REPORT ON TEST OF SURFACE PROPELLERS

Experimental Model Basin
Navy Yard
Washington, D. C.

August 1922

Report 57

REPORT ON TEST OF SURFACE PROPELLERS

1. There were tested in the Model Basin fourteen propellers run as surface propellers, with the bottom of the hub at the surface of the water. Two diameters, three width ratios and four pitch ratios were represented, as follows:

Diameter = 7.00"

a) Width ratio = 0.200; blade thickness fraction = 0.06
Pitch ratios = 0.75, 1.00, 1.25, 1.50

b) Width ratio = 0.325; blade thickness fraction = 0.04
Pitch ratios = 0.75, 1.00, 1.25, 1.50

c) Width ratio = 0.450; blade thickness fraction = 0.03
Pitch ratios = 0.75, 1.00*, 1.25, 1.50

Diameter = 8.00"

a) Width ratio = 0.325; blade thickness fraction = 0.04
Pitch ratios = 1.00, 1.50.

The projected outline of all propellers was elliptical and the blade section ogival. The width ratio is the maximum projected width divided by the diameter. The propeller marked with an asterisk (*) had actual dimensions slightly different from those given above. The diameter was 6.70", pitch ratio 1.045, width ratio 0.470. Allowance was made for this in working up the results which are reported for even values. The diameter of each hub was 1/5 of the propeller diameter. Each propeller had three blades.

2. The propellers were tested at 4 knots speed of advance and at slip ratios up to about 60%. Readings were taken of speed of advance, torque, thrust, and r.p.m. The full range of slip ratio was covered three times for each propeller, giving three sets of runs for each.

3. The results are given on the accompanying curve sheets and table. The curves give the results for the individual propellers comprising the 7" diameter, 0.450 width ratio group, the faired results for constant width ratios, and a comparison of the performance of a propeller of diameter 6.70", width ratio 0.470, and pitch ratio 1.045 when on the surface and when submerged. The faired results hold good only up to the point at which the break in the curves (q.v.) occurs. The table gives the difference between the results for 8" and 7" propellers.

4. As the tests were being run it was observed that the flow about the propellers was not always of the same character. Two distinct types were recognized, one associated with lower slips and the other with higher slips. There was also for each propeller a narrow range of slip at which either type of flow was possible, depending on whether this unstable region was entered from above or below. For slips up to approximately 40%, but depending somewhat on the proportions of the propeller, the emerging blade tips flung a certain quantity of water up into the air, the most of which fell again on the same side of the propeller axis from which it arose. At higher slips the propellers seemingly tried to bury themselves in the water, which was now carried entirely around over the propeller axis, noise increased, and torque and thrust dropped off markedly. A dynamometer card showing the effect on torque and thrust of a change from low speed to high speed type of flow is given herewith. In working up the results the point of change in

flow was found to be clearly marked by discontinuity of the torque and thrust curves when plotted on r.p.m., which results in similar discontinuity of the curves of coefficients and efficiency.

TABLE I - Difference Between Results from 8" Propellers and Faired Results of 7" Series

A - Pitch Ratio = 1.00; width ratio = 0.325

Slip	Torque Coefficient		Thrust Coefficient		Efficiency		% Difference		
Ratio	7"	8"	7"	8"	7"	8"	C_Q	C_T	e
0%	.0070	.0061	.0260	.0178	.591	.468	-12.8	-31.5	-20.8
10%	.0098	.0090	.0485	.0432	.710	.691	- 8.2	-10.9	- 2.7
20%	.0118	.0113	.0658	.0627	.710	.708	- 4.2	- 4.7	- 0.3
30%	.0131	.0132	.0771	.0738	.656	.635	+ 0.8	- 4.3	- 3.2

B - Pitch Ratio = 1.50; width ratio = 0.325

0%	.0033	.0034	.0086	.0114	.415	.536	+ 3.0	+32.5	+29.1
10%	.0057	.0060	.0295	.0314	.741	.751	+ 5.2	+ 6.4	+ 1.3
20%	.0078	.0079	.0462	.0465	.753	.750	+ 1.3	+ 0.6	- 0.4
30%	.0092	.0092	.0564	.0570	.683	.689	0.0	+ 1.0	+ 0.9
40%	.0097	.0098	.0578	.0628	.572	.610	+ 1.0	+ 5.0	+ 6.6

PROPELLER Nº 406

SURFACE PROPELLERS

CURVES OF TORQUE AND THRUST COEFFICIENTS AND EFFICIENCY.

WIDTH RATIO = 0.450 PITCH RATIO = 0.75

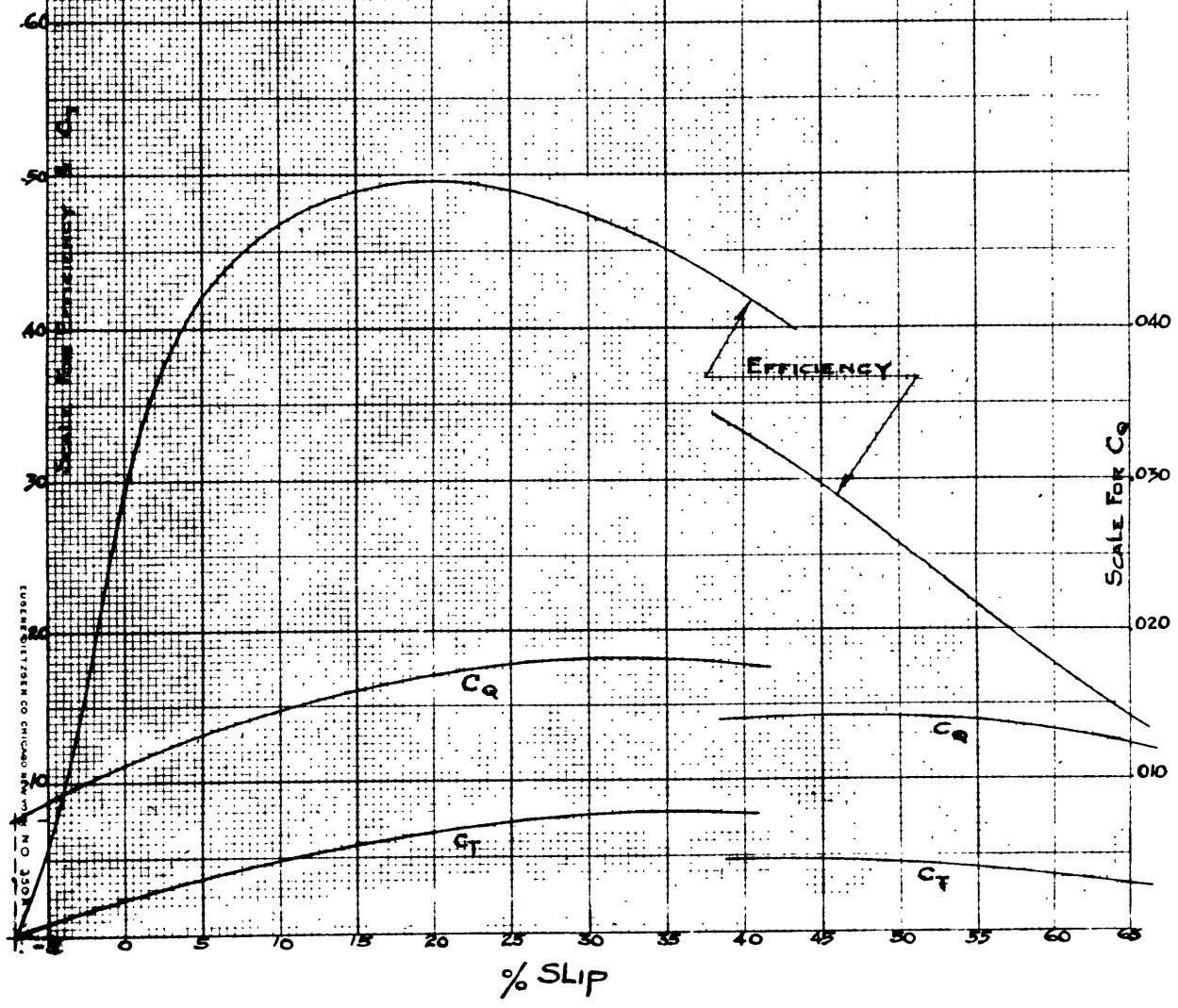
TORQUE COEFFICIENT = $C_Q = \frac{Q}{N^2P^3D^2}$

THRUST " = $C_T = \frac{T}{N^2P^2D^2}$

EFFICIENCY = $e = \frac{TV}{2\pi QN}$

Q = TORQUE (LBS.-FT.)
T = THRUST (LBS.)
P = PITCH (FT.)
D = DIAMETER (FT.)
N = REV./SEC.
V = SPEED OF ADVANCE (FT./SEC.)

NOTE:
DIAMETER OF PROPELLERS TESTED = 7.00"
SPEED OF ADVANCE = 4.08 KNOTS
BOTTOM OF HUB AT SURFACE OF WATER.
DIAMETER OF HUB = 1.40"



PROPELLER Nº 412

SURFACE PROPELLERS

CURVES OF TORQUE AND THRUST COEFFICIENTS AND EFFICIENCY

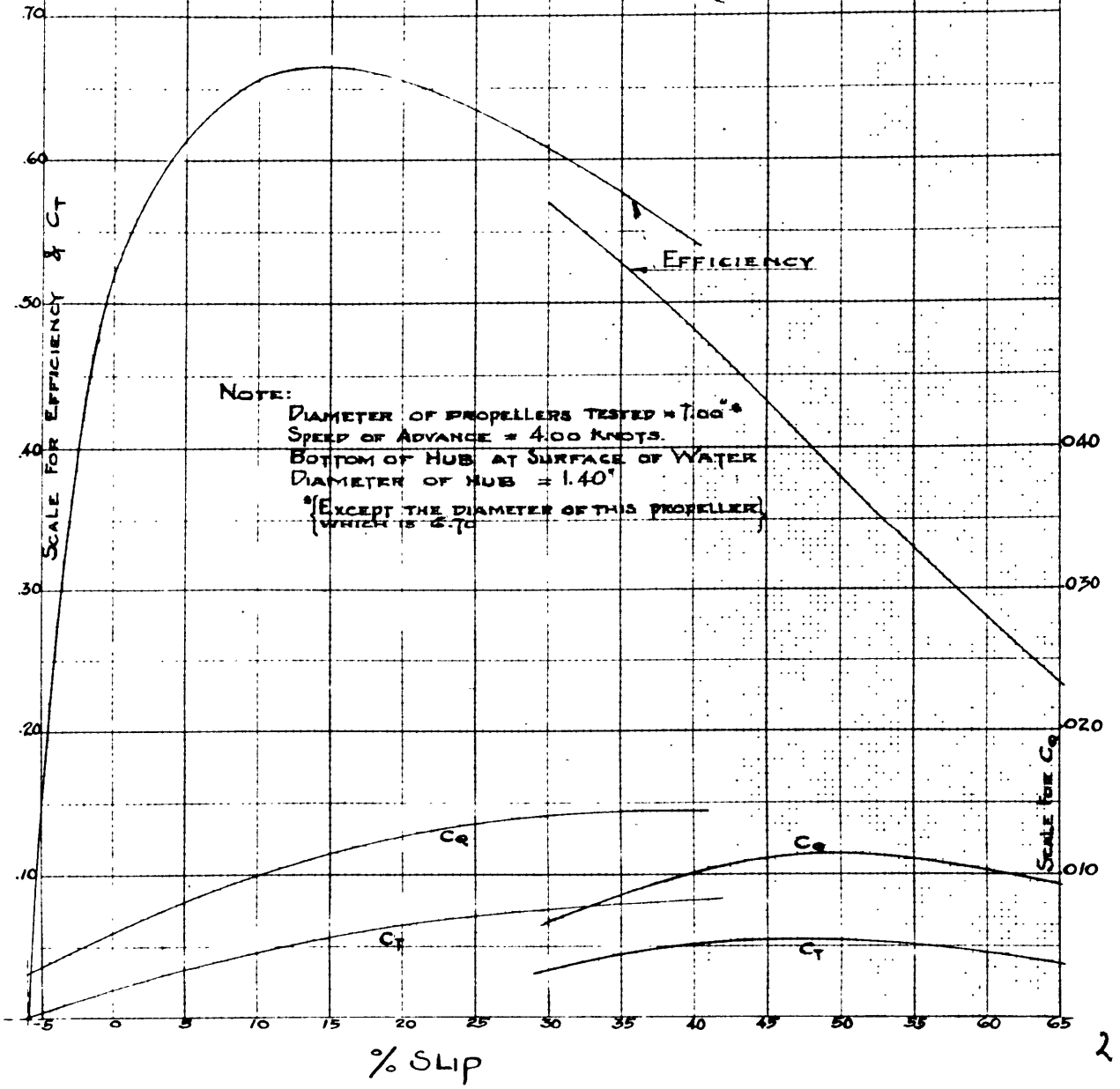
WIDTH RATIO = 0.470 PITCH RATIO = 1.045

TORQUE COEFFICIENT = $C_Q = \frac{Q}{N^2 P^3 D^2}$

THRUST COEFFICIENT = $C_T = \frac{T}{N^2 P^2 D^2}$

EFFICIENCY = $e = \frac{TV}{2\pi Q N}$

Q = TORQUE (LBS-FT)
T = THRUST (LBS.)
P = PITCH (FT.)
D = DIAMETER (FT.)
N = REV./SEC.
V = SPEED OF ADVANCE (FT./SEC.)



NOTE:
DIAMETER OF PROPELLERS TESTED = 7.00"*
SPEED OF ADVANCE = 4.00 KNOTS.
BOTTOM OF HUB AT SURFACE OF WATER
DIAMETER OF HUB = 1.40"
*{EXCEPT THE DIAMETER OF THIS PROPELLER WHICH IS 6.70}

PROPELLER Nº 418

SURFACE PROPELLERS

Curves of Torque and Thrust Coefficients and Efficiency

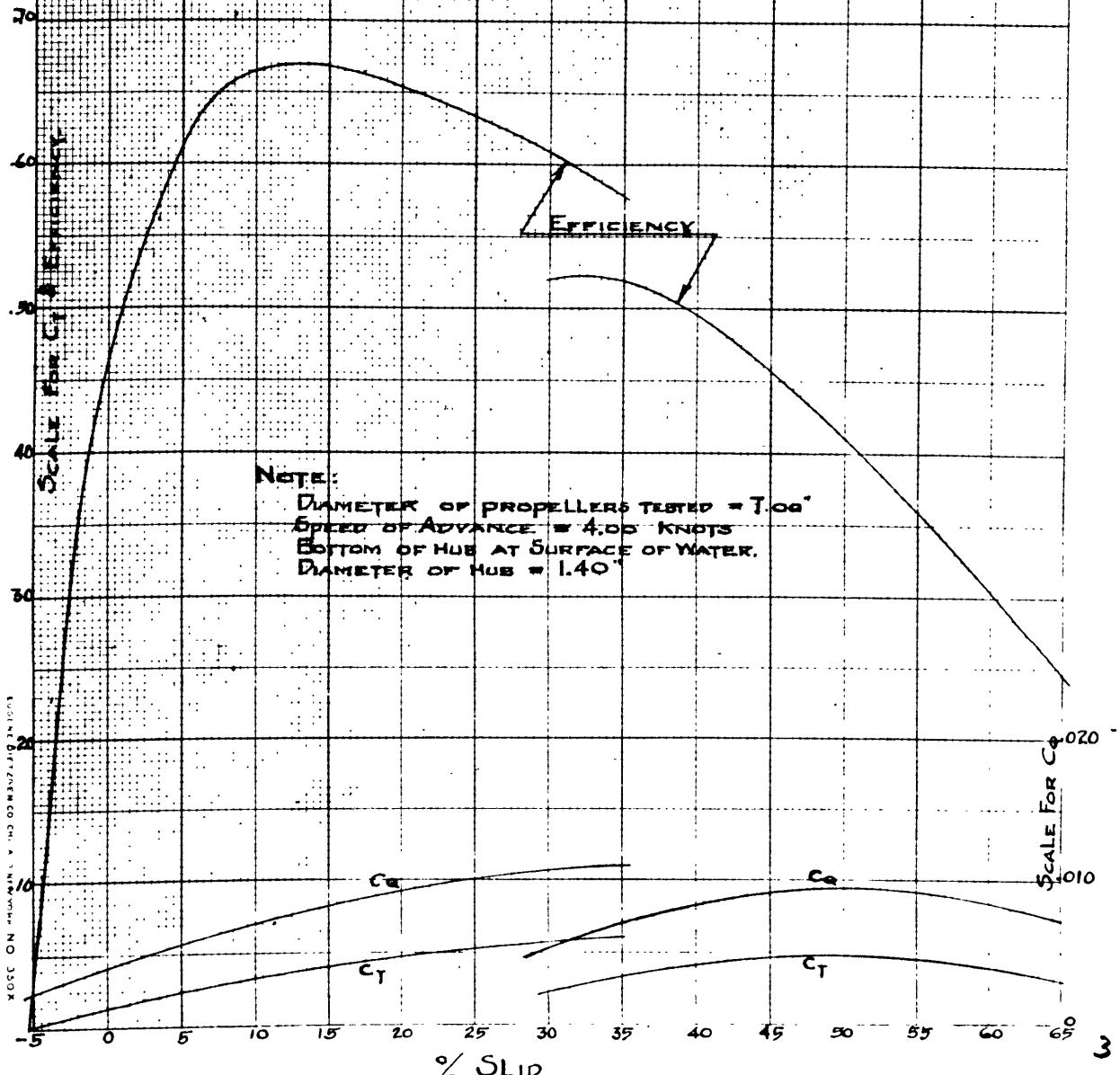
Width Ratio = 0.450 Pitch Ratio = 1.25

Torque Coefficient = $C_Q = \frac{Q}{n^2 P^3 D^2}$

Thrust Coefficient = $C_T = \frac{T}{n^2 P^2 D^2}$

Efficiency = $\frac{T V}{2\pi n Q}$

Q = Torque (Lbs.-Ft.)
T = Thrust (Lbs.)
P = Pitch (Ft.)
D = Diameter (Ft.)
N = Rev./Sec.
V = Speed of Advance (Ft./Sec.)



PROPELLER No 424

SURFACE PROPELLERS

CURVES OF TORQUE AND THRUST COEFFICIENTS AND EFFICIENCY

WIDTH RATIO = 0.450 PITCH RATIO = 1.50

TORQUE COEFFICIENT = $C_Q = \frac{Q}{n^2 p D^5}$

THRUST " = $C_T = \frac{T}{n^2 p D^4}$

EFFICIENCY = $e = \frac{TV}{2\pi Q n}$

Q = TORQUE (LBS-FT)
T = THRUST (LBS.)
P = PITCH (FT.)
D = DIAMETER (FT.)
N = REV./SEC.
V = SPEED OF ADVANCE (FT./SEC.)

SCALE FOR C_T & EFFICIENCY

80
70
60
50
40
30
20
10
0

EFFICIENCY

NOTE:
DIAMETER OF PROPELLERS TESTED = 7.00"
SPEED OF ADVANCE = 4.00 KNOTS.
BOTTOM OF HUB AT SURFACE OF WATER.
DIAMETER OF HUB = 1.40"

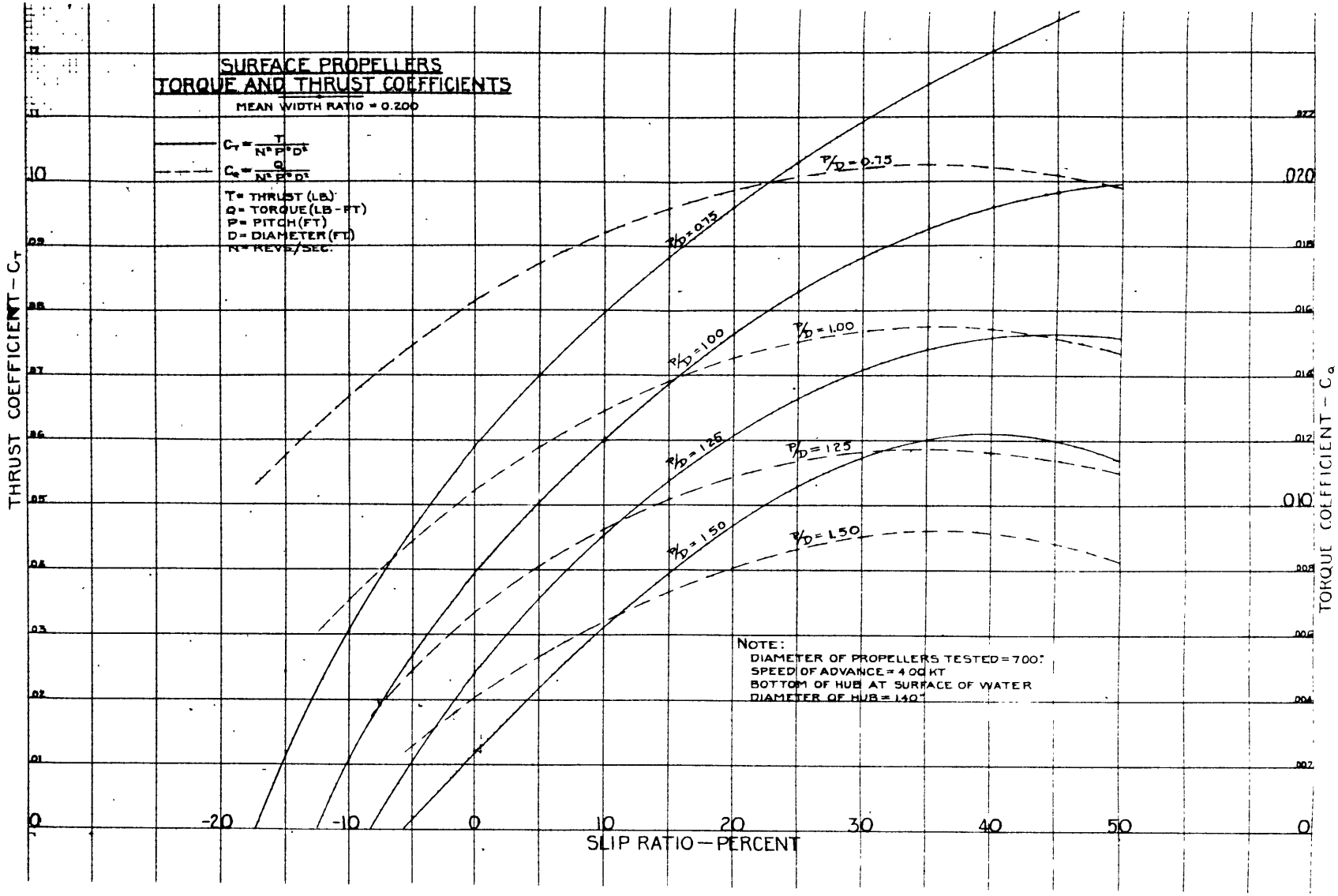
C_Q
C_T
C_Q
C_T

5 10 15 20 25 30 35 40 45 50 55 60

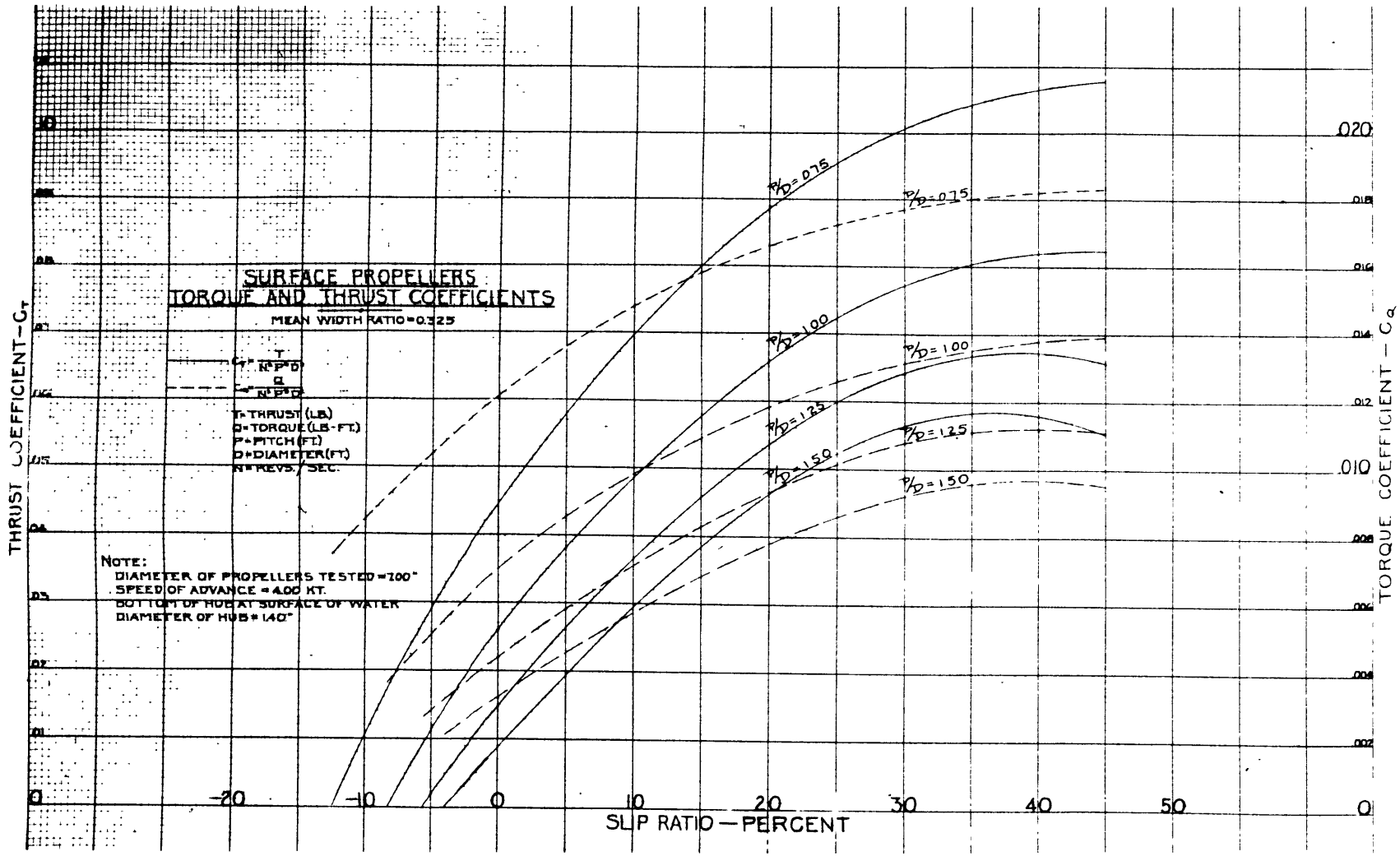
% SLIP

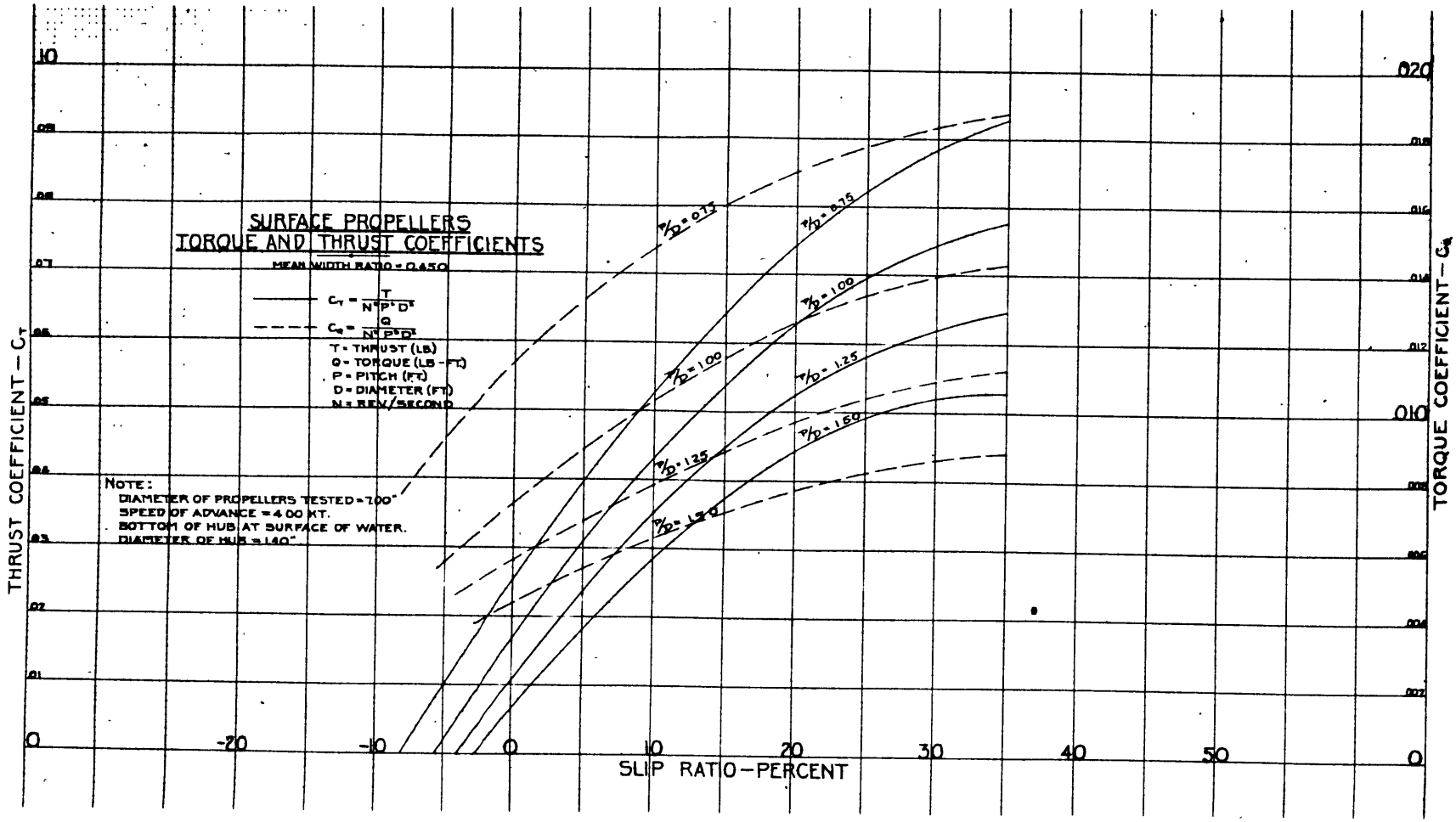
SCALE FOR C_Q

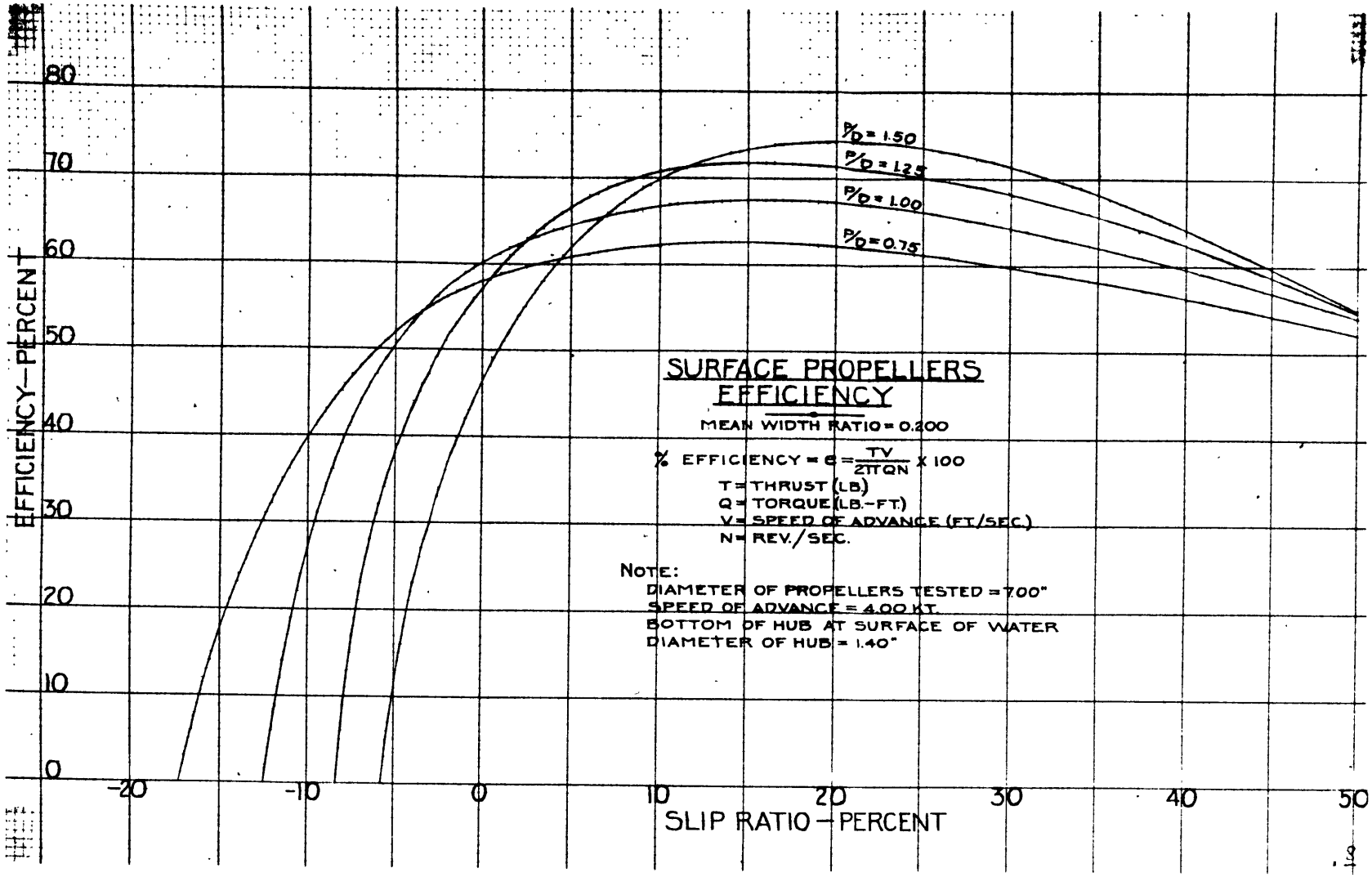
.020
.010
0

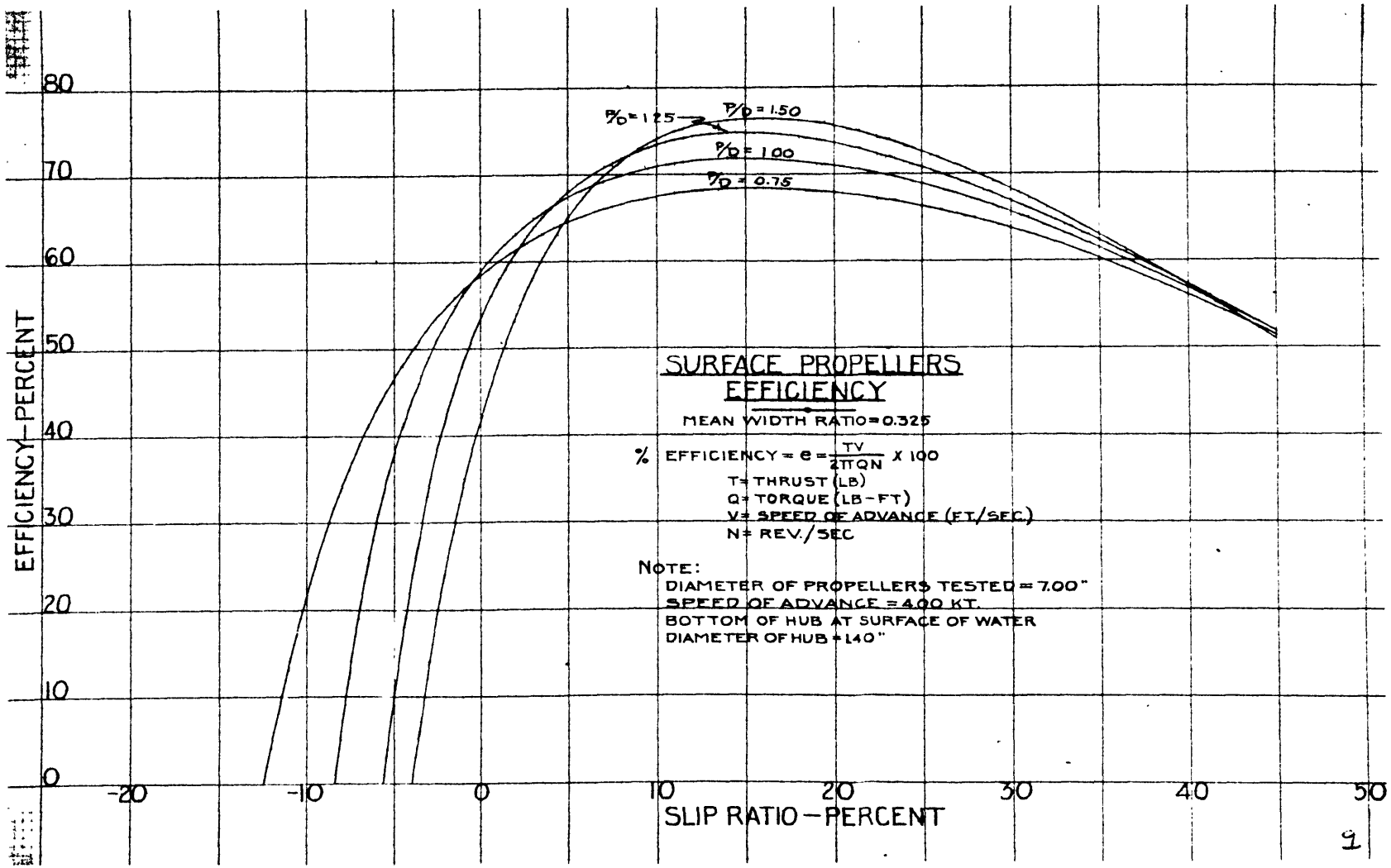

SURFACE PROPELLERS
TORQUE AND THRUST COEFFICIENTS
MEAN WIDTH RATIO = 0.200
$C_T = \frac{T}{N^2 P^2 D^4}$
$C_Q = \frac{Q}{N^2 P^2 D^5}$
T = THRUST (LB)
Q = TORQUE (LB-FT)
P = PITCH (FT)
D = DIAMETER (FT)
N = REVS/SEC.
P/D = 0.75
P/D = 1.00
P/D = 1.25
P/D = 1.50
NOTE:
DIAMETER OF PROPELLERS TESTED = 700"
SPEED OF ADVANCE = 4.00 KT
BOTTOM OF HUB AT SURFACE OF WATER
DIAMETER OF HUB = 140"
THRUST COEFFICIENT – C_T
TORQUE COEFFICIENT – C_Q
SLIP RATIO – PERCENT
-20
-10
0
10
20
30
40
50
.020
.010

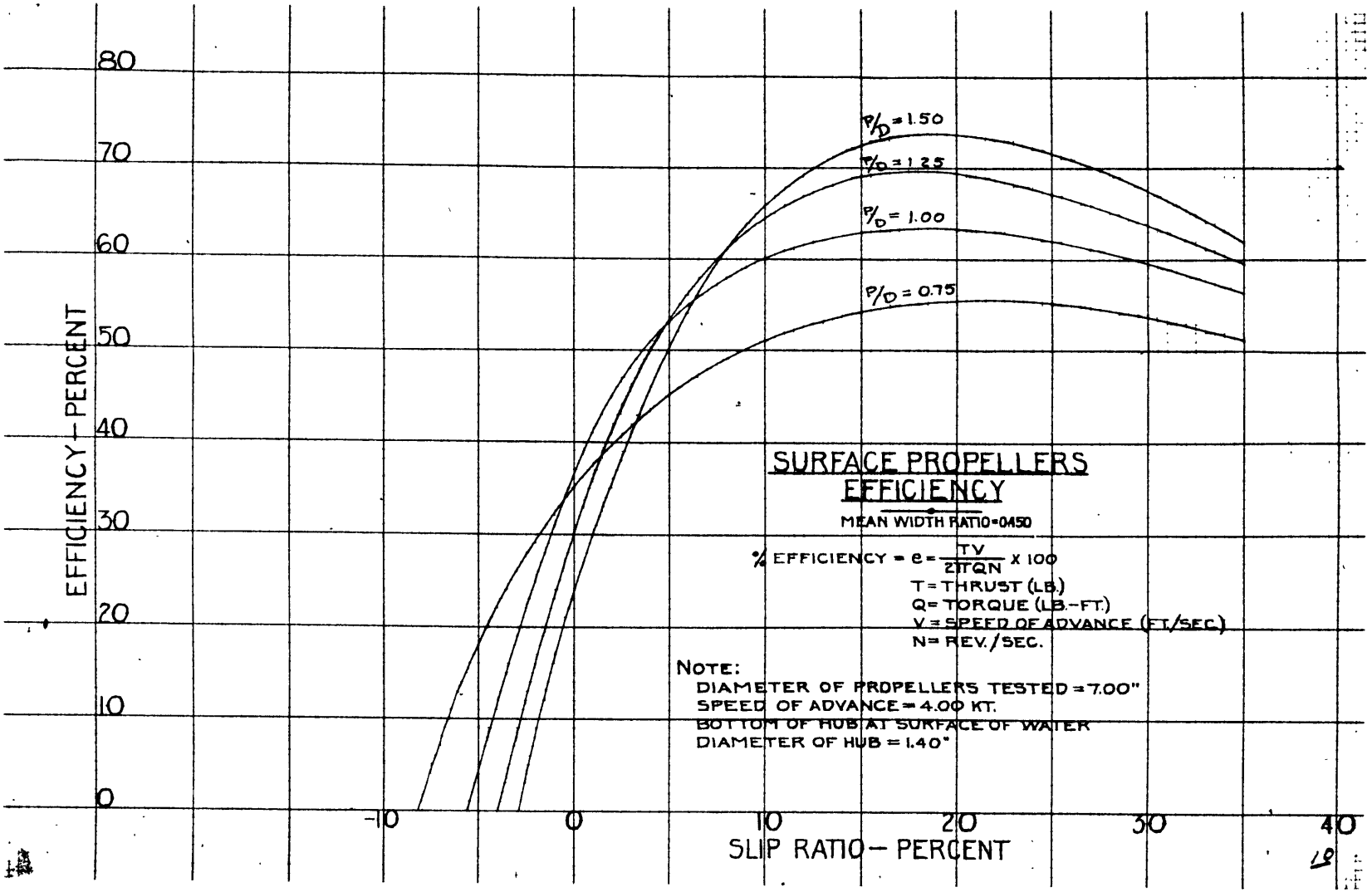
5

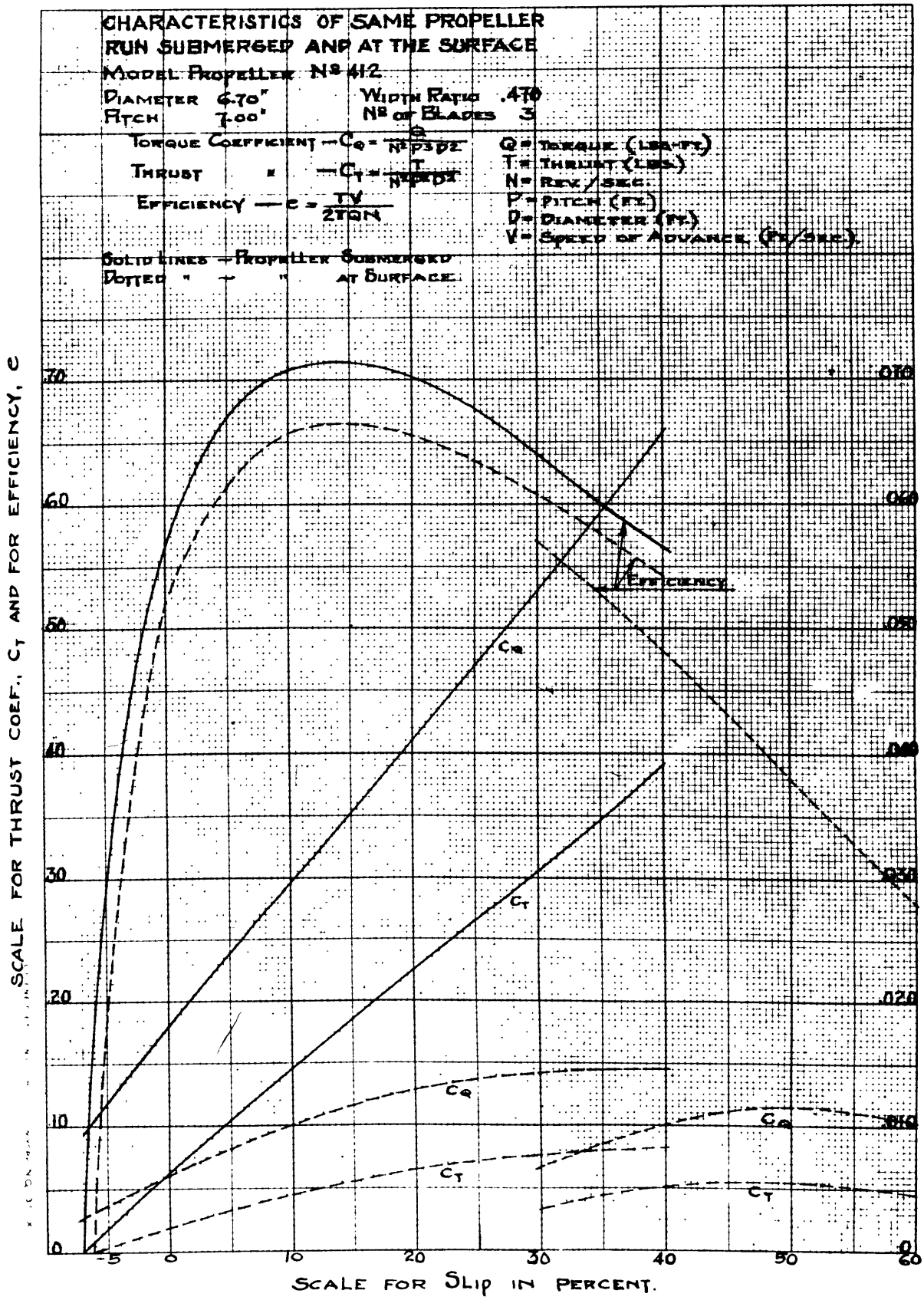

SURFACE PROPELLERS
TORQUE AND THRUST COEFFICIENTS
MEAN WIDTH RATIO = 0.325
$C_T = \frac{T}{N^2 P^4 D}$
$C_Q = \frac{Q}{N^2 P^4 D}$
T = THRUST (LB.)
Q = TORQUE (LB-FT.)
P = PITCH (FT.)
D = DIAMETER (FT.)
N = REVS. / SEC.
NOTE:
DIAMETER OF PROPELLERS TESTED = 7.00"
SPEED OF ADVANCE = 4.00 KT.
BOTTOM OF HUB AT SURFACE OF WATER
DIAMETER OF HUB = 1.40"
P/D = 0.75
P/D = 1.00
P/D = 1.25
P/D = 1.50
THRUST COEFFICIENT — C_T
TORQUE COEFFICIENT — C_Q
SLIP RATIO — PERCENT
-20
-10
0
10
20
30
40
50
.020
.010
0


SURFACE PROPELLERS
TORQUE AND THRUST COEFFICIENTS
MEAN WIDTH RATIO = 0.450
$C_T = \frac{T}{N^2 P^2 D^4}$
$C_Q = \frac{Q}{N^2 P^2 D^5}$
T = THRUST (LB)
Q = TORQUE (LB - FT)
P = PITCH (FT)
D = DIAMETER (FT)
N = REV/SECOND
NOTE:
DIAMETER OF PROPELLERS TESTED = 7.00"
SPEED OF ADVANCE = 4.00 KT.
BOTTOM OF HUB AT SURFACE OF WATER.
DIAMETER OF HUB = 1.40"
P/D = 0.75
P/D = 1.00
P/D = 1.25
P/D = 1.50
THRUST COEFFICIENT — C_T
TORQUE COEFFICIENT — C_Q
SLIP RATIO — PERCENT
10
.09
.08
.07
.06
.05
.04
.03
.02
.01
0
.020
.018
.016
.014
.012
.010
.008
.006
.004
.002
0
-20
-10
0
10
20
30
40
50

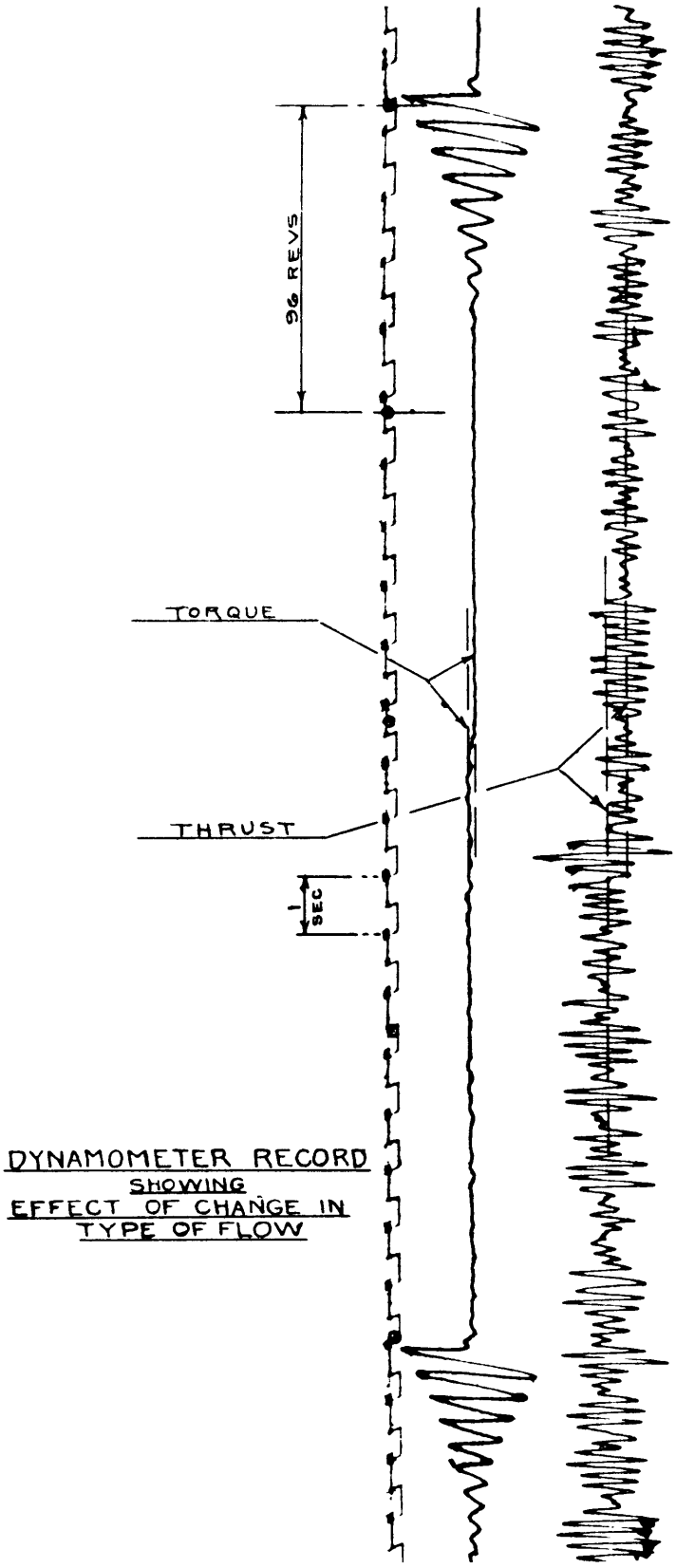

EFFICIENCY—PERCENT
80
70
60
50
40
30
20
10
0
-20
-10
0
10
20
30
40
50
SLIP RATIO—PERCENT
P/D = 1.50
P/D = 1.25
P/D = 1.00
P/D = 0.75
SURFACE PROPELLERS
EFFICIENCY
MEAN WIDTH RATIO = 0.200
% EFFICIENCY = e = TV / 2πQN X 100
T = THRUST (LB)
Q = TORQUE (LB.-FT.)
V = SPEED OF ADVANCE (FT/SEC.)
N = REV./SEC.
NOTE:
DIAMETER OF PROPELLERS TESTED = 7.00"
SPEED OF ADVANCE = 4.00 KT.
BOTTOM OF HUB AT SURFACE OF WATER
DIAMETER OF HUB = 1.40"


EFFICIENCY—PERCENT
80
70
60
50
40
30
20
10
0
-20
-10
0
10
20
30
40
50
SLIP RATIO—PERCENT
P/D = 1.25
P/D = 1.50
P/D = 1.00
P/D = 0.75
SURFACE PROPELLERS
EFFICIENCY
MEAN WIDTH RATIO = 0.325
% EFFICIENCY = e = TV / 2πQN X 100
T = THRUST (LB)
Q = TORQUE (LB-FT)
V = SPEED OF ADVANCE (FT/SEC.)
N = REV./SEC
NOTE:
DIAMETER OF PROPELLERS TESTED = 7.00"
SPEED OF ADVANCE = 4.00 KT.
BOTTOM OF HUB AT SURFACE OF WATER
DIAMETER OF HUB = 1.40"


80
70
60
50
40
30
20
10
0
EFFICIENCY – PERCENT
P/D = 1.50
P/D = 1.25
P/D = 1.00
P/D = 0.75
SURFACE PROPELLERS
EFFICIENCY
MEAN WIDTH RATIO=0.450
% EFFICIENCY = e = TV / 2πQN X 100
T = THRUST (LB.)
Q = TORQUE (LB.-FT.)
V = SPEED OF ADVANCE (FT./SEC.)
N = REV./SEC.
NOTE:
DIAMETER OF PROPELLERS TESTED = 7.00"
SPEED OF ADVANCE = 4.00 KT.
BOTTOM OF HUB AT SURFACE OF WATER
DIAMETER OF HUB = 1.40"
-10
0
10
20
30
40
SLIP RATIO – PERCENT


CHARACTERISTICS OF SAME PROPELLER
RUN SUBMERGED AND AT THE SURFACE
Model Propeller Nº 412
Diameter 6.70"
Pitch 7.00"
Width Ratio .470
Nº of Blades 3
Torque Coefficient — $C_Q = \frac{Q}{N^2 P^3 D^2}$
Thrust " — $C_T = \frac{T}{N^2 P^2 D^2}$
Efficiency — $e = \frac{TV}{2\pi QN}$
Q = Torque (Lbs-Ft.)
T = Thrust (Lbs.)
N = Rev./Sec.
P = Pitch (Ft.)
D = Diameter (Ft.)
V = Speed of Advance (Ft./Sec.)
Solid Lines — Propeller Submerged
Dotted " — " at Surface.
Efficiency
C_Q
C_T
70
60
50
40
30
20
10
0
-5
0
10
20
30
40
50
60
Scale for Slip in Percent.
Scale for Thrust Coef., C_T and for Efficiency, e
Scale for Torque Coefficient, C_Q

11



DYNAMOMETER RECORD
SHOWING
EFFECT OF CHANGE IN
TYPE OF FLOW