NAVY DEPARTMENT
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WASHINGTON 7, D.C.

DYNAMIC CALIBRATION OF 35-HP PROPELLER DYNAMOMETER

by

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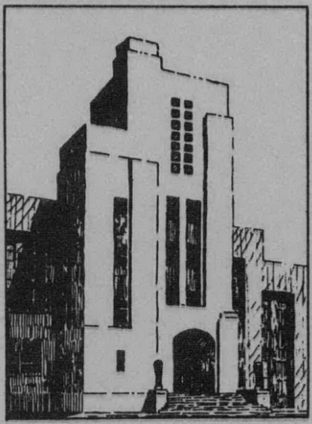

February 1952

Report 805

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G.L. SANTORE

ABSTRACT

A dynamic calibration was performed on a 35-hp propulsion dynamometer of the transmission type. It was found that no interactions existed between torque and thrust. Although a speed effect was noted, it produced no change in the sensitivity of the torque and thrust elements.

1. INTRODUCTION

The 35-hp propulsion dynamometer is a transmission type dynamometer and employs for its measuring devices two magnigages used in conjunction with elastic shaft elements. The mechanism is designed so that the two measuring devices, torque and thrust, are included in the power train, and as such rotate with the shaft. Similar dynamometers have been used to measure the torque and thrust transmitted by ship propeller shafts during full-scale trials. The calibrations for these early models were obtained statically, that is, without the added complexities of simultaneous loadings, and rotating elastic elements.

The reliability of dynamometers of this type can be enhanced considerably if the measuring units are placed adjacent to the propeller. However, in the design of the 35-hp dynamometer, hydrodynamic and mechanical considerations dictated that several bearings and a seal be placed between the propeller under test and the sensing elements. With this arrangement, the torque and thrust sensing elements do not experience the full loads as applied by the propeller, but react to forces which have been conditioned by the friction losses of the intermediate shaft elements. With dynamometers so designed, the calibration is usually obtained by including no-load readings of torque and thrust. Since the no-load values are an indication of the intermediate friction and other factors, they form the zero curve from which the applied loads are measured.

In the case of the 35-hp dynamometer an initial static calibration and several no-load tests were conducted, see Figures 7 and 8. Although both the torque and thrust meters indicated a speed effect, its effect upon torque was unexpected.

Referring to Figure 7, the torque curve for clockwise rotation showed a gradual increase with speed. The torque curve for counterclockwise rotation showed first an increase, then a decrease as speed increased. This gave rise to the suspicion that there might exist a pure speed-effect rather than a decrease in friction with speed. The word "pure" as used here means an effect which is a function of speed alone, i.e., a centrifugal effect.

The existence of a speed effect at no loads gave rise to the question of a possible modification of it under load which could be answered by a dynamic calibration. Also, since the magnigages are sensitive enough to record the previously unsuspected effect of the centrifugal forces, it seemed prudent to determine the interaction, if any, between thrust and torque.

Actual shakedown tests were made with two propellers. These propellers were believed to be of similar design such that results of one test could be predicted on the basis of the other test. The final results were not in accord with the predictions and furthered the suspicion that a dynamic calibration was desirable. Therefore, a dynamic calibration program involving simultaneous loadings of torque and thrust was planned and executed.

2. DESCRIPTION OF APPARATUS

2.1. DESCRIPTION OF 35-HP PROPULSION DYNAMOMETER

The streamlined underwater portion of the dynamometer contains the right-angle gear box, torque and thrust meters, and the propeller shaft. The propeller shaft extends through the streamlined body and cylindrical extension with the propeller under test keyed to the end of the shaft. The driving motor sits astride the vertical strut and is connected to the gear box by a vertical shaft inside the strut. The cylindrical extension houses two water lubricated journal bearings and a shaft seal. A third bronze journal is oil lubricated and is located inside the body and supports the shaft immediately forward of the torque and thrust sensing elements. The relative positions of the components are shown in Figure 1.

2.2. DESCRIPTION OF CALIBRATION SETUP

It was decided to use the 400-hp electrical dynamometer available at TMB as a generator to apply the torque load, and since its bearings were capable of resisting thrust, the thrust load was applied directly through a calibrated ring gage to the tail of the 35-hp dynamometer. A parallel motion system consisting of four stilt-like legs supported the 35-hp unit so as to align its shaft with the shafting of the dynamometers. This device allowed the 35-hp dynamometer to be moved axially under thrust load. See Figure 2 for the schematic arrangement. The torque load applied by the 400-hp generator was obtained by multiplying the length of the moment arm by the Toledo scale reading.

The shafts of the loading generator and the 35-hp dynamometer were accurately aligned in order to eliminate additional friction losses in the shaft bearing. Alignment was facilitated by the inclusion of adjusting components in the supporting bases. The pivots incorporated self-aligning ball bearings.

3. PROCEDURE

3.1. THE EFFECT OF THRUST UPON TORQUE

The words "tension" and "compression" as used hereinafter refer to shaft thrust. "Tension" refers to thrust which produces tensile stresses in the shaft. "Compression" refers to thrust which produces compression stresses in the shaft.

To determine the effect of thrust upon torque, a series of three tests was made. During each test run, the speed was held constant while the torque load was varied in increments to a maximum load. The first run was made with zero thrust load. The test was repeated for the second run except that a constant load of 700 pounds compression was applied while the torque was varied through the same range. The test was repeated for the third run except that the compression load was reversed to tension. The tests for the three torque curves were conducted in identical fashion except for thrust conditions, and therefore were compared to determine the effect of thrust upon torque.

3.2. THE EFFECT OF TORQUE UPON THRUST

To determine the effect of torque upon thrust a series of four tests was conducted. The speed was held constant during each run while the thrust was varied in increments from zero to 700 pounds. The first run was made with zero applied torque (as nearly as could be read on Toledo scale) over a range of compression loads. The test was repeated for the second run except that a constant load of high torque was applied while the thrust compression load was varied through the same range. The third run was made identical to the first run, and the fourth run was identical to the second run except that the compression load was reversed to tension. The compression curve with zero torque was compared with the compression curve of high torque to determine the effect of torque upon thrust. Comparisons were also made with the tension curves.

3.3. TESTS REPEATED AND MISCELLANEOUS

The interaction effects were investigated at 500, 1000, 1400, and 1750 rpm, and the direction of rotation was reversed thereby including both senses of torque and thrust.

The maximum values of applied torque were limited during the calibration due to excessive heating of the drive motor of the 35-hp dynamometer. The condition was aggravated by the length of time required to adjust the equipment to the desired loads of torque and thrust.

4. RESULTS

Four sets of curves were drawn from the test data. Figures 3 and 4 are torque calibration curves and indicate the effect of thrust upon torque while Figures 5 and 6 are thrust calibration curves indicating the effect of torque upon thrust. All the curves are not presented here since they fall along the curves shown and are omitted in the interests of legibility. Although the curves shown are representative of the main mass of data, they were chosen to indicate interaction effects at the extreme conditions of loading and rpm. All the data recorded during the calibration are bound into the copy of the report retained by the Mechanical Engineering Division.

5. CONCLUSIONS

5.1. INTERACTIONS AND SPEED EFFECTS

It is evident that centrifugal force has an effect upon the elastic elements. This effect manifests itself in the no-load change of torque and thrust indicator readings when the rpm is changed. However, the dynamic calibration data which were recorded at the various speeds indicate that the elastic elements do not experience a change in sensitivity since the family of torque and thrust curves are parallel. The parallel curves also indicate the absence of interaction effects between torque and thrust.

5.2. SIGNIFICANCE OF CURVE SPREAD

The family of curves, both torque and thrust, are spaced close together. This condition minimizes the introduction of an error which would occur had the spread between curves been large. Such a condition would indicate that the no-load frictions were affected by torque and thrust loads, and therefore if used directly to obtain net indicator readings would result in inaccurate determination of the applied loads.

6. RECOMMENDATIONS

6.1. FUTURE CALIBRATIONS

Future calibrations should be made statically and with the added accuracy obtained with dead weights. The thrust calibrations should be obtained with sensing elements in place in the dynamometer body so as to include the effect of the seal. The torque calibration, however, will require that the sensing elements be removed and placed in the static calibration stand unless bearing and seal friction is very small or can be vibrated out.

6.2. SENSITIVITY OF INDICATORS

While balancing the magnigages throughout the entire range of load and speed, the indicators will respond with a sensitivity that is essentially constant. Slight losses can go undetected without effect upon the balance point, while large losses in sensitivity will lead to spurious readings, and should be investigated.

During calibration, occasional loss of sensitivity was experienced. This condition was remedied by sanding of the torque and thrust meter slip rings after which the test was rerun. Subsequent to the calibration reported here the brush riggings were redesigned. No loss of sensitivity has been experienced since the modification.

7. REFERENCES

1. 35-hp Propeller Dynamometer Calibration Gear, Drawing Number E-450-1.

2. Memorandum (223:GLS:mlb) dtd 13 Jun 1951, Program for Dynamic Calibration of 35-hp Dynamometer.

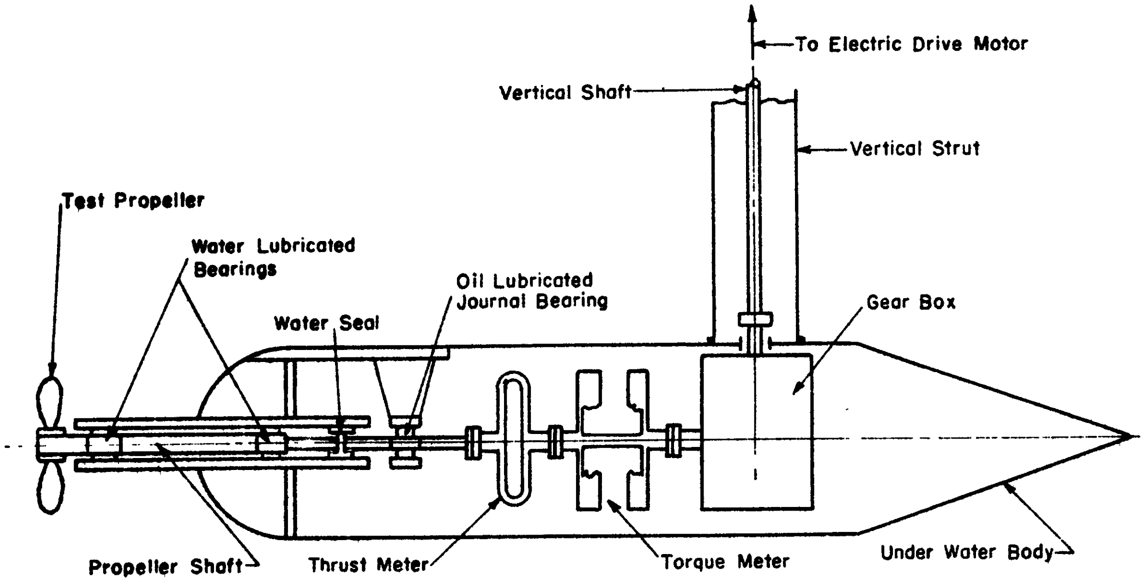

Figure 1 - 35-hp Propulsion Dynamometer

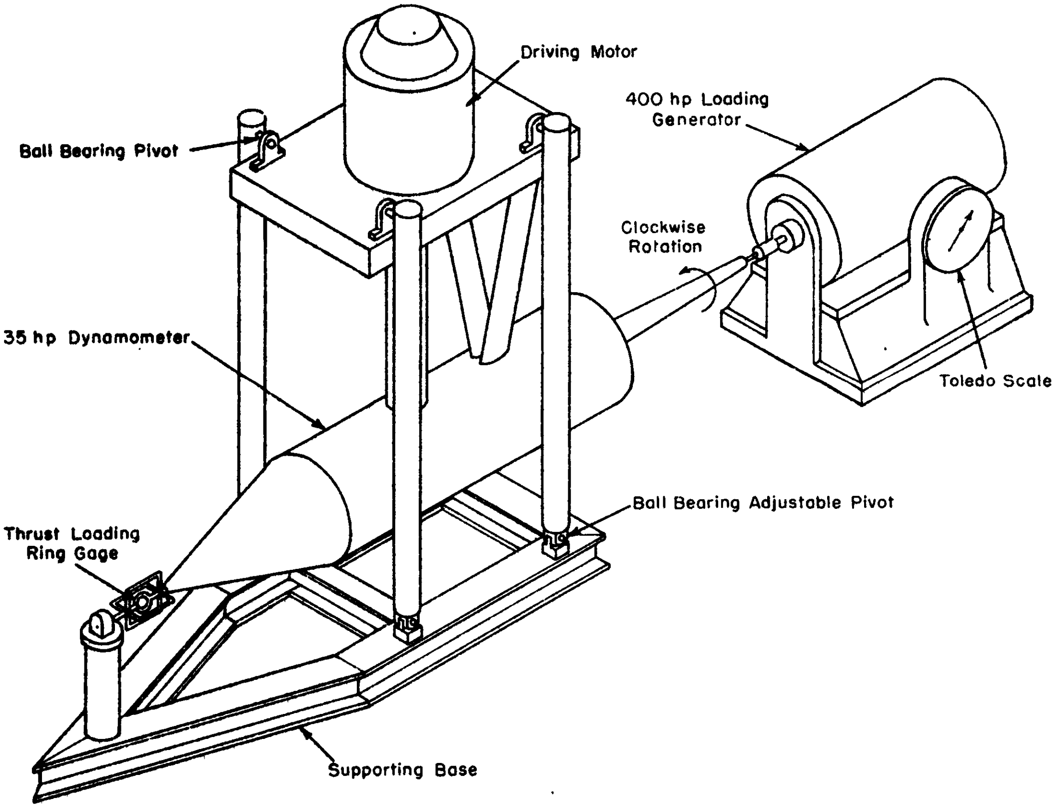

Figure 2 - Dynamic Calibration Setup

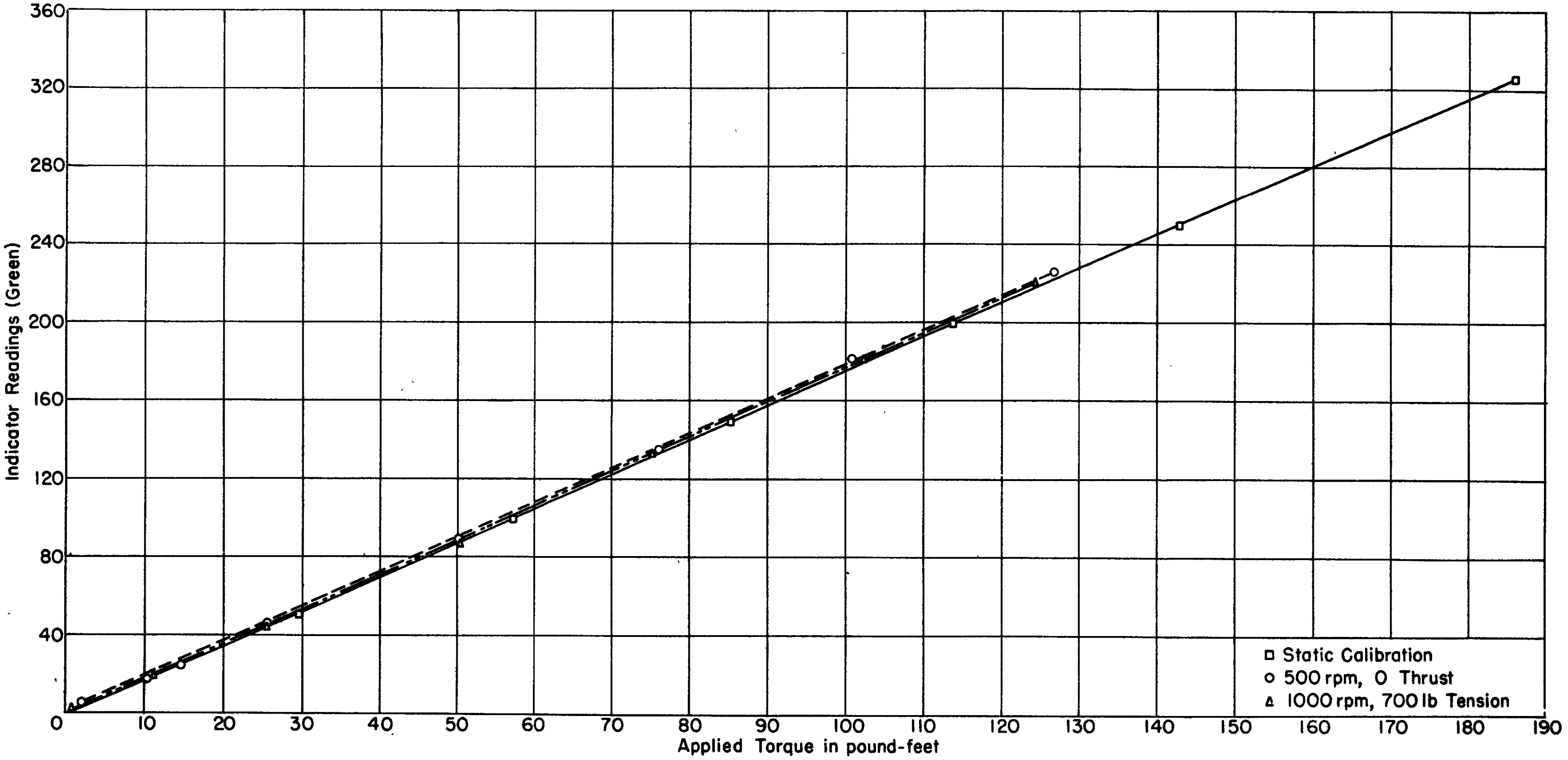

Figure 3 - Torque Calibration Curve, Clockwise Rotation

Colors are given to show the color of the indicator used and serve to differentiate between the several different indicators.

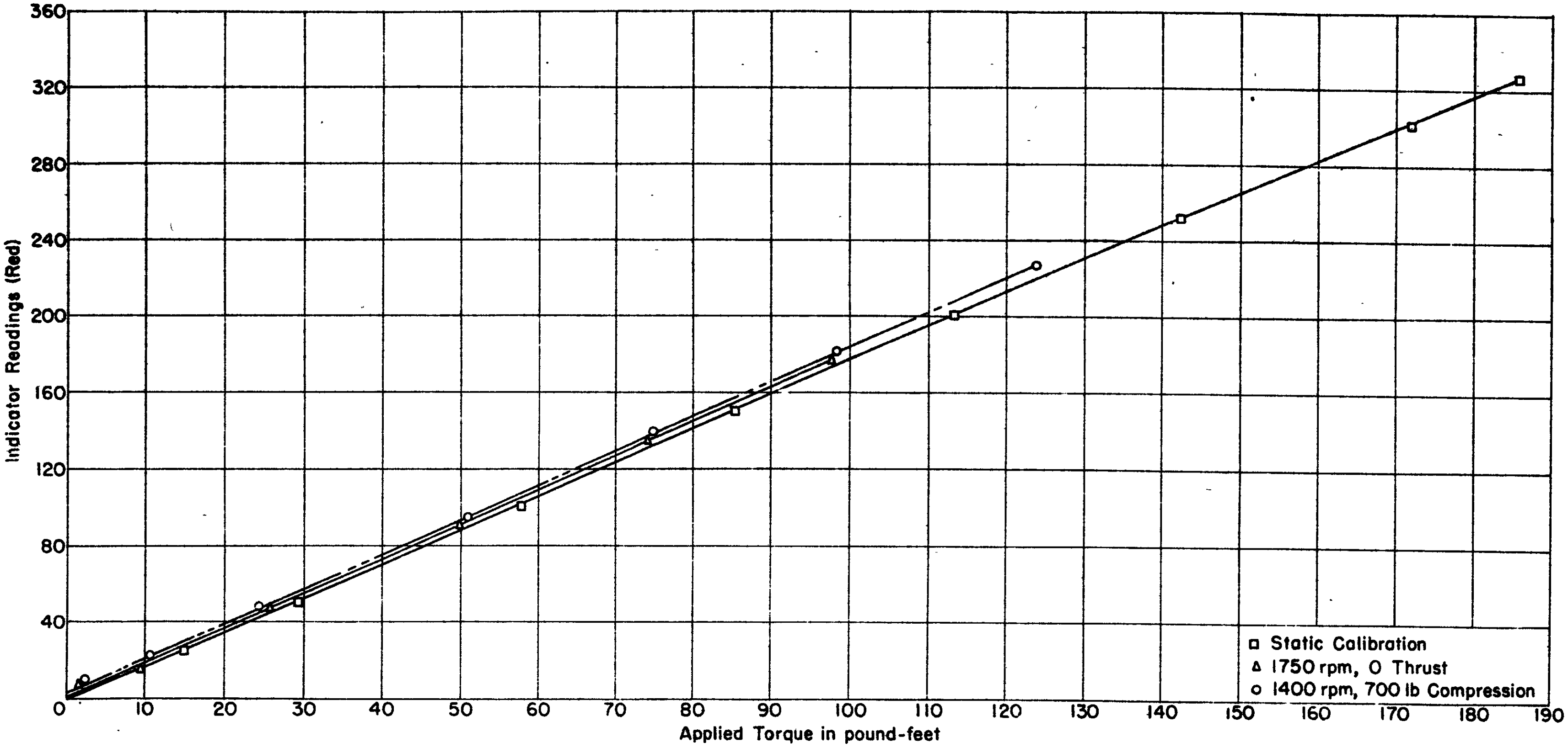

Figure 4 - Torque Calibration Curve, Counterclockwise Rotation

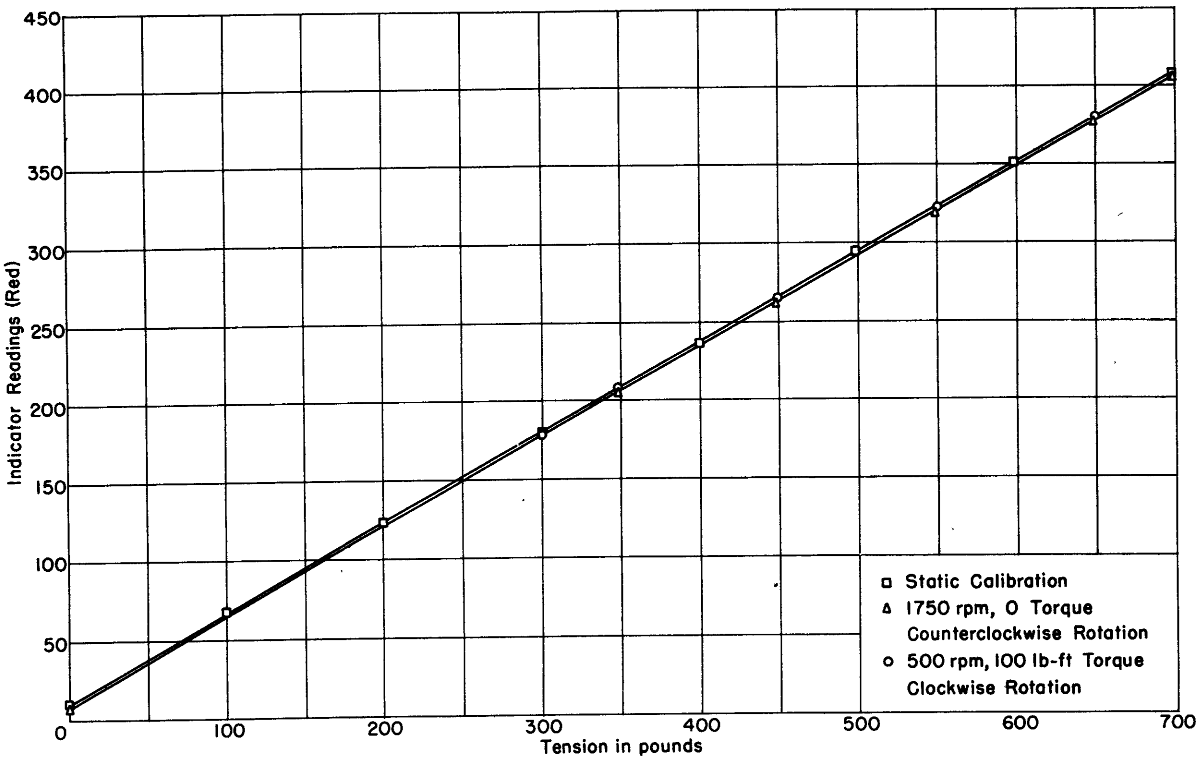

Figure 5 - Thrust Calibration Curve (Tension)

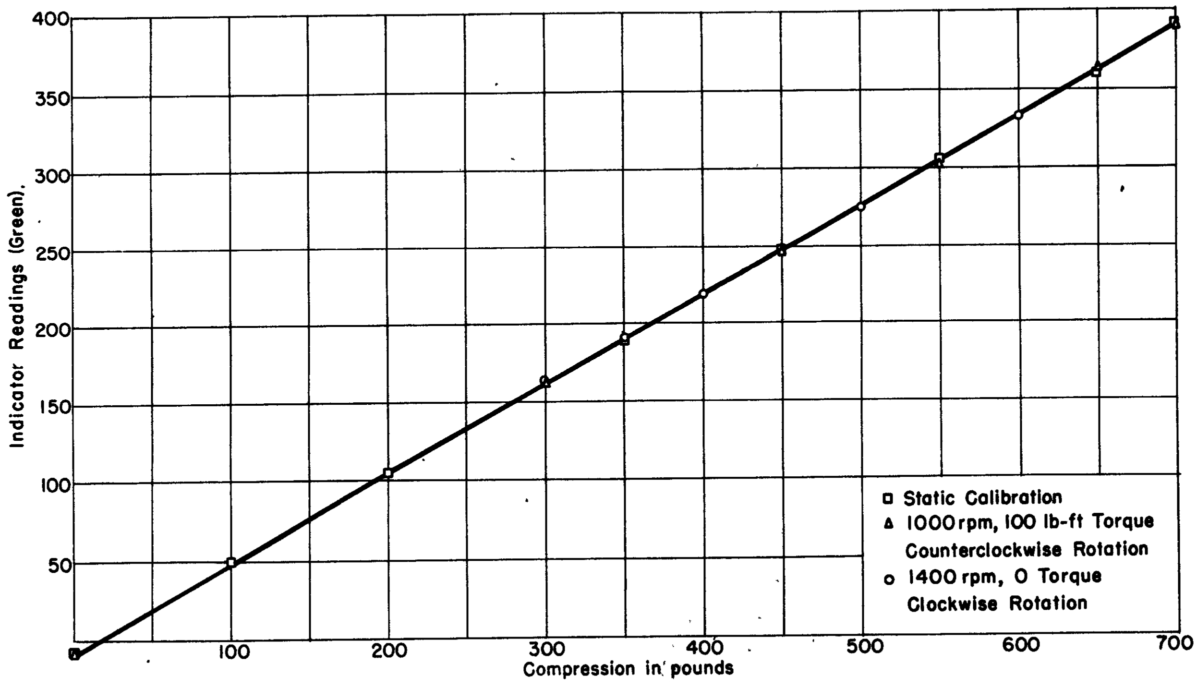

Figure 6 - Thrust Calibration Curve (Compression)

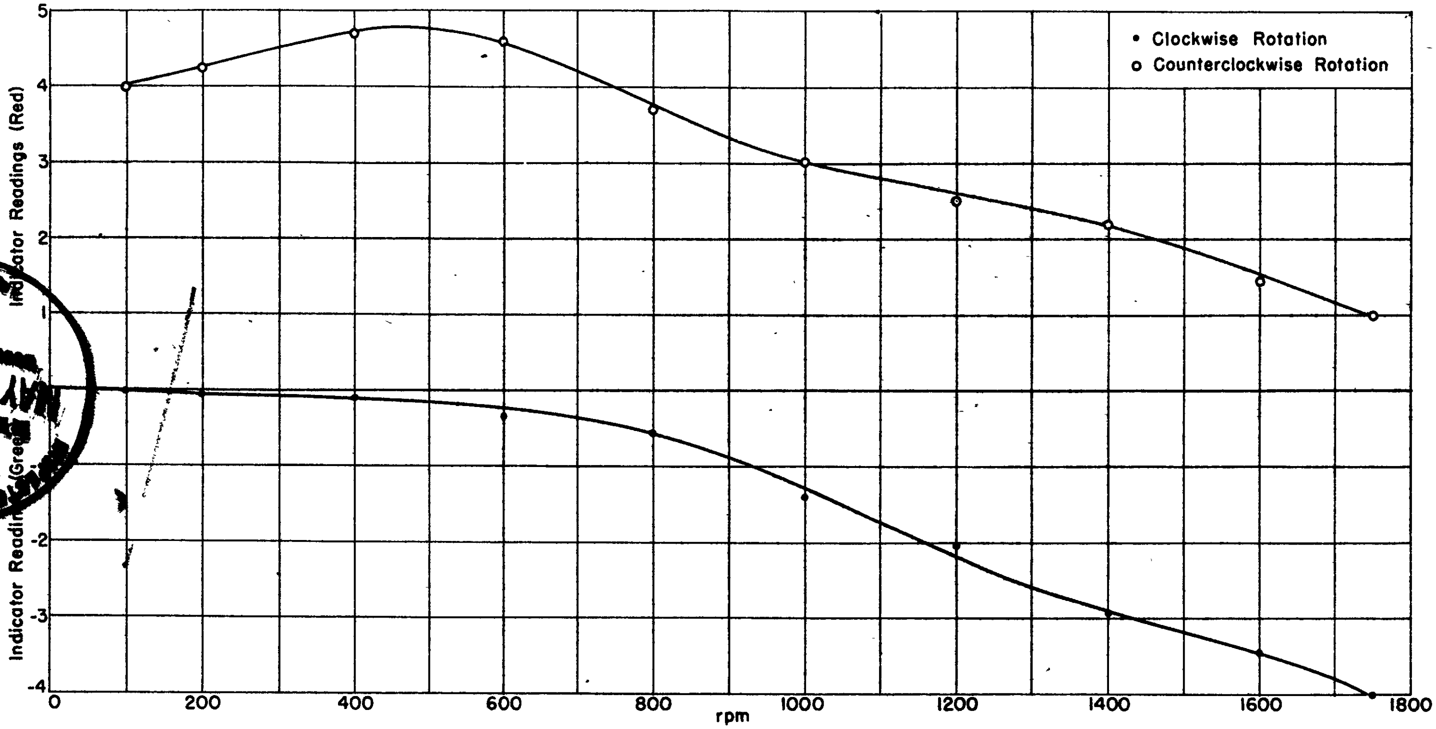

Figure 7 - Torque No-Load Curve

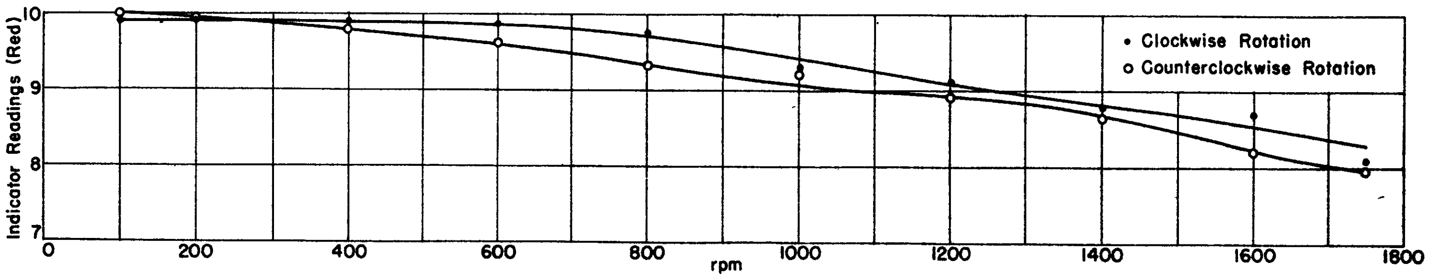

Figure 8 - Thrust No-Load Curve

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