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WIND-TUNNEL TESTS OF SINGLE- AND DUAL-ROTATING TRACTOR PROPELLERS AT LOW BLADE ANGLES AND OF TWO- AND THREE-BLADE TRACTOR PROPELLERS AT BLADE ANGLES UP TO 65°

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L-316

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SUMMARY

Tests were conducted in the propeller-research tunnel of the Langley Memorial Aeronautical Laboratory to determine the characteristics at low blade angles of propellers for which data at high blade angles are already available. In addition to the low-blade-angle results there are included data on two- and three-blade propellers of the same blade design, which have not been published and which cover a range of blade angles from 20° to 65°.

A chart lists the NACA reports in which data on related tests of the same blade design may be found.

INTRODUCTION

With the advent of high altitude airplanes, operation of propellers at low blade angles becomes necessary for the take-off condition. Results of tests at blade angles applicable to this condition are presented herein. Inasmuch as the tests were made at low speeds, the effects of compressibility could not be measured. Reference 1, however, presents results for propellers embodying several sections at high tip speeds with low blade angles and also presents a method of correcting propeller characteristics for compressibility effects at tip speeds below 0.9 the speed of sound. In the results reported in references 2, 3, and 4, charts are presented of data on single- and dual-rotating propellers of different number of blades. These charts included results for blade angles ranging from 20° to 65°. The data presented herein extend the results to include blade angles of 10° and 15°.

Because a part of the data for two- and three-blade propellers has not previously been published, all such data are included in this report.

APPARATUS AND METHODS

The tests were made with the test setup used in previous dual-rotating propeller investigations in the propeller-research tunnel (reference 2). A photograph and a dimensioned drawing of the test setup are shown in figures 1 and 2. A symmetrical wing was mounted in the slipstream for all the tests except those of the two-blade propeller at blade angles ranging from 20° to 65°. The over-all length of the spinner was 5 inches greater for the 10° and 15° blade-angle tests than for the tests at higher blade angles. (See fig. 2.)

The propeller blades were of Hamilton-Standard design designated 3155-6 (right hand) and 3156-6 (left hand). The plan-form and the blade-form curves are given in figure 3.

For the six- and eight-blade single- and dual-rotating propellers and for the four-blade dual-rotating propellers, the blades were mounted in separate hubs spaced 15 inches. For the two-, three-, and four-blade single-rotating propellers, however, the blades were mounted in the rear hub for the low blade angle tests. For the single-rotation tests, the front blades led the rear blades by 75.0° for the six-blade propeller and by 52.5° for the eight-blade propeller.

In order to facilitate reading values from the charts, the test points have been omitted from most of the curves. The general accuracy of the fairings is indicated, however, by the plotted points for the 15° curves of figure 4. The test limitations of tunnel speed (110 mph) and propeller rotational speed (550 rpm) resulted in a tip speed below 300 feet per second and no effects of compressibility would therefore be expected.

In a few preliminary dual-rotation tests at blade settings of 10° and 15°, setting the front and rear blades at the same angle was found to result in nearly equal power absorption at peak efficiency for each component. The front and rear blades were consequently set at the same blade angle for the entire series of low blade-angle tests.

L-316

RESULTS

The results are presented in the usual nondimensional form of thrust coefficient, power coefficient, and propulsive efficiency,

$$C_T = \frac{\text{effective thrust}}{\rho n^2 D^4}$$

$$C_P = \frac{P}{\rho n^3 D^5}$$

$$\eta = \frac{C_T}{C_P} \frac{V}{nD}$$

P	power absorbed by propeller, foot-pounds per second
V	airspeed, feet per second
n	propeller rotational speed, revolutions per second
D	propeller diameter, feet
ρ	mass density of the air, slugs per cubic foot
β_F	front blade angle at 0.75R, degrees
β_R	rear blade angle at 0.75R, degrees
C_{P_F}	power-coefficient for front propeller
C_{P_R}	power-coefficient for rear propeller

The effective thrust is the measured thrust of the propeller-body combination plus the drag of the body measured without a propeller.

The figures giving the propeller characteristics are listed in the following table:

Figure	Number of blades	Blade angle at 0.75R (deg)	Rotation	Test condition
4	2	10 to 15	Single	Rear hub, with wing
5	3	10 to 15	---do---	Do.
6	4	10 to 20	---do---	Do.
7 and 8	4	10 to 20	Dual	With wing
9	6	10 to 20	Single	Do.
10 and 11	6	10 to 20	Dual	Do.
12	8	10 to 20	Single	Do.
13 and 14	8	10 to 20	Dual	Do.
15 to 17	2	20 to 65	Single	Front hub, without wing
18 to 20	2	20 to 60	---do---	Rear hub, without wing
21 to 23	3	20 to 65	---do---	Front hub, with wing

No attempt has been made to present comparisons between dual and single rotation at the low blade angles since no appreciable gain in thrust from dual rotation would be expected. Curves of propeller characteristics at blade angles of 20° (from references 2 and 4) have been included with the 10° and 15° curves whenever the data were available in order to give a clearer picture of the relation of the 10° and 15° blade-angle data to the data for the higher blade angles.

It should be noted that the power-coefficient curve for the six-blade, single-rotating propeller at 15° blade angle has been obtained by cross-fairing since the test curve appeared to be in error.

Table I is furnished for the purpose of relating the present program with previous work in which the same body and the same basic propeller were used. In the table are listed the important test conditions.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va.

L-316

REFERENCES

1. Biermann, David, and Hartman, Edwin P.: The Effect of Compressibility on Eight Full-Scale Propellers Operating in the Take-Off and Climbing Range. NACA Rep. No. 639, 1938.

2. Biermann, David, and Hartman, Edwin P.: Wind-Tunnel Tests of Four- and Six-Blade, Single- and Dual-Rotating Tractor Propellers. NACA Rep. No. 747, 1942.

3. Biermann, David, Hartman, Edwin P., and Pepper, Edward: Full-Scale Tests of Several Propellers Equipped with Spinners, Cuffs, Airfoil and Round Shanks, and NACA 12-Series Sections. NACA ACR, Oct. 1940.

4. Biermann, David, and Gray, W. H.: Wind-Tunnel Tests of Eight-Blade Single- and Dual-Rotating Propellers in the Tractor Position. NACA ARR, Nov. 1941.

5. Biermann, David, and Gray, W. H.: Wind-Tunnel Tests of Single- and Dual-Rotating Pusher Propellers Having from Two to Eight Blades. NACA ARR, Feb. 1942.

6. Biermann, David, Gray, W. H., and Maynard, Julian D.: Wind-Tunnel Tests of Single- and Dual-Rotating Tractor Propellers of Large Blade Width. NACA ARR, Sept. 1942.

TABLE I.- AVAILABLE DATA FROM PREVIOUS TESTS OF PROPELLERS WITH BLADE DESIGN 3155-6 AND 3156-6

Nacelle position	Number of blades	Blade location	Other test conditions	Rotation	Blade angle range of tests (deg)	Blades used	Reference
Tractor	3	Tested in both hubs	Without wing	Single	20 to 65	Normal width	3
Tractor	4	2 in each hub	With and without wing	Single	20 to 60	Normal width	2
	4	--------do-----------	---------do-----------	Dual	20 to 60		
	6	3 in each hub	---------do-----------	Single	20 to 65		
	6	--------do-----------	---------do-----------	Dual	20 to 65		
Tractor	8	4 in each hub	With and without wing	Single	20 to 65	Normal width	4
	8	--------do-----------	---------do-----------	Dual	20 to 65		
Pusher	3	In front hub	Without wing	Single	20 to 75	Normal width	5
	4	Tested in both hubs, also 2 in ea.	---------do-----------	Single	20 to 70		
	4	2 in each hub	---------do-----------	Dual	20 to 70		
	6	3 in each hub	---------do-----------	Single	20 to 70		
	6	--------do-----------	---------do-----------	Dual	20 to 70		
	8	4 in each hub	---------do-----------	Single	20 to 70		
	8	--------do-----------	---------do-----------	Dual	20 to 70		
Tractor	2	In rear hub	With wing	Single	10 to 65	50 percent wider and thicker than normal	6
	3	--------do-----------	---------do-----------	--do--	10 to 65		
	4	--------do-----------	---------do-----------	--do--	10 to 65		
	4	2 in each hub	---------do-----------	Dual	10 to 65		
	6	3 in each hub	---------do-----------	Single	10 to 65		
	6	--------do-----------	---------do-----------	Dual	10 to 65		
	8	4 in each hub	---------do-----------	Single	10 to 65		
	8	--------do-----------	---------do-----------	Dual	10 to 60		

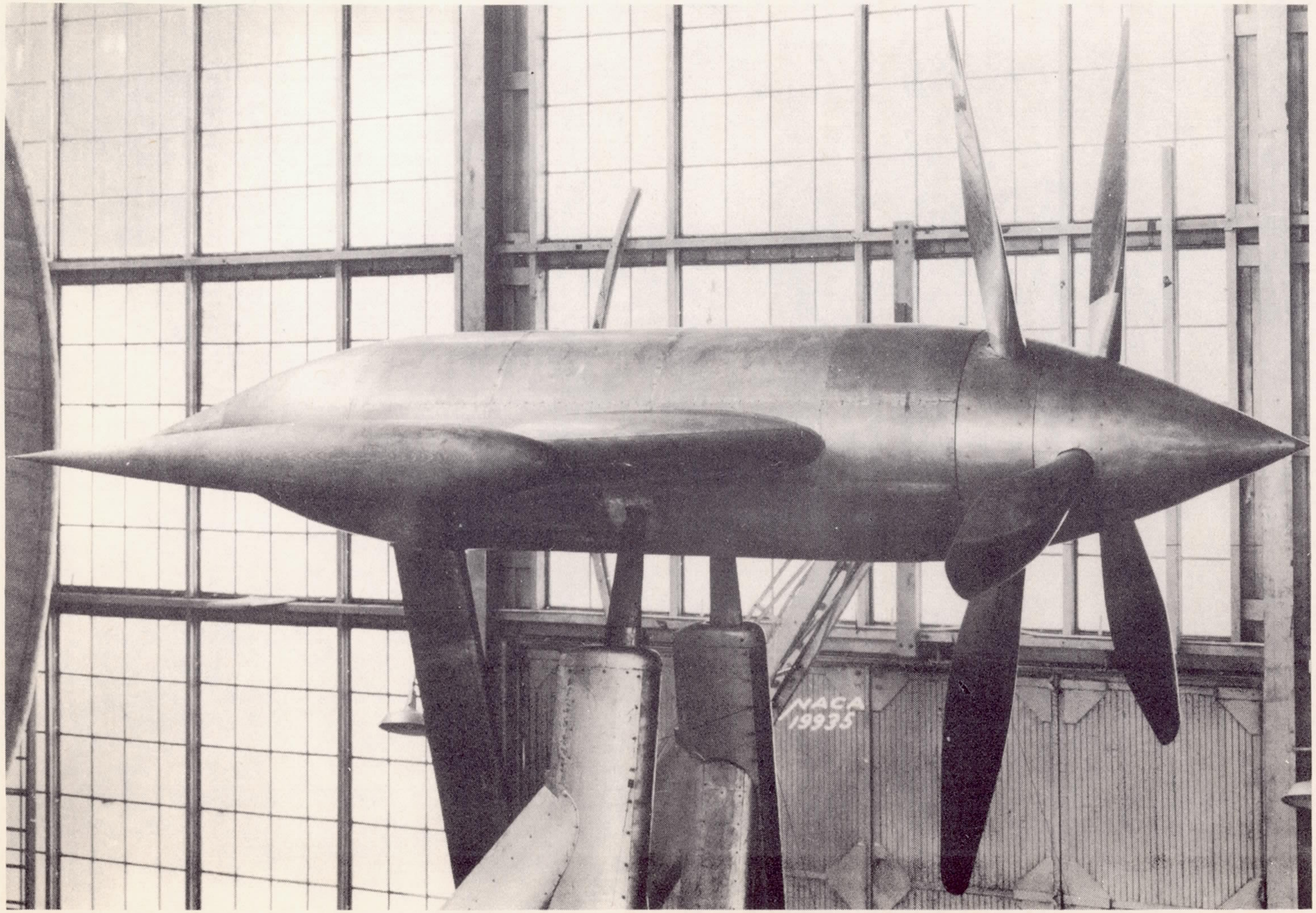

Figure 1.- Test set up. Six-blade single-rotating propeller with wing.

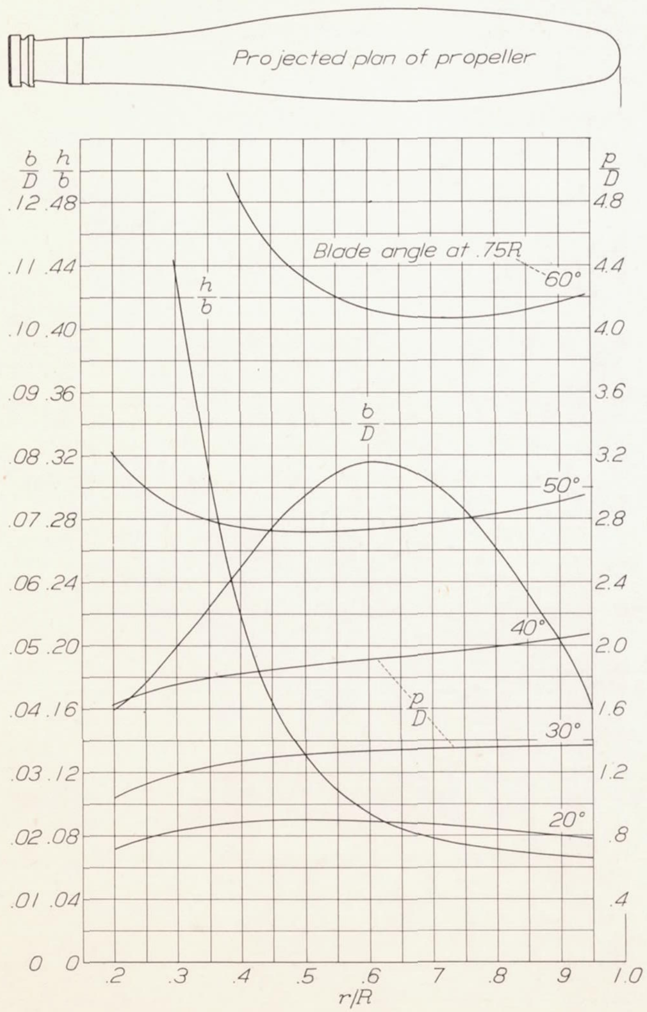

Figure 3.- Plan-form and blade-form curves for propellers 3155-6 and 3156-6. D, diameter; R, radius; r, station radius; b, section chord; h, section thickness; p, geometric pitch.

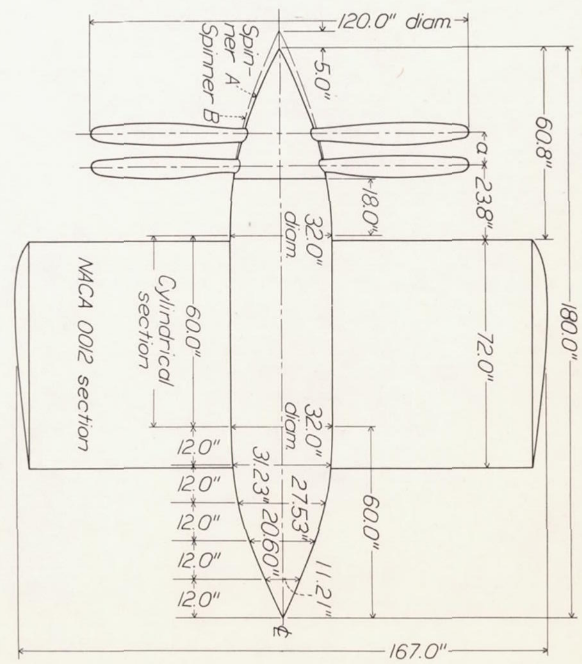

Figure 2.- Plan view showing dimensional details of wing and nacelle. Front and rear nacelle lines substantially identical. Spinner A used when a = 10 in.; B used when a = 15 in.

(1 block = 10 divisions on 1/30 Engr. scale)

L-316

(1 block = 10 divisions on 1/32 Arch. scale)

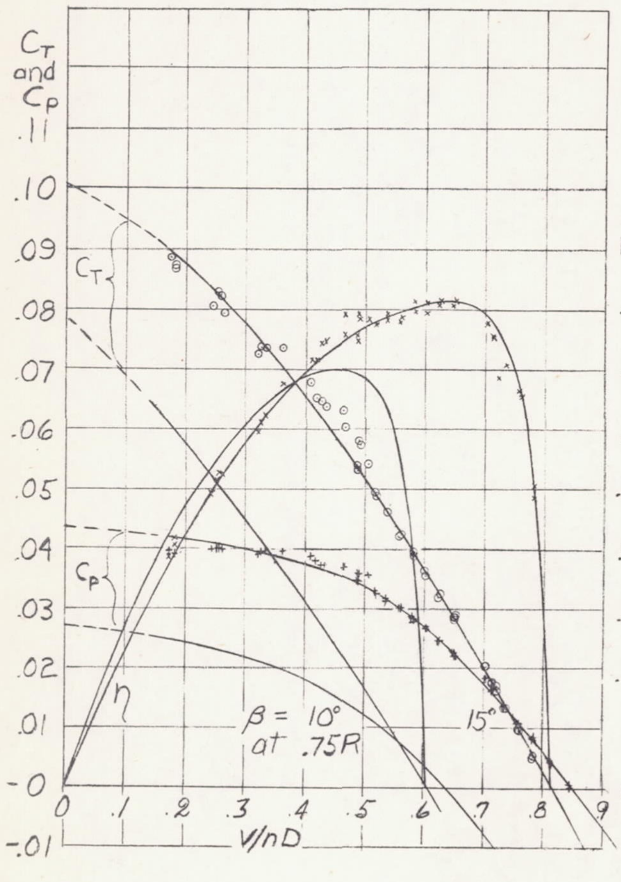

FIGURE 4. - PROPELLER CHARACTERISTICS AT LOW BLADE ANGLES. TWO-BLADE PROPELLER IN REAR HUB.

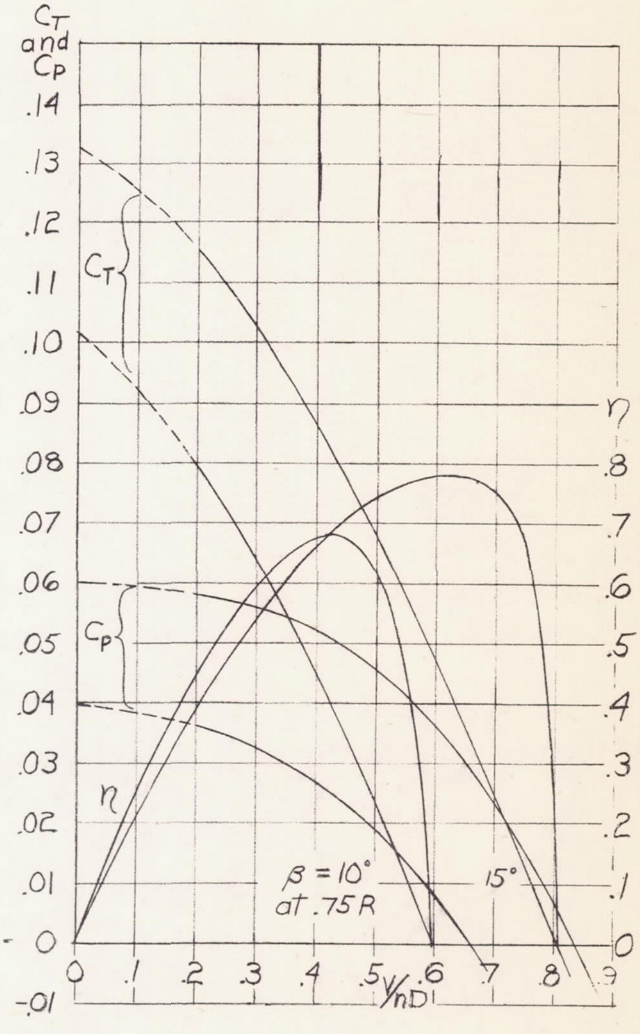

FIGURE 5. - PROPELLER CHARACTERISTICS AT LOW BLADE ANGLE. THREE-BLADE PROPELLER IN REAR HUB.

(1 block = 10 divisions on 1/40 Engr. scale)

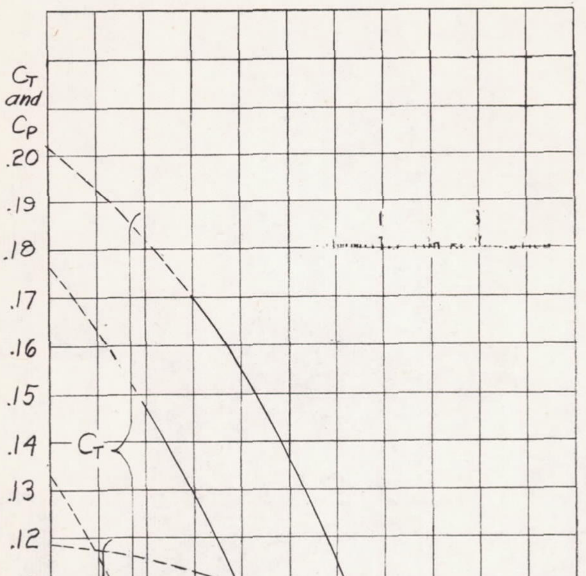

Figure 6.- Propeller characteristics at low blade angles. Four-blade single-rotating propeller in rear hub.

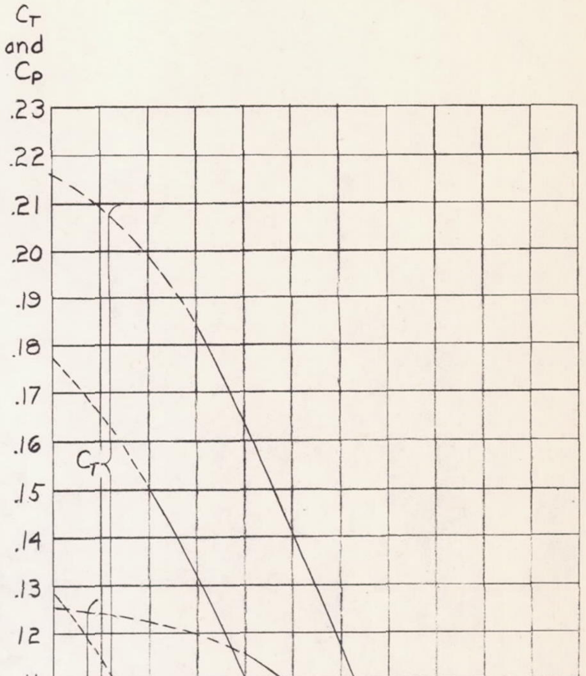

Figure 7.- Propeller characteristics at low blade angles. Four-blade dual-rotating propeller.

L-316

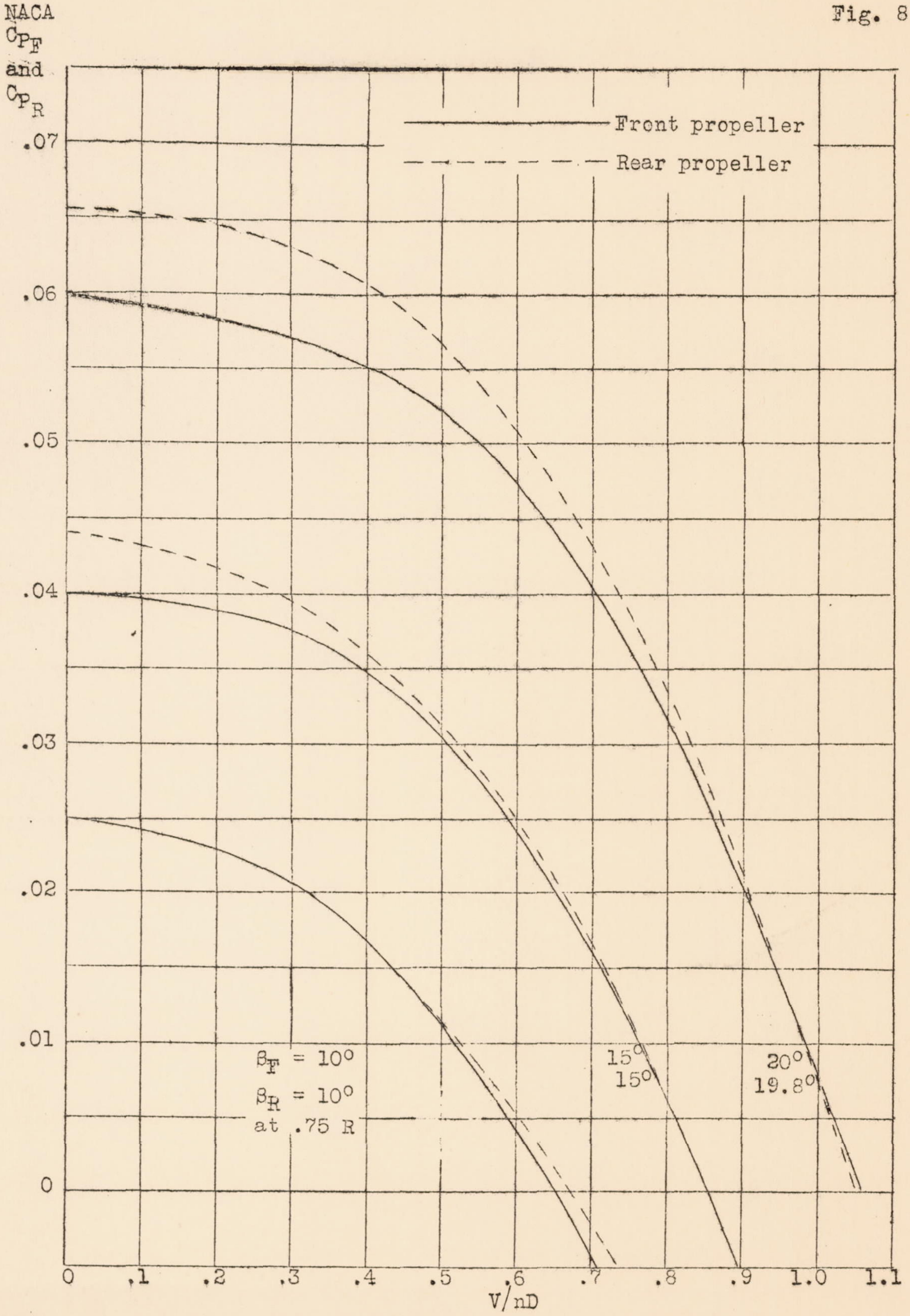

Figure 8.- Individual power-coefficient curves for four-blade dual-rotating propeller.

(1 block = 10/40")

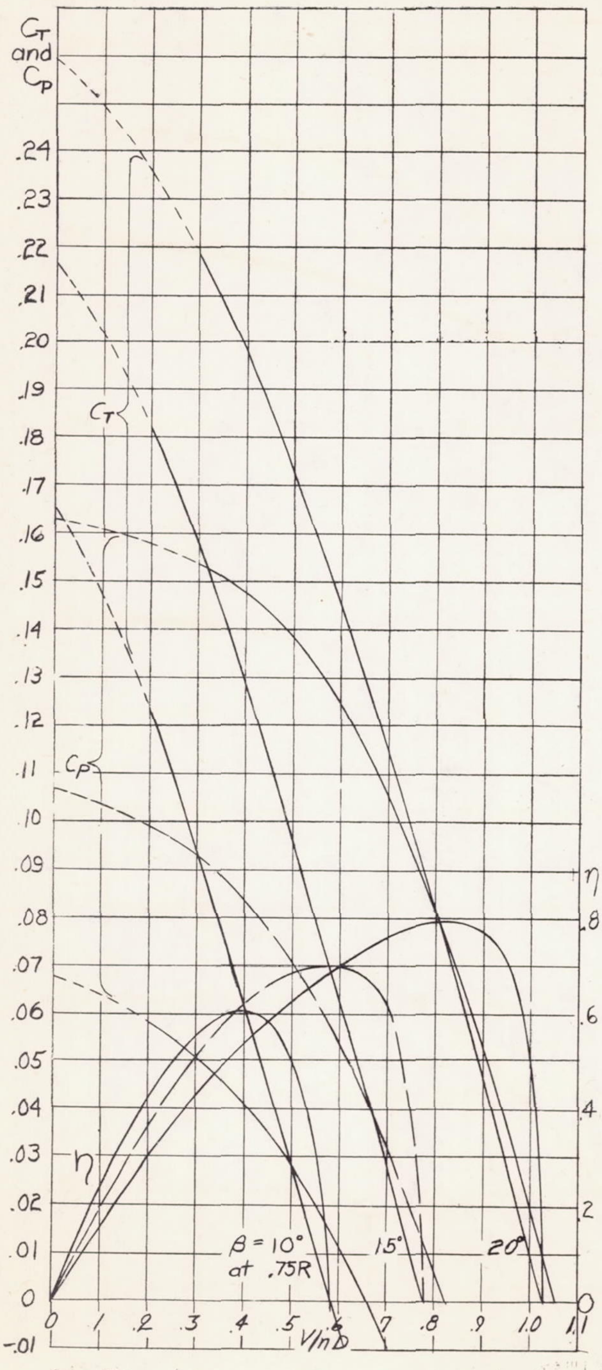

Figure 9.- Propeller characteristics at low blade angles. Six-blade single-rotating propeller.

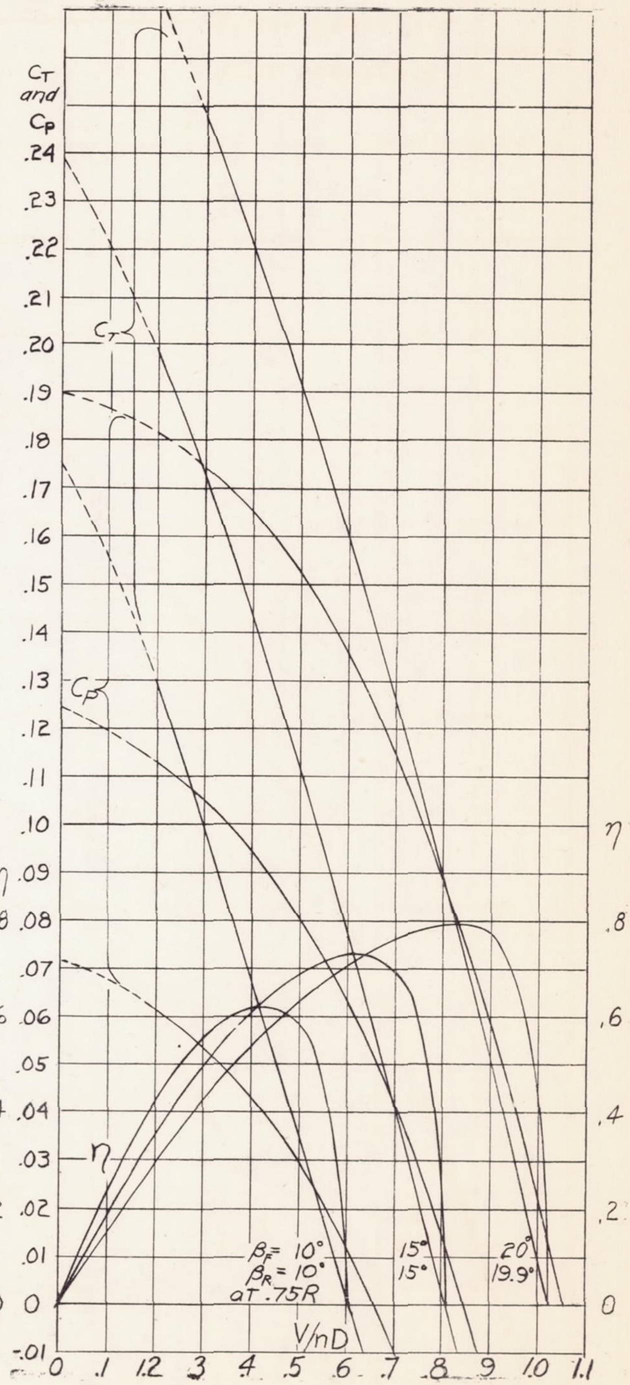

Figure 10.- Propeller characteristics at low blade angles. Six-blade dual-rotating propeller.

(1 block = 10/40")

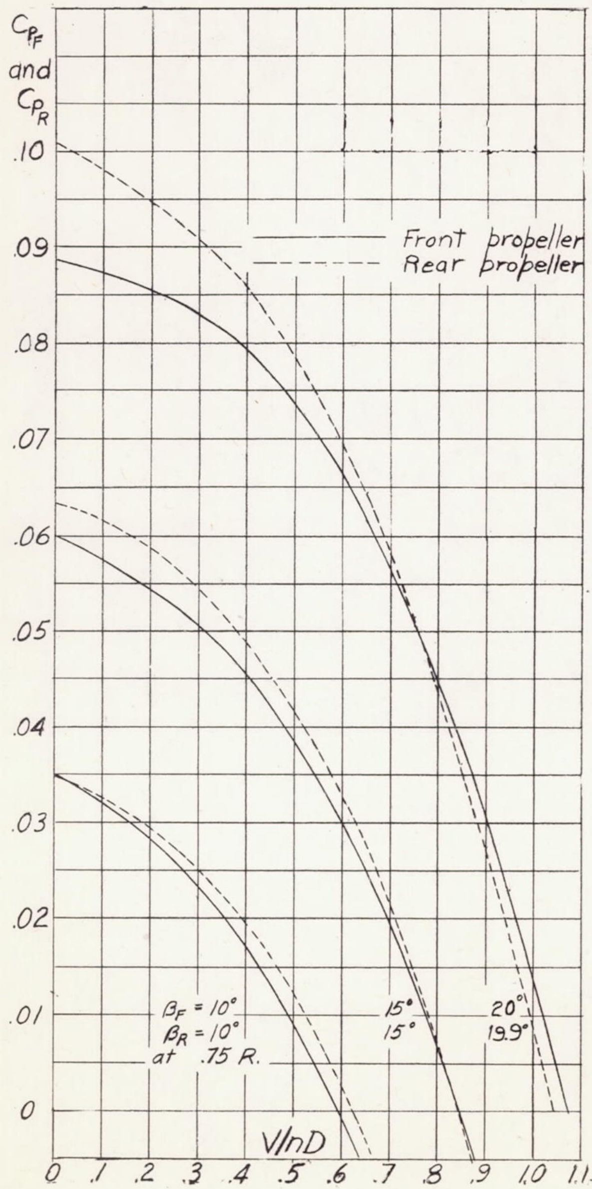

Figure 11.- Individual power-coefficient curves for six-blade dual-rotating propeller.

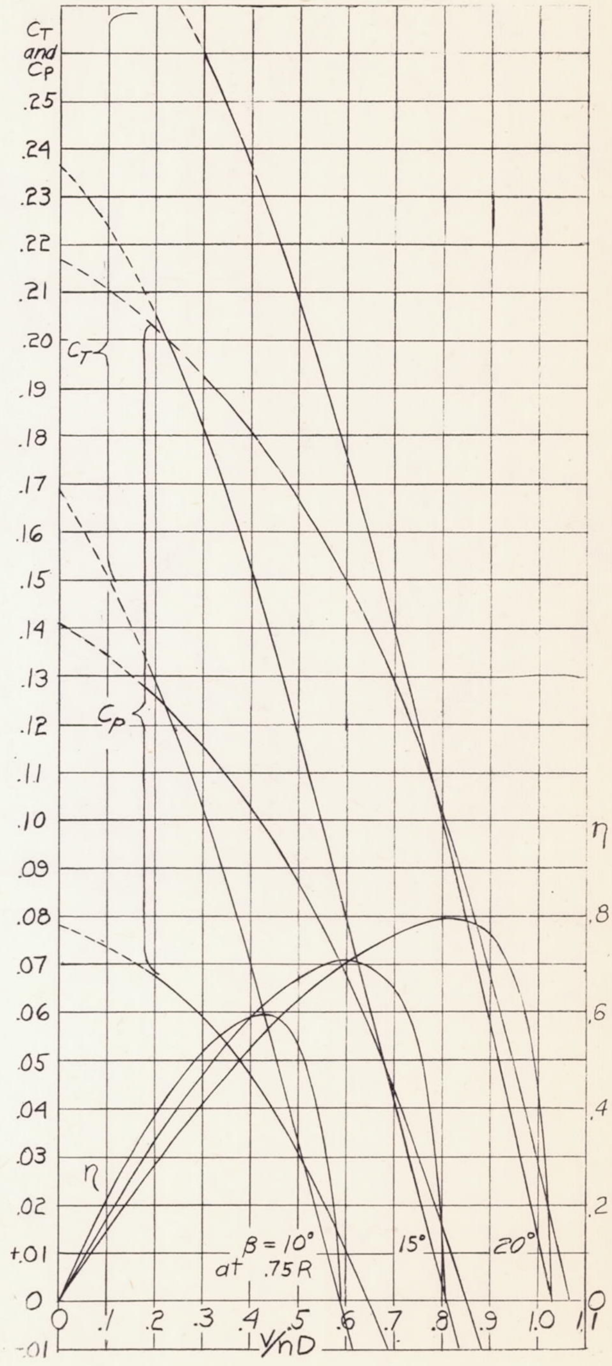

Figure 12.- Propeller characteristics at low blade angles. Eight-blade single-rotating propeller.

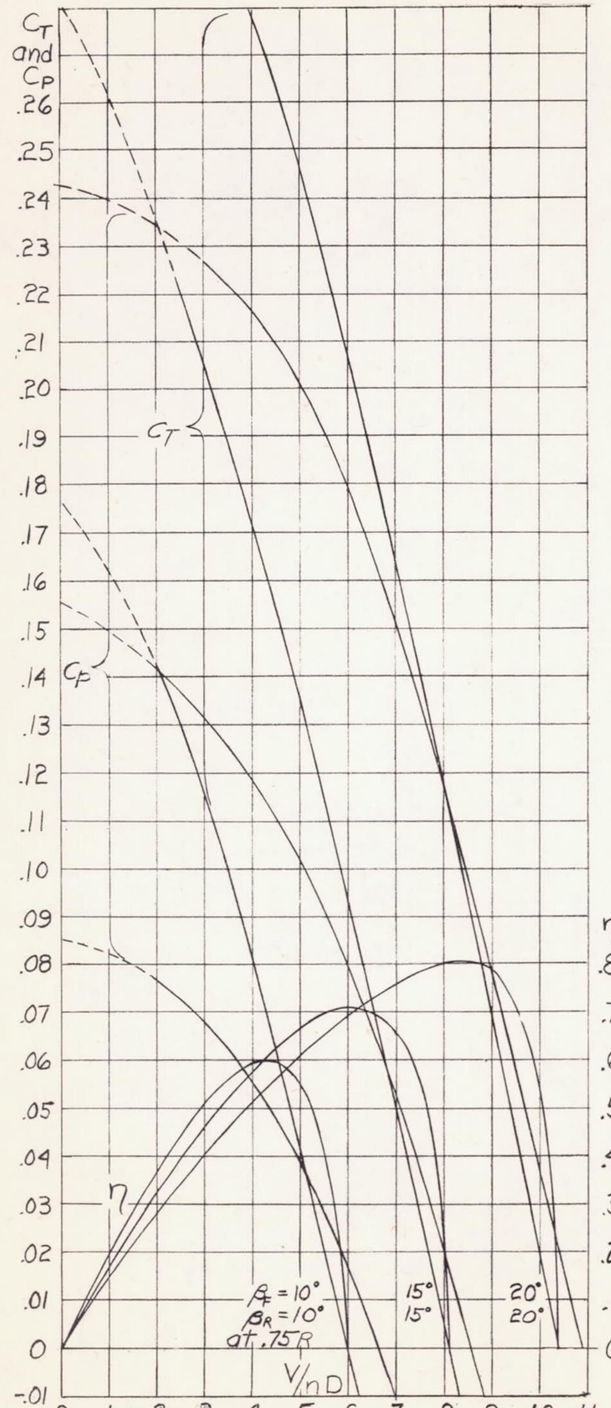

Figure 13.- Propeller characteristics at low blade angles. Eight -blade dual-rotating propeller.

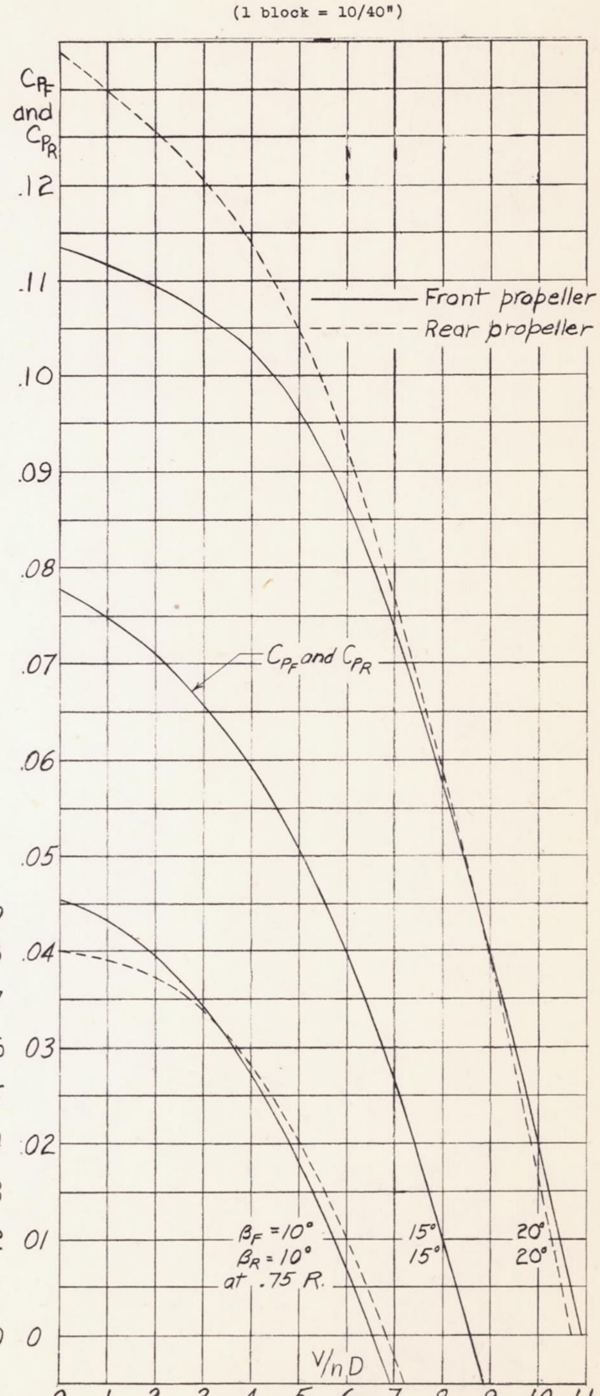

Figure 14.- Individual power-coefficient curves for eight-blade dual-rotating propeller.

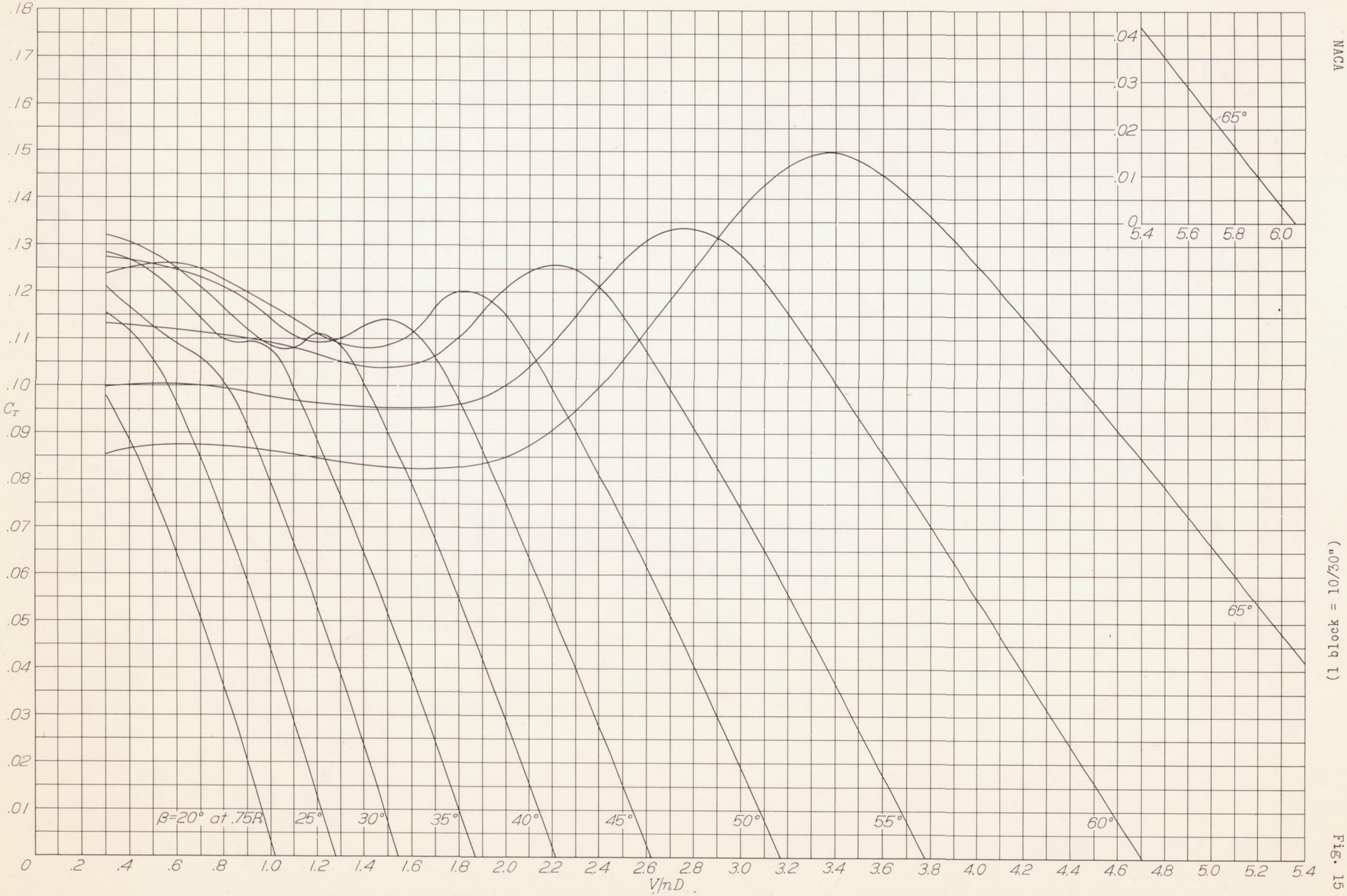

Figure 15.- Thrust-coefficient curves for two-blade propellers in front hub without wing.

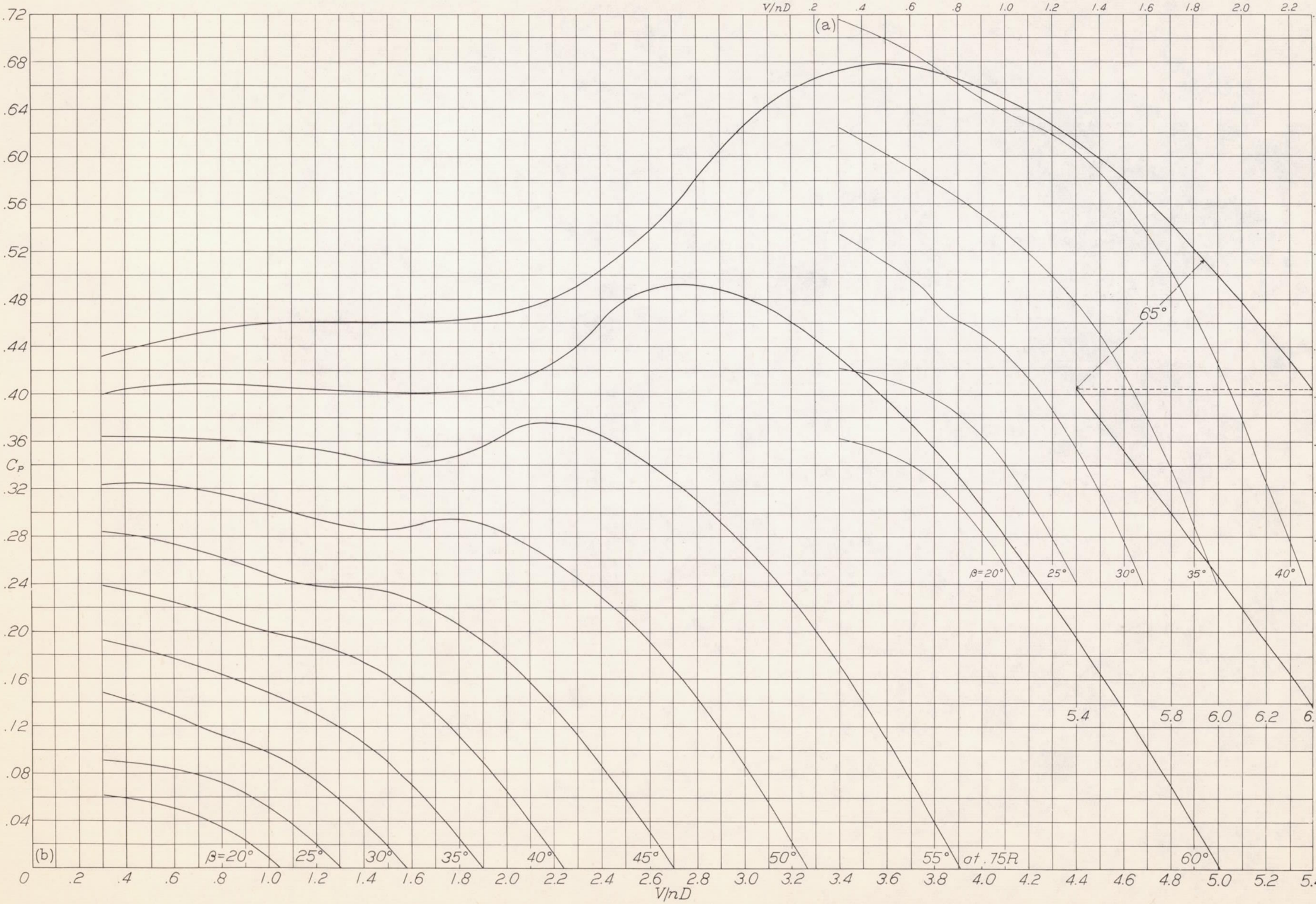

Figure 16.- Power-coefficient curves for two-blade propeller in front hub without wing.

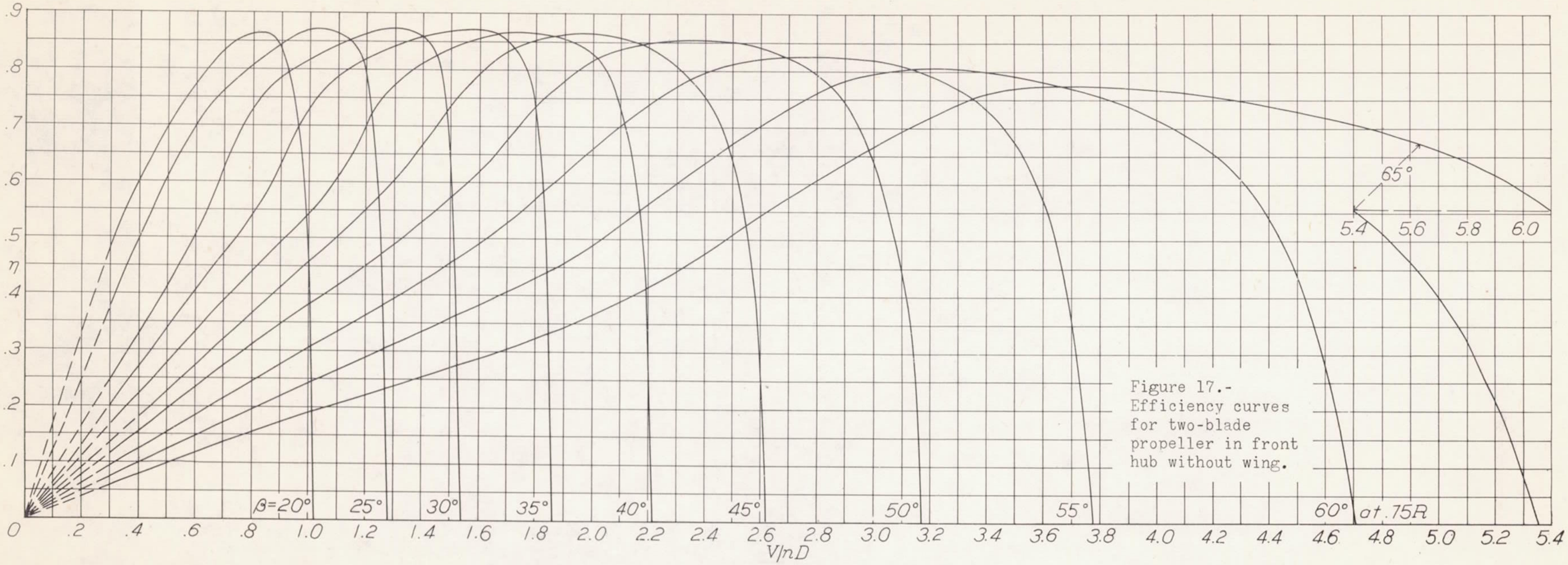

Figure 17.- Efficiency curves for two-blade propeller in front hub without wing.

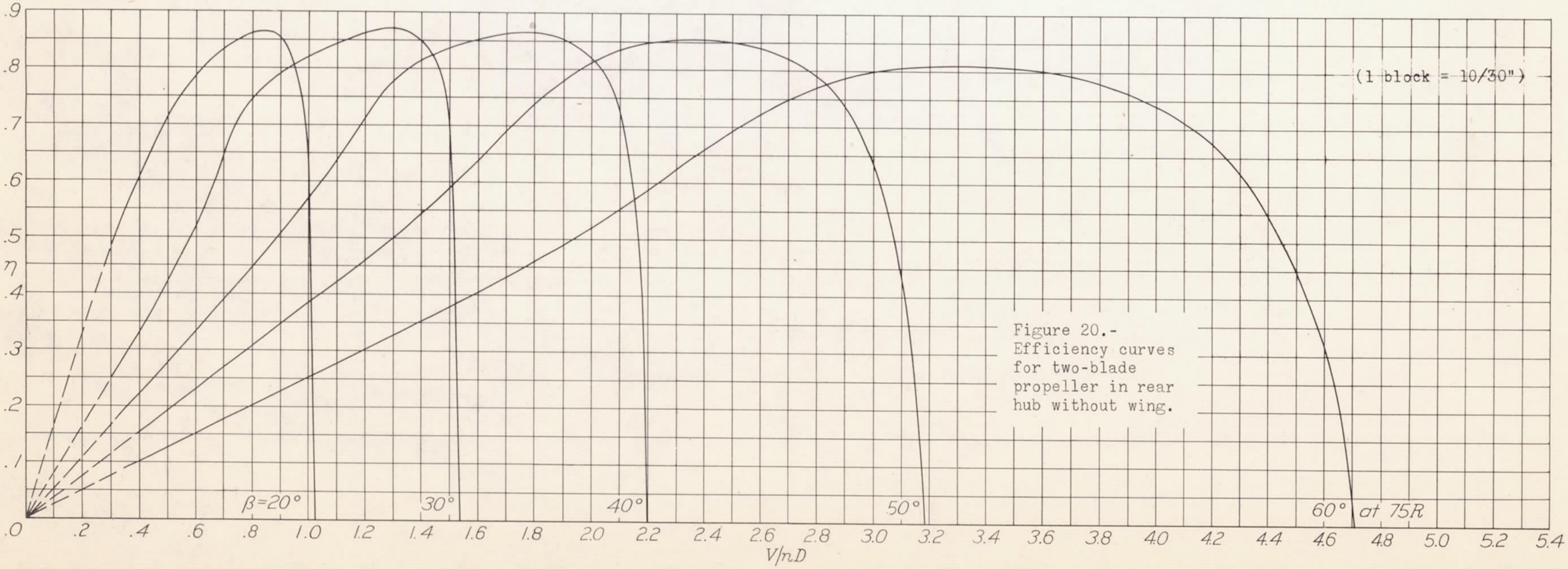

Figure 20.- Efficiency curves for two-blade propeller in rear hub without wing.

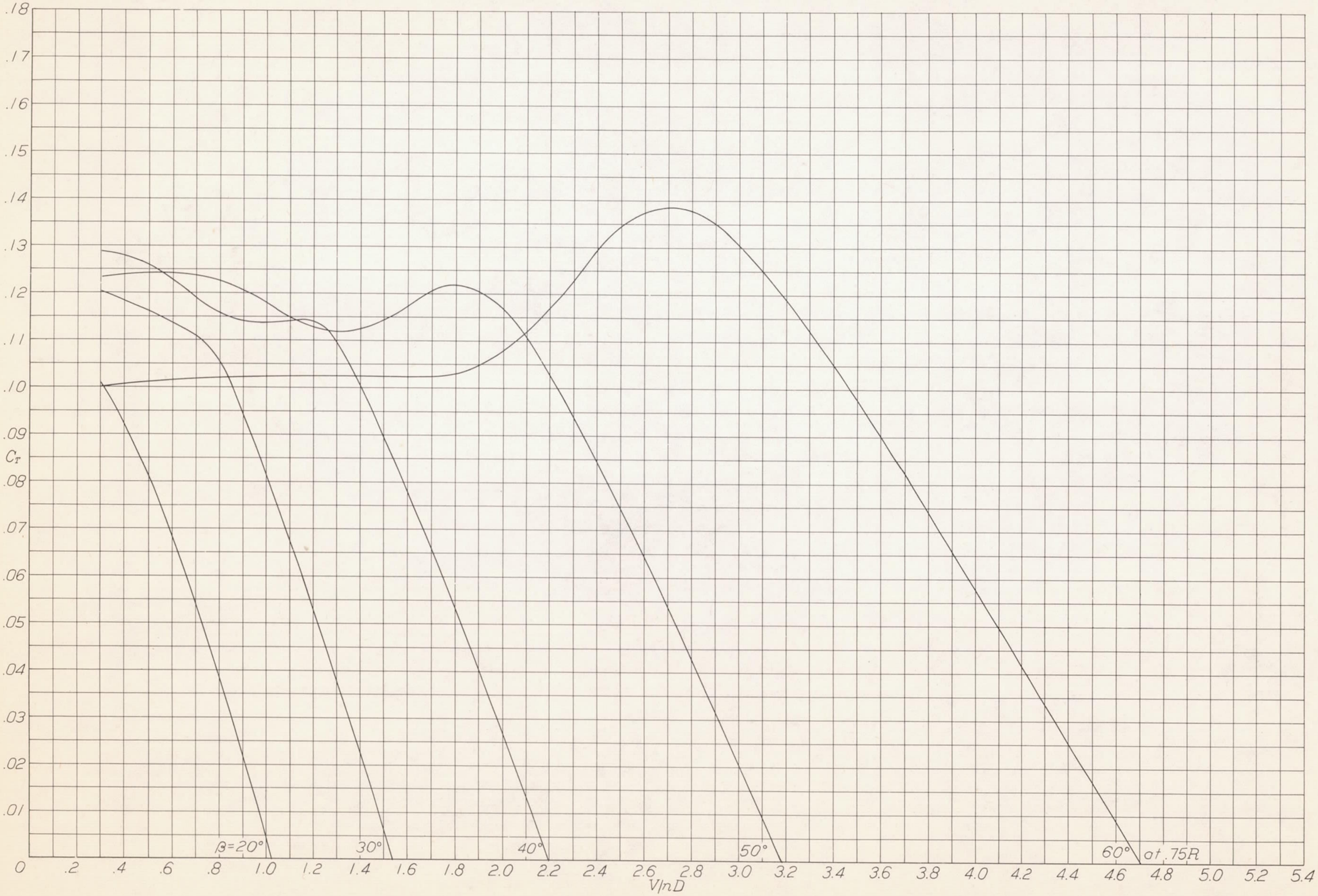

Figure 18.- Thrust-coefficient curves for two-blade propellers in rear hub without wing.

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(1 block = 10/30")

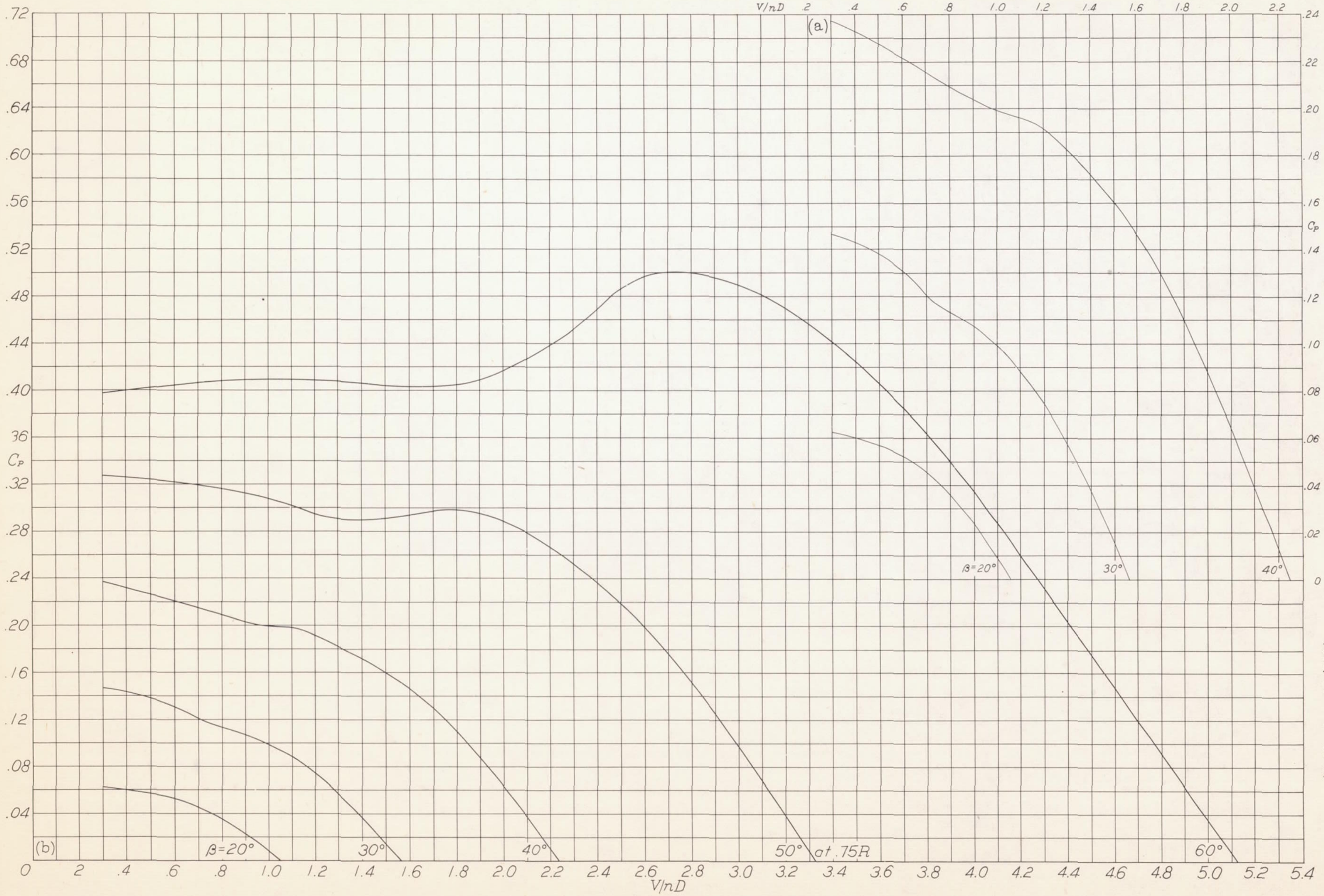
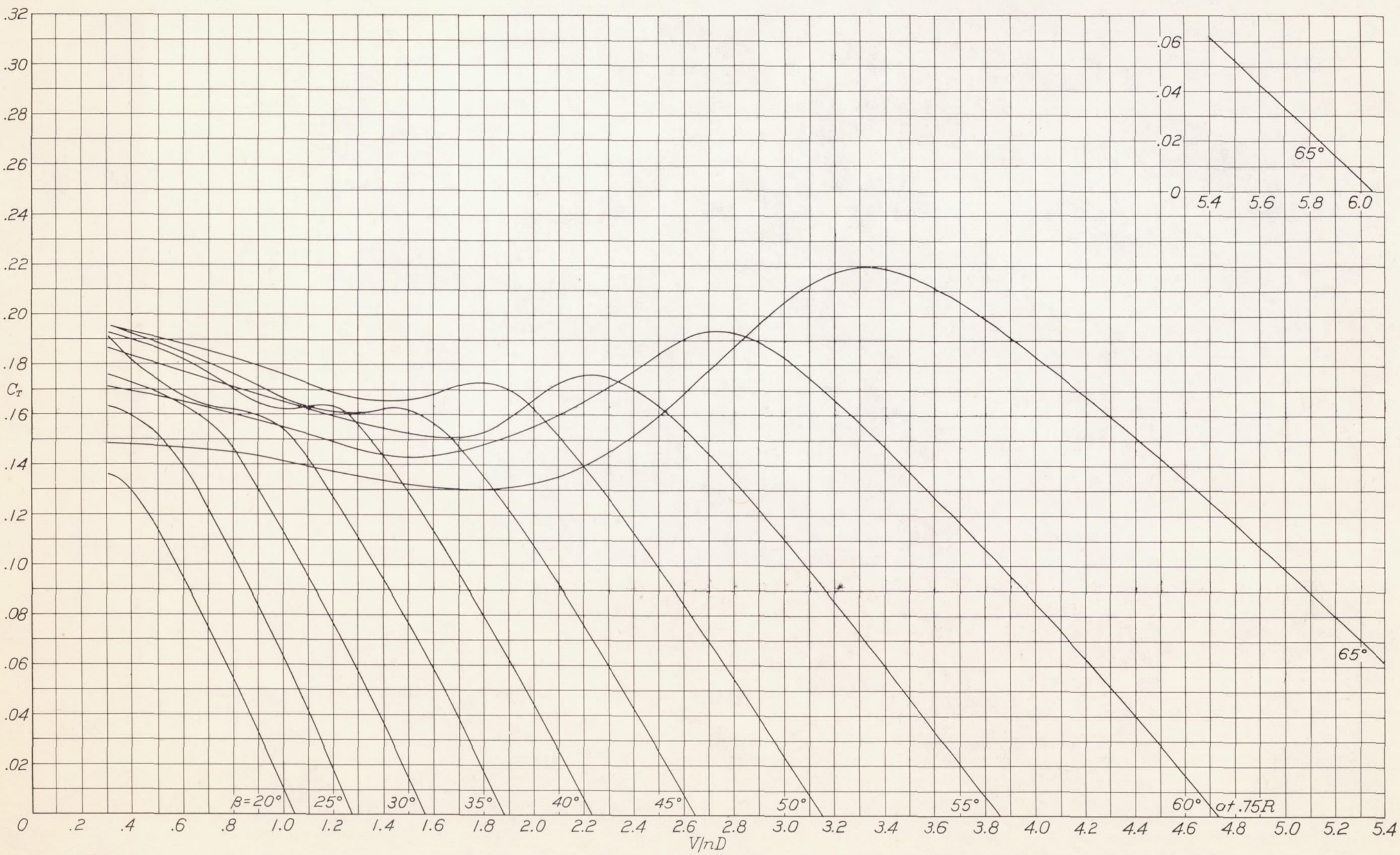


Figure 19.- Power-coefficient curves for two-blade propeller in rear hub without wing.



(1 block = 10/30")

Figure 21.- Thrust-coefficient curves for three-blade propeller in front hub with wing.

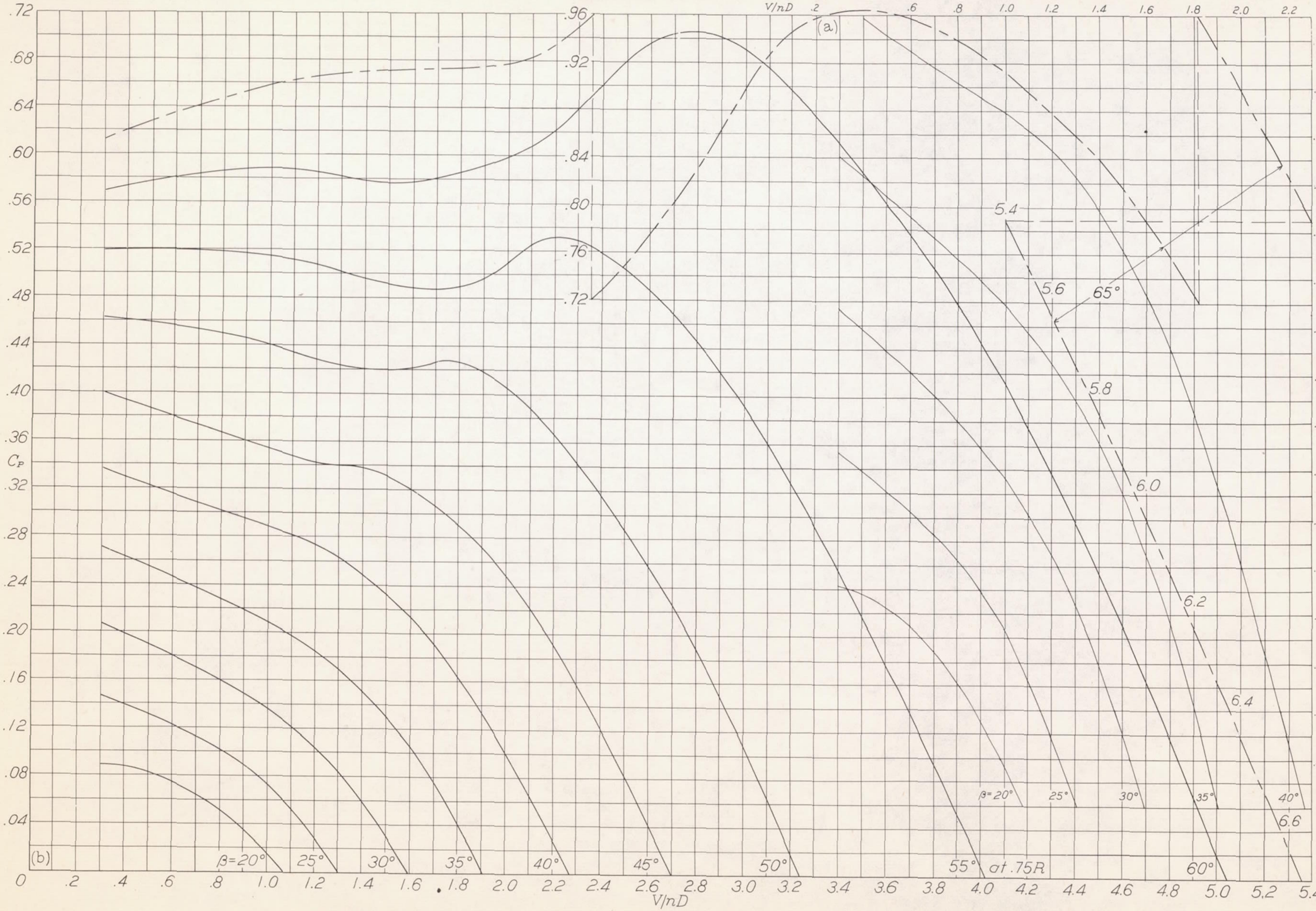


Figure 22.- Power-coefficient curves for three-blade propeller in front hub with wing.

(1 block = 10/30")

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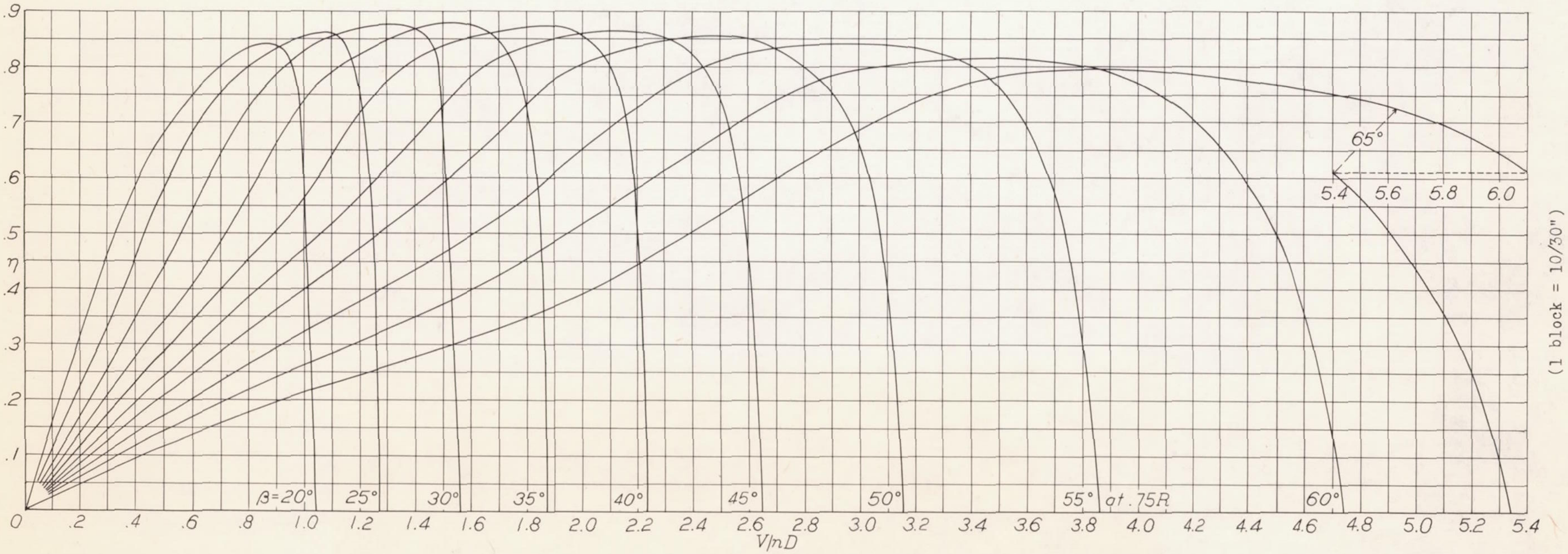

Figure 23.- Efficiency curves for three-blade propeller in front hub with wing.