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Tests of

PARTIALLY SUBMERGED PROPELLERS OF THE SEA-SLED TYPE

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U.S. EXPERIMENTAL MODEL BASIN
Navy Yard, Washington, D.C.

April 1919

Report R-132

Tests of

PARTIALLY SUBMERGED PROPELLERS OF THE SEA-SLED TYPE

1. The investigation was undertaken in order to determine by tests of models the characteristics and the limiting conditions of efficiency and thrust developed when a propeller is operated with the propeller shaft above the water level. The investigation was made in connection with the 50' x 10' x 44,000 pounds sea-sleds built for the Navy by the Murray & Tregurtha Company of Boston. The sea-sleds were designed for use in launching from the water heavy bombing airplanes of the land type.

2. A model of the sea-sled to 1/9th scale was made and run in the Model Basin to determine the E.H.P. curves for the full size boat as shown in Sheet I. These curves show the powers for a displacement of 44,000 pounds and for an initial trim of 6° by the stern. A curve of E.H.P. for varying displacement resulting from the estimated lift of the airplane before it is released is also shown. It is to be noted that the angle of trim has a decided effect on the E.H.P. When trimmed 6° by the stern the hump in the E.H.P. curve occurs at a speed of about 16 knots; whereas when trimmed on an even keel the resistance continues to increase to high speeds in a manner similar to that of a displacement boat, the E.H.P. required being greater at all speeds above 22.5 knots.

3. On completion of the model resistance tests an investigation by means of a Pitot tube was made to determine the wake at the stern of the model in the position where the propellers would work. This investigation showed that the

wake was practically zero and that it was unnecessary to take into account the wake factor or the thrust deduction coefficient in the experiments with the propellers on the model. The propeller dynamometer was then mounted on the model as shown on photographic sheet VII and tests made as described later to determine the propeller characteristics with propellers partially submerged, the center of the propeller shaft at center of propeller hub being 1/8 inch above the water surface when the sea-sled model was running at full speed. These tests were made with the sea-sled model running in the water at a displacement corresponding to 44,000 pounds for the full size boat. Two propellers, models No. 452 and No. 484, were tested. Model No. 452 is a model of the U.S.S. WADSWORTH; propeller model No. 484 was in accordance with the Bureau of Steam Engineering design prepared for the sea-sled. The models to 1/9th scale corresponded to the following dimensions for the full size boat:

	452	484
Diameter	37."4	30."5
Pitch	42.3	44"
Pitch ratio	1.13	1.445
$\frac{P\ A}{D\ A}$	.557	.365
Mean width ratio	.334	.284
Number of blades	3	3
Linear ratio of ship to model	9	9

4. Both propeller models were tested under the normal conditions, that is, wholly submerged and running in free water at a uniform speed of five knots and at varying slips.

The characteristics of the propellers as determined by these tests are shown in sheets II and III. The results may be compared with the test of propeller No. 484 tested on the sea-sled model at a speed of eight knots, the characteristics of which are shown on sheet IV. It will be seen that when the propeller is run partially submerged the character of efficiency curve is very similar to that obtained when running wholly submerged. The maximum efficiency in each case occurs at a slip of about 15%. The thrust, however, developed for the surface condition is considerably less than that obtained when submerged, varying from about 1/2 at zero slip to about 17th at 40% slip. On Sheet IV is shown a comparison of the ratio of the thrust constants for the two conditions from which it will be seen how the ratio decreases with increase in slip. This condition apparently results from the fact that the propeller at the surface when running at the higher slips is in a condition approximating to cavitation, that is, the water ahead of the propeller cannot flow into the disc with sufficient velocity to supply the necessary mass upon which the propeller works. It may also be noted that, though for the surface and submerged conditions the maximum efficiencies are practically equal and occur at the same slip, yet the efficiency curve for the surface condition falls off with increase of slip much more rapidly than for the submerged condition.

5. Owing to the large amount of power installed in the sea-sled, compared with its dimensions, it was not possible to arrange the model for self propulsion in the ordinary manner, as it was not feasible to install four

dynamometers and operate them simultaneously so that the model would be self-propelled. It was, therefore, arranged to run the model at its designed displacement and to test one propeller with one dynamometer, arranging so that it would take its proportional share of the total thrust. Aside from the tests made at constant speed of advance and varying slips, it was possible to make tests under two other conditions; first, running a model at varying speeds and supplying a constant torque to the propeller, the torque being estimated as corresponding to that necessary on one propeller to propel the sea-sled at a speed of 24 knots, this speed being beyond the hump of the resistance curve. It will be seen from the curves on Sheet V that while the torque and the resulting thrust are sufficient to propel the sea-sled at a speed of 24 knots, the thrust, the torque being constant, is much too low to get the sea-sled over the hump in the resistance curve, which occurs at a ship speed of about 15 knots. This indicates that in the design of both propeller and motor for a given sea sled the limiting conditions are the ratio of the thrust and torque of the propeller and the torque developed by the motor at the hump of the resistance curve. In other words, though a motor may have ample power at high speeds, its torque may be insufficient to permit the boat to get over the initial hump.

6. A second method of test was with the varying speed of the sled model to vary the thrust of the propeller so that it would be proportional to the resistance of the sea-sled at corresponding speeds. The first condition approx-

imates that of a gasoline motor, which except at high speeds, delivers approximately constant torque. The second condition corresponds to the actual working condition of the propeller in that the thrust developed must be equal to the resistance. The results of these two sets of experiments are shown on Sheets V and VI. At the hump of the resistance curve, which occurred at a model speed of about five knots, the thrust on the model propeller estimated from the corresponding full size sea-sled was 3.93 pounds. Neither of the two propellers tested would actually develop that thrust at a speed of five knots. The maximum thrust, irrespective of R.P.M., which it was possible to obtain at five knots from propeller No. 484, was 2.1 pounds and for propeller No. 452 2.65 pounds. As the dimensions of these propellers corresponded to 30.5 inches and 37.45 inches it was apparent from this test that the sea-sleds fitted with these propellers could not be expected to get over the hump of the resistance curve no matter how much power might be applied to them or the number of R.P.M. at which they might be run. If it is assumed that the forces acting on propellers at a given slip vary as the square of the diameter, it is estimated that the diameter of No. 484 propeller would have to be increased to 42 inches and No. 452 propeller to 45 inches without change in pitch ratio, before they would develop sufficient thrust to get the sea-sled over the resistance hump. It may be noted here that the pitch ratio of No. 452 is 1.13 while that of No. 484 is 1.445. In other words, the propeller of highest pitch ratio requires the smaller diameter to develop a given maximum thrust.

7. Aside from the conclusion as to the minimum diameter of propellers which could be expected to get the sea-sled past the resistance hump, it appears clear that with propellers of this type the critical point as to whether they will work on a given boat depends on their developing a sufficient thrust to get over the initial hump and that this limitation may require the use of a propeller which is less efficient at high speeds than another propeller which could not get by the resistance hump. Though the range of the test did not cover a sufficient scope to permit a definite conclusion as to maximum obtainable efficiencies with partially submerged propellers, the indications are that about the same maximum efficiency may be expected as with the same propellers run wholly submerged and that the thrust developed will be increasingly less than for the submerged condition as the slip is increased.

CURVES OF EFFECTIVE HORSE POWER.

FOR

44000 LBS. HYDROPLANE

FOR USE IN LAUNCHING SEAPLANES.

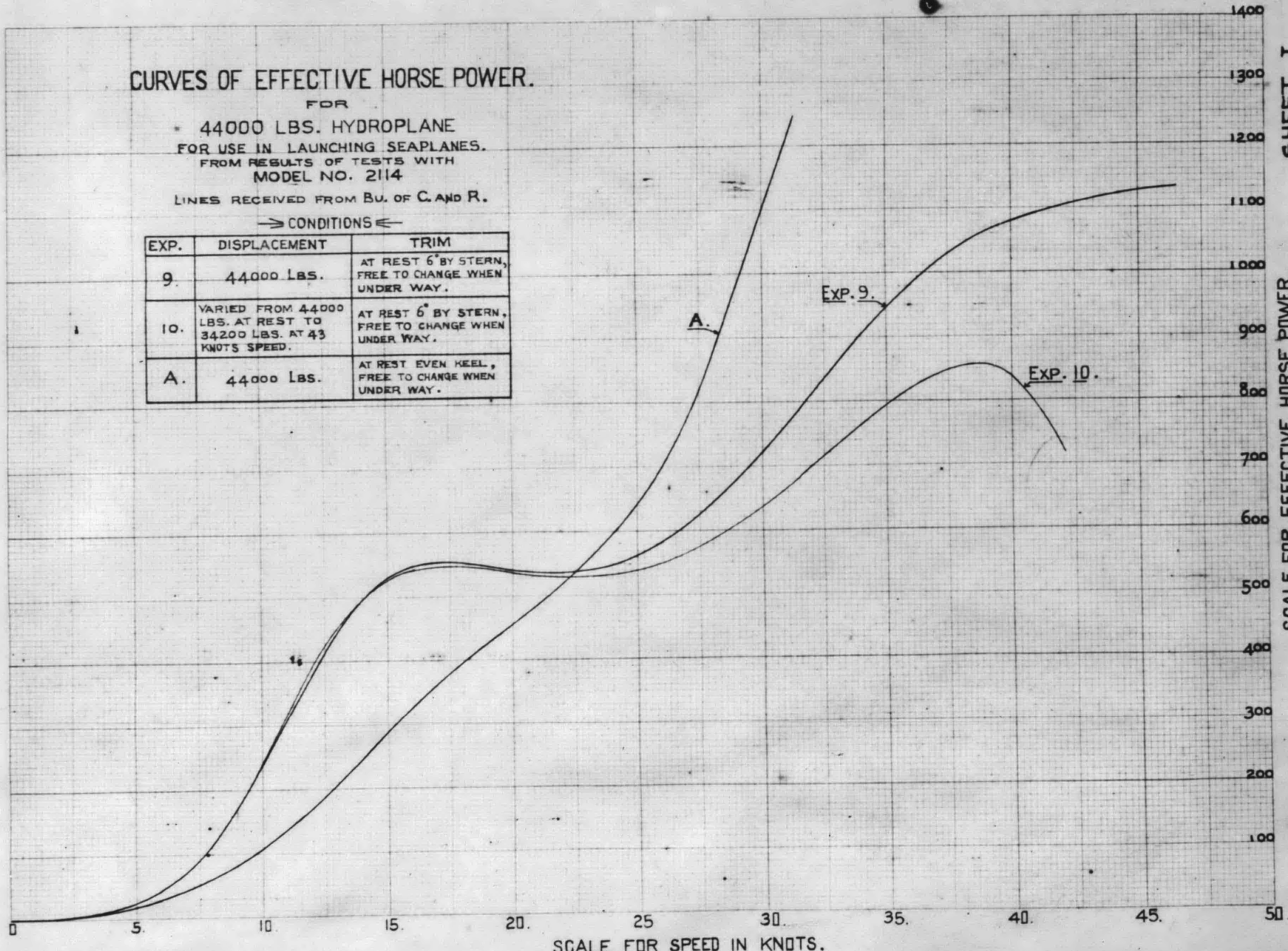
FROM RESULTS OF TESTS WITH

MODEL NO. 2114

LINES RECEIVED FROM BU. OF C. AND R.

→ CONDITIONS ←

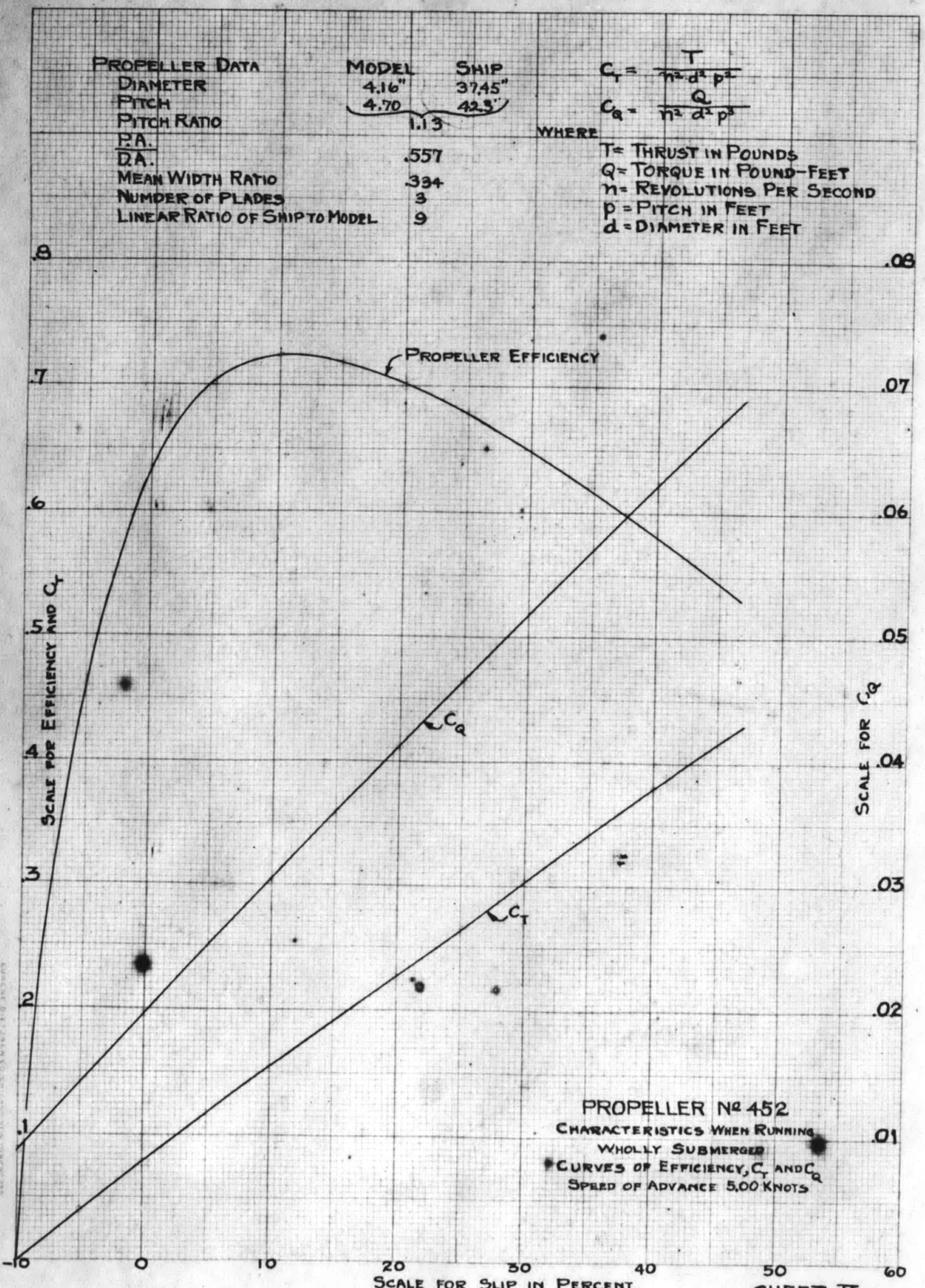
EXP.	DISPLACEMENT	TRIM
9.	44000 LBS.	AT REST 6° BY STERN, FREE TO CHANGE WHEN UNDER WAY.
10.	VARIED FROM 44000 LBS. AT REST TO 34200 LBS. AT 43 KNOTS SPEED.	AT REST 6° BY STERN, FREE TO CHANGE WHEN UNDER WAY.
A.	44000 LBS.	AT REST EVEN KEEL, FREE TO CHANGE WHEN UNDER WAY.



SHEET I

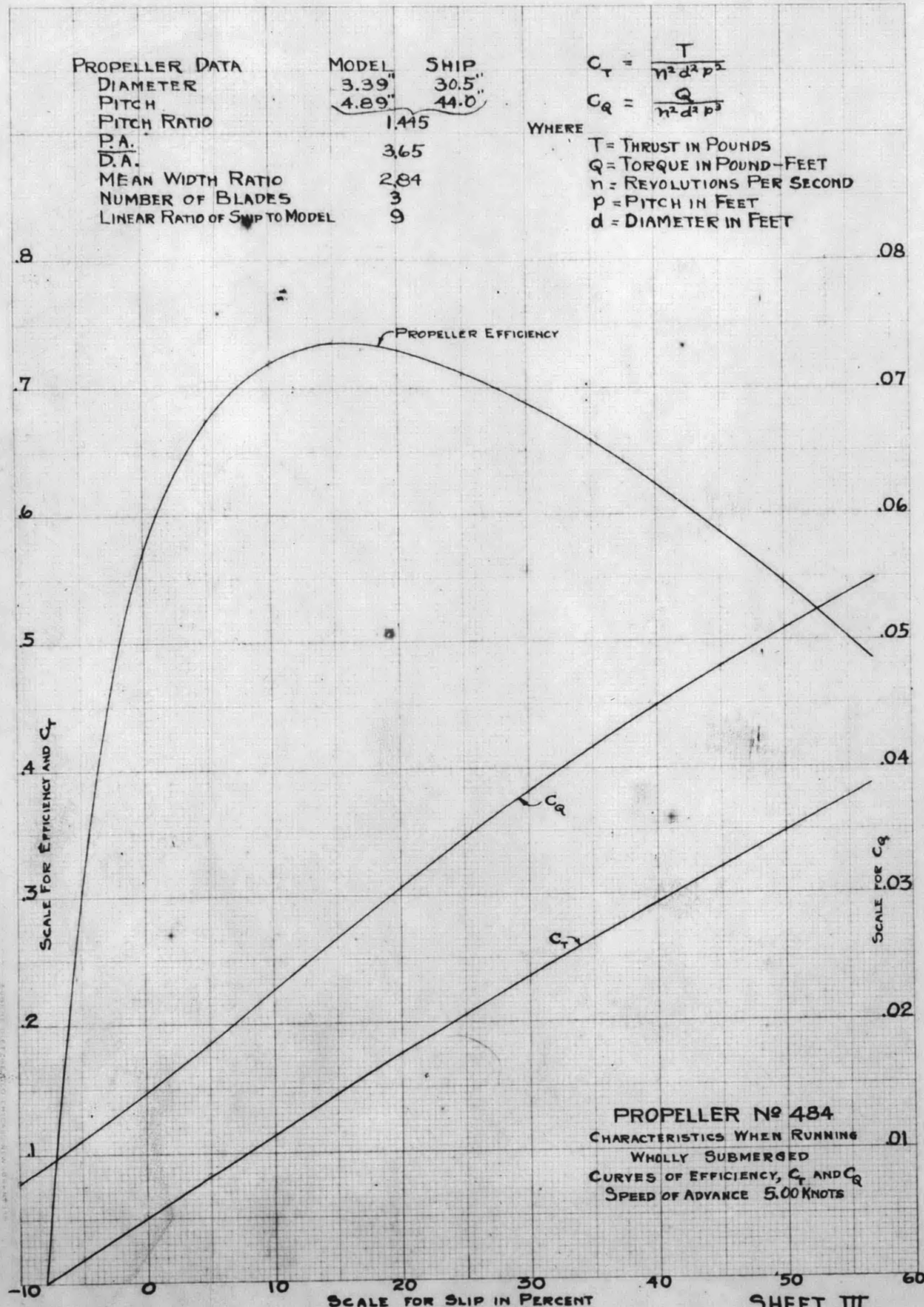
R/32

R-132

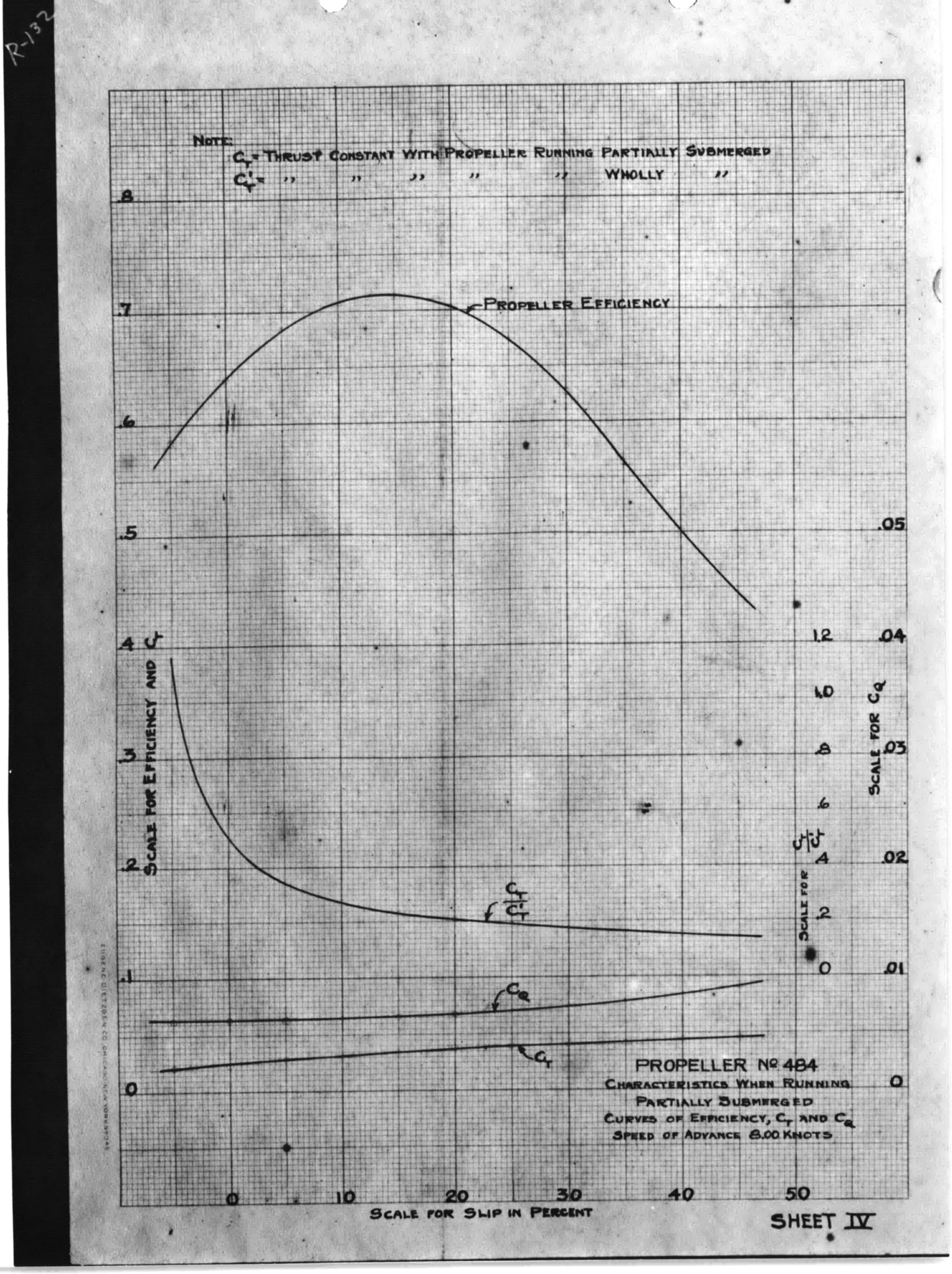


SHEET II

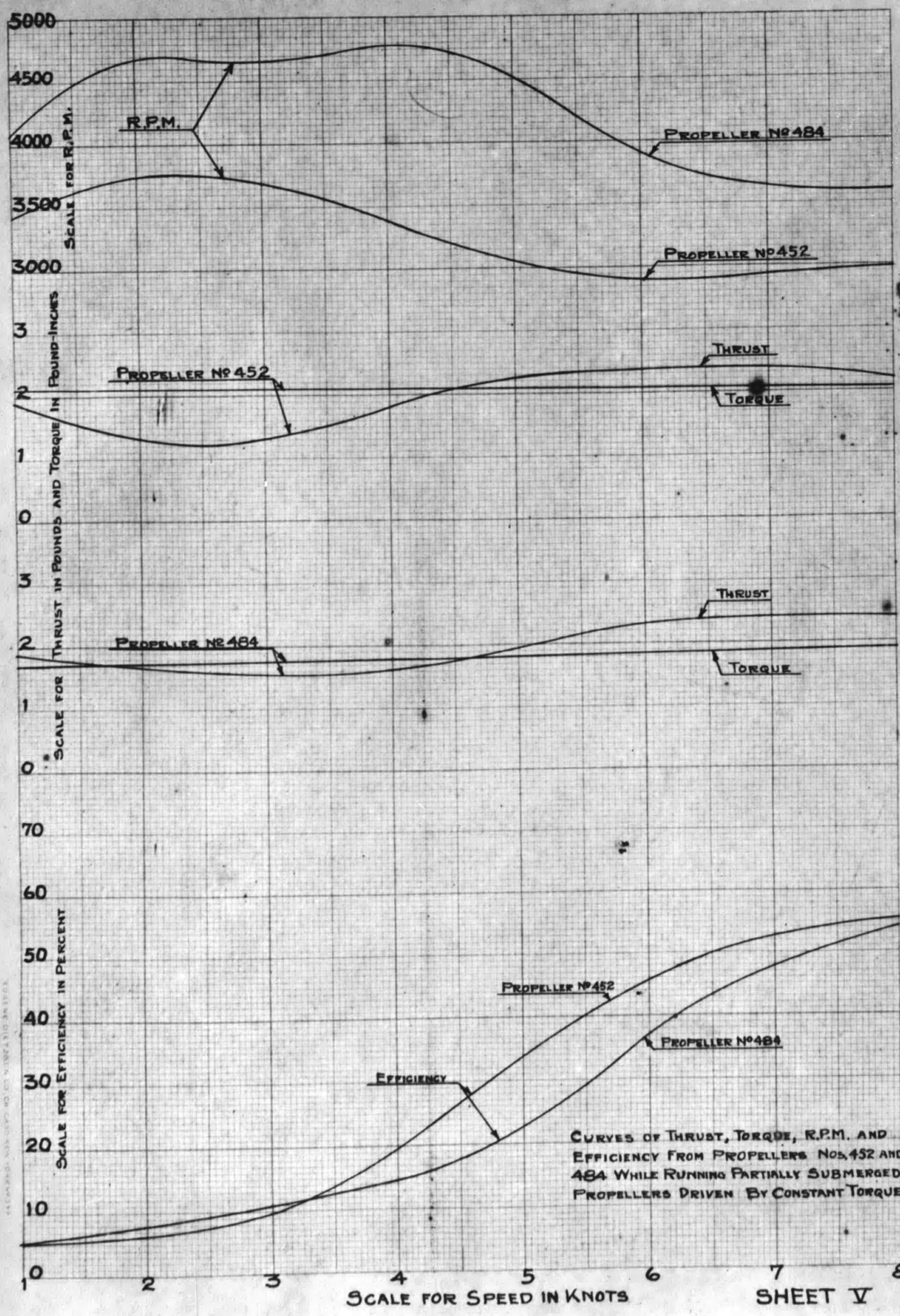
R-132



SHEET III

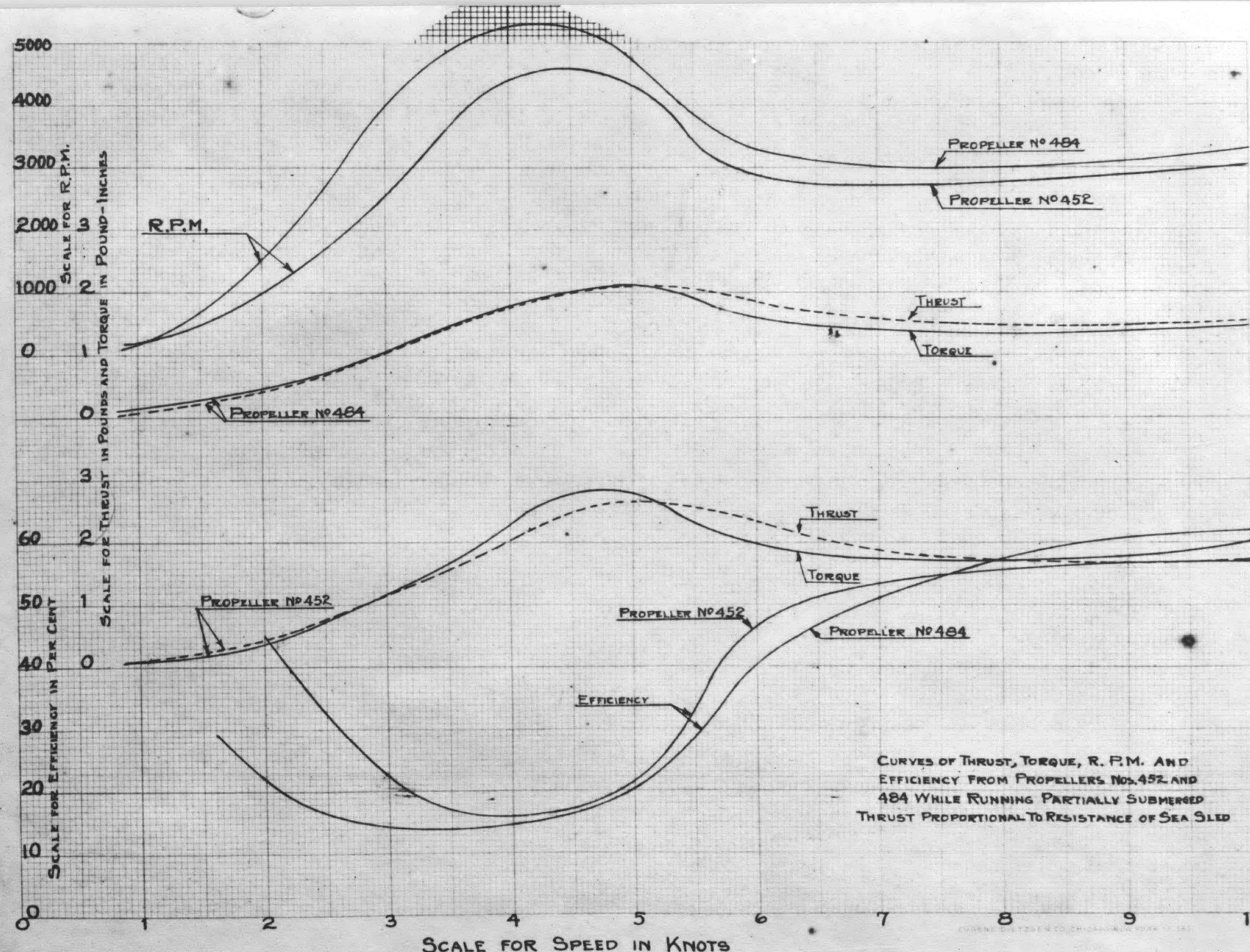

R-132
NOTE:
C_T = THRUST CONSTANT WITH PROPELLER RUNNING PARTIALLY SUBMERGED
C_T' = " " " " " WHOLLY "
PROPELLER EFFICIENCY
$\frac{C_T}{C_T'}$
C_Q
C_T
SCALE FOR EFFICIENCY AND C_T
SCALE FOR C_T/C_T'
SCALE FOR C_Q
SCALE FOR SLIP IN PERCENT
.8
.7
.6
.5
.4
.3
.2
.1
0
1.2
1.0
.8
.6
.4
.2
0
.05
.04
.03
.02
.01
0
0
10
20
30
40
50
PROPELLER No 484
CHARACTERISTICS WHEN RUNNING
PARTIALLY SUBMERGED
CURVES OF EFFICIENCY, C_T AND C_Q
SPEED OF ADVANCE 8.00 KNOTS
SHEET IV

R-132



Curves of Thrust, Torque, R.P.M. and Efficiency from Propellers Nos. 452 and 484 While Running Partially Submerged Propellers Driven By Constant Torque

SHEET V



Curves of Thrust, Torque, R.P.M. and Efficiency from Propellers Nos. 452 and 484 While Running Partially Submerged Thrust Proportional To Resistance of Sea Sled

R-132

EXPERIMENTAL MODEL BASIN
SEA SLED MODEL 2148 FITTED WITH ONE SURFACE PROPELLER
APRIL 1917

SHEET VII

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