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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

REPORT No. 421

MEASUREMENT OF THE DIFFERENTIAL AND TOTAL THRUST AND TORQUE OF SIX FULL-SCALE ADJUSTABLE-PITCH PROPELLERS

By GEORGE W. STICKLE



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AERONAUTICAL SYMBOLS

1. FUNDAMENTAL AND DERIVED UNITS

	Symbol	Metric		English	
		Unit	Symbol	Unit	Symbol
Length-----	<i>l</i>	meter-----	m	foot (or mile)-----	ft. (or mi.)
Time-----	<i>t</i>	second-----	s	second (or hour)-----	sec. (or hr.)
Force-----	<i>F</i>	weight of one kilogram-----	kg	weight of one pound-----	lb.
Power-----	<i>P</i>	kg/m/s-----	k. p. h.	horsepower-----	hp
Speed-----		{ km/h-----		{ m. p. s.	{ mi./hr.-----
		{ m/s-----		{ ft./sec.-----	{ f. p. s.

2. GENERAL SYMBOLS, ETC.

<p><i>W</i>, Weight = mg</p> <p><i>g</i>, Standard acceleration of gravity = 9.80665 m/s² = 32.1740 ft./sec.²</p> <p><i>m</i>, Mass = $\frac{W}{g}$</p> <p>ρ, Density (mass per unit volume). Standard density of dry air, 0.12497 (kg-m⁻⁴ s²) at 15° C. and 760 mm = 0.002378 (lb.-ft.⁻⁴ sec.²).</p> <p>Specific weight of "standard" air, 1.2255 kg/m³ = 0.07651 lb./ft.³.</p>	<p>mk^2, Moment of inertia (indicate axis of the radius of gyration <i>k</i>, by proper subscript).</p> <p><i>S</i>, Area.</p> <p><i>S_w</i>, Wing area, etc.</p> <p><i>G</i>, Gap.</p> <p><i>b</i>, Span.</p> <p><i>c</i>, Chord.</p> <p>$\frac{b^2}{S}$, Aspect ratio.</p> <p>μ, Coefficient of viscosity.</p>
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3. AERODYNAMICAL SYMBOLS

<p><i>V</i>, True air speed.</p> <p><i>q</i>, Dynamic (or impact) pressure = $\frac{1}{2}\rho V^2$.</p> <p><i>L</i>, Lift, absolute coefficient $C_L = \frac{L}{qS}$</p> <p><i>D</i>, Drag, absolute coefficient $C_D = \frac{D}{qS}$</p> <p><i>D_o</i>, Profile drag, absolute coefficient $C_{D_o} = \frac{D_o}{qS}$</p> <p><i>D_i</i>, Induced drag, absolute coefficient $C_{D_i} = \frac{D_i}{qS}$</p> <p><i>D_p</i>, Parasite drag, absolute coefficient $C_{D_p} = \frac{D_p}{qS}$</p> <p><i>C</i>, Cross-wind force, absolute coefficient[†] $C_C = \frac{C}{qS}$</p> <p><i>R</i>, Resultant force.</p> <p><i>i_w</i>, Angle of setting of wings (relative to thrust line).</p> <p><i>i_s</i>, Angle of stabilizer setting (relative to thrust line).</p>	<p><i>Q</i>, Resultant moment.</p> <p>Ω, Resultant angular velocity.</p> <p>$\frac{Vl}{\mu}$, Reynolds Number, where <i>l</i> is a linear dimension. e. g., for a model airfoil 3 in. chord, 100 mi./hr. normal pressure, at 15° C., the corresponding number is 234,000; or for a model of 10 cm chord 40 m/s, the corresponding number is 274,000.</p> <p><i>C_p</i>, Center of pressure coefficient (ratio of distance of <i>c. p.</i> from leading edge to chord length).</p> <p>α, Angle of attack.</p> <p>ϵ, Angle of downwash.</p> <p>α_o, Angle of attack, infinite aspect ratio.</p> <p>α_i, Angle of attack, induced.</p> <p>α_a, Angle of attack, absolute. (Measured from zero lift position.)</p> <p>γ, Flight path angle.</p>
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**MEASUREMENT OF THE DIFFERENTIAL
AND TOTAL THRUST AND TORQUE OF SIX FULL-SCALE
ADJUSTABLE-PITCH PROPELLERS**

**By GEORGE W. STICKLE
Langley Memorial Aeronautical Laboratory**

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

NAVY BUILDING, WASHINGTON, D. C.

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SUMMARY

Force measurements giving total thrust and torque, and propeller slip stream surveys giving differential thrust and torque were simultaneously made on each of six full-scale propellers in the 20-foot propeller-research tunnel of the National Advisory Committee for Aeronautics. They were adjustable-pitch metal propellers 9.5 feet in diameter; three had modified Clark Y blade sections and three had modified R.A.F. 6 blade sections. This report gives the differential thrust and torque and the variation caused by changing the propeller tip speed, $\frac{V}{nD}$, and the pitch setting. The total thrust and torque obtained from integration of the thrust and torque distribution curves are compared with those obtained by direct force measurements.

In the above comparison the torques measured by the two methods were directly comparable but the thrusts derived from the slip-stream survey differed from those obtained from the force measurements by two factors, the drag of the hub and the increase of body drag due to the slip stream. Since single values of two coefficients used to obtain the factors brought all the thrust curves measured by the two methods into very good agreement, it is believed that the factors represent accurately the drag of the hub and the increase of body drag due to the slip stream.

INTRODUCTION

An investigation of propeller characteristics, conducted in the 20-foot propeller-research tunnel of the National Advisory Committee for Aeronautics, included tests on six full-scale propellers, three having modified Clark Y blade sections and three modified R.A.F. 6 blade sections. Simultaneous readings were taken of the total thrust and torque and of the differential thrust and torque at six stations along the blade. The results of the total force measurements are given in references 1 and 2. The present report gives the results of measuring the differential thrust and torque at six stations along the blade and derives factors for hub drag and increase of body drag due to the propeller slip stream. A later report will give the airfoil

characteristics of the propeller sections deduced from the measurements given in this report.

The differential thrust and torque for each station along the blade was determined by measurements of the total head and the twist of the propeller slip stream. The thrust and torque distribution along the blade for any operating condition was obtained by plotting the elementary thrust and torque for each section against the radius of the propeller. Since it was impossible to survey the air stream behind the hub portion of the propeller, that part of the distribution curves was undetermined. This made it necessary to find a hub-drag coefficient that could be used to account for the negative thrust of the hub.

The total thrust (integrated thrust corrected for hub drag) obtained in the above manner differs from that obtained in the force tests of references 1 and 2 by an amount equal to the effect of the propeller slip stream on the drag of the body, since only the net force was measured on the thrust balance in the force tests. From a comparison of the thrust curves obtained by the two methods the value of the increase of body drag due to the slipstream was obtained.

APPARATUS AND METHODS

The measurement of total head and angular twist at a series of points in the slip stream, which are the essential quantities required in computing the propeller thrust and torque, was accomplished by the use of yawmeters of the type used by G. P. Douglas, of the British Aeronautical Research Committee. (References 3 and 4.) The term "yawmeter" is used to designate the combination of a yaw head and a recording manometer. A suitable yawmeter for the purpose is one that gives a differential pressure, proportional to the resultant dynamic pressure multiplied by the sine of twice the angle of twist of the slip stream, or $H_y K = \rho W^2 \sin 2\psi$. (See list of symbols.) A yaw head constructed of three small tubes (fig. 1) with the forward ends of the two outside tubes turned 45° to the central tube, was found to have a calibration that conformed to the above standard up to approximately 40° of yaw. This angle is much greater than the angle

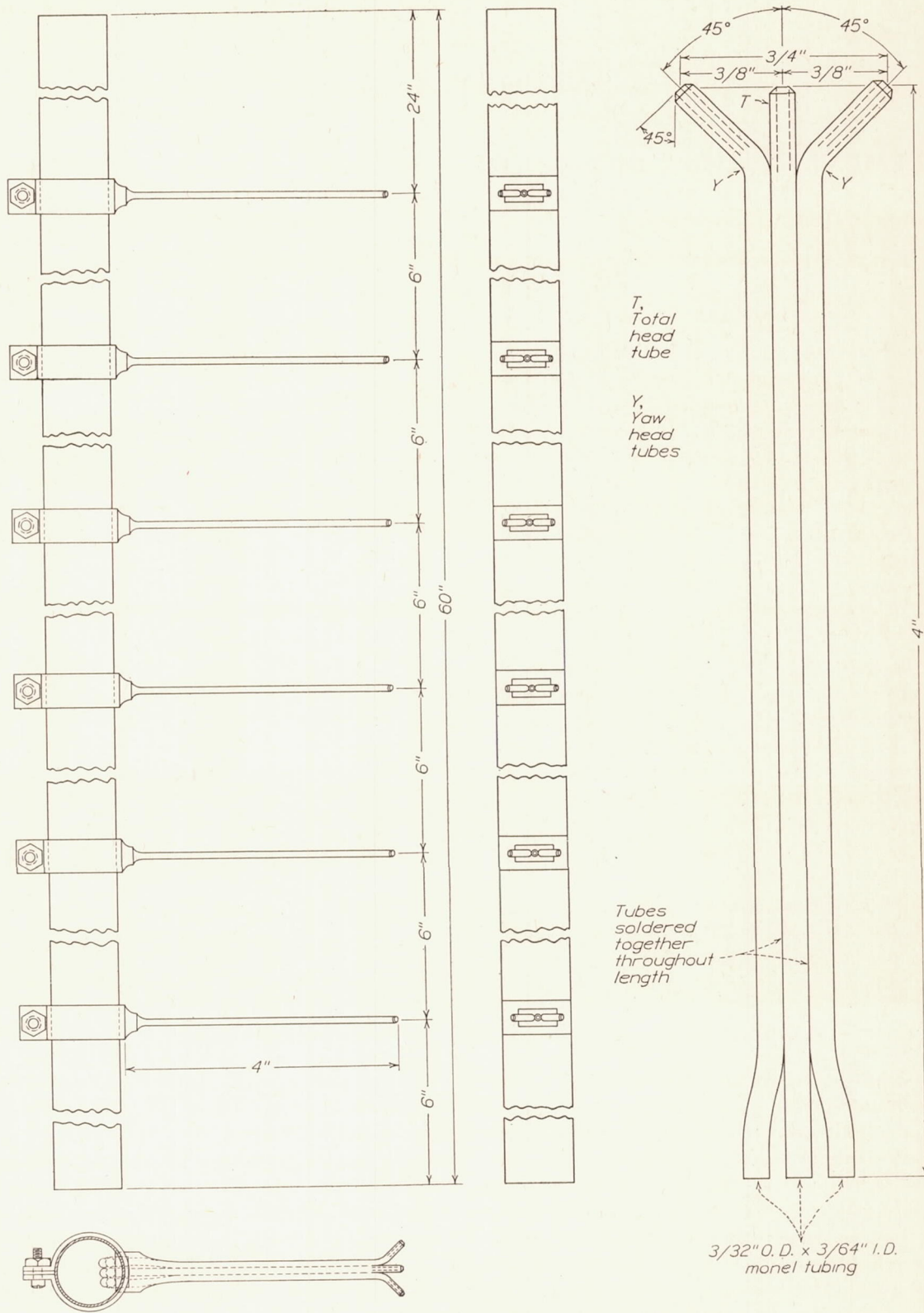


FIGURE 1.—Yaw-head bank assembly and detail

of yaw (twist) encountered in the slip stream of ordinary propellers. The central tube was used to measure the total head.

Six of these yaw heads were clamped at intervals of 6 inches on a tube (fig. 1) which was mounted vertically below the crankshaft central in the rear of the propeller as shown in Figure 2. The vertical position of the tube was such that the yaw heads were 24, 30, 36, 42, 48, and 54 inches from the center of the crankshaft.

This distance was chosen to allow a sufficient clearance (0.3 inch) for the 24-inch station yaw head with the propeller set 27° at the 42-inch radius. The yaw heads were connected by small copper tubes to a photographically-recording multiple-tube manometer, located in a dark room under the entrance cone of the tunnel. Pressures were recorded simultaneously with the readings for the force tests reported in references 1 and 2. The yawmeters were calibrated

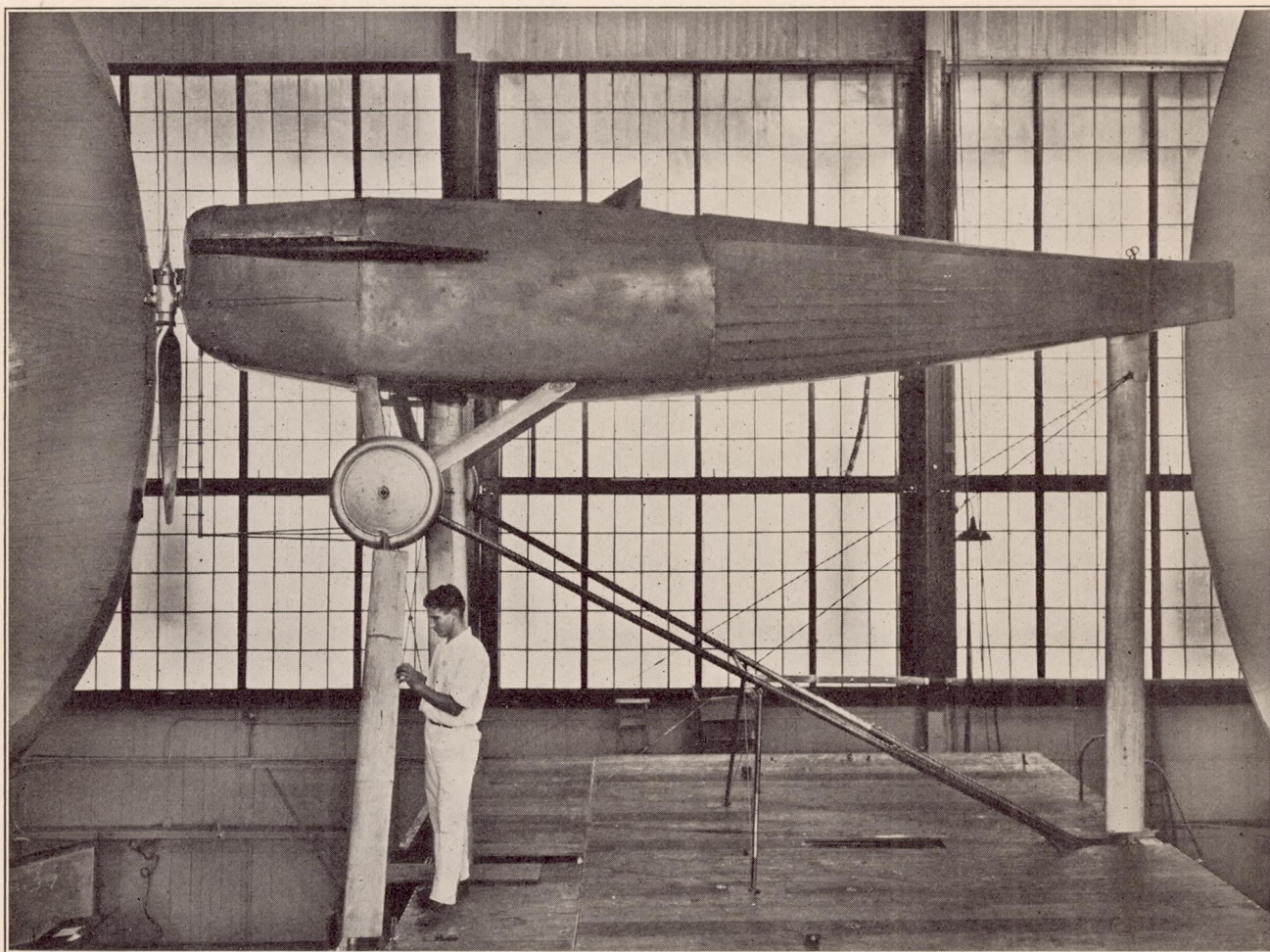


FIGURE 2.—Set-up in propeller-research tunnel with yaw-head bank in place

The yaw head at the 54-inch station was thus 3 inches above the propeller tip.

The tube supports were arranged to allow a fore-and-aft adjustment of the tube position. The model experiments of reference 3 indicated that the readings might be seriously affected by the distance between the tip of the yaw head and the trailing edge of the propeller. A few position trials showed no appreciable effect up to 3 inches between the trailing edge and the yaw heads. Therefore the tube was fixed with a maximum distance from the trailing edge of the propeller to the tip of the yaw heads equal to 2.5 inches.

with the yaw heads in front of the body for angles of yaw from 5° to the left to 15° to the right for use with right-hand propellers.

The propeller-research tunnel and its equipment are described in reference 5. A Curtiss D-12 engine rated at 435 hp. at 2,300 r. p. m. was mounted in a tractor fuselage (fig. 2) to drive the propellers.

Results from tests on six 9.5-foot adjustable-pitch metal propellers, three having modified Clark Y blade sections, and three having modified R.A.F. 6 blade sections, are presented in this report. The outer third of all six propeller blades have sections of constant

thickness/chord ratio. This ratio is used to designate the propellers, as shown in the following table:

PROPELLER DESIGNATION

R.A.F. 6	Clark Y	Thickness/ chord ratio
R-6	C-6	0.06
R-8	C-8	.08
R-10	C-10	.10

The blade-form curves for these propellers are given in Figure 3. Section characteristics may be obtained from reference 1. Each propeller was tested at five pitch settings (11°, 15°, 19°, 23°, and 27° at 42-inch radius) to cover the range ordinarily used. The propeller tip speed for these tests was kept below 900 feet per second in order to minimize the compressibility effects of high tip speeds. In addition, an investiga-

$$\text{Now} \quad dT = dC_T \rho n^2 D^4$$

$$\text{Therefore} \quad \frac{dC_T}{dx} = \frac{\pi H x}{2 \rho n^2 D^2}$$

The values of $\frac{dC_T}{dx}$ for each propeller section behind which a yaw head is located are plotted against $\frac{V}{nD}$ and faired curves are drawn through the points. An example of these curves is given for the C-10 propeller at $x=0.526$ (30-inch radius) in Figure 4. Values of $\frac{dC_T}{dx}$ at even values of $\frac{V}{nD}$ are given in Tables I to XIV. The thrust-gradient curves for even values of $\frac{V}{nD}$ are plotted from these tables, as in Figures 5 to 7. The curves are drawn through 0 at 0.2 of the radius because that is approximately where the pro-

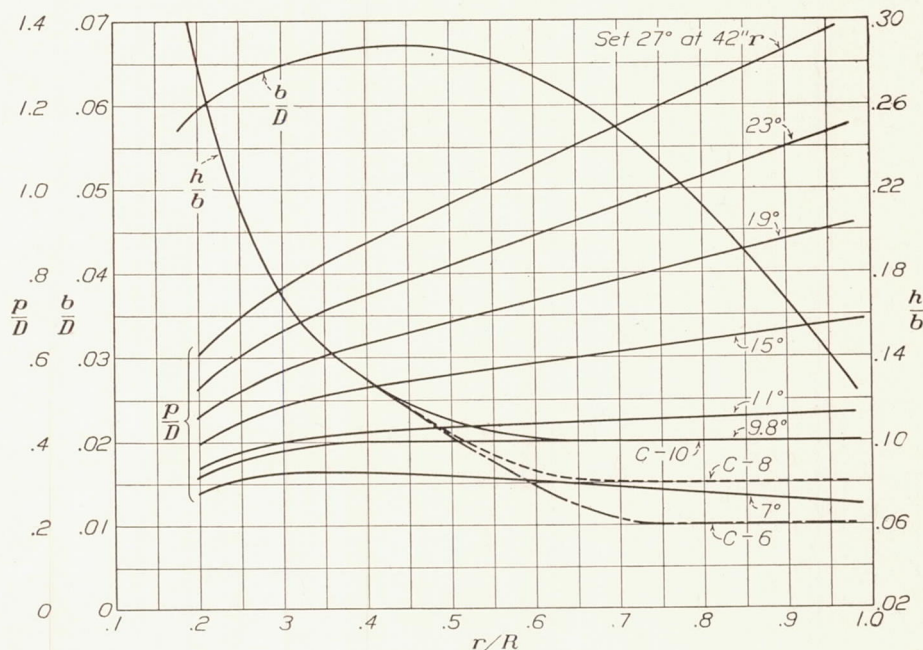


FIGURE 3.—Pitch distribution and blade form curves

tion of the effect of high tip speed was made in which the pitch was set to 9.8° at 42-inch radius on all propellers and also to 7° at 42-inch radius on C-6 and R-6.

RESULTS

Thrust distribution.—The thrust of a differential element of a propeller is equal to the increase in total head due to the thrust, multiplied by the differential annular area described by the element.

$$dT = HdA$$

$$\text{Substituting,} \quad dT = H(2\pi r dr)$$

$$\text{Therefore} \quad \frac{dT}{dr} = 2\pi r H$$

$$\text{Let} \quad x = \frac{r}{R} = \frac{2r}{D}$$

$$\text{Then} \quad \frac{dT}{dx} = \frac{\pi}{2} D^2 H x$$

PELLER changes to a circular section. It is impossible to determine exactly where this point of zero thrust along the blade occurs, but for convenience 0.2 of the radius was adopted as a standard. The total thrust is not very sensitive to a small shift of this point one way or the other, but whatever change does occur is taken care of in the correction for the increased drag of the body due to the slip stream. Graphical integration of these curves gives the total thrust coefficient C_T uncorrected for hub drag, as shown in Figure 8.

Inasmuch as the same hub was used for all the propellers, it seems reasonable to suppose that a constant hub-drag coefficient could be applied to all propellers and all pitch settings. At zero thrust the C_T curves from force measurements and total-head measurements should coincide since at this point the increase of body drag due to the slip stream should be zero. Therefore it is permissible to assume that the separa-

tion of the curves for force measurements and total-head measurements as shown in Figure 8 at the $\frac{V}{nD}$ for zero measured thrust is due to the negative area that

responding to zero thrust from the force measurements, were converted into this form they were found to be nearly constant; therefore an arithmetical mean was taken of them which gave:

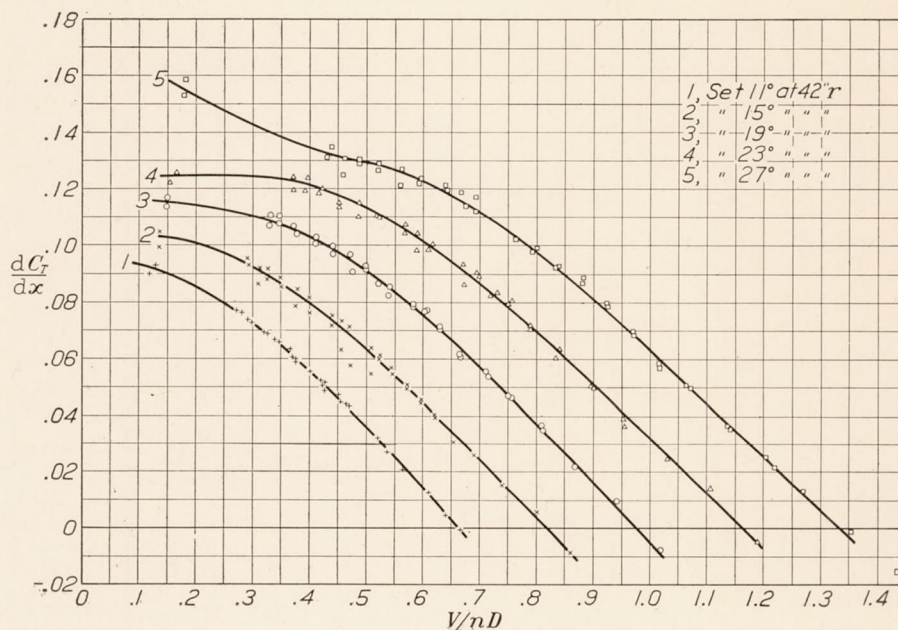


FIGURE 4.—Differential-thrust coefficient. Propeller C-10. $x=0.526$

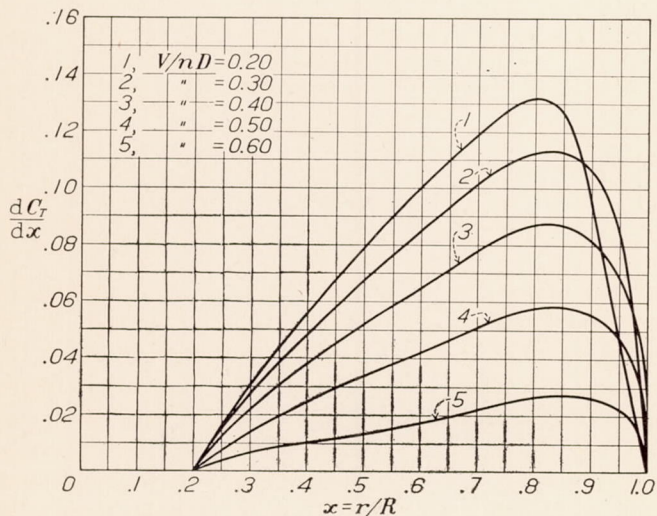


FIGURE 5.—Thrust-gradient curves. Propeller C-10. Set 11° at 42-inch radius

should be added to the distribution curves between $x=0$ and $x=0.2$. If the thrust coefficient, $C_T = \frac{T}{\rho n^2 D^4}$, is divided by $\left(\frac{V}{nD}\right)^2$ it becomes $\frac{T}{\rho V^2 D^2}$ which is in the form of a drag coefficient. When the values of C_T from the total-head measurements, at values of $\frac{V}{nD}$ corre-

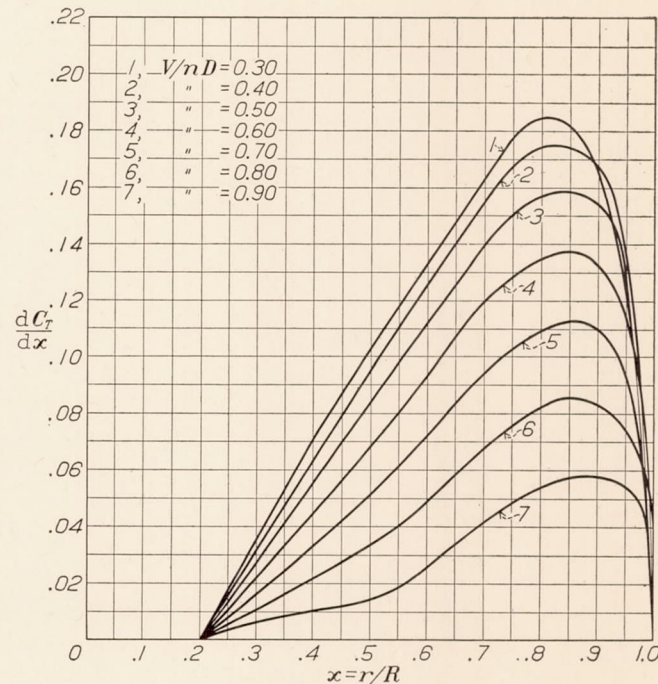


FIGURE 6.—Thrust-gradient curves. Propeller C-10. Set 19° at 42-inch radius

$$\text{Drag coefficient} = 0.005 = \frac{\text{Drag}}{\rho V^2 D^2}$$

$$C_T \text{ correction} = 0.005 \left(\frac{V}{nD}\right)^2$$

This hub-drag coefficient is approximately equal to 25 per cent of that of a circular flat plate of a diameter equal to that of the hub.

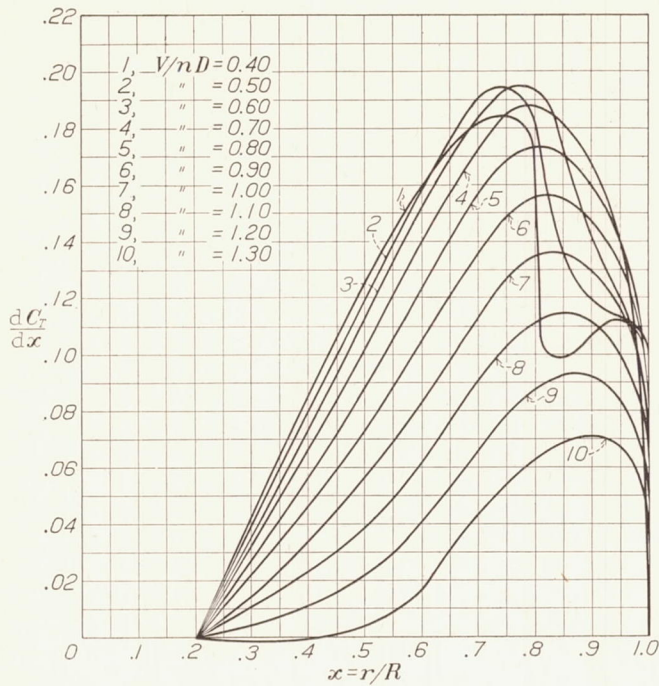


FIGURE 7.—Thrust-gradient curves. Propeller C-10. Set 27° at 42-inch radius

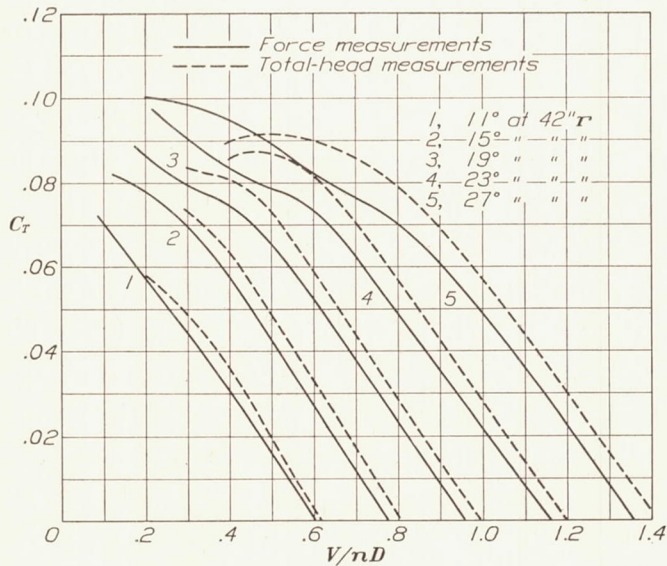


FIGURE 8.—Comparison of effective thrust coefficient from force measurements and integrated thrust coefficient from total-head measurements. Propeller C-6

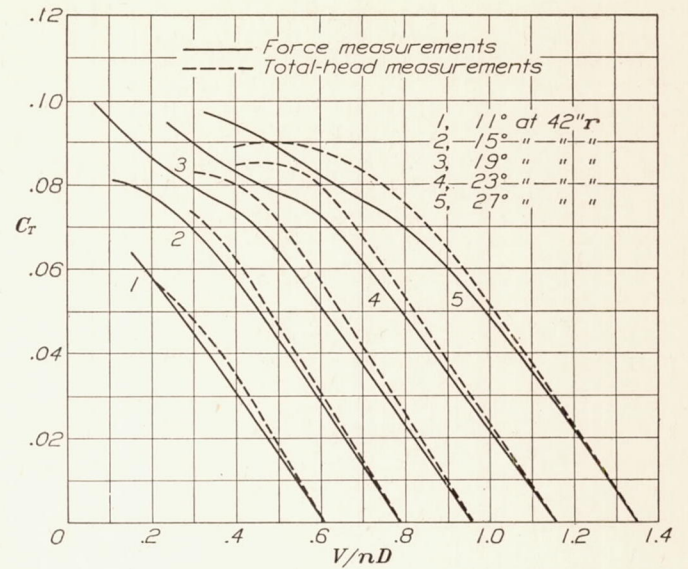


FIGURE 9.—Comparison of effective thrust coefficient from force measurements and total thrust coefficient (integrated thrust coefficient corrected for hub drag) from total-head measurements. Propeller C-6

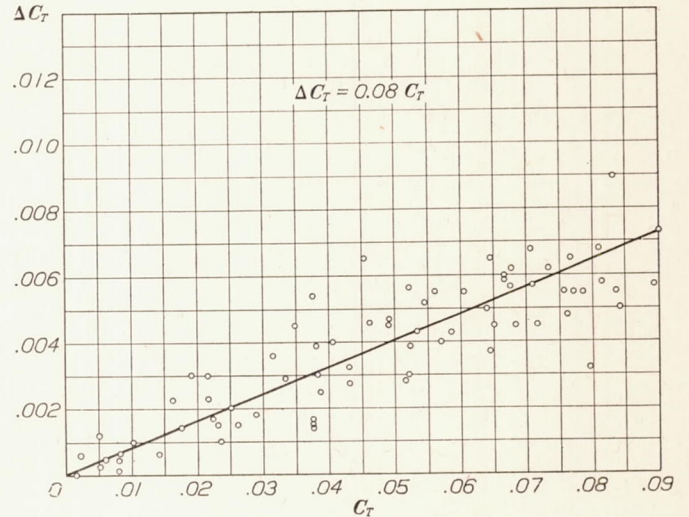


FIGURE 10.—Increase of body drag due to the propeller slip stream

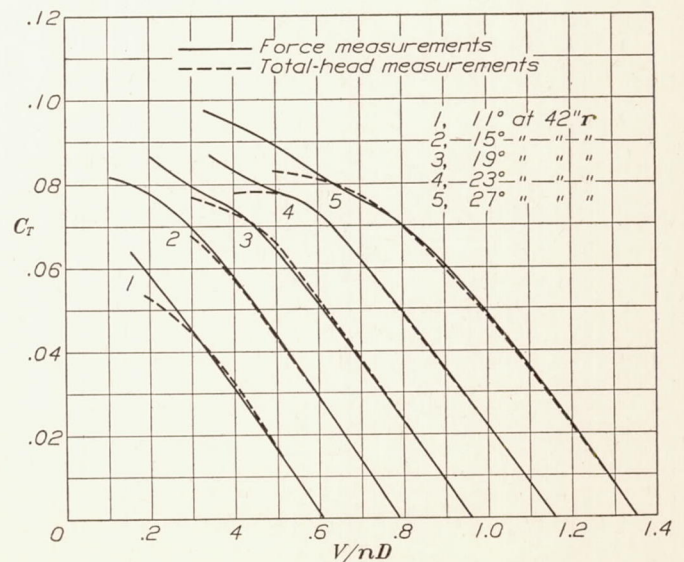


FIGURE 11.—Comparison of effective thrust coefficient from force measurements and corrected total head-measurements. Propeller C-6

Figure 9 gives a comparison of the total thrust computed from total-head measurements and the measured effective thrust from the force measurements. The difference in the two values (ΔC_T) at any $\frac{V}{nD}$ may be accounted for by the increase in body drag due to the slip stream. In Figure 10, ΔC_T is plotted against the total C_T and a straight line determined by the theory of least squares is drawn through these points. Figures 11 to 16 give a comparison of effective thrust coefficients obtained by the two methods.

Torque distribution.—From a consideration of the angular momentum in the wake of a propeller, the differential torque of a propeller element can be expressed as:

$$dQ = rV_1 dM$$

Substituting $dM = \rho U dA = \rho U 2\pi r dr$

$$\frac{dQ}{dr} = 2\pi r^2 V_1 U \rho$$

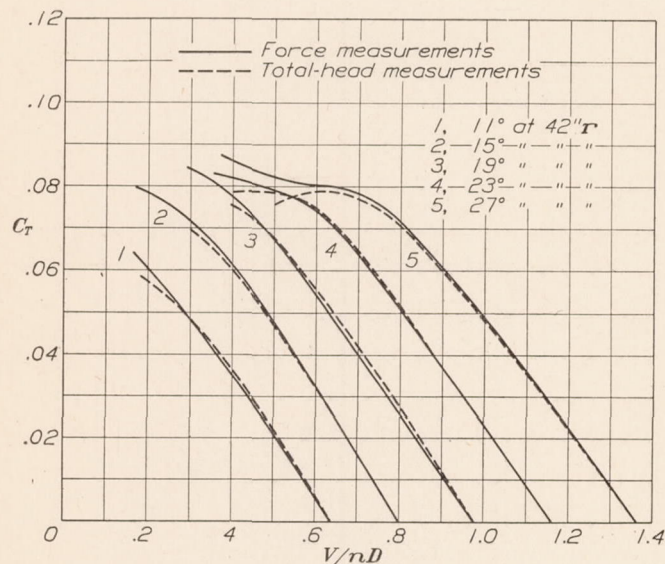


FIGURE 12.—Comparison of effective thrust coefficient from force measurements and corrected total-head measurements. Propeller C-8

But $V_1 = W \sin \psi U = W \cos \psi$

Therefore $\frac{dQ}{dr} = 2\pi r^2 W^2 \sin \psi \cos \psi$

or $= \pi r^2 W^2 \sin 2\psi$

From the calibration of the yawmeter,

$$\rho W^2 \sin 2\psi = KH_y$$

Therefore $\frac{dQ}{dr} = \pi r^2 KH_y$

Substituting $\frac{dQ}{dx} = \frac{\pi x^2 D^3 KH_y}{8}$

Now $dQ = dC_Q \rho n^2 D^5$

Hence $\frac{dC_Q}{dx} = \frac{\pi x^2 KH_y}{8 \rho n^2 D^2}$

Owing to the type of mounting and the sensitivity of the yawmeters, it was impossible to get them all to record zero differential pressure in the undisturbed air stream. This initial deflection for zero twist must be subtracted before the H_y can be used in the above

formula. The amount to be subtracted is determined by plotting the yawmeter reading for each radius against total head from the 0° calibration run. This plot gives the yawmeter correction as a straight-line function of the total head. With the propeller running, this function is theoretically in error by the

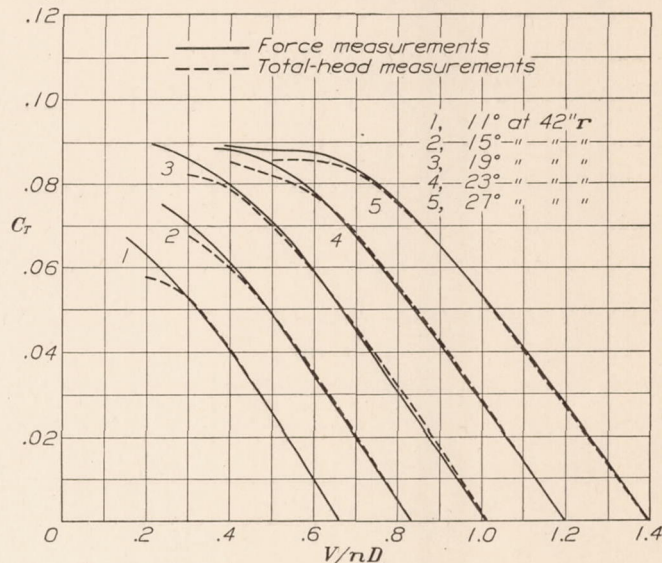


FIGURE 13.—Comparison of effective thrust coefficient from force measurements and corrected total-head measurements. Propeller C-10

change in static pressure, but this error is much smaller than the experimental error, and consequently the method may be used with confidence. The only place the error could become appreciable is at low values of $\frac{V}{nD}$, and in this range the yawmeter method of measuring torque is admittedly not very accurate.

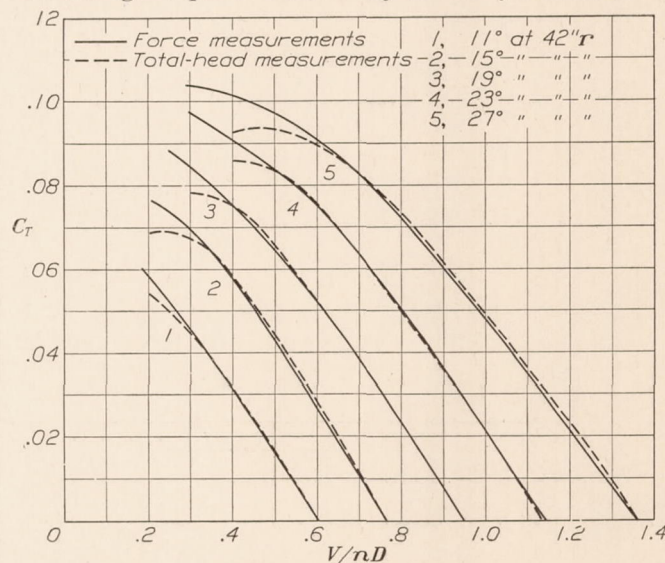


FIGURE 14.—Comparison of effective thrust coefficient from force measurements and corrected total-head measurements. Propeller R-6

The values of $\frac{dC_Q}{dx}$ are plotted against $\frac{V}{nD}$ and faired curves drawn through them, as in Figure 17. Values are read from these curves at even values of $\frac{V}{nD}$ and are given in Tables I to XIV.

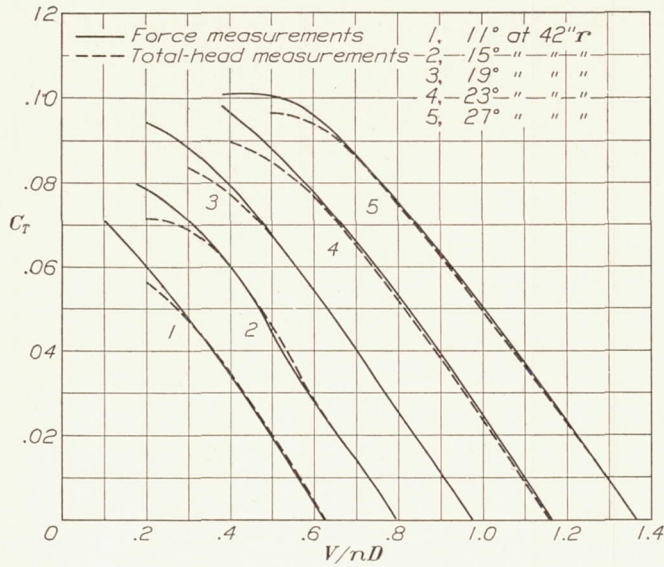


FIGURE 15.—Comparison of effective thrust coefficient from force measurements and corrected total-head measurements. Propeller R-8

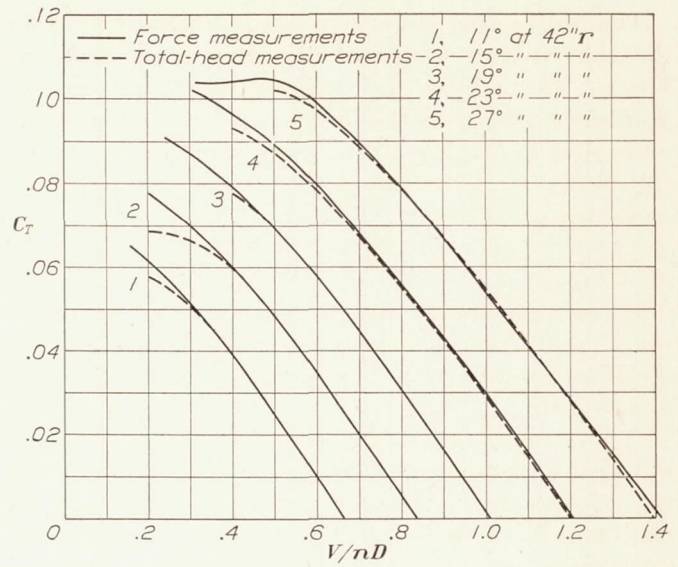


FIGURE 16.—Comparison of effective thrust coefficient from force measurements and corrected total-head measurements. Propeller R-10

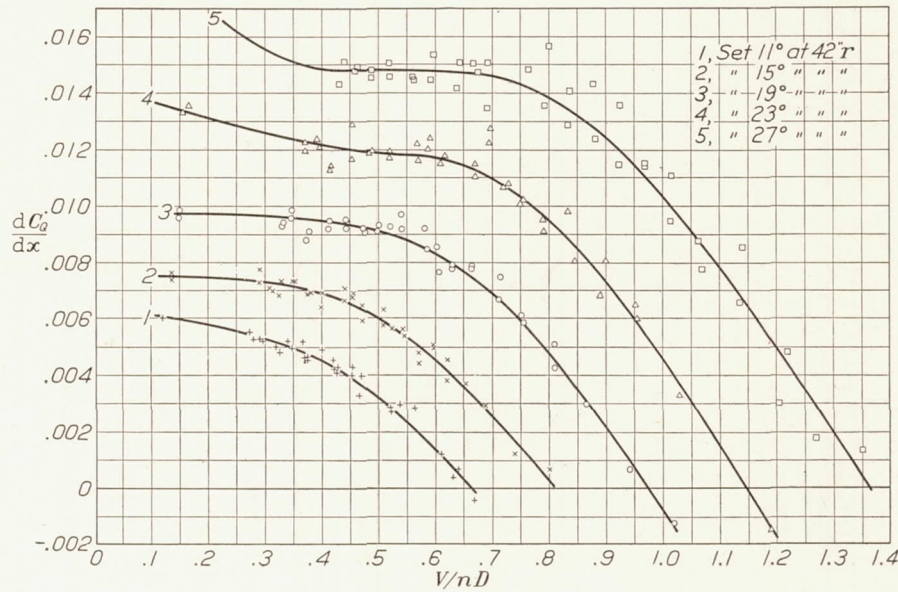


FIGURE 17.—Differential torque coefficient. Propeller C-10. $x=0.526$

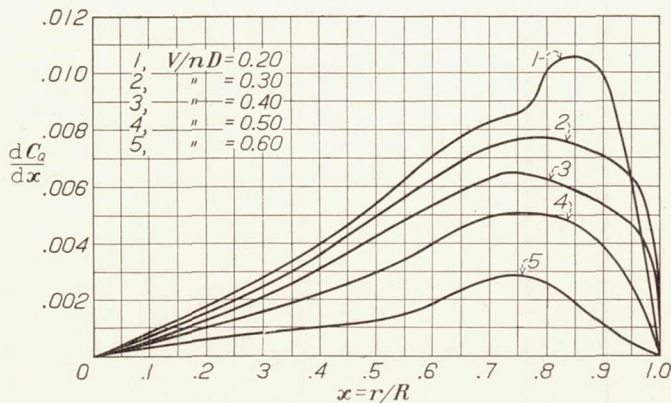


FIGURE 18.—Torque-gradient curves. Propeller C-10. Set 11° at 42-inch radius

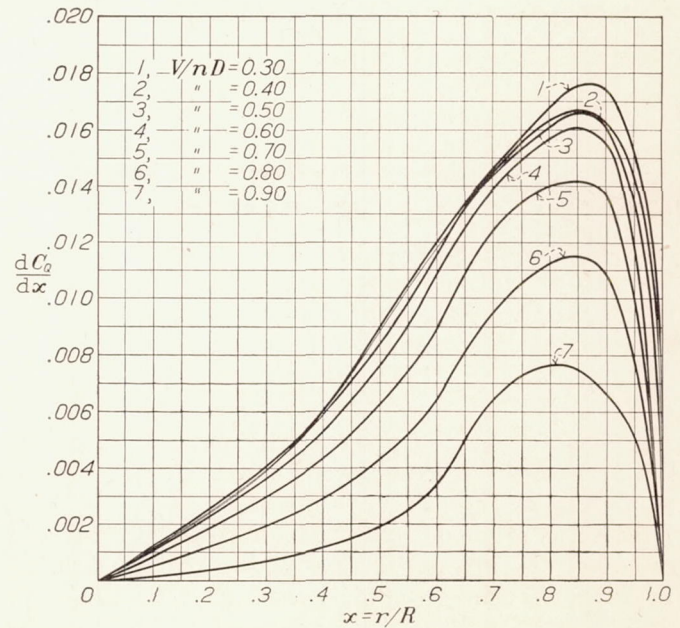


FIGURE 19.—Torque-gradient curves. Propeller C-10. Set 19° at 42-inch radius

The torque-gradient curves are obtained by plotting the tabular values against percentage radius, as in Figures 18 to 20. The integration of the torque-gradient curves gives the torque coefficient C_Q which if multiplied by 2π , gives the power coefficient C_P . The C_P obtained in this manner is compared with the measured C_P in Figures 21 to 26.

DISCUSSION

Differential thrust and torque.—A brief study of the thrust and torque gradient curves for different blade settings, Figures 5 to 7, and 18 to 20, shows the following:

(1) As the blade setting is increased, the thrust of the outer sections increases more rapidly than the thrust of the inner sections, which causes the point of maximum unit thrust to shift toward the tip. This shift results from the fact that the pitch increases more

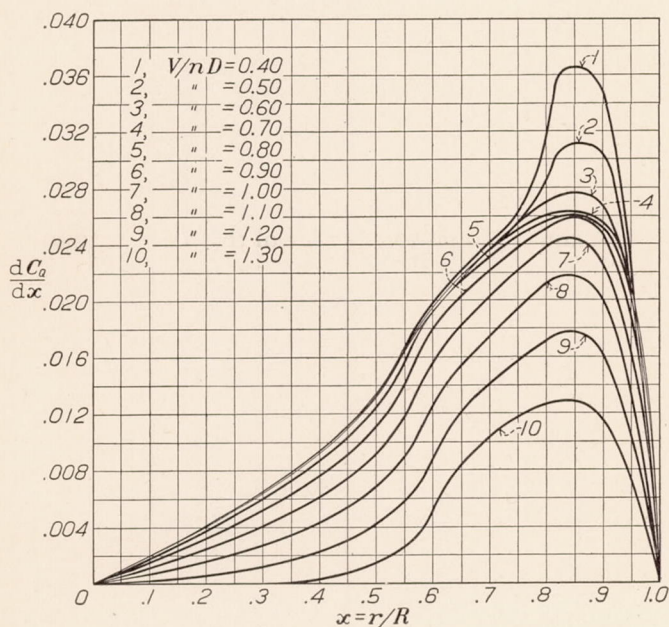


FIGURE 20.—Torque-gradient curves. Propeller C-10. Set 27° at 42-inch radius

rapidly toward the tip of the blade than near the hub.
 (2) As the V/nD is lowered from the point of zero thrust, the increments of thrust are large and nearly uniform, because the propeller sections are working on the straight-line portion of their lift curves.

(3) As the propeller approaches maximum thrust for the high pitch settings, the tip sections begin to fall off in thrust, owing to the blade sections operating near their stalling angles.

(4) At the lowest V/nD given for the 27° pitch setting (figs. 7 and 20), the blade is stalled from the 75 per cent radius to the tip, showing a pronounced decrease of thrust and an increase of torque.

Effect of propeller speed on differential thrust and torque.—The change in the thrust and torque distribution resulting from the variation of the rotational

velocity of the propeller is given in Figures 27 to 30. These curves are taken for the V/nD of maximum efficiency in order to show the results of most interest to the designer. For tip speeds up to 1,050 feet per second (2,100 r. p. m.), the ordinates of the thrust and torque

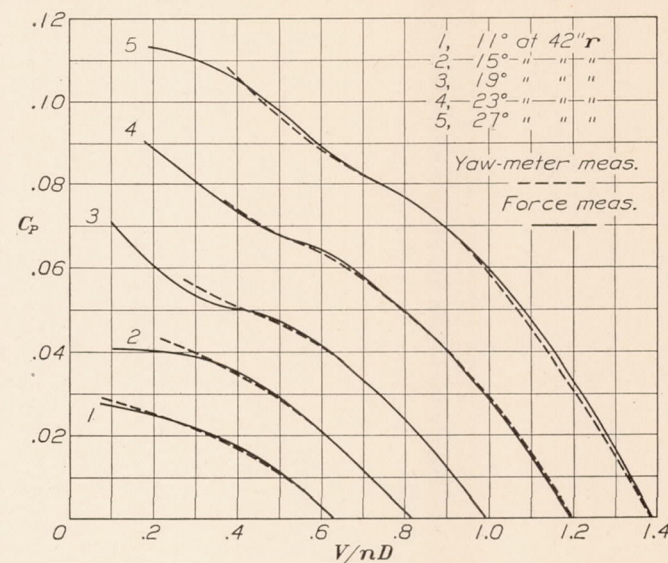


FIGURE 21.—Comparison of power coefficient from force measurements and yaw-meter measurements. Propeller C-6

gradient curves are continually increasing. Above this speed, the outer sections begin to fall off in thrust and increase in torque, whereas the inner sections increase in thrust as before. At 1,250 feet per second (2,500 r. p. m.) and above, the outer 10 per cent of the blade for propeller C-6 is producing negative thrust

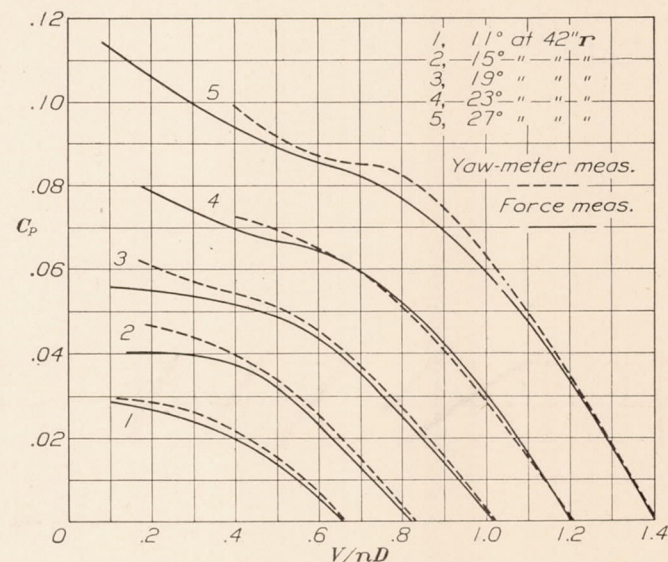


FIGURE 22.—Comparison of power coefficient from force measurements and yaw-meter measurements. Propeller C-8

and positive torque. At 1,350 feet per second (2,700 r. p. m.), the whole outer 25 per cent of the blade is traveling above 1,050 feet per second, and showing a corresponding decrease in thrust along the blade. The R.A.F. 6 propeller does not drop off as much in thrust toward the tip above 2,500 r. p. m. as the Clark Y

propeller but otherwise shows very nearly the same characteristics.

Total thrust and torque.—From a comparison of the total propeller thrust and torque from the force

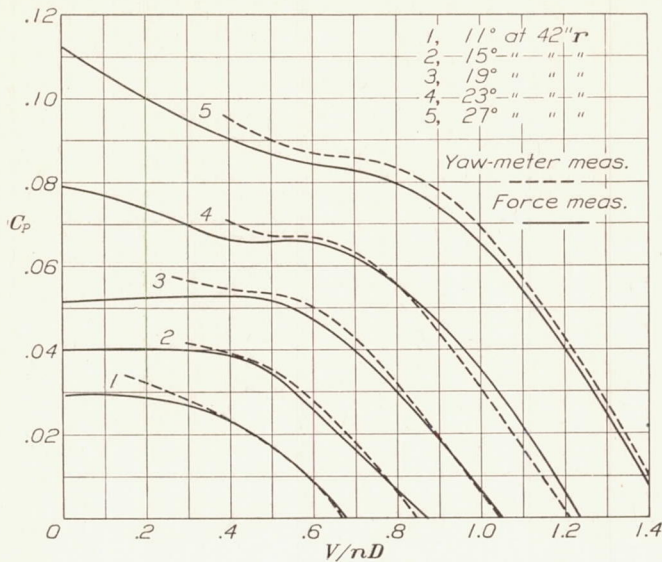


FIGURE 23.—Comparison of power coefficient from force measurements and yaw-meter measurements. Propeller C-10

tests and yawmeter tests, Figures 11 to 16, and 21 to 26, respectively, the following may be noted:

(1) The constant hub-drag coefficient brings all of the thrust curves like those shown in Figure 9 into very good agreement at the point of zero thrust. It

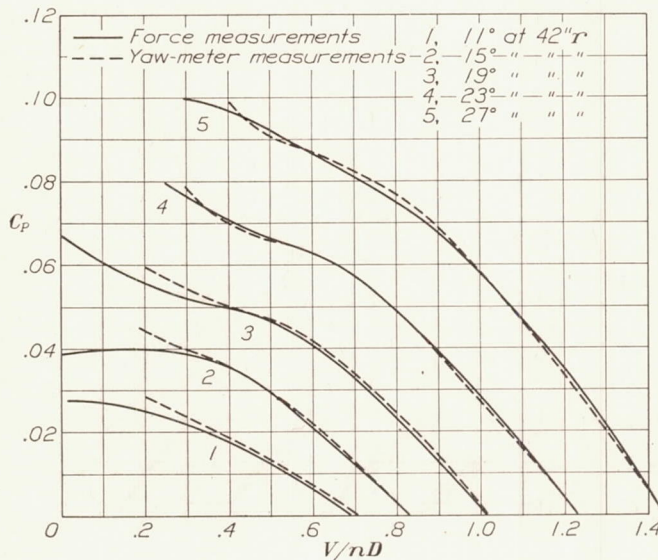


FIGURE 24.—Comparison of power coefficient from force measurements and yaw-meter measurements. Propeller R-6

should do this for ordinary propellers that have a washout of pitch toward the hub, since where there is zero thrust the slip stream should be negligible and consequently the drag due to the slip stream should be zero.

(2) The thrust curves of Figure 9 have a very uniform separation which is due to the increase in

body drag caused by the slip stream. This difference in the ordinates of the two thrust curves at any $\frac{V}{nD}$ is called ΔC_T and is plotted against the total C_T in

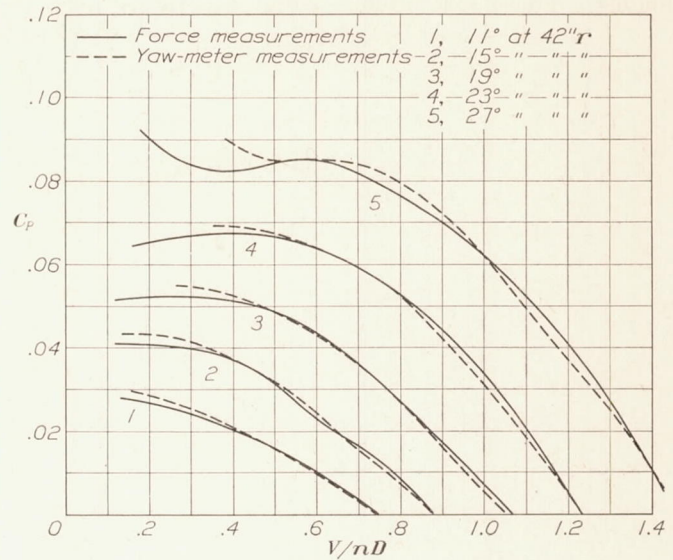


FIGURE 25.—Comparison of power coefficient from force measurements and yaw-meter measurements. Propeller R-8

Figure 10. The increase in body drag due to the slip stream is approximately equal to 8 per cent of the total thrust of the propeller for this particular type of body. This relationship is independent of pitch setting, provided that the propeller is set to have a

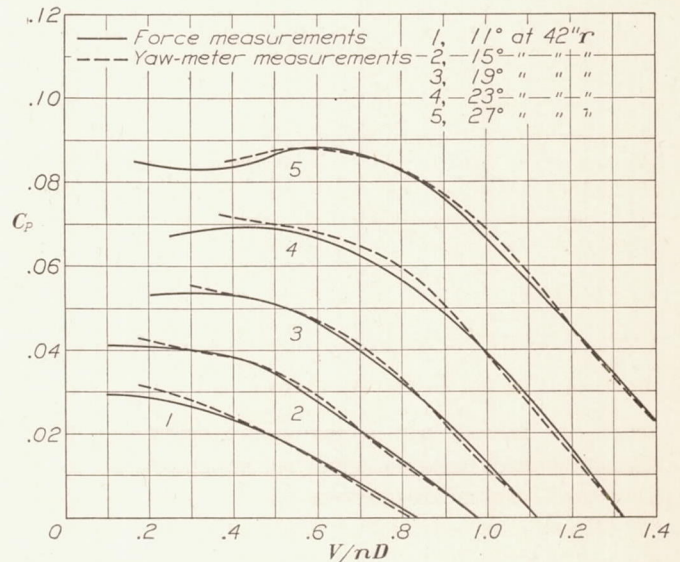


FIGURE 26.—Comparison of power coefficient from force measurements and yaw-meter measurements. Propeller R-10

washout of pitch toward the hub. If, as with the 9.8° and 7° settings (fig. 3), the geometric pitch is constant along the blade, or increases toward the hub, the curves of integrated and measured thrust do not go through zero at the same $\frac{V}{nD}$, consequently this relationship does not hold. In such propellers, when

the total thrust is zero, the velocity of the slip stream over the body is greater than the free-air velocity, because of the positive thrust on the inner sections and negative thrust on the outer sections of the blades. These low pitch settings are rarely used in

above factors are very satisfactory in predicting total thrust from total head measurements.

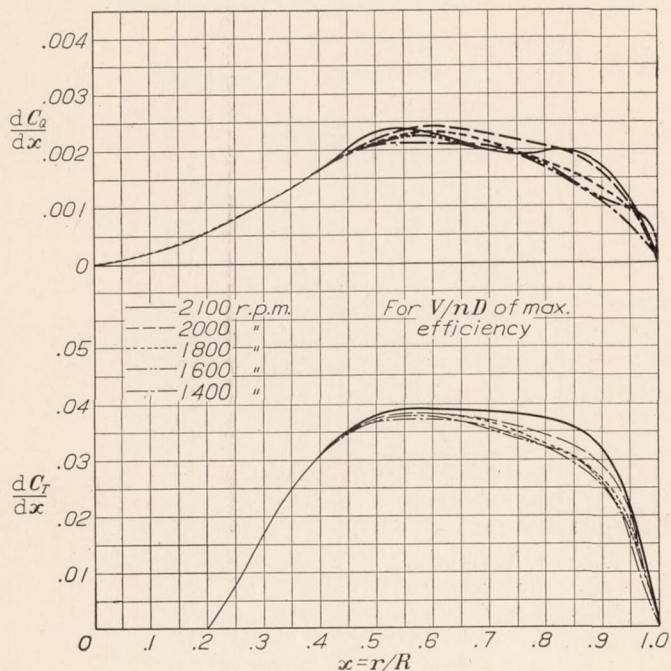


FIGURE 27.—Variation of thrust and torque distribution due to change in r. p. m. Propeller C-6. Set 7° at 42-inch radius. Low r. p. m.

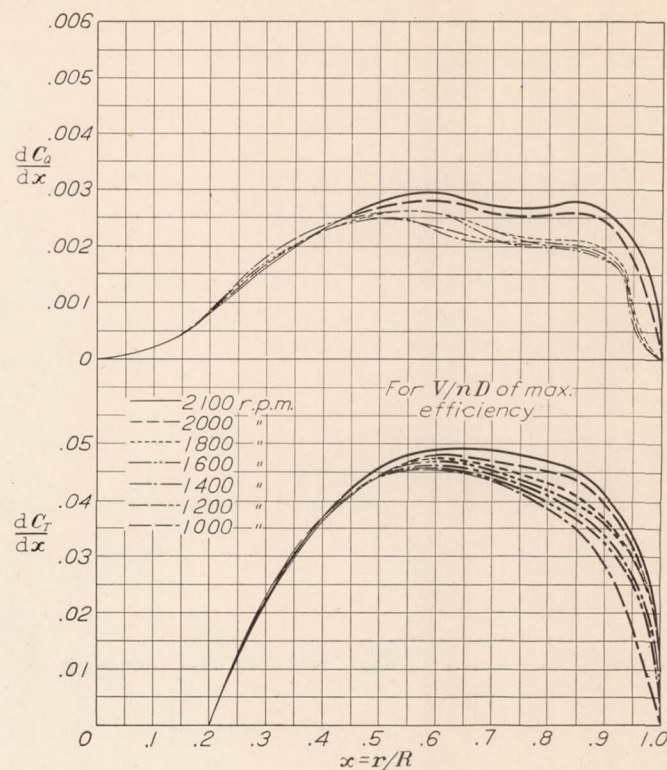


FIGURE 29.—Variation of thrust and torque distribution due to change in r. p. m. Propeller R-6. Set 7° at 42-inch radius. Low r. p. m.

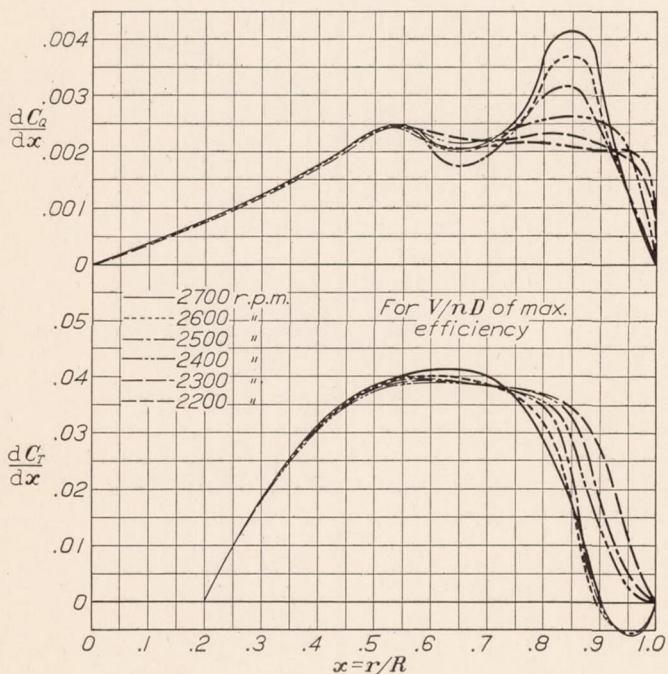


FIGURE 28.—Variation of thrust and torque distribution due to change in r. p. m. Propeller C-6. Set 7° at 42-inch radius. High r. p. m.

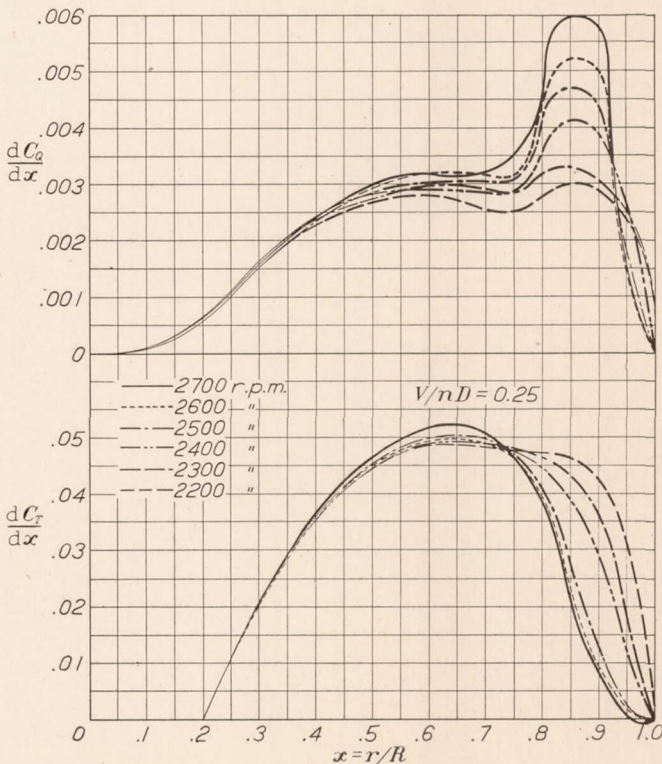


FIGURE 30.—Variation of thrust and torque distribution due to change in r. p. m. Propeller R-6. Set 7° at 42-inch radius. High r. p. m.

practice, consequently the above relationship is sufficiently accurate for practical purposes.

(3) The agreement of the effective thrust coefficients obtained by the two methods indicates that the

(4) The power curves are in good agreement.

LANGLEY MEMORIAL AERONAUTICAL LABORATORY,
NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS,
LANGLEY FIELD, VA., April 15, 1932.

LIST OF SYMBOLS

H_y —recorded differential pressure in yaw head tubes due to the twist of the slip stream
 H_T —recorded total head behind the propeller with propeller running
 H_{T_0} —recorded total head at the same point with the propeller off
 H —total head added by the propeller = $H_T - H_{T_0}$
 U —axial velocity through the propeller plane
 V_T —tangential velocity through the propeller plane
 W —resultant velocity through the propeller plane
 ψ —angle of twist of the slip stream
 K —constant for each yawmeter
 ρ —mass density of the air
 r —radius of any blade element
 D —total diameter of the propeller
 R —tip radius of the propeller
 n —revolutions of the propeller per unit time
 P —propeller pitch
 h —blade thickness
 b —blade width
 V —free-air velocity
 M —mass of air passing through the propeller per unit time

Q —torque of the propeller
 $C_P = \frac{\text{Power}}{\rho n^3 D^5}$
 T —thrust
 $C_T = \frac{T}{\rho n^2 D^4}$
 $\Delta C_T = \frac{\text{propeller thrust—effective thrust}}{\rho n^2 D^4}$
 $C_Q = \frac{Q}{\rho n^2 D^5}$

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5. Weick, Fred E., and Wood, Donald H.: The Twenty-Foot Propeller Research Tunnel of the National Advisory Committee for Aeronautics. T. R. No. 300, N. A. C. A., 1928.

TABLE I

Values of $\frac{dC_T}{dx}$ and $\frac{dC_Q}{dx}$ for propeller C-6. (From faired curves)

Setting	$\frac{V}{nD}$	$x=0.421$		$x=0.526$		$x=0.631$		$x=0.737$		$x=0.842$		$x=0.947$	
		$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
11°	0.20	0.0568	0.00354	0.0795	0.00570	0.0961	0.00550	0.1086	0.00700	0.1112	0.00800	0.0660	0.00506
11°	.30	.0480	.00313	.0652	.00435	.0777	.00455	.0870	.00570	.0905	.00580	.0675	.00500
11°	.40	.0362	.00260	.0475	.00348	.0554	.00335	.0605	.00420	.0630	.00430	.0460	.00390
11°	.50	.0220	.00196	.0275	.00240	.0300	.00300	.0315	.00240	.0315	.00250	.0230	.00210
11°	.60	.0072	.00105	.0061	.00072	.0040	.00010	.0010	.00020	.0020	.00025	.0005	.00000
15°	.20	.0708	.00470	.1001	.00708	.1249	.00795	.1427	.01250	.1478	.01565		
15°	.30	.0648	.00460	.0920	.00680	.1147	.00730	.1352	.01075	.1465	.01225	.1128	.01250
15°	.40	.0548	.00432	.0780	.00621	.0980	.00650	.1142	.00900	.1254	.01025	.1057	.01050
15°	.50	.0421	.00374	.0588	.00510	.0738	.00560	.0862	.00720	.0954	.00835	.0811	.00811
15°	.60	.0288	.00287	.0390	.00355	.0485	.00430	.0580	.00510	.0653	.00625	.0553	.00550
15°	.70	.0152	.00172	.0193	.00168	.0231	.00235	.0298	.00280	.0350	.00380	.0295	.00265
19°	.20	.0802	.00600	.1150	.00900	.1428	.01125	.1482	.01705	.1320	.02520		
19°	.30	.0758	.00595	.1092	.00897	.1375	.01090	.1560	.01450	.1500	.01800	.1240	.01800
19°	.40	.0705	.00585	.1012	.00873	.1290	.01040	.1530	.01310	.1550	.01550	.1265	.01540
19°	.50	.0600	.00550	.0881	.00814	.1130	.00970	.1350	.01190	.1460	.01430	.1220	.01400
19°	.60	.0478	.00560	.0690	.00700	.0908	.00870	.1090	.01030	.1200	.01250	.1015	.01200
19°	.70	.0345	.00418	.0500	.00546	.0665	.00700	.0815	.00820	.0920	.01050	.0783	.00970
19°	.80	.0213	.00295	.0305	.00345	.0425	.00430	.0540	.00590	.0640	.00830	.0550	.00710
19°	.90	.0075	.00132	.0113	.00102	.0180	.00080	.0263	.00310	.0363	.00570	.0315	.00410
23°	.20	.0963	.00780	.1370	.01215	.1484	.01880	.1323	.03105	.1325	.03570		
23°	.30	.0900	.00782	.1295	.01185	.1522	.01635	.1522	.02500	.1432	.02930		
23°	.40	.0830	.00775	.1208	.01145	.1515	.01460	.1620	.02040	.1485	.02420	.1050	.02210
23°	.50	.0755	.00760	.1111	.01098	.1440	.01380	.1612	.01790	.1575	.02130	.1260	.02010
23°	.60	.0670	.00730	.0983	.01028	.1290	.01290	.1526	.01660	.1595	.01940	.1345	.01880
23°	.70	.0550	.00668	.0822	.00920	.1090	.01160	.1340	.01520	.1425	.01750	.1195	.01690
23°	.80	.0422	.00563	.0640	.00750	.0860	.01000	.1063	.01370	.1175	.01550	.1000	.01440
23°	.90	.0293	.00422	.0448	.00550	.0625	.00820	.0810	.01180	.0925	.01340	.0810	.01160
23°	1.00	.0163	.00255	.0253	.00330	.0388	.00590	.0540	.00910	.0675	.01080	.0612	.00850
23°	1.10	.0035	.00070	.0055	.00100	.0150	.00310	.0280	.00500	.0425	.00750	.0415	.00540
27°	.30	.1049	.01038	.1495	.01648	.1745	.02600	.1100	.03700				
27°	.40	.0970	.01000	.1428	.01583	.1840	.02270	.1360	.03450	.1400	.03520	.1035	.02990
27°	.50	.0895	.00980	.1333	.01497	.1735	.01980	.1580	.03030	.1490	.03140	.1195	.02760
27°	.60	.0814	.00960	.1220	.01410	.1590	.01750	.1660	.02560	.1550	.02810	.1275	.02570
27°	.70	.0724	.00930	.1095	.01314	.1430	.01630	.1625	.02210	.1600	.02560	.1315	.02390
27°	.80	.0620	.00880	.0960	.01210	.1260	.01590	.1520	.02030	.1600	.02380	.1295	.02210
27°	.90	.0500	.00795	.0798	.01075	.1080	.01440	.1340	.01840	.1600	.02160	.1210	.02040
27°	1.00	.0380	.00660	.0617	.00888	.0870	.01170	.1115	.01590	.1258	.01850	.1075	.01780
27°	1.10	.0260	.00485	.0423	.00650	.0635	.00890	.0865	.01250	.1025	.01480	.0910	.01460
27°	1.20	.0140	.00285	.0225	.00385	.0394	.00570	.0600	.00860	.0770	.01070	.0720	.01050

TABLE VI

Values of $\frac{dC_T}{dx}$ and $\frac{dC_Q}{dx}$ for propeller C-10. Set 9.8° at 42-inch radius. (From faired curves)

R. p. m.	$\frac{V}{nD}$	x=0.421		x=0.526		x=0.631		x=0.737		x=0.842		x=0.947	
		$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
1200	0.10	0.0610	0.00377	0.0842	0.00456	0.1007	0.00588	0.1130	0.00640	0.1040			0.00070
1200	.20	.0555	.00340	.0743	.00420	.0895	.00519	.0997	.00567	.0946	0.00480	0.0630	0.0168
1200	.30	.0460	.00297	.0603	.00377	.0732	.00443	.0811	.00486	.0785	.00387	.0575	.00213
1200	.40	.0340	.00240	.0434	.00318	.0527	.00354	.0585	.00395	.0590	.00290	.0442	.00184
1200	.50	.0202	.00166	.0245	.00229	.0300	.00245	.0335	.00286	.0347	.00173	.0267	.00080
1200	.60	.0054	.00047	.0045	.00082	.0055	.00090	.0070	.00137	.0083	.00003	.0066	.00100
1400	.10	.0610	.00380	.0830	.00450	.1001	.00614	.1140	.00668	.1068		-.0200	
1400	.20	.0552	.00353	.0738	.00413	.0892	.00545	.0995	.00587	.0982	.00558	.0440	.00420
1400	.30	.0456	.00320	.0593	.00370	.0717	.00470	.0800	.00500	.0794	.00424	.0585	.00331
1400	.40	.0330	.00247	.0421	.00323	.0506	.00380	.0570	.00405	.0565	.00322	.0440	.00235
1400	.50	.0192	.00180	.0237	.00220	.0275	.00260	.0320	.00293	.0320	.00198	.0260	.00118
1400	.60	.0040	.00051	.0031	.00112	.0045	.00070	.0060	.00148	.0075	.00030		
1600	.10	.0610	.00380	.0842	.00468	.1019	.00625	.1175	.00685	.1135		-.0245	
1600	.20	.0554	.00353	.0741	.00433	.0899	.00555	.1012	.00610	.1005	.00530	.0425	.00465
1600	.30	.0458	.00320	.0598	.00390	.0730	.00480	.0810	.00528	.0820	.00446	.0603	.00370
1600	.40	.0332	.00247	.0433	.00330	.0522	.00394	.0588	.00435	.0592	.00348	.0462	.00265
1600	.50	.0193	.00180	.0245	.00242	.0295	.00278	.0345	.00322	.0340	.00228	.0278	.00145
1600	.60	.0042	.00051	.0040	.00135	.0055	.00098	.0060	.00166	.0075	.00050	.0075	.00018
1800	.10	.0620	.00380	.0860	.00474	.1040	.00643	.1222	.00732	.1180		-.0245	
1800	.20	.0560	.00353	.0762	.00440	.0923	.00571	.1055	.00645	.1075	.00590	.0435	.00535
1800	.30	.0460	.00320	.0617	.00400	.0743	.00493	.0845	.00554	.0874	.00495	.0658	.00420
1800	.40	.0333	.00247	.0437	.00340	.0535	.00402	.0605	.00450	.0625	.00382	.0490	.00300
1800	.50	.0191	.00180	.0242	.00252	.0293	.00285	.0340	.00330	.0355	.00250	.0273	.00162
1800	.60	.0037	.00051	.0029	.00148	.0050	.00104	.0050	.00169	.0050	.00062	.0030	
2000	.10	.0612	.00380	.0850	.00484	.1050	.00657	.1208	.00776	.1080		-.0185	
2000	.20	.0558	.00353	.0765	.00450	.0930	.00585	.1080	.00683	.1050	.00808	.0435	.00645
2000	.30	.0463	.00320	.0625	.00410	.0770	.00505	.0892	.00583	.0924	.00590	.0618	.00502
2000	.40	.0336	.00247	.0437	.00352	.0548	.00415	.0638	.00475	.0700	.00423	.0545	.00350
2000	.50	.0195	.00180	.0226	.00262	.0280	.00298	.0335	.00345	.0395	.00275	.0272	.00186
2100	.10	.0600	.00380	.0845	.00505	.1037	.00680	.1222	.00806	.1073		-.0127	
2100	.20	.0556	.00353	.0773	.00463	.0940	.00608	.1093	.00710	.0925	.01040	.0315	.00685
2100	.30	.0465	.00320	.0636	.00416	.0775	.00530	.0905	.00608	.0885	.00760	.0540	.00555
2100	.40	.0337	.00247	.0450	.00354	.0557	.00438	.0652	.00495	.0683	.00502	.0455	.00415
2100	.50	.0187	.00180	.0245	.00263	.0307	.00317	.0367	.00351	.0338	.00295	.0102	
2200	.20	.0555	.00342	.0760	.00453	.0936	.00581	.1097	.00676	.0720	.01064	.0320	.00420
2200	.25	.0517	.00350	.0706	.00460	.0865	.00576	.1015	.00664	.0830	.00980	.0490	.00506
2200	.30	.0467	.00338	.0634	.00440	.0775	.00547	.0913	.00629	.0820	.00874	.0465	.00537
2200	.35	.0403	.00310	.0545	.00404	.0666	.00500	.0785	.00572	.0757	.00745	.0403	.00520
2200	.40	.0334	.00266	.0445	.00353	.0547	.00434	.0633	.00496	.0634	.00596	.0300	.00486
2200	.45	.0250	.00210	.0330	.00285	.0413	.00350	.0480	.00400	.0466	.00433	.0150	.00412
2300	.30	.0460	.00320	.0620	.00433	.0765	.00570	.0890	.00662	.0734	.00807	.0473	.00577
2300	.35	.0404	.00303	.0544	.00396	.0673	.00522	.0788	.00607	.0646	.00728	.0365	.00574
2300	.40	.0334	.00260	.0445	.00343	.0546	.00457	.0643	.00534	.0534	.00605	.0223	.00493
2300	.45	.0248	.00196	.0325	.00276	.0390	.00372	.0450	.00440	.0404	.00516	.0055	.00400

TABLE VII

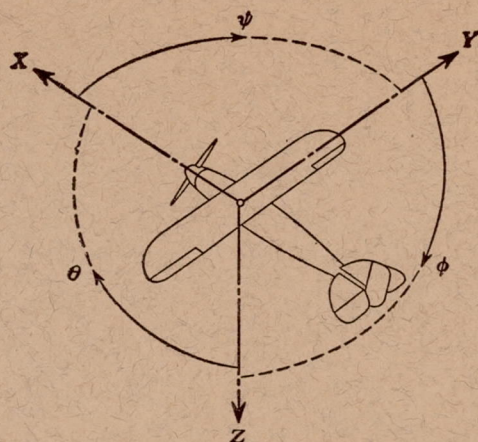
Values of $\frac{dC_T}{dx}$ and $\frac{dC_Q}{dx}$ for propeller C-6. Set 7° at 42-inch radius. (From faired curves)

R. p. m.	$\frac{V}{nD}$	$x=0.421$		$x=0.526$		$x=0.631$		$x=0.737$		$x=0.842$		$x=0.947$	
		$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{c.x}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
1200	0.10	0.0511	0.00226	0.0638	0.00290	0.0681	0.00315	0.0662	0.00320	0.0584	0.00328	-0.0215	-0.00048
1200	.20	.0441	.00199	.0528	.00260	.0545	.00299	.0533	.00292	.0478	.00240	.0240	.00121
1200	.30	.0334	.00161	.0375	.00215	.0365	.00240	.0337	.00201	.0303	.00130	.0162	.00050
1200	.40	.0201	.00107	.0193	.00141	.0154	.00130	.0096	.00070	.0060	.00025	.0048	.00105
1200	.45	.0128	.00070	.0093	.00086	.0040	.00057	-.0038	-.00022	-.0080	-.00140	-.0160	-.00190
1400	.10	.0515	.00240	.0645	.00300	.0685	.00335	.0688	.00331	.0630	.00380	-.0190	-.00016
1400	.20	.0440	.00196	.0529	.00275	.0560	.00283	.0562	.00269	.0496	.00237	.0335	.00116
1400	.30	.0339	.00180	.0370	.00213	.0370	.00212	.0345	.00197	.0300	.00159	.0164	.00071
1400	.40	.0197	.00130	.0190	.00132	.0147	.00106	.0090	.00103	.0053	.00052	-.0045	.00024
1400	.45	.0122	.00090	.0085	.00085	.0020	.00026	-.0040	.00042	-.0084	-.00023	-.0155	-.00090
1600	.10	.0515	.00240	.0644	.00310	.0705	.00312	.0720	.00346	.0660	.00405	-.0210	-.00016
1600	.20	.0436	.00196	.0533	.00284	.0563	.00274	.0560	.00278	.0518	.00226	.0335	.00150
1600	.30	.0325	.00180	.0375	.00223	.0370	.00213	.0340	.00200	.0310	.00147	.0180	.00100
1600	.40	.0190	.00130	.0185	.00140	.0140	.00110	.0083	.00096	.0048	.00062	-.0050	.00021
1600	.45	.0118	.00090	.0085	.00094	.0016	.00030	-.0060	.00028	-.0100	.00012	-.0178	-.00032
1800	.10	.0505	.00240	.0640	.00327	.0710	.00374	.0740	.00363	.0690	.00416	-.0200	.00020
1800	.20	.0432	.00196	.0530	.00288	.0573	.00312	.0580	.00292	.0548	.00259	.0333	.00155
1800	.30	.0322	.00180	.0375	.00222	.0380	.00232	.0355	.00207	.0310	.00161	.0190	.00116
1800	.40	.0185	.00130	.0175	.00135	.0138	.00110	.0080	.00090	.0025	.00060	-.0058	.00044
1800	.45	.0112	.00090	.0078	.00087	.0005	.00017	-.0070	.00010	-.0125	.00002	-.0183	-.00010
2000	.10	.0510	.00240	.0647	.00325	.0730	.00374	.0780	.00384	.0770	.00515	-.0125	.00025
2000	.20	.0435	.00196	.0538	.00295	.0582	.00305	.0610	.00308	.0598	.00313	.0360	.00250
2000	.30	.0325	.00180	.0380	.00228	.0380	.00235	.0360	.00215	.0330	.00194	.0205	.00110
2000	.40	.0185	.00130	.0180	.00144	.0145	.00120	.0075	.00083	.0025	.00065	-.0065	.00060
2000	.45	.0110	.00090	.0075	.00095	.0012	.00028	-.0072	-.00010	-.0140	-.00014	-.0210	.00012
2100	.10	.0518	.00261	.0662	.00338	.0755	.00378	.0825	.00406	.0823	.00578	-.0400	.00050
2100	.20	.0440	.00201	.0550	.00295	.0600	.00283	.0642	.00311	.0640	.00362	.0380	.00273
2100	.30	.0328	.00182	.0387	.00237	.0390	.00221	.0385	.00195	.0363	.00201	.0223	.00122
2100	.40	.0190	.00132	.0188	.00145	.0150	.00120	.0075	.00095	.0010	.00085	-.0090	.00055
2100	.45	.0116	.00087	.0075	.00040	.0020	.00000	-.0090	-.00032	-.0185	-.00040	-.0250	.00015
2200	.10	.0508	.00252	.0663	.00335	.0755	.00400	.0822	.00425	.0815	.00700	-.1000	.00025
2200	.20	.0440	.00211	.0550	.00301	.0600	.00277	.0640	.00330	.0665	.00378	.0410	.00327
2200	.30	.0328	.00183	.0385	.00241	.0388	.00225	.0383	.00223	.0351	.00230	.0228	.00193
2200	.40	.0183	.00128	.0180	.00137	.0140	.00103	.0080	.00073	-.0010	.00066	-.0100	.00120
2200	.45	.0100	.00079	.0066	.00047	.0002	-.00020	-.0085	-.00028	-.0210	-.00039	-.0288	.00108
2300	.10	.0518	.00266	.0677	.00356	.0777	.00371	.0860	.00430	.0800	.00961	-.00071	.00071
2300	.20	.0445	.00216	.0556	.00310	.0613	.00300	.0656	.00328	.0660	.00443	.0318	.00311
2300	.30	.0328	.00186	.0384	.00238	.0392	.00208	.0380	.00215	.0340	.00210	.0125	.00205
2300	.40	.0183	.00128	.0177	.00115	.0131	.00068	.0046	.00067	-.0052	.00075	-.0205	.00135
2300	.45	.0103	.00068	.0065	.00017	-.0010	-.00026	-.0133	-.00100	-.0260	.00010	-.0386	.00110
2400	.10	.0520	.00275	.0683	.00375	.0795	.00416	.0880	.00485	.0640	.00950	-.0385	.00113
2400	.20	.0448	.00211	.0560	.00306	.0625	.00315	.0670	.00340	.0604	.00578	+.0200	.00260
2400	.30	.0324	.00190	.0382	.00245	.0390	.00215	.0375	.00238	.0310	.00263	+.0033	.00218
2400	.40	.0172	.00116	.0170	.00096	.0110	.00035	.0018	.00015	-.0098	.00015	-.0285	.00040
2500	.15	.0492	.00264	.0634	.00366	.0723	.00373	.0804	.00447	.0640	.00865	-.0136	.00103
2500	.20	.0448	.00220	.0566	.00323	.0628	.00300	.0683	.00356	.0540	.00622	.0025	.00207
2500	.30	.0328	.00185	.0390	.00245	.0393	.00188	.0377	.00225	.0263	.00316	-.0050	.00128
2500	.35	.0252	.00160	.0273	.00205	.0260	.00141	.0200	.00182	.0087	.00202	-.0173	.00073
2600	.20	.0450	.00220	.0571	.00310	.0645	.00278	.0688	.00343	.0512	.00625	.0075	.00104
2600	.25	.0398	.00207	.0488	.00280	.0525	.00243	.0537	.00298	.0365	.00492	.0022	.00125
2600	.30	.0333	.00188	.0392	.00242	.0400	.00202	.0374	.00235	.0204	.00368	-.0052	.00135
2600	.35	.0255	.00163	.0285	.00195	.0263	.00158	.0203	.00155	.0030	.00255	-.0147	.00137
2700	.20	.0438	.....	.0565	.....	.0635	.....	.0654	.....	.0465	.....	.0090	.....
2700	.25	.0392	.00211	.0486	.00290	.0532	.00278	.0530	.00306	.0340	.00518	.0022	.00132
2700	.30	.0332	.00189	.0394	.00247	.0412	.00204	.0378	.00245	.0192	.00414	-.0055	.00135
2700	.35	.0261	.00158	.0290	.00194	.0277	.00122	.0202	.00182	.0025	.00310	-.0138	.00132

TABLE XIV

Values of $\frac{dC_T}{dx}$ and $\frac{dC_Q}{dx}$ for propeller R-6 set 7° at 42-inch radius. (From faired curves)

R. p. m.	$\frac{V}{nD}$	x=0.421		x=0.526		x=0.631		x=0.737		x=0.842		x=0.947	
		$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$	$\frac{dC_T}{dx}$	$\frac{dC_Q}{dx}$
1000	0.15	0.0480	0.00255	0.0579	0.00283	0.0605	0.00290	0.0582	0.00292	0.0510	0.00311	0.0130	0.00077
1000	.25	.0385	.00235	.0450	.00250	.0450	.00215	.0420	.00208	.0355	.00203	.0180	.00092
1000	.35	.0255	.00192	.0275	.00193	.0242	.00135	.0191	.00116	.0135	.00082	.0070	.00040
1000	.45	.0104	.00113	.0075	.00095	.0000	.00050	-.0082	.00015	-.0135	-.00040	-.0125	-.00135
1200	.15	.0479	.00260	.0585	.00284	.0608	.00280	.0598	.00215	.0542	.00302	.0250	.00110
1200	.25	.0385	.00233	.0450	.00248	.0454	.00225	.0425	.00205	.0373	.00205	.0260	.00090
1200	.35	.0261	.00191	.0280	.00201	.0260	.00168	.0208	.00141	.0155	.00130	.0093	.00000
1200	.45	.0115	.00118	.0088	.00137	.0040	.00080	-.0040	.00062	-.0095	.00040	-.0115	-.00140
1400	.15	.0485	.00285	.0595	.00300	.0610	.00330	.0610	.00305	.0560	.00295	.0205	.00078
1400	.25	.0388	.00245	.0452	.00256	.0458	.00252	.0435	.00215	.0385	.00200	.0275	.00073
1400	.35	.0260	.00196	.0279	.00204	.0254	.00177	.0195	.00161	.0145	.00133	.0090	.00040
1400	.45	.0110	.00135	.0082	.00140	.0020	.00102	-.0078	.00098	-.0140	.00090	-.0142	-.00012
1600	.15	.0472	.00258	.0590	.00292	.0615	.00305	.0612	.00283	.0582	.00260	.0320	.00080
1600	.25	.0382	.00235	.0452	.00260	.0466	.00250	.0440	.00202	.0400	.00193	.0302	.00081
1600	.35	.0270	.00195	.0287	.00218	.0270	.00205	.0205	.00183	.0152	.00172	.0096	.00075
1600	.45	.0122	.00128	.0090	.00148	.0015	.00131	-.0082	.00127	-.0146	.00131	-.0150	.00055
1800	.15	.0468	.00264	.0590	.00300	.0630	.00331	.0645	.00310	.0620	.00313	.0320	.00120
1800	.25	.0380	.00235	.0455	.00260	.0470	.00275	.0460	.00220	.0415	.00214	.0308	.00100
1800	.35	.0260	.00200	.0280	.00212	.0260	.00197	.0200	.00181	.0150	.00169	.0082	.00093
1800	.45	.0103	.00132	.0075	.00146	.0005	.00125	-.0088	.00118	-.0152	.00125	-.0155	.00079
2000	.15	.0470	.00275	.0595	.00318	.0648	.00340	.0677	.00345	.0665	.00402	.0215	.00210
2000	.25	.0381	.00240	.0455	.00273	.0480	.00275	.0461	.00255	.0440	.00260	.0325	.00179
2000	.35	.0255	.00196	.0275	.00218	.0260	.00221	.0195	.00215	.0152	.00190	.0078	.00145
2000	.45	.0095	.00100	.0070	.00150	.0005	.00145	-.0105	.00132	-.0168	.00115	-.0165	.00089
2100	.15	.0483	.00280	.0612	.00328	.0668	.00345	.0720	.00345	.0740	.00418	.0250	.00318
2100	.25	.0387	.00242	.0470	.00287	.0490	.00290	.0482	.00270	.0455	.00282	.0345	.00214
2100	.35	.0258	.00200	.0282	.00230	.0260	.00231	.0190	.00228	.0140	.00202	.0070	.00164
2100	.45	.0103	.00125	.0065	.00143	.0000	.00132	-.0112	.00148	-.0182	.00122	-.0218	.00093
2200	.15	.0478	.00277	.0602	.00318	.0675	.00345	.0730	.00352	.0747	.00490	-----	-----
2200	.25	.0375	.00240	.0460	.00275	.0480	.00277	.0475	.00250	.0470	.00300	.0325	.00243
2200	.35	.0245	.00198	.0274	.00222	.0250	.00222	.0178	.00210	.0120	.00210	.0042	.00190
2200	.45	.0093	.00128	.0053	.00138	-.0018	.00145	-.0148	.00150	-.0230	.00111	-.0252	.00100
2300	.15	.0479	.00283	.0615	.00331	.0682	.00358	.0742	.00362	.0733	.00670	-----	-----
2300	.25	.0380	.00245	.0463	.00282	.0490	.00296	.0485	.00285	.0443	.00330	.0197	.00260
2300	.35	.0249	.00195	.0269	.00231	.0242	.00229	.0175	.00228	.0090	.00244	-.0070	.00215
2300	.45	.0098	.00124	.0050	.00130	-.0042	.00130	-.0170	.00148	-.0280	.00138	-.0340	.00130
2400	.15	.0478	.00286	.0613	.00338	.0682	.00360	.0750	.00385	.0642	.00752	-----	-----
2400	.25	.0380	.00253	.0462	.00288	.0492	.00290	.0482	.00282	.0400	.00410	.0132	.00278
2400	.35	.0246	.00200	.0268	.00238	.0242	.00222	.0155	.00212	.0058	.00250	-.0150	.00141
2400	.45	.0088	.00111	.0042	.00142	-.0048	.00127	-.0210	.00133	-.0310	.00128	-----	-----
2500	.15	.0481	.00296	.0628	.00338	.0702	.00371	.0765	.00388	.0565	.00792	-.0130	.00165
2500	.25	.0383	.00247	.0470	.00292	.0500	.00305	.0483	.00304	.0310	.00470	.0028	.00195
2500	.35	.0245	.00195	.0275	.00220	.0240	.00228	.0155	.00227	.0015	.00313	-.0166	.00125
2600	.20	.0434	.00271	.0548	.00335	.0600	.00358	.0612	.00357	.0410	.00665	.0098	.00125
2600	.30	.0320	.00226	.0375	.00262	.0375	.00272	.0325	.00267	.0120	.00395	-.0058	.00170
2600	.40	.0178	.00150	.0165	.00167	.0097	.00150	-.0018	.00167	-.0180	.00224	-.0225	.00125
2700	.25	.0390	.00253	.0483	.00310	.0521	.00316	.0480	.00341	.0245	.00595	.0010	.00181
2700	.30	.0323	.00233	.0385	.00275	.0383	.00285	.0325	.00309	.0110	.00448	-.0060	.00165
2700	.35	.0178	.00209	.0278	.00238	.0241	.00248	.0160	.00265	-.0035	.00333	-.0138	.00145



Positive directions of axes and angles (forces and moments) are shown by arrows

Axis		Force (parallel to axis) symbol	Moment about axis			Angle		Velocities	
Designation	Sym- bol		Designation	Sym- bol	Positive direction	Designa- tion	Sym- bol	Linear (compo- nent along axis)	Angular
Longitudinal	X	X	rolling	L	Y → Z	roll	φ	u	p
Lateral	Y	Y	pitching	M	Z → X	pitch	θ	v	q
Normal	Z	Z	yawing	N	X → Y	yaw	ψ	w	r

Absolute coefficients of moment

$$C_l = \frac{L}{qbS} \quad C_m = \frac{M}{qcS} \quad C_n = \frac{N}{qbS}$$

Angle of set of control surface (relative to neutral position), δ . (Indicate surface by proper subscript.)

4. PROPELLER SYMBOLS

D , Diameter.

p , Geometric pitch.

p/D , Pitch ratio.

V' , Inflow velocity.

V_s , Slipstream velocity.

T , Thrust, absolute coefficient $C_T = \frac{T}{\rho n^2 D^4}$

Q , Torque, absolute coefficient $C_Q = \frac{Q}{\rho n^2 D^5}$

P , Power, absolute coefficient $C_P = \frac{P}{\rho n^3 D^5}$.

C_s , Speed power coefficient = $\sqrt[5]{\frac{\rho V'^5}{P n^2}}$.

η , Efficiency.

n , Revolutions per second, r. p. s.

Φ , Effective helix angle = $\tan^{-1} \left(\frac{V}{2\pi r n} \right)$

5. NUMERICAL RELATIONS

1 hp = 76.04 kg/m/s = 550 lb./ft./sec.

1 kg/m/s = 0.01315 hp

1 mi./hr. = 0.44704 m/s

1 m/s = 2.23693 mi./hr.

1 lb. = 0.4535924277 kg.

1 kg = 2.2046224 lb.

1 mi. = 1609.35 m = 5280 ft.

1 m = 3.2808333 ft.