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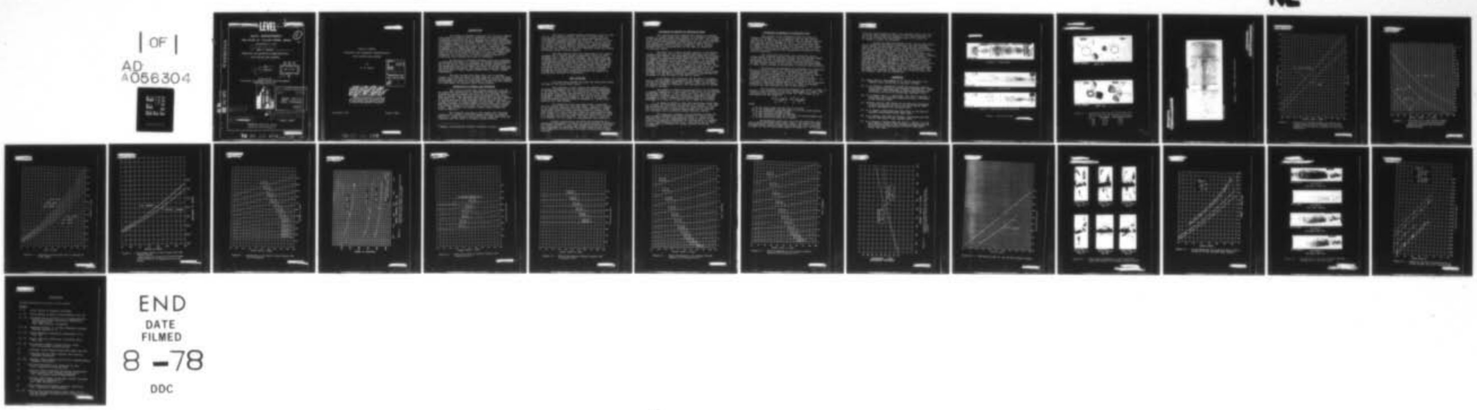

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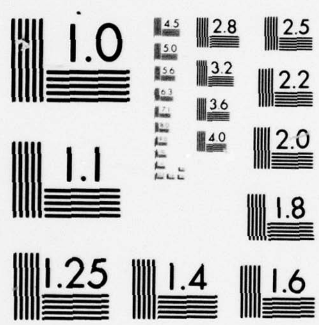

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NAVY DEPARTMENT

THE DAVID W. TAYLOR MODEL BASIN

WASHINGTON 7, D.C.

(6)

MARK 41 TORPEDO

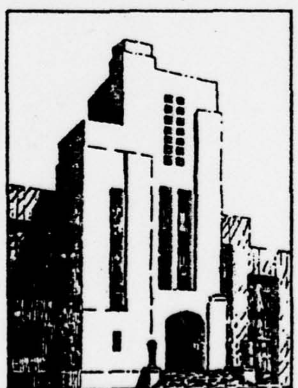
RESISTANCE AND PROPULSION CHARACTERISTICS

WITH VARIOUS BODY LENGTHS ;

By

(10) H. A. Eggers

Prepared for
The Bureau of Ordnance Under Task Assignment
DTMB-Re6a-220-21-51



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Report C-526

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MARK 41 TORPEDO

RESISTANCE AND PROPULSION CHARACTERISTICS WITH VARIOUS BODY LENGTHS

By

H. A. Eggers

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INTRODUCTION

The Bureau of Ordnance requested (1)* the David Taylor Model Basin to conduct tests to determine the resistance and propulsion characteristics of a Mark 41 type torpedo assembled successively with five different lengths of parallel middle body. The primary purpose of the tests was to provide shaft horsepower and propeller RPM data which could be used to evaluate the performance of a chemically fueled internal combustion engine designated as the "Ranol Engine". This engine was designed and built by the Fairchild Engine Division (2) as a "packaged" power plant for use in the Mark 35 and Mark 41 torpedoes. However, because of its versatility, it could be readily adapted to propelling other lengths and sizes of torpedoes.

In addition to the main program, tests were conducted to determine the effect on resistance of surface discontinuities and of the shroud ring; to determine the torque unbalance of the propellers; and to determine the effect of exhaust gases on the propeller performance. The exhaust gas tests were conducted only on a Mark 35 type torpedo equipped with a "Ranol" engine compartment.

The data derived from these tests are of general interest to torpedo designers in that they can be used for basic design studies as well as for modifications of existing torpedoes. Consequently, an effort has been made to present the test results in a form which can usefully serve these purposes.

DESCRIPTION OF TORPEDO AND PROPELLERS

The various torpedo body lengths which were used for the tests were produced by the insertion of different lengths of cylindrical section between the nose and tail sections of a Mark 41 torpedo which had been tested previously at the Taylor Model Basin (3). The shortest body tested had a parallel section 50 inches long which when combined with the 22-inch nose and 61-inch tail gave an overall length of 133 inches. For the four remaining lengths, 23-inch parallel sections were added to produce overall lengths of 156, 179, 202, and 225 inches, respectively. The shortest and longest torpedo bodies tested are shown in Figure 1.

The component sections of the torpedo were fastened together by a system of bolts and pocket recesses as shown on Figure 1C. These recesses were covered by a thin band which was rabbetted into the shell to produce a flush surface.

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* Numbers in parentheses indicate reference on page.

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Two sets of contra-rotating propellers, Figure 2, were used in the propulsion tests. Set A is a standard pair of 4-bladed Mark 13 torpedo propellers which were manufactured from ordnance drawings TP-17103 and TP-17104. Set B is a pair of 4-bladed aluminum propellers which were previously used in the first tests of the Mark 41 torpedo (3). These propellers are defined by General Electric Drawings 501E521 and 501E522 except for the diameter of the after propeller which was reduced from 15.00 inches to 14.00 inches.

The skin exhaust tests were conducted on the torpedo equipped with a "Ranol" engine compartment, Figure 3, which replaced some of the parallel sections. This compartment was outfitted with a number of gas cylinders which were connected to an annular ring grooved into the outside of the shell. The ring was covered by a perforated band for diffusing the gases into the surrounding fluid. A metering device, controlled by a solenoid valve, was provided such that, with a pressure of 800 psi in the cylinders, a quantity of flow was produced through the exhaust band which approximated the quantity of gaseous waste products of combustion.

TEST APPARATUS

The tests were carried out using the high-speed towing carriage at the Taylor Model Basin.

The resistance of the torpedo was measured with a resistance dynamometer secured within the forward compartment of the torpedo, Figure 1A. The torpedo was further supported by an after strut which was fastened to it by a ball bearing slide which allowed the torpedo to move freely in an axial direction. With this arrangement, the drag of the torpedo could be measured directly with an accuracy of 1 pound over a range of 0 to 1000 pounds.

The propulsion tests were made using a converted Mark 26 torpedo motor for the power plant. The motor consists of two identical armatures and field coils placed in a single frame which permits counter rotating propeller studies to be made either with equal propeller torque or equal propeller RPM. Each armature is capable of delivering 300 pound-feet of torque at a maximum speed of 3000 RPM. The tare value of torque for each armature for this power is approximately one pound-foot.

Before installation, the motor was calibrated in a cradle-type dynamometer to obtain the current-torque relationship. The torque required to drive each propeller during the test was thus determined by measuring the current input to each motor. After completion of the tests, the motor calibration was again verified.

DISCUSSION OF RESULTS OF RESISTANCE TESTS

The resistance data obtained from towing the various lengths of torpedo bodies were reduced to resistance coefficients by the methods described in References (4) and (5). The average value of residual-resistance coefficient, C_r, for each particular body length, as determined from the variable speed data, are plotted against torpedo length on Figure 5. The C_r values obtained from two previous tests on the Mark 35 torpedo (6) (7) are also shown.

The Mark 35 is similar in most respects to the Mark 41 torpedo, differing only in its slightly finer nose and overall length of 160 inches. The difference shown between the C_r values is, therefore, considered almost entirely due to the difference in surface roughness of the torpedoes. In Test 1 of the Mark 35 torpedo, there were fewer joint rings and these were machined smoother than those on the Mark 41. In Test 2 of the Mark 35, the entire forward portion of the torpedo was made out of a solid piece of paraffin wax. This wax surface was very smooth and probably represents the optimum surface finish which can be obtained from production techniques. Consequently, the C_r given for Test 2 of the Mark 35 torpedo represents a near-minimum for torpedoes of both the Mark 35 and Mark 41 types.

At 30 knots, the resistance for the Mark 35 torpedo, Test 2, was 620 pounds as compared to 700 pounds for the Mark 41 torpedo of equivalent length (160 inches). Thus, by smoothing the production Mark 41 torpedoes, the resistance will be reduced by about 11 percent.

The effect of surface discontinuities on the resistance is further exemplified by the results of the tests on the 225-inch length body, Figure 6. These curves show that, when each band was removed to expose the bolt recesses, a resistance increase amounting to about 8 percent of the normal Mark 41 resistance resulted, or a total of 40 percent when 5 bands were removed.

As shown by Figure 7, when the stabilizing shroud ring was removed, the resistance was reduced by 8 percent. This gain can be realized only in part since, for equal stability, more flat fin area would be required which would tend to increase the resistance of an operating torpedo without a shroud.

For comparison purposes, the resistances derived for equal volume prototypes are shown in Figure 9. These curves indicate that, if the length-diameter ratio is varied by the insertion of parallel middlebody, the optimum value is somewhat above a length-diameter ratio of 11. This value can be taken to apply only to torpedoes of similar surface finish and appendages.

DISCUSSION OF RESULTS OF PROPULSION TESTS

The results of the propulsion tests are given on Figures 10 through 13. It is observed that the RPM (before cavitation) of both sets of propellers does not change appreciably for the various lengths of bodies. This indicates that the expected increase in RPM for the higher thrust loads must be offset by the increase in wake with increase of body length. As shown on Figure 14, the apparent increase in wake is also reflected in an increase in the propulsive efficiency for both sets of propellers.

The propulsive efficiency with propellers, Set B, varies almost linearly from 82.3 percent for the 130-inch length to 87.6 percent for the 230-inch length. The propulsive efficiency with Set A likewise varies linearly from 82 percent for the 130-inch length to 84.7 percent for the 180-inch length at which point, because of cavitation, it deviates from linearity.

The locus of the inception of cavitation for propellers, Set A, is shown on Figure 10. The position of this line was determined by the speed at which the RPM curve deviated from linearity as shown on Figure 15. Since the RPM curve for Set B remained linear throughout the speed range tested, it was assumed that cavitation was not present on these propellers. In order to verify the presence or lack of cavitation on the propellers, high speed photographs were obtained of the propellers operating at different speeds, Figure 16. These photographs indicate the same findings as with the RPM curves.

The particular cavitation boundary line shown on Figure 10 applies to the propellers at an axial submergence of 8 feet. The points at which cavitation would occur for other depths can be determined from the equation:

$$2g\left[\frac{h + h_a}{V^2}\right] = 2g\left[\frac{h' + h_a}{V'^2}\right]$$

where

- h is the axial depth for the test (= 8 feet),
- h_a is the atmospheric pressure head (= 33 feet, fresh water),
- h' is any arbitrary running depth,
- g is the acceleration due to gravity,
- V is the cavitation speed for the test (at 8-foot depth), and
- V' is the cavitation speed at h' depth.

The propulsion tests were run with the propellers turning at equal RPM rather than equal torque. The amount of torque unbalance which existed between the forward and after propellers is shown for the 179-inch long torpedo on Figure 17. It is seen that the torque balance of Set A was somewhat closer than that of Set B, even though the diameter of the after propeller of Set B was reduced from the designed value of 15 inches to 14 inches to remedy the unbalance.

Figure 18 shows photographs of the torpedo when either air or carbon dioxide (CO_2) is exhausted into the boundary layer through the perforated ring. Although the photographs show that quantities of air and CO_2 going through the propellers are of equal magnitude, the effect of the two gases on propulsion is quite different. In the case of the gases, the shaft torque with or without gas flowing did not change. However, as shown on Figure 19, the RPM values for Set A increased considerably with the air exhaust and only increased slightly with the CO_2 exhaust. The RPM for Set B was also increased with the air exhaust although to a lesser extent than for Set A. The CO_2 did not affect the RPM of Set B to any great extent. Since the actual exhaust gases contain considerable quantities of steam which is more soluble than CO_2, it is apparent that the effect on powering of exhausting the combustion gases into the boundary layer will be negligible.

REFERENCES

(1) BuOrd CONF ltr Reoa-BCB:jp NP 21 dtd 16 Aug 1951 with BuShips End-1 C-S75(312) 31 Aug 1951 to DTMB.

(2) A. T. Gregory, "Chemically Fueled Reciprocating Engines, Operational Experience and Potential Performance". Paper presented at Navy Symposium on Modern Hydropropulsion, California Institute of Technology, September 1951.

(3) H. A. Eggers and J. L. Beveridge, "The Mark 41 Torpedo - Resistance and Propulsion Characteristics", TMB Report C-400, February 1951.

(4) Gertler, Morton, "The Prediction of Effective Horsepower of Ships by Methods in use at the David Taylor Model Basin", TMB Report 576, December 1947.

(5) H. A. Eggers, "Resistance and Wake Tests of the Mark 37 Torpedo", TMB Report C-300, March 1950.

(6) H. A. Eggers, "The Mark 35 Torpedo - Resistance and Flow Tests", TMB Report C-381, January 1950.

(7) H. A. Eggers, "Torpedo Mark 35, Part 2 - Effect of a Sea Water Battery Scoop on the Powering Characteristics of the Torpedo for Three Angles of Pitch", TMB Report C-426, June 1951.

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Figure 1A - 133-Inch Length

Figure 1B - 225-Inch Length

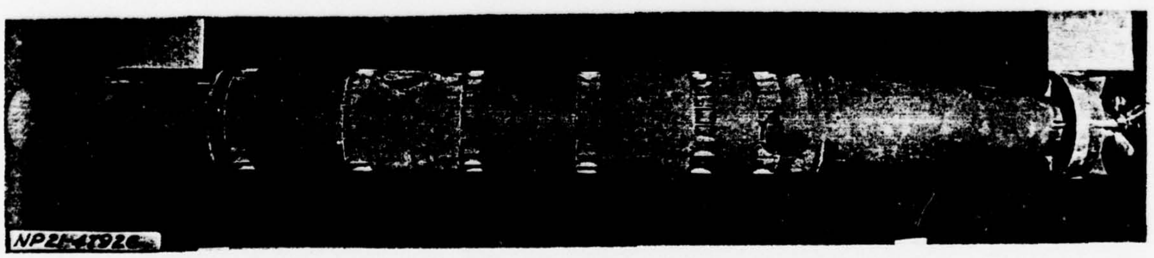

Figure 1C - 225-Inch Length with 6 Bands Removed

Figure 1 - Mark 41 Test Torpedo

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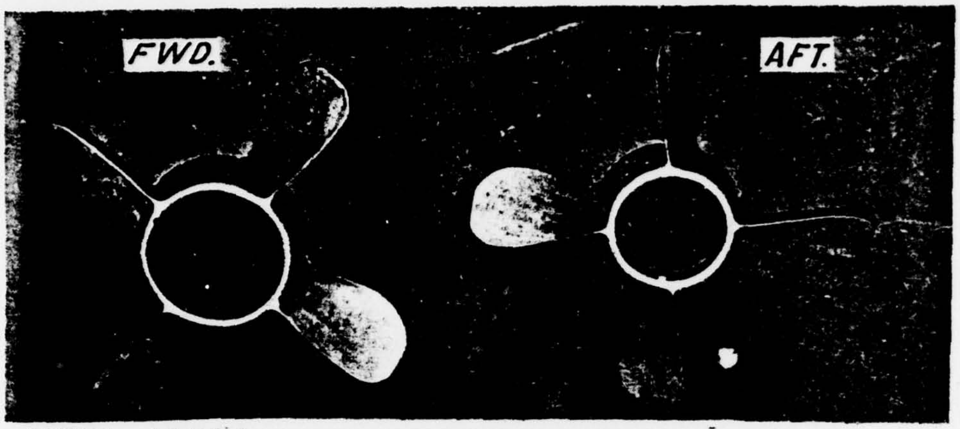

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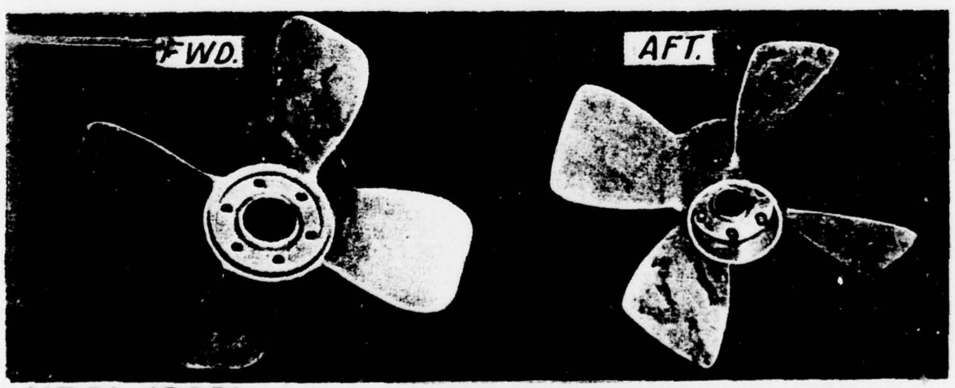

NP21-49091 SET B

Figure 2 - Propellers Used in the Propulsion Tests

The propellers have the following dimensions:-

Set		Dia. Inches	Pitch at 0.7R Inches
A	FWD	16.00	30.00
	AFT	14.375	29.50
B	FWD	15.83	24.82
	AFT	14.00	24.11

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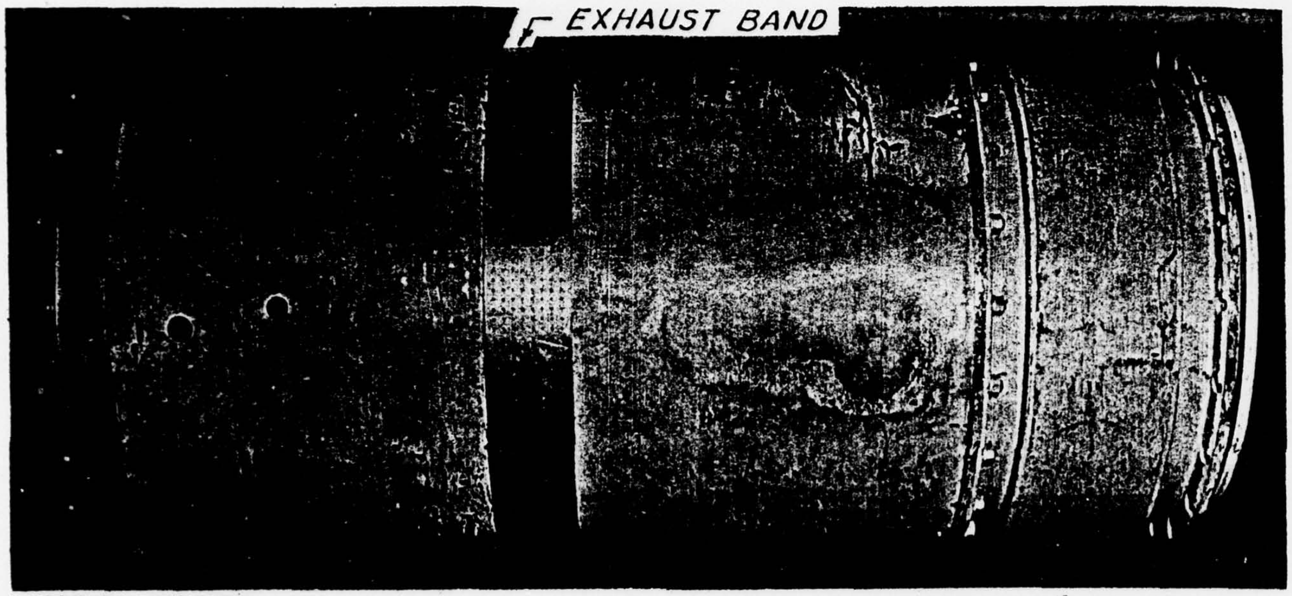

Figure 3 - "Ranol" Engine Compartment

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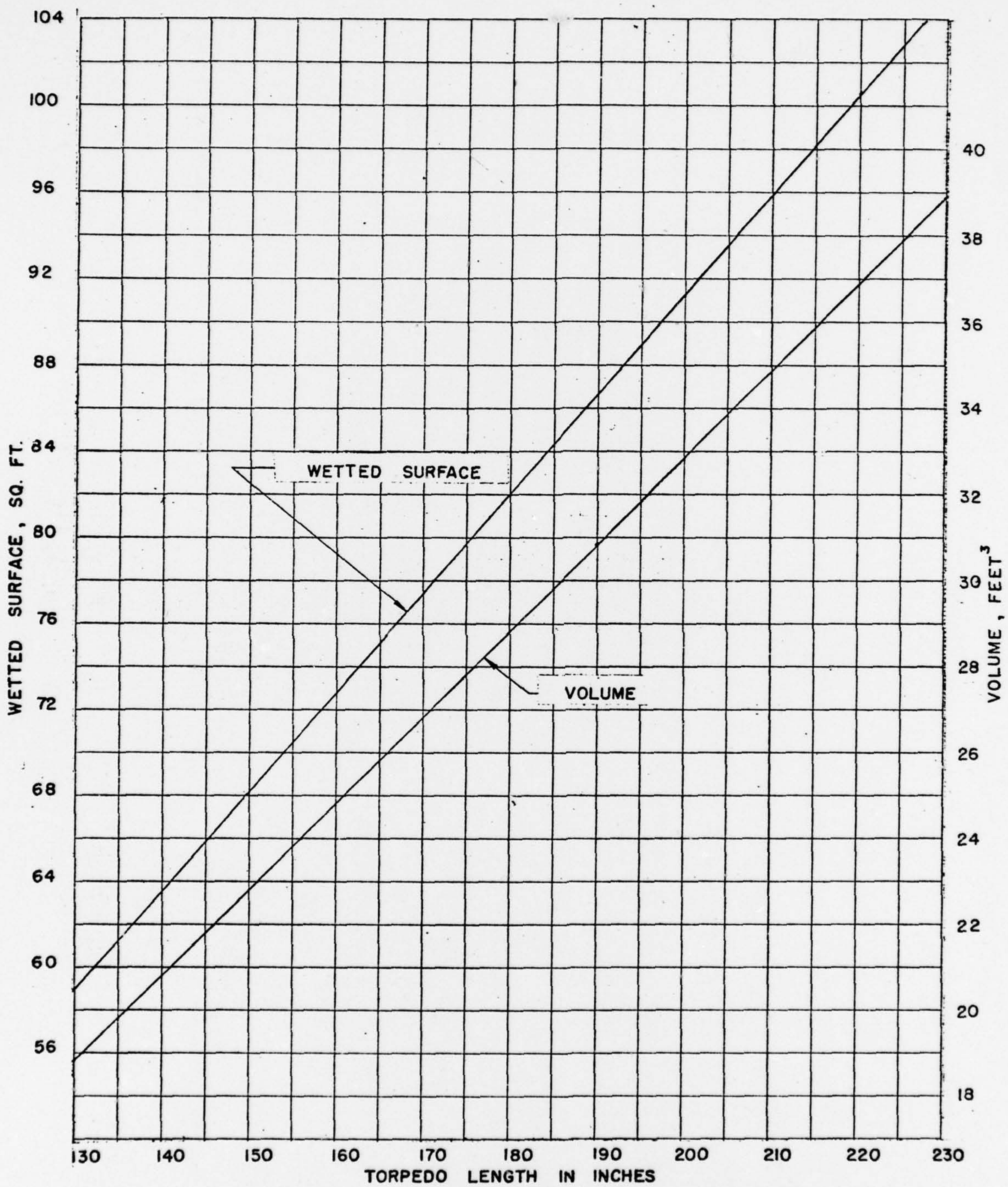

Figure 4 - Variation of Wetted Surface and Volume with Length Using the Nose, Afterbody and Control Surfaces of the Mark 41 Torpedo for the Basic Dimensions

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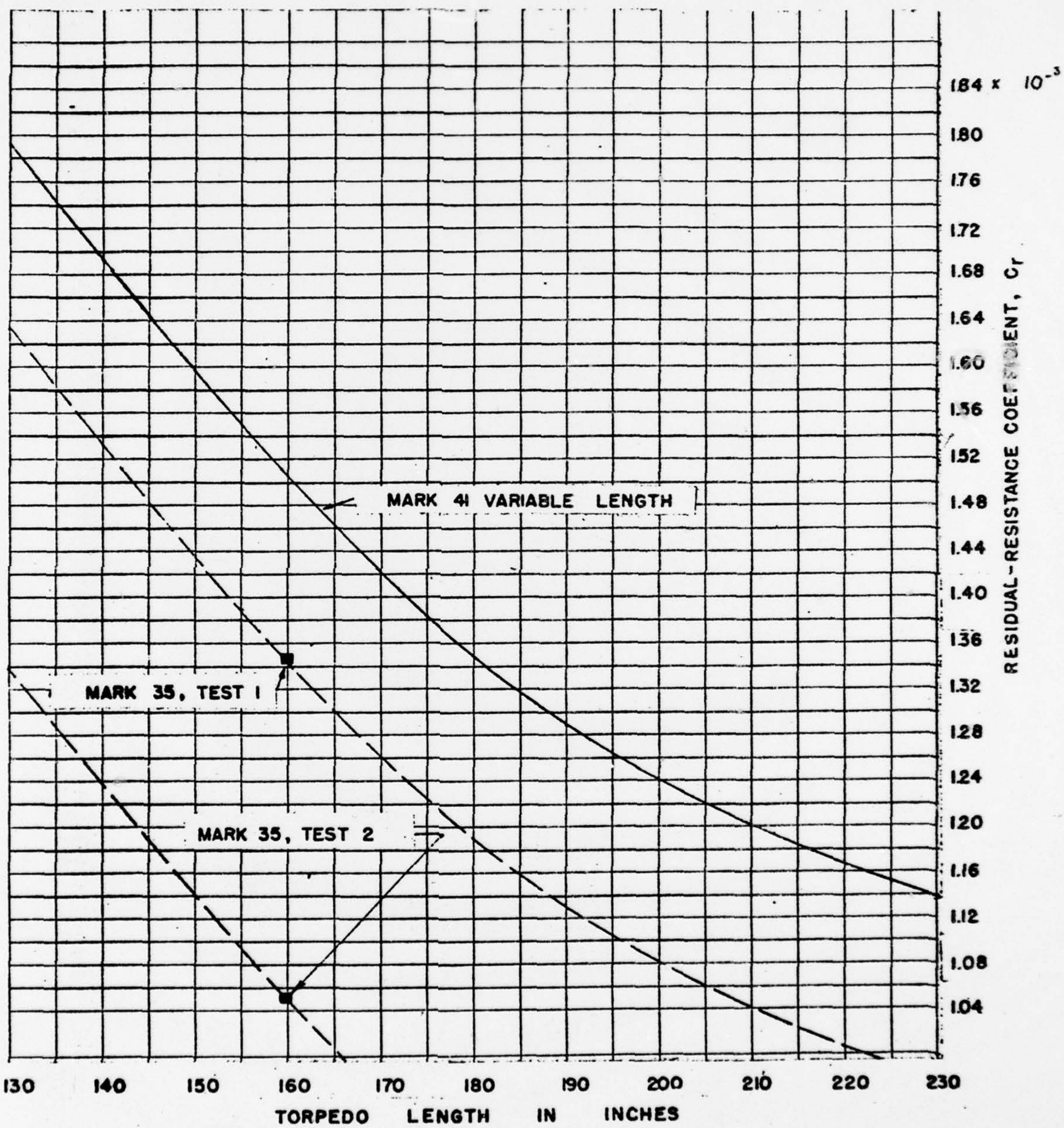

Figure 5 - Variation of C_r with Torpedo Length
The dotted lines represent C_r values for torpedoes of the Mark 41 type but having smoother surfaces.

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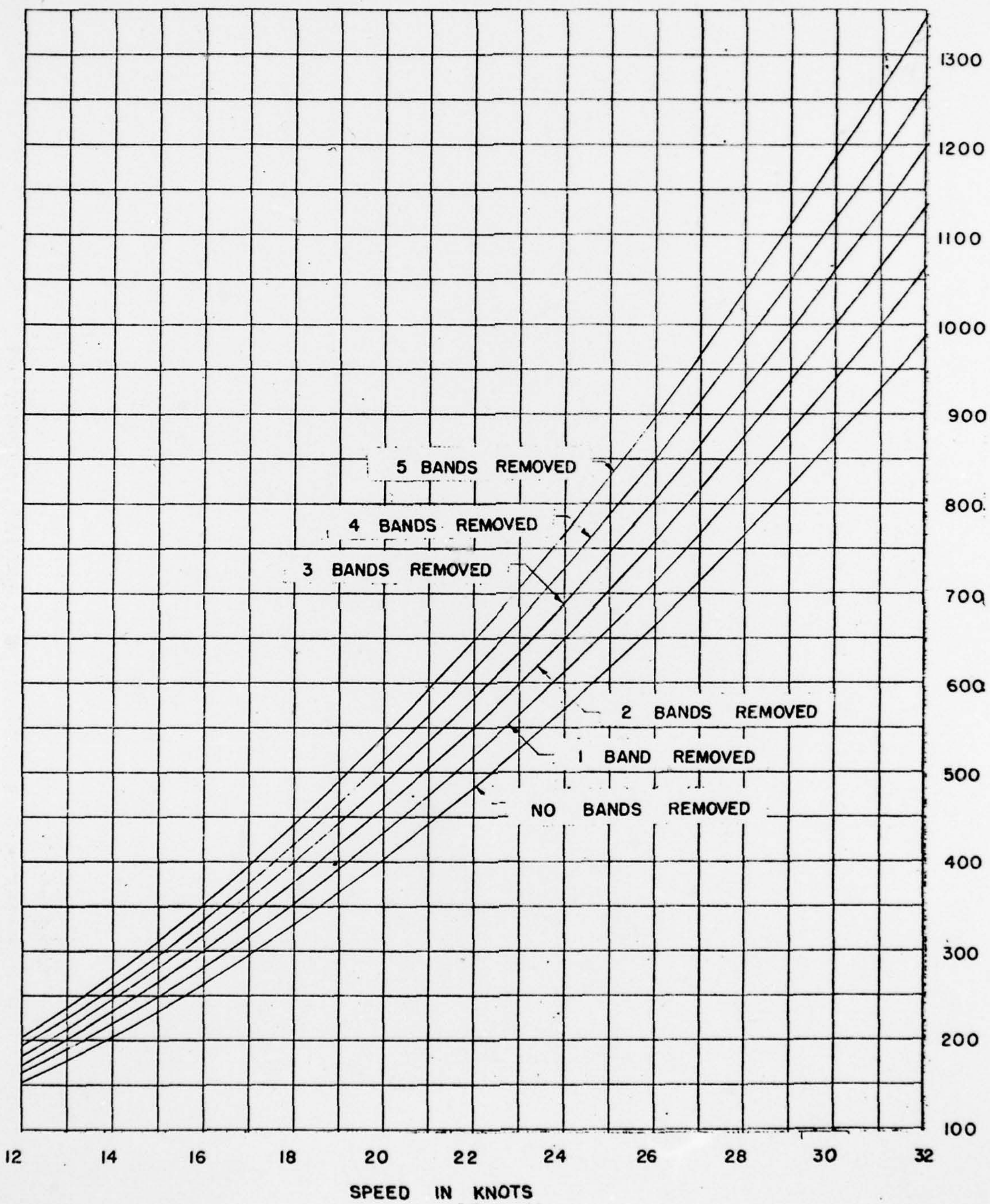

Figure 6 - Variation of Resistance Due to Removal of Cover Bands

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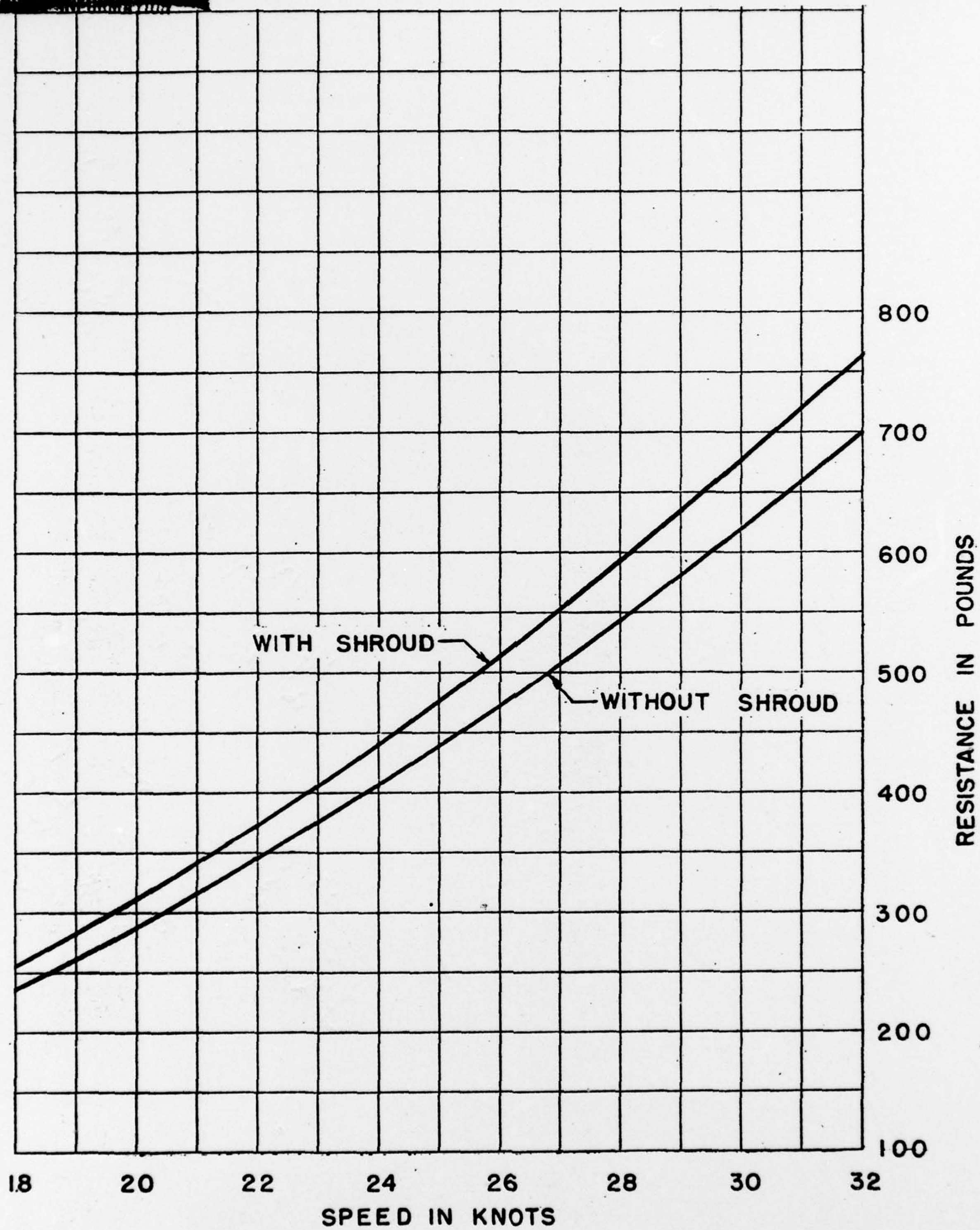

Figure 7 - Resistance Curves of the Torpedo with and without Shroud

These curves were obtained with the Ranol Engine section inserted in the parallel portion of the torpedo.

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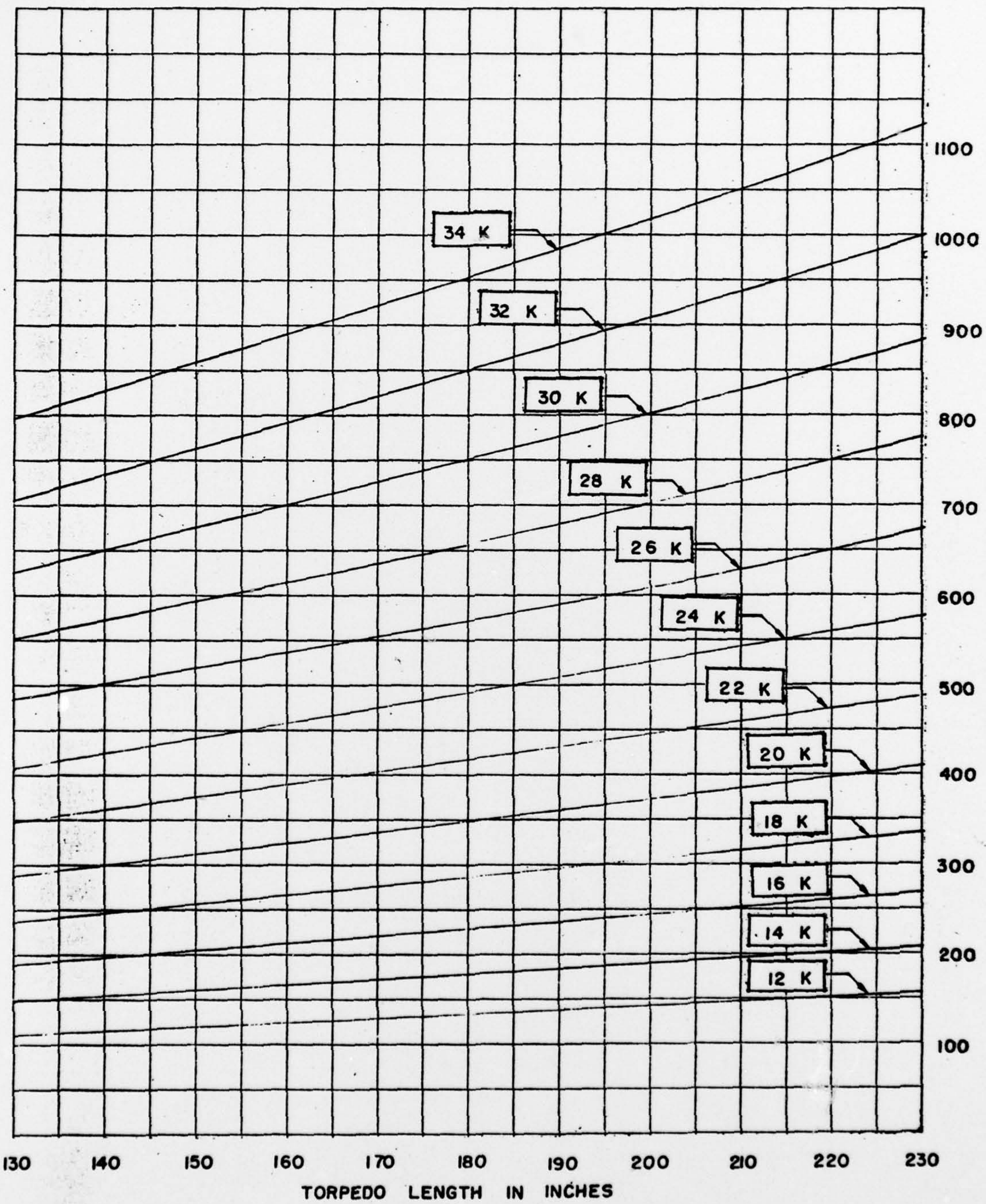

Figure 8 - Resistance of the Mark 41 Type Torpedo for Various Lengths

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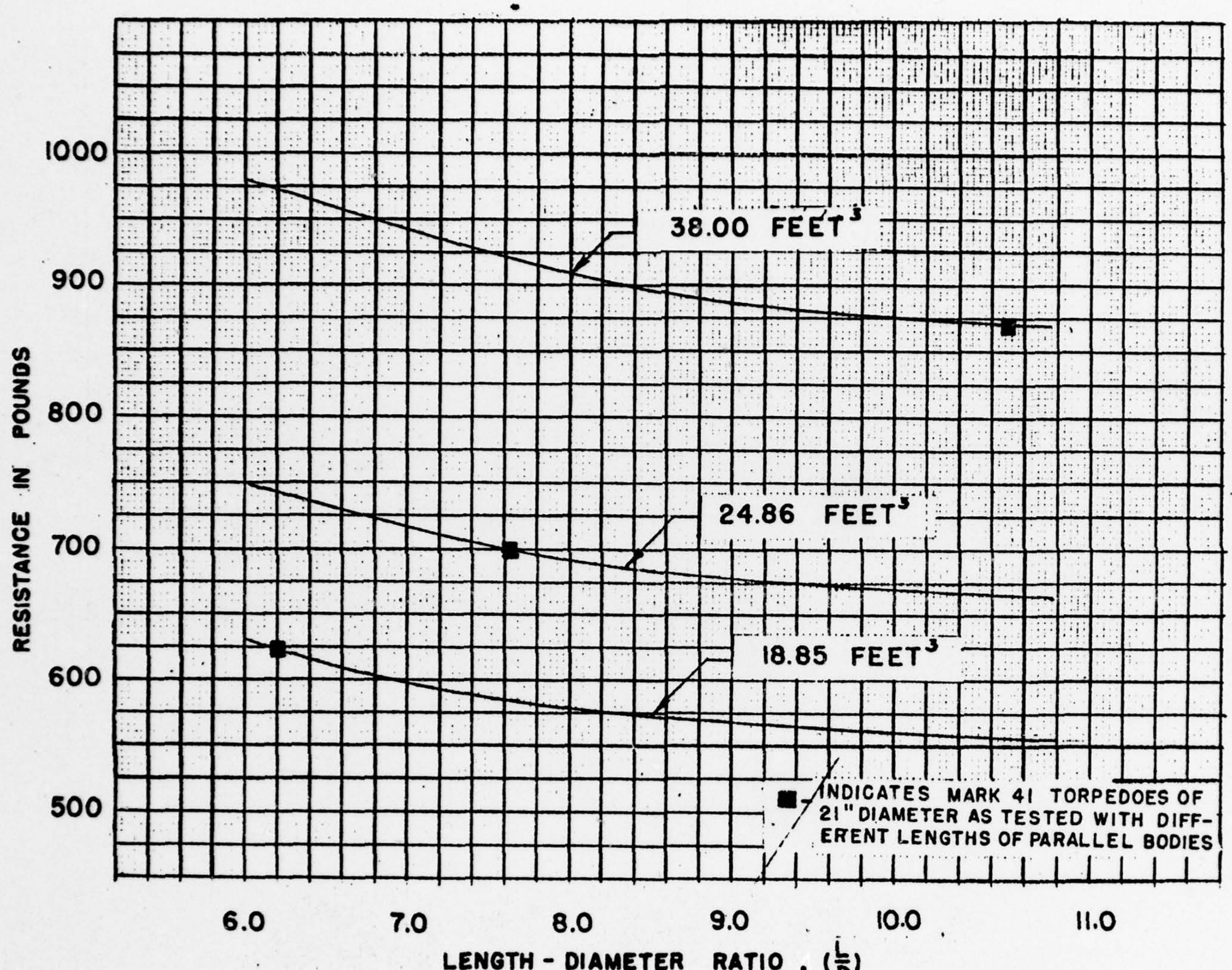

Figure 9 - Variation of Resistance with Length-Diameter Ratio for Equal Volume Prototypes

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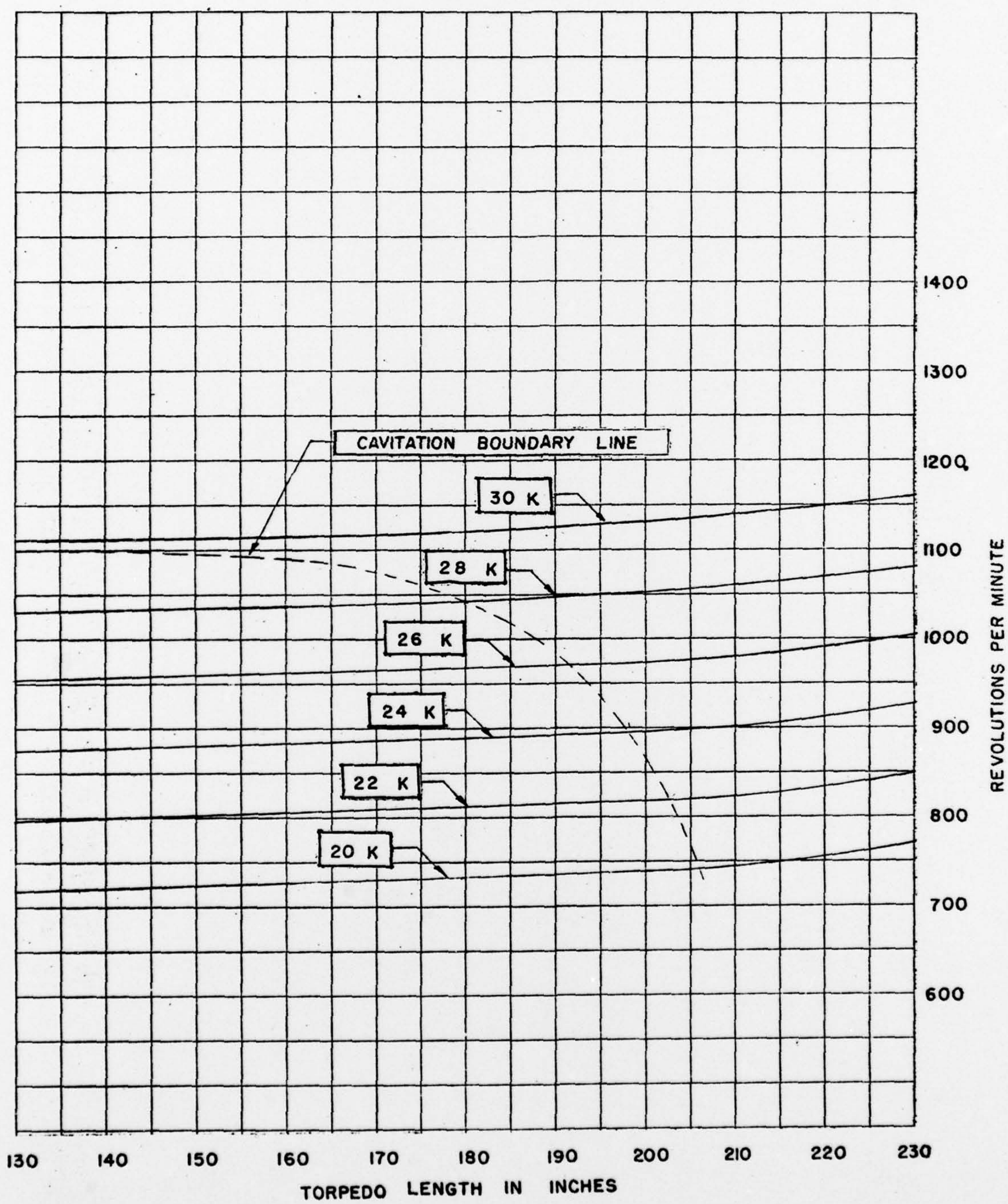

Figure 10 - RPM of the Various Torpedo Lengths with Propeller Set A

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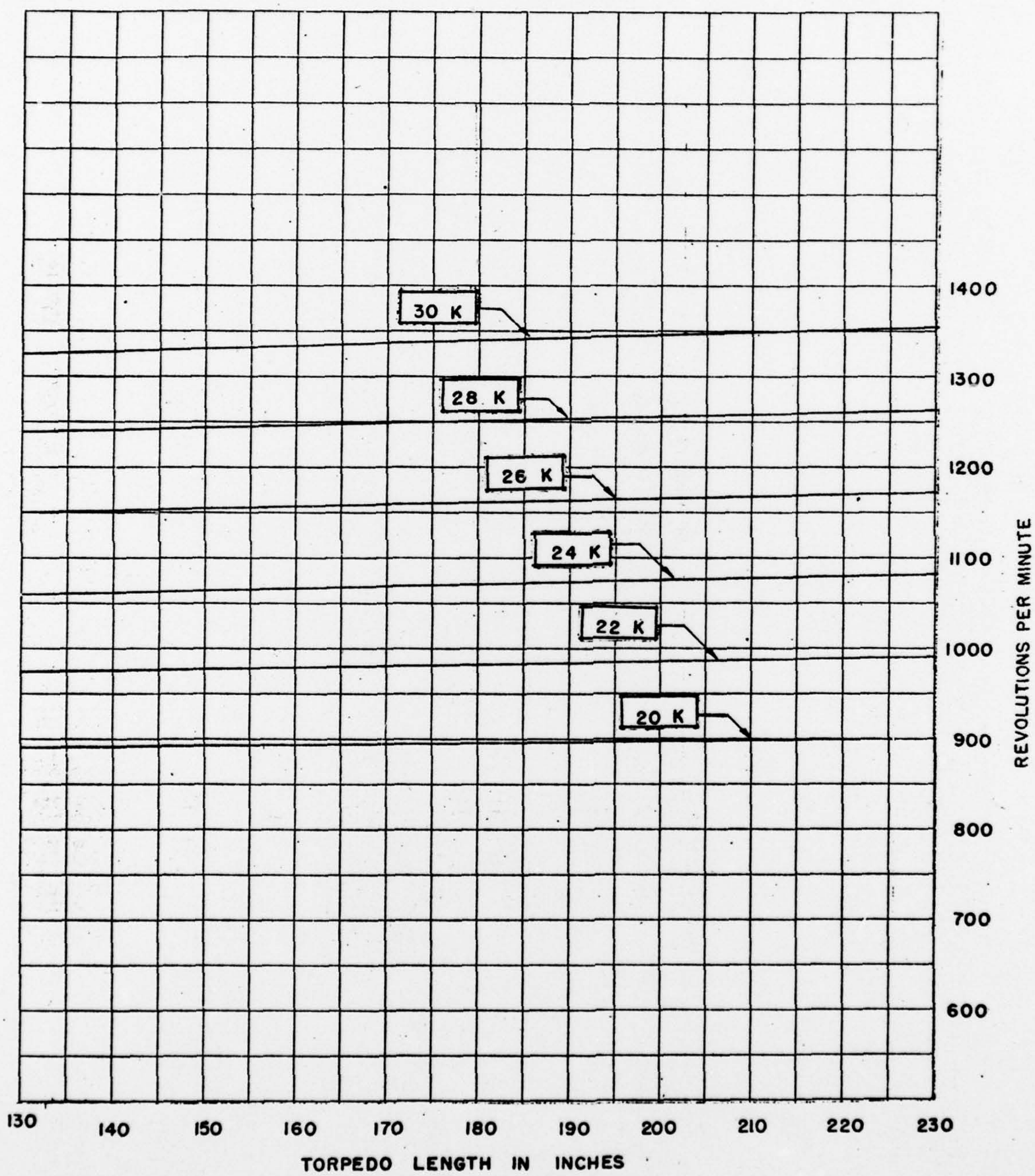

Figure 11 - RPM of the Various Torpedo Lengths with Propeller Set B

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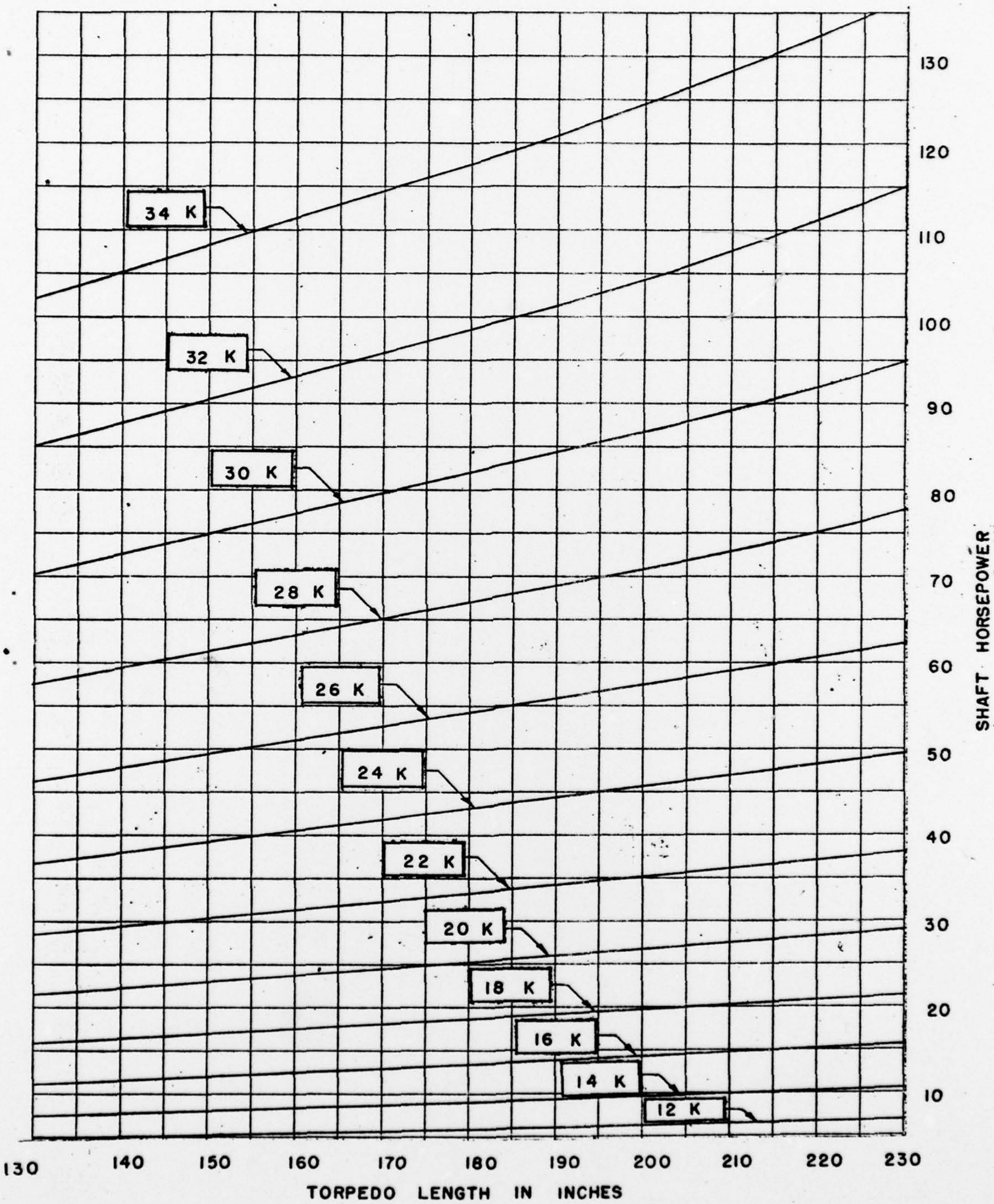

Figure 12 - Shaft Horsepower of the Various Torpedo Lengths with Propeller Set A

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[redacted]

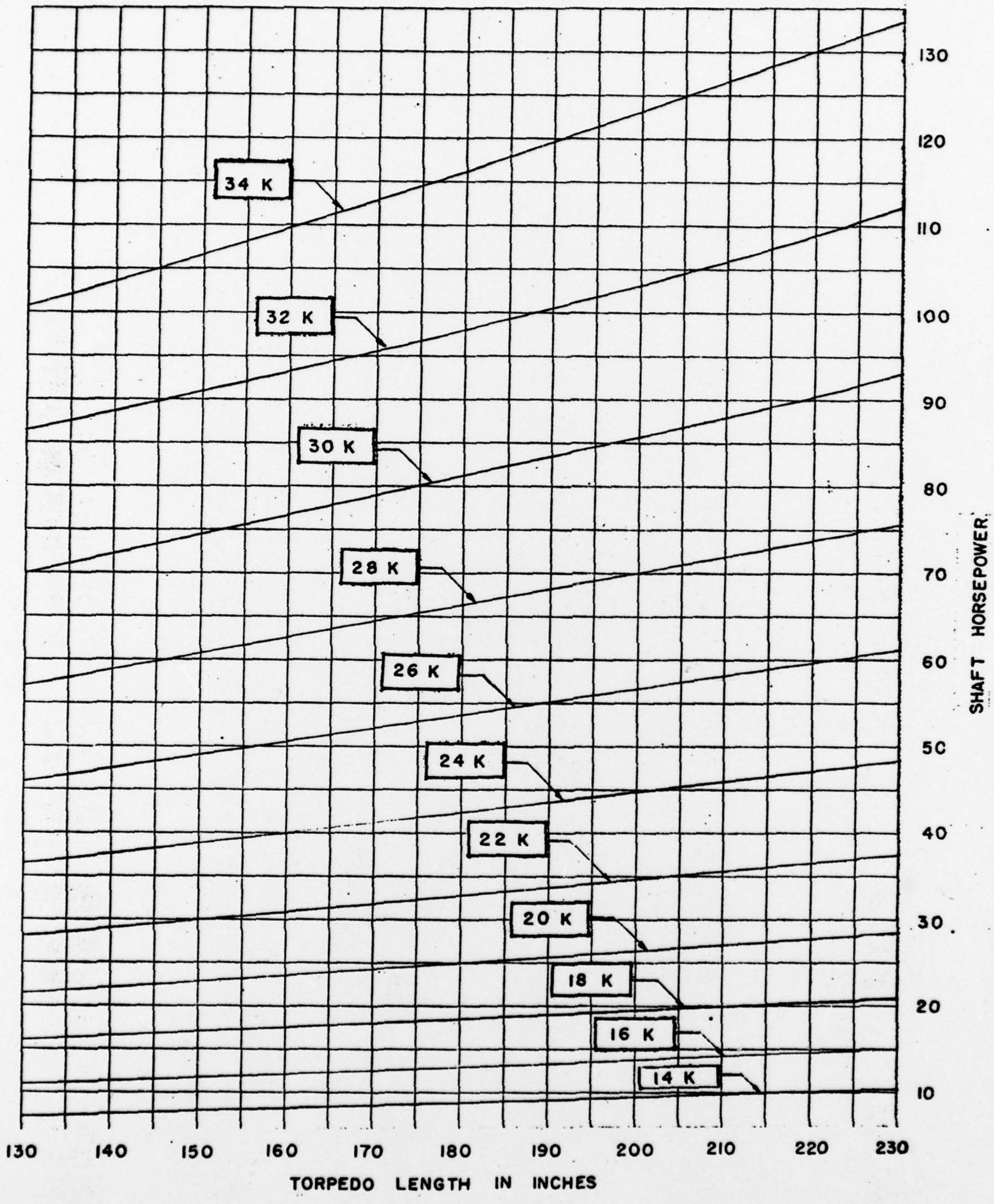

Figure 13 - Shaft Horsepower of the Various Torpedo Lengths with Propeller Set B

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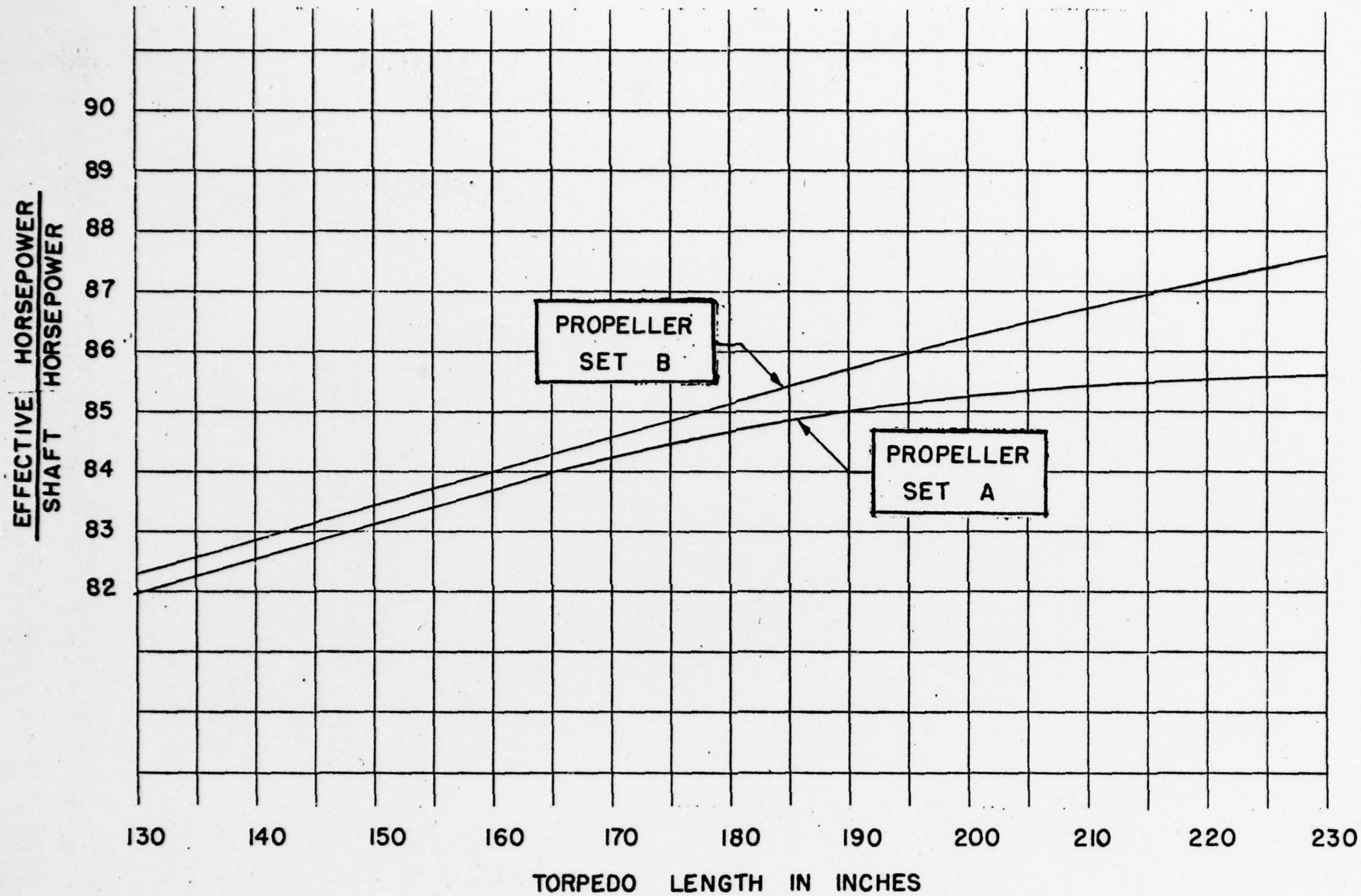

Figure 14 - Propulsive Efficiencies of the Various Torpedo Lengths Driven by Propeller Sets A and B

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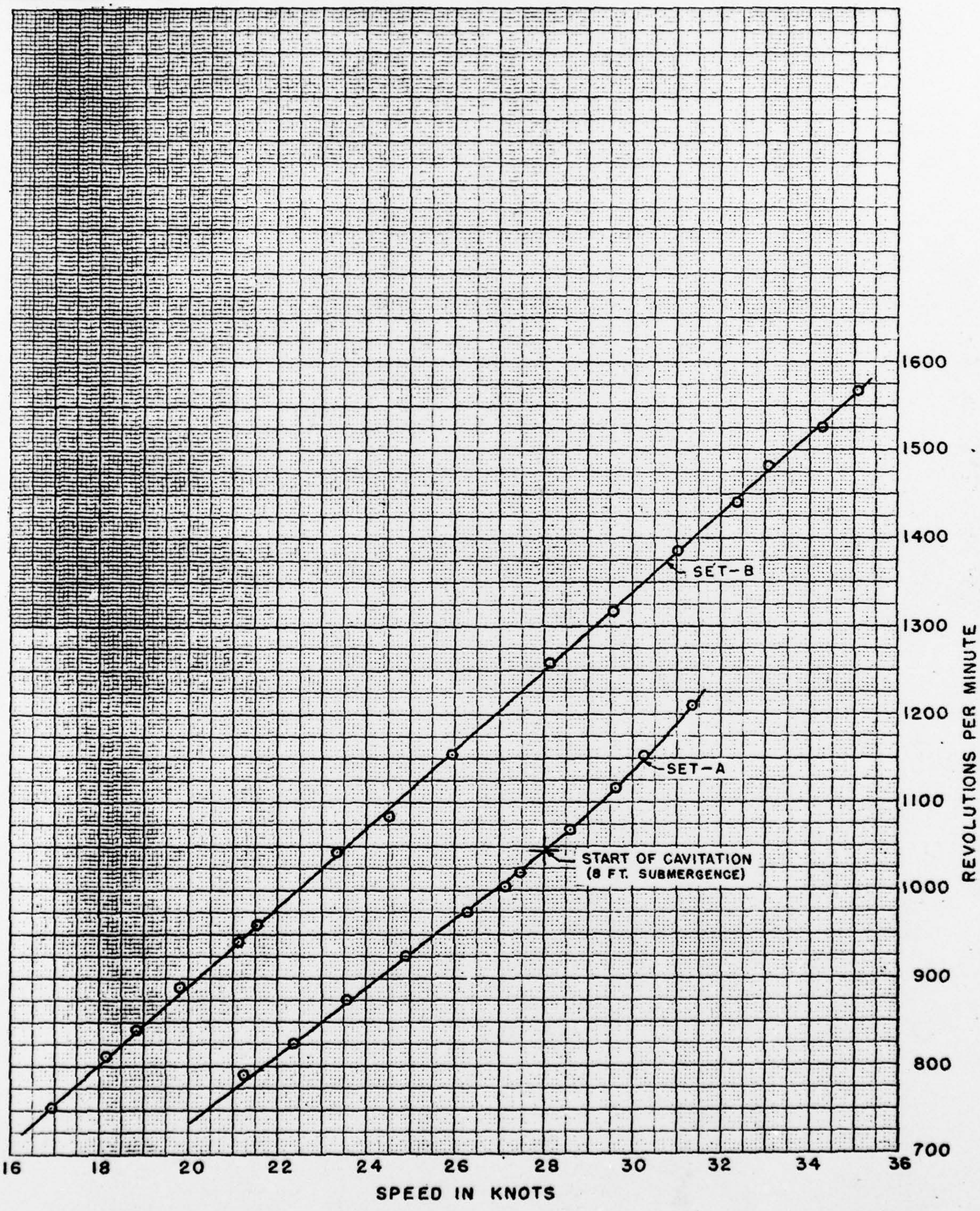

Figure 15 - RPM Versus Speed for the 179-Inch Length Torpedo

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NP21-48109
27.96 KNOTS
SET-A

NP21-48107
29.81 KNOTS
SET-A

NP21-48102
32.74 KNOTS
SET-A

NP21-48129
34.29 KNOTS
SET-A

NP21-48149
34.18 KNOTS
SET-B

NP21-48146
38.81 KNOTS
SET-B

Figure 16 - High Speed Photographs of the Propellers Operating Behind the 179-Inch Length Torpedo

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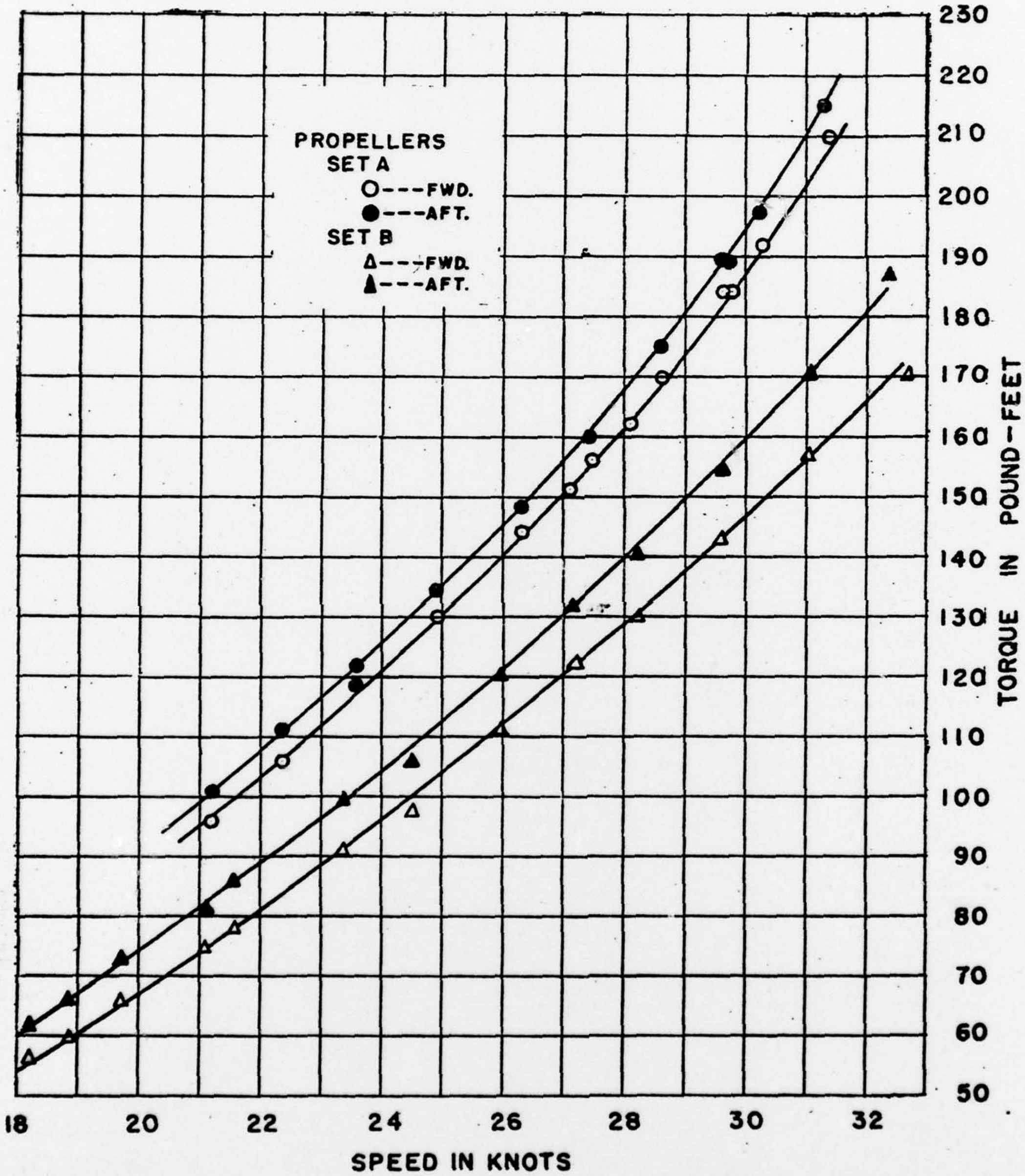

Figure 17 - Torque Unbalance for Propeller Sets A and B Installed on the 179-Inch Long Torpedo

[redacted]

NP 21-48123

28 KNOTS
CO_2 900—750 PSI

NP 21-48132

28 KNOTS
AIR 910—710 PSI

NP 21-48124

30 KNOTS
CO_2 840—650 PSI

NP 21-48134

30 KNOTS
AIR 910—750 PSI

Figure 18 - Photographs of Air and of Carbon Dioxide Exhaust in the Boundary Layer

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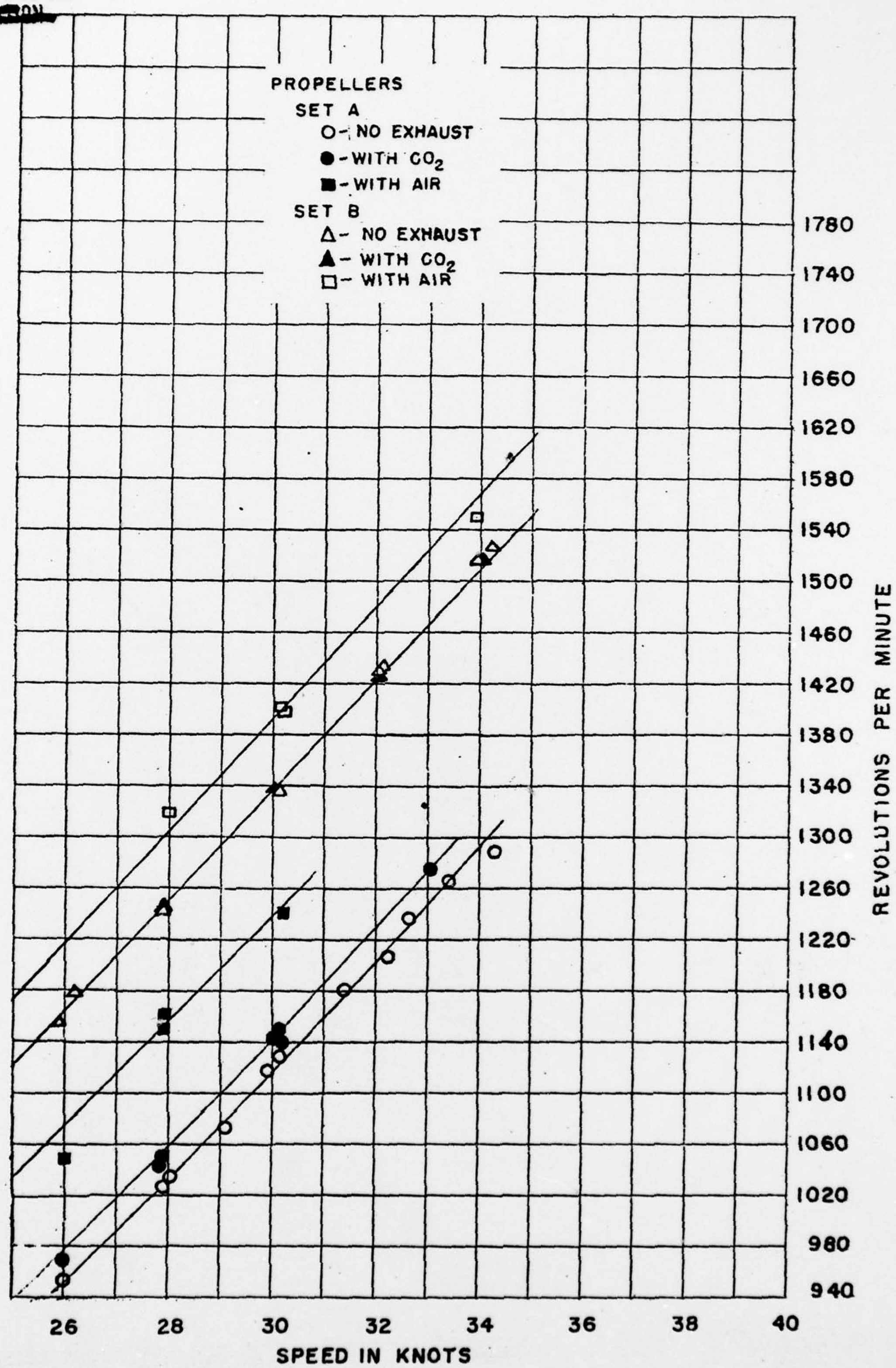

Figure 19 - Effect on the RPM of Exhausting Air or Carbon Dioxide into the Propeller Race

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