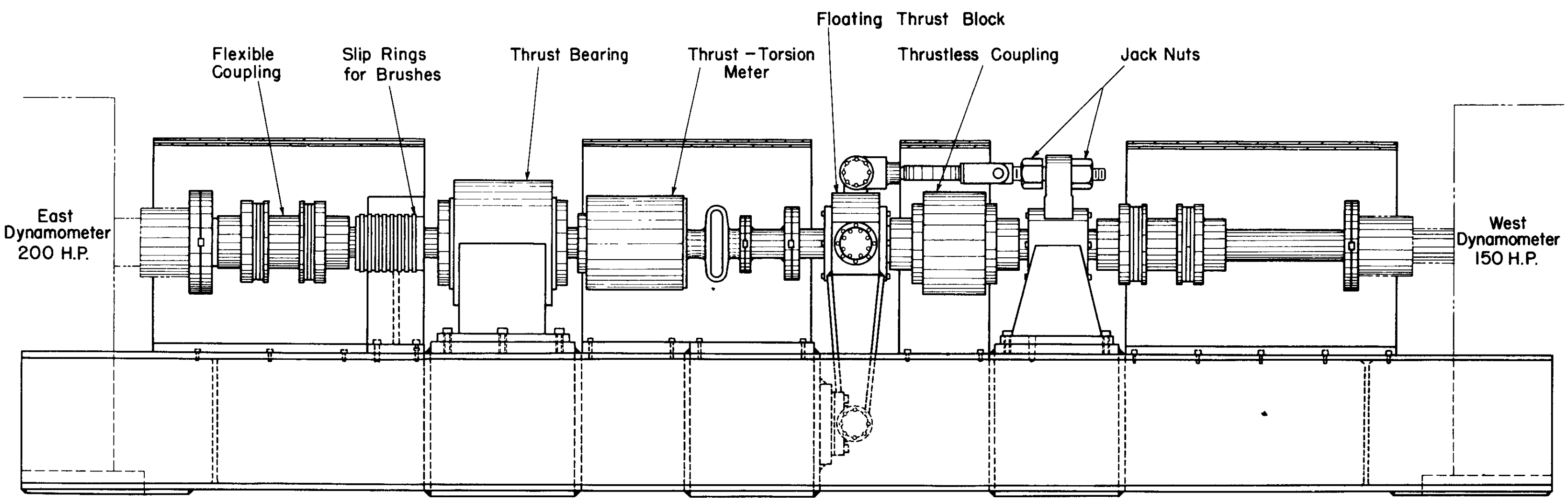


Figure 2 - Transmission Dynamometer Development, General Arrangement for Dynamic Tests

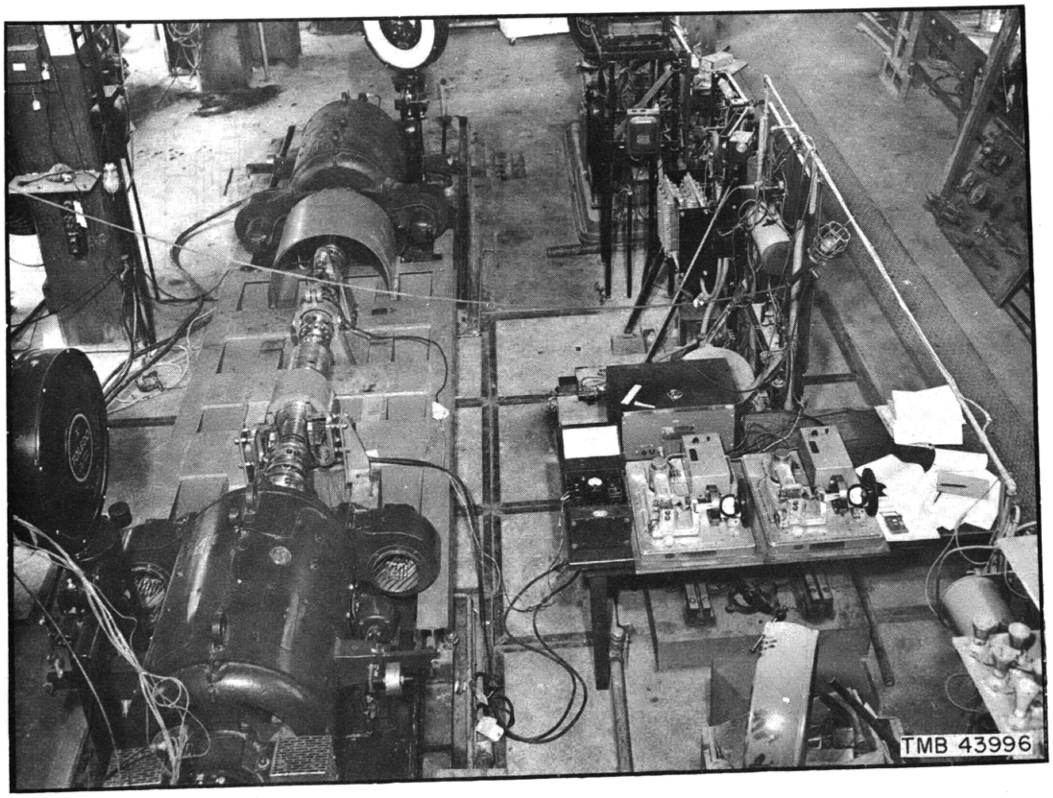


Figure 3 - Transmission Dynamometer, View of Test Apparatus

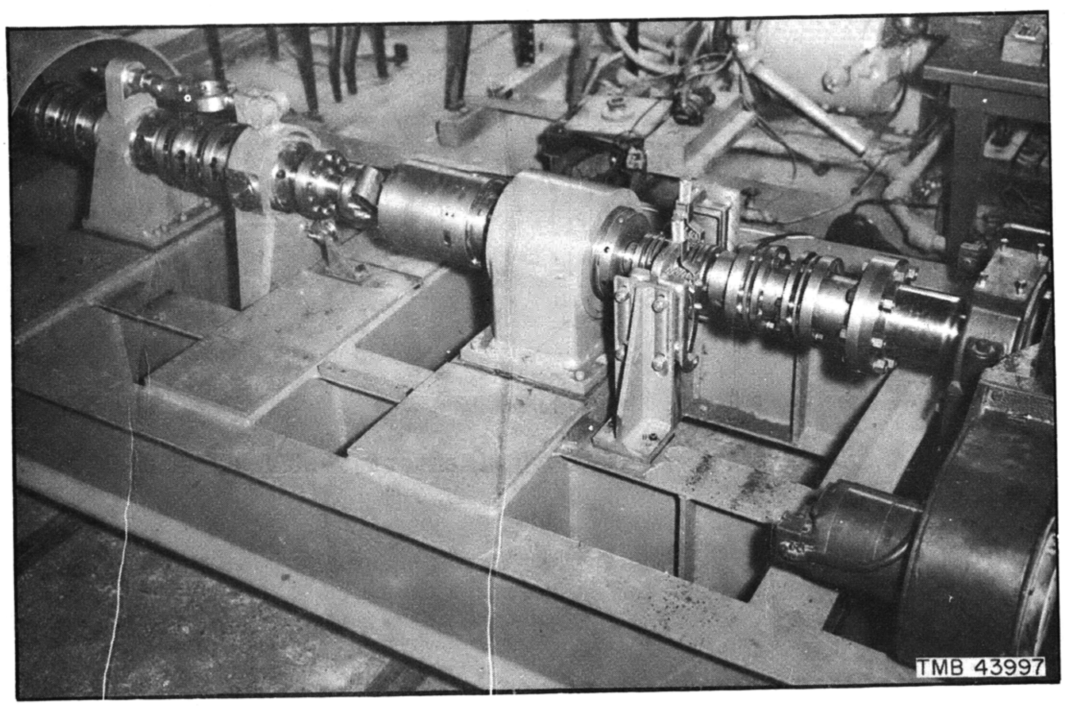


Figure 4 - Transmission Dynamometer, View of Shaft Assembly

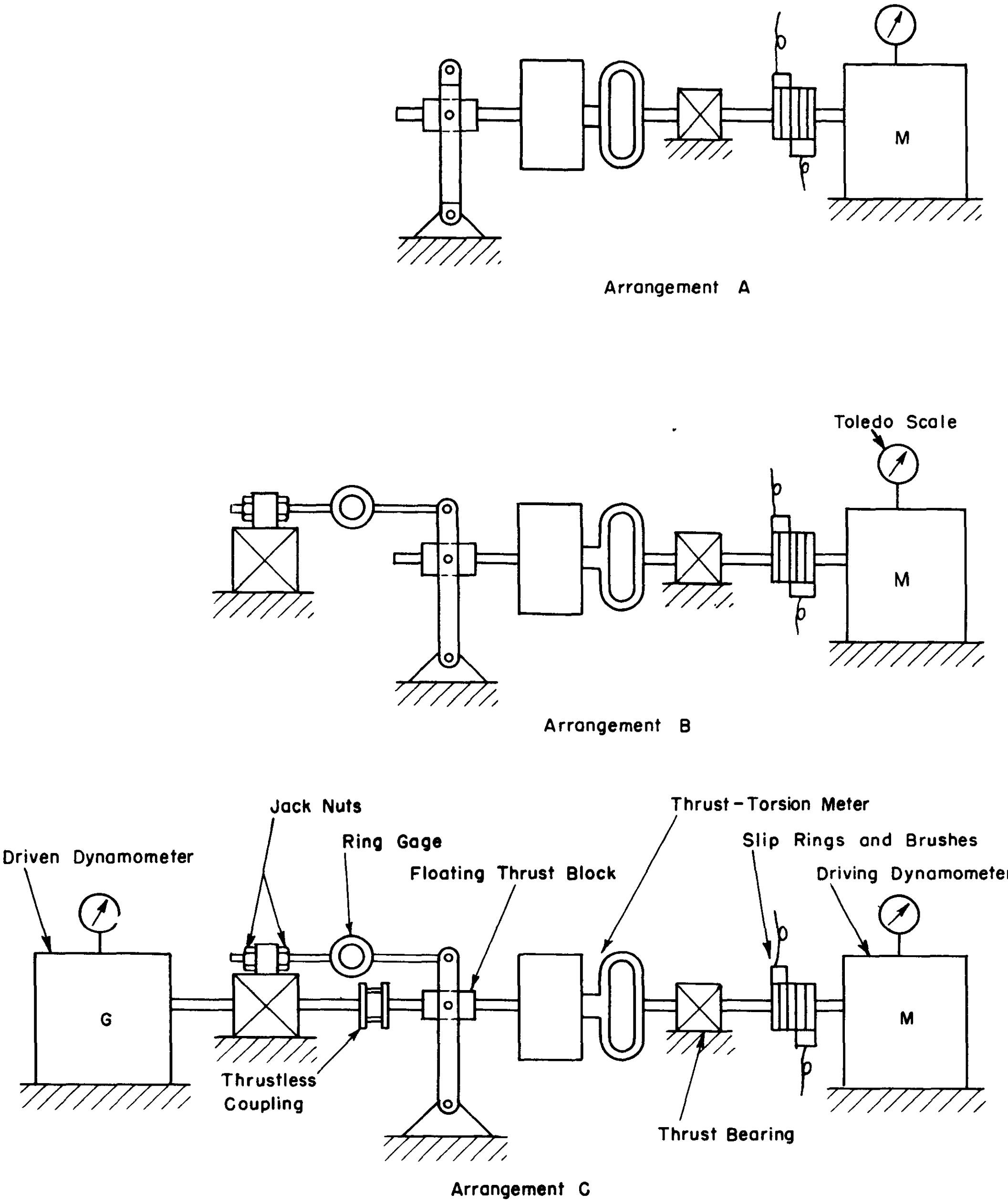


Figure 5 - Schematic Arrangement of Test Apparatus

4. Effect of Speed on Thrust.

a. Determination of speed effect on thrust with zero applied thrust.

The test apparatus was arranged as shown by Figure 5, Arrangement A. The shaft was rotated counterclockwise at speeds varying from 130 rpm to 3500 rpm and readings of thrust magnigage and shaft speed were taken. The test was repeated for clockwise rotation of the shaft.

b. Determination of speed effect on thrust with an applied thrust load.

The test apparatus was arranged as shown by Figure 5, Arrangement B. A thrust load of approximately 5000 lb was applied by loading the proving ring by means of the jack nuts. The shaft was rotated at 3500 rpm and simultaneous readings of the ring gage and the thrust magnigage were taken. The shaft was then rotated at 140 rpm, the ring gage was readjusted to obtain the same reading indicated at 3500 rpm and the corresponding thrust magnigage reading was taken. The readjustment of the ring gage was necessary because heating of the bearings caused elongation of the shaft with a consequent change in the thrust load. This procedure was performed with tension and compression loading of the thrust gage, and for both directions of rotation.

5. Effect of Torque on Thrust.

Test apparatus was arranged as shown by Figure 5, Arrangement C. The dynamometer indicated as M in the figure was used to drive the shaft, and the dynamometer indicated at G in the figure was used for absorption of power. A thrustless coupling was used as illustrated in the figure to prevent the application of spurious thrust loads.

The shaft was rotated at a speed of 600 rpm while a thrust load of approximately 5000 lb and a small torque were applied. Simultaneous readings were taken of all thrust and torque meters and of shaft speed. With the speed and applied thrust load held constant, the torque was rapidly increased to the maximum value obtainable, and all readings were taken again. The test was repeated for speeds of 1000, 2000, and 3000 rpm, tension and compression loading, and both directions of rotation.

6. Effect of Speed on Torque.

Test apparatus was arranged as shown by Figure 5, Arrangement A. The shaft was rotated counterclockwise at speeds varying from 130 to 3500 rpm. Torque magnigage and Toledo scale readings were taken at 500 rpm intervals. The test was repeated for clockwise rotation of the shaft.

7. Effect of Thrust on Torque.

Test apparatus was arranged as shown by Figure 5, Arrangement C. The shaft was rotated counterclockwise at 600 rpm with zero applied thrust load and approximately 225 lb-ft torque. A thrust load of approximately 5000 lb was applied with speed and torque held constant. Torque and thrust readings were taken before and after the application of the thrust load. The test was repeated for clockwise rotation of the shaft at 600 rpm and also for clockwise and counterclockwise rotation at 2000 rpm.

RESULTS

Results are discussed in the same sequence as the section on "Procedure;" the numbers refer to the sub-divisions presented therein.

1. Static calibration of 10,000-pound proving ring on dead-weight testing machine at the National Bureau of Standards.

Calibration factors obtained:

a. Tension - 2.0478 x net indicator divisions = load in pounds.

b. Compression - 2.0476 x net indicator divisions = load in pounds.

2. Static calibration of thrust unit of thrust-torsion meter on dead-weight testing machine at the National Bureau of Standards.

a. Tension - Calibration curve and correction curve are shown in Figure 6.

b. Compression - Calibration curve and correction curve are shown in Figure 7.

3. Static calibration of torque unit of thrust-torque meter on the torque testing machine at the National Bureau of Standards.

Torque calibration curve and correction curve are shown in Figure 8.

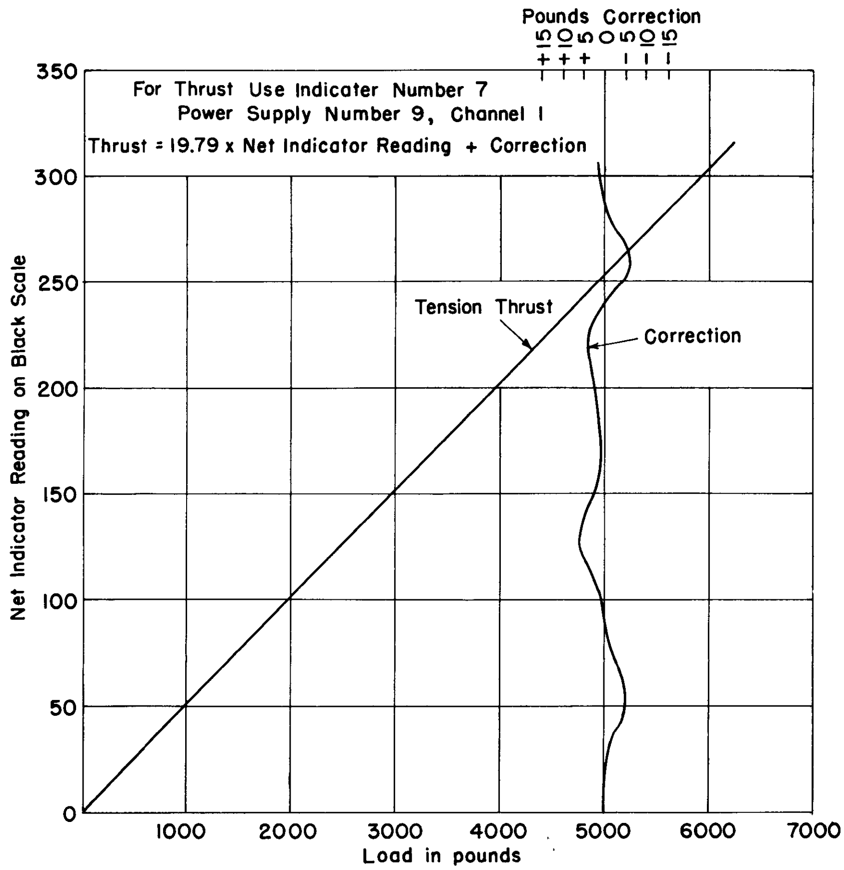


Figure 6 - Transmission Dynamometer, Thrust Calibration (Static), Tension

4. Effect of Speed on Thrust.

a. Speed effect with zero applied torque and thrust. The thrust reading was found to vary with speed as shown by Figure 9. The variation at 3500 rpm was 4.9 magnigage divisions, which represents approximately a 2 percent variation of full scale, based on a full-scale range of 250 magnigage divisions. The variation was in the direction of a compression loading for both clockwise and counterclockwise rotation, which definitely indicates that centrifugal forces on the thrust unit produced the observed speed effect. In addition, a comparison of the observed curve with the power function $y = ax^2$ shows close correlation. This is illustrated by Figure 9.

b. Determination of speed effect on thrust with maximum thrust load and zero applied torque. Data obtained showed that the speed effect on thrust was not affected by the value of the applied thrust load. With an applied thrust load of 5000 pounds the change in the

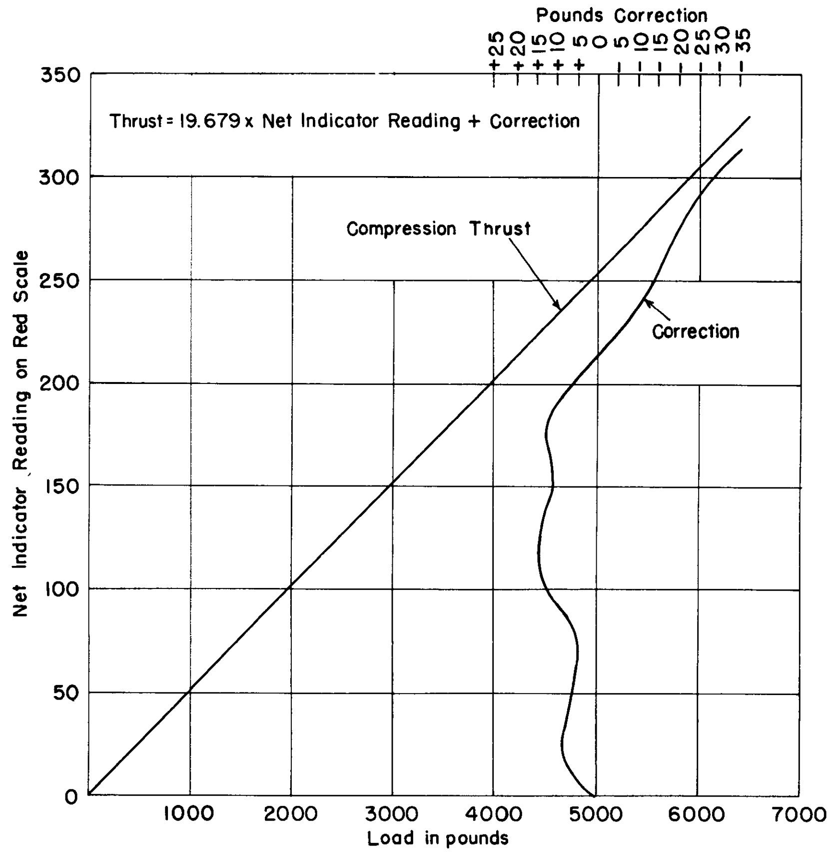


Figure 7 - Transmission Dynamometer, Thrust Calibration (Static), Compression

thrust magnigage reading (average of four readings) was 5.05 magnigage divisions when the shaft speed was increased from 140 rpm to 3500 rpm. This compares with an average deviation of 4.9 magnigage divisions with zero applied thrust. The speed effect on thrust was in the direction of a compression loading.

5. Effect of Torque on Thrust.

There was no observable effect of torque on thrust in the range of the torque capacity of the testing apparatus. The maximum torque obtainable was approximately 270 lb-ft, whereas the design capacity of the torque element of the thrust-torque meter was 1000 lb-ft.

6. Effect of Speed on Torque.

A change in shaft speed from 130 rpm to 3000 rpm produced a centrifugal effect of 3.6 lb-ft torque (0.92 magnigage divisions). At 2000 rpm the centrifugal effect was 1.75 lb-ft (0.45 magnigage divisions).

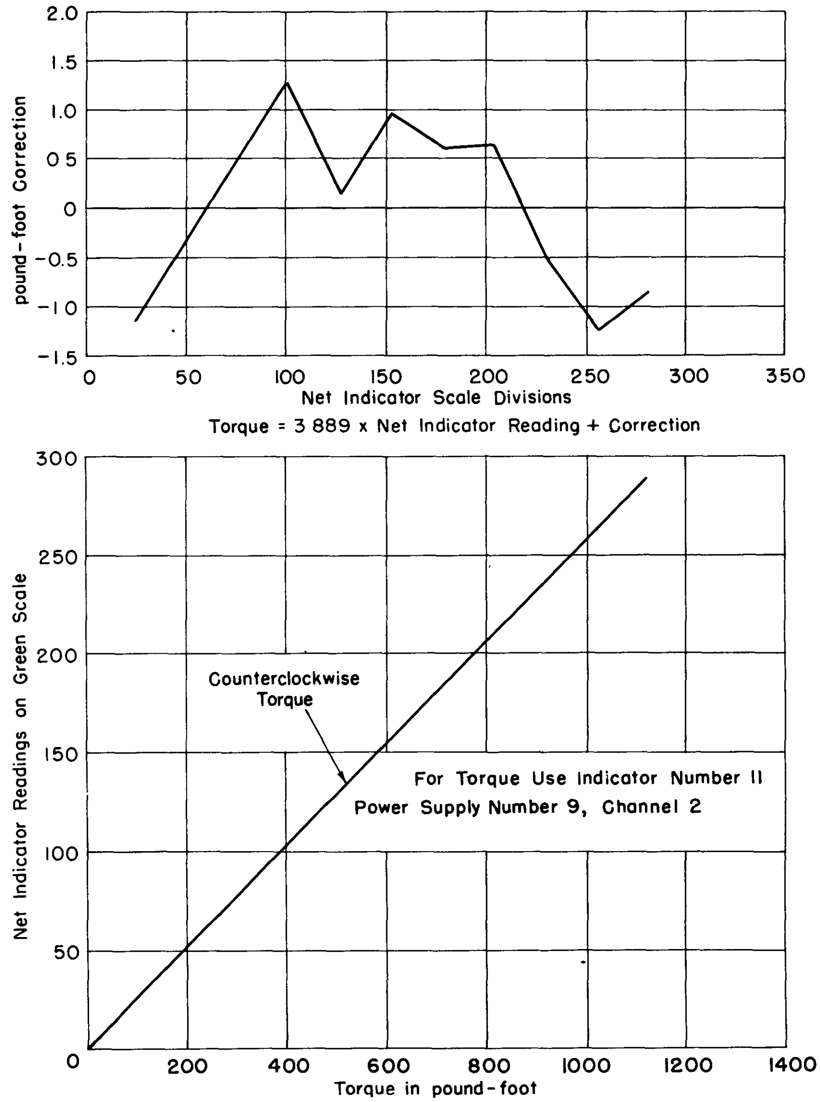


Figure 8 - Transmission Dynamometer, Torque Calibration (Static)

The curves of magnigage readings versus rpm shown in Figure 10 indicate that the torque increases in a clockwise sense as the speed increases. If centrifugal effects were not present, the curves for counterclockwise rotation would have a negative slope due to bearing friction.

7. Effect of Thrust on Torque.

There was no observable effect of thrust on torque readings. This was demonstrated by applying a constant torque to the shaft then rapidly applying a thrust load of 5000 pounds and noting the change in torque magnigage reading. Twelve readings showed an average deviation of 0.12 divisions of the torque magnigage, whereas

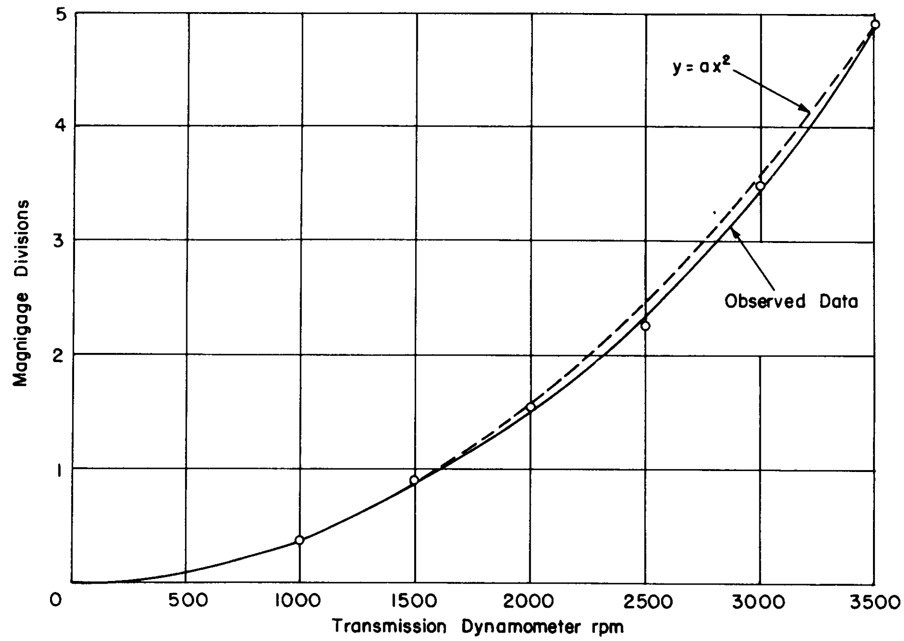


Figure 9 - Transmission Dynamometer, Effect of Speed on Thrust

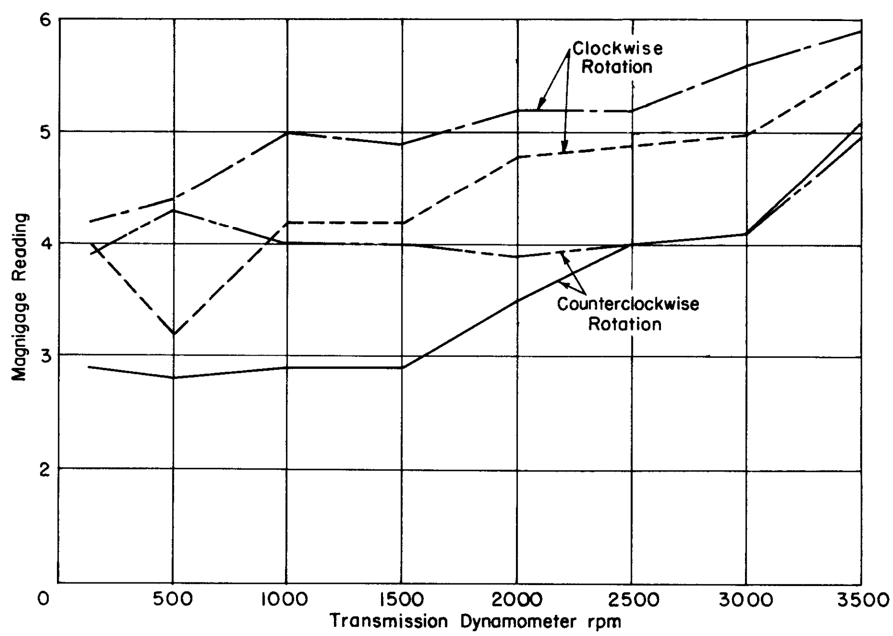


Figure 10 - Transmission Dynamometer, Effect of Speed on Torque

the over-all repeatability of the testing equipment for this testing condition was estimated to be ±0.4 magnigage divisions. Therefore, the observed deviation cannot be attributed to thrust interaction.

The experimental data are not included as a part of this report. However, they are available for reference in the Mechanical Engineering Division of the David Taylor Model Basin.

CONCLUSIONS

1. There was a definite centrifugal effect on thrust readings. For the particular thrust gage tested, the centrifugal effect did not vary with changes in applied thrust load. However, it cannot be assumed that gages of similar type which are designed for smaller thrust loads and greater deflections, will not show a combined effect of speed and thrust.

For the thrust gage tested, accurate thrust readings can be obtained by applying a correction based on shaft speed alone. If no-load runs were made in test work, the centrifugal effect would be included in the thrust tare readings.

2. There was no observable interaction between torque and thrust. Accordingly, it is not necessary to calibrate either torque or thrust for combined torque-thrust effects.

3. A slight speed effect was observed in the torque readings. Its value was 0.93 magnigage divisions for a speed change from 130 rpm to 3000 rpm. This change is equivalent to an error of approximately 0.4 percent based on a full-scale torque deflection of 250 magnigage divisions. The cause of this speed effect is not definitely known because the accuracy of the equipment was not great enough to isolate the speed effect accurately. However, it is believed that the speed effect was caused by a mechanical displacement of the magnigage core with respect to the coil due to bending or distortion of the core support or core shaft produced by centrifugal forces on these parts. Further investigation with more refined equipment than that used during this test would be necessary to isolate the speed effect on torque. Because the error was so very small and because it was found independent of the applied torque and thrust, the refined equipment indicated above is not considered necessary or justifiable. No torque corrections need be made if no-load torque values for each speed are obtained when using the instrument.

The results of this investigation show that it is not necessary to perform dynamic calibrations of thrust and torque for the particular thrust-torsion meter or for similarly proportioned thrust-torsion meters, provided that a series of no-load runs covering the speed range are made. The speed effects on torque and thrust would be included in the no-load readings, and therefore it is not necessary to know the absolute value of the speed effect.