NACA-TR-434

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

REPORT No. 434

LIFT AND DRAG CHARACTERISTICS AND GLIDING PERFORMANCE OF AN AUTOGIRO AS DETERMINED IN FLIGHT

By JOHN B. WHEATLEY

1932

AERONAUTICAL SYMBOLS

1. FUNDAMENTAL AND DERIVED UNITS

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

2. GENERAL SYMBOLS, ETC.

W, Weight $= mg$

g, Standard acceleration of gravity $= 9.80665$ m/s$^2 = 32.1740$ ft./sec.^{2}

m, Mass $= \frac{W}{g}$

ρ, Density (mass per unit volume).

Standard density of dry air, 0.12497 (kg-m^{-4} s^2) at 15° C. and 760 mm $= 0.002378$ (lb.-ft.$^{-4}$ sec.^{2}).

Specific weight of "standard" air, 1.2255 kg/m^3 $= 0.07651$ lb./ft.^{3}

mk^2, Moment of inertia (indicate axis of the radius of gyration k, by proper subscript).

S, Area.

S_w, Wing area, etc.

G, Gap.

b, Span.

c, Chord.

$\frac{b^2}{S}$, Aspect ratio.

μ, Coefficient of viscosity.

3. AERODYNAMICAL SYMBOLS

V, True air speed.

q, Dynamic (or impact) pressure $= \frac{1}{2}\rho V^2$

L, Lift, absolute coefficient $C_L = \frac{L}{qS}$

D, Drag, absolute coefficient $C_D = \frac{D}{qS}$

D_0, Profile drag, absolute coefficient $C_{D_0} = \frac{D_0}{qS}$

D_i, Induced drag, absolute coefficient $C_{D_i} = \frac{D_i}{qS}$

D_p, Parasite drag, absolute coefficient $C_{D_p} = \frac{D_p}{qS}$

C, Cross-wind force, absolute coefficient $C_C = \frac{C}{qS}$

R, Resultant force.

i_w, Angle of setting of wings (relative to thrust line).

i_t, Angle of stabilizer setting (relative to thrust line).

Q, Resultant moment.

Ω, Resultant angular velocity.

$\rho\frac{Vl}{\mu}$, Reynolds Number, where l 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.

C_p, Center of pressure coefficient (ratio of distance of *c. p.* from leading edge to chord length).

α, Angle of attack.

ϵ, Angle of downwash.

α_0, Angle of attack, infinite aspect ratio.

α_i, Angle of attack, induced.

α_a, Angle of attack, absolute.

(Measured from zero lift position.)

γ, Flight path angle.

[redacted]

REPORT No. 434

LIFT AND DRAG CHARACTERISTICS AND GLIDING PERFORMANCE OF AN AUTOGIRO AS DETERMINED IN FLIGHT

By JOHN B. WHEATLEY
Langley Memorial Aeronautical Laboratory

130470—32

1

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

NAVY BUILDING, WASHINGTON, D. C.

(An independent Government establishment, created by act of Congress approved March 3, 1915, for the supervision and direction of the scientific study of the problems of flight. Its membership was increased to 15 by act approved March 2, 1929 (Public, No. 908, 70th Congress). It consists of members who are appointed by the President, all of whom serve as such without compensation.)

2

REPORT No. 434

LIFT AND DRAG CHARACTERISTICS AND GLIDING PERFORMANCE OF AN AUTOGIRO AS DETERMINED IN FLIGHT

By John B. Wheatley

SUMMARY

The results of flight tests made by the National Advisory Committee for Aeronautics on a Pitcairn "PCA-2" autogiro are presented in this report. Lift and drag coefficients with the propeller stopped have been determined over approximately a 90° range of angles of attack. Based on the sum of fixed-wing and swept-disk areas, the maximum lift coefficient is 0.895, the minimum drag coefficient with propeller stopped is 0.015, and the maximum L/D with propeller stopped is 4.8. Lift coefficients were found also with the propeller delivering positive thrust and did not differ consistently from those found with propeller stopped. Curves of gliding performance included in this report show a minimum vertical velocity of 15 feet per second at an air speed of 36 miles per hour and a flight-path angle of −17°. In vertical descent the vertical velocity is 35 feet per second.

INTRODUCTION

Research on the autogiro has been undertaken by the National Advisory Committee for Aeronautics in connection with the study of the general problem of safety in flight. The essential characteristic of the autogiro that distinguishes it from conventional airplanes is that the velocity of the lifting surfaces with respect to the air is almost entirely independent of the velocity of the machine as a whole. The value of this attribute with respect to safety lies in the increase in the useful range of air speeds at which flight may be maintained.

The determination of lift and drag characteristics was decided upon as the initial step into an extensive program of research because of the lack of reliable full-scale information on the fundamental aerodynamic characteristics of the autogiro and the need to establish clearly a datum to which further work will be referred. The curves and data contained in the body of this report constitute, so far as is known, the first authentic full-scale information concerning autogiro characteristics that has been published. This report presents the results of a series of glide tests, made to determine the lift and drag characteristics of a Pitcairn *PCA-2* autogiro over the full range of angles of attack. The tests were performed by the National Advisory Committee for Aeronautics at Langley Field, Va.

APPARATUS AND METHODS

The tests were performed on a Pitcairn *PCA-2* autogiro, shown in Figure 1. The essential physical characteristics of the autogiro are as follows:

Rotor	Symbol	
Number of blades	b	4.
Profile of section		Göttingen 429.
Diameter	$2R$	45.0 ft.
Blade chord (outer straight portion)	c	1.833 ft.
Disk area	S_D	1,588 sq. ft.
Solidity	Total blade area/disk area.	0.0976.
Wing		
Profile		Modified N.A.C.A.-M3.
Span		30 ft. 3⅝ in.
Chord—root		4 ft. 4 in.
Area—projected	S_W	101 sq. ft.
Aspect ratio		9.1.
Incidence		1.7°.
General		
Total area	$S=S_D+S_W$	1,689 sq. ft.
Gross weight as flown	W	2,940 lb.
Wing loading	W/S	1.74 lb./sq. ft.
Engine		Wright R-975.
Power—rated		300 hp

The essential quantities necessary to a determination of lift and drag characteristics are dynamic pressure, flight-path angle, and attitude angle. Measurements of dynamic pressure and flight-path angle were obtained during a portion of the tests from an N. A. C. A. flight-path-angle and air-speed recorder suspended 80 feet below the aircraft. (Reference 1.) Subsequently it became necessary to alter the standard instrument so that it could record glides at an angle as great as 90°. The alteration consisted of the incorporation in the instrument of a yoke suspension and a 90° inclinometer unit, the yoke being shown in Figure 2. At low speeds, however, the instrument proved to be unstable and the inclinometer failed to function. An alternate method of obtaining flight-path angle was applied, in which the vertical velocity was calculated from a time history of altitude obtained by the observer with a sensitive altimeter and battery of stop watches. Flight-path angle followed directly from the ratio between the vertical velocity and true air speed. The attitude of the autogiro was recorded by a pendulum-type inclinometer (reference 1) fixed in the fuselage.

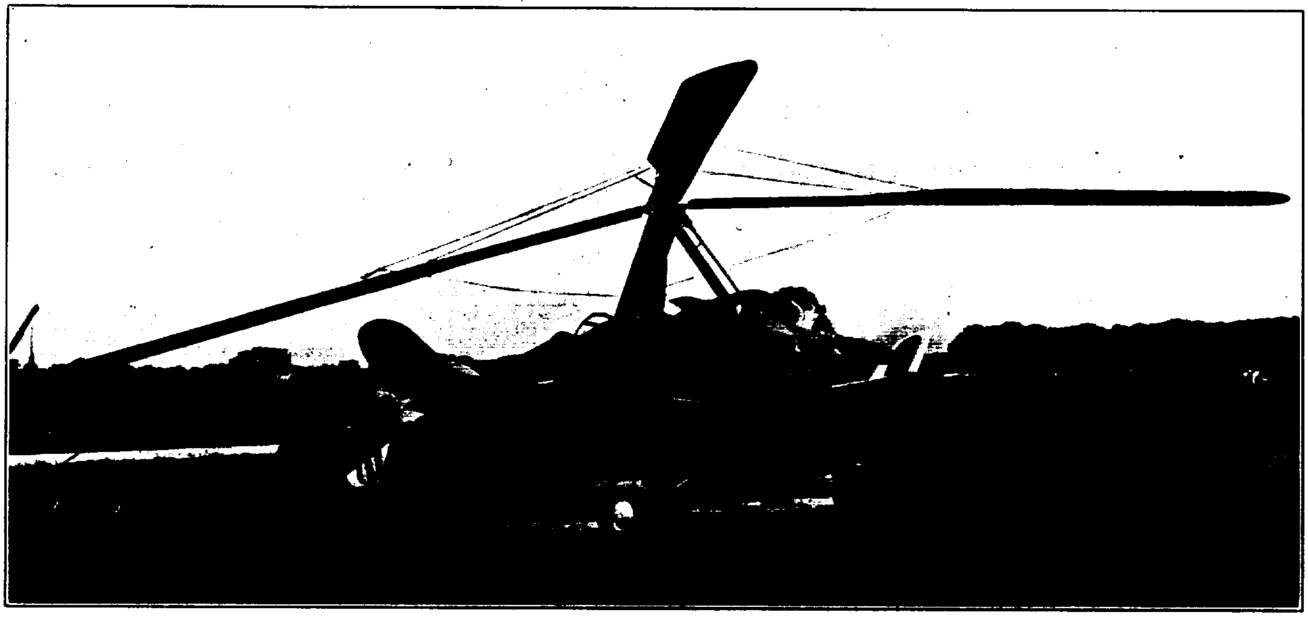


FIGURE 1.—Three-quarter view of *PCA-2* autogiro

Complementary quantities required during the glide tests included air density, control position, rotor speed, and, in a few cases, engine speed. Data from which air density was calculated were obtained by visual observations of a liquid-in-glass type thermometer placed in the air stream and a sensitive altimeter in the observer's cockpit. During a part of the tests atmospheric pressure was recorded by an aneroid-type recording altimeter, but the observations of pressure altitude proved to be a more desirable method. Rotor speeds were obtained visually by the pilot or observer from the indicating tachometer installed in the aircraft. In auxiliary tests made with positive thrust, the pilot also noted engine speed from the engine tachometer.

The flight tests consisted principally of steady 30-second glides at angles of attack ranging approximately from 0° to 90° with the propeller stopped in a vertical position by means of a brake. From the average values of dynamic pressure, attitude angle, and flight-path angle given by the continuous records obtained in each glide, the lift and drag characteristics were calculated as described in reference 2. A correction was made for the drag of the suspended instrument from data given in reference 2.

In order to determine the effect of the slipstream on the rotor characteristics, an auxiliary group of glide tests was made with the propeller rotating at sufficient speed to develop varied small amounts of positive thrust. Test procedure in this case was identical with that when the propeller was stopped. Owing to the lack of reliable information on the propeller characteristics, no attempt was made to calculate thrust directly from engine speed and air speed. The magnitude of the thrust was closely approximated by a considera-

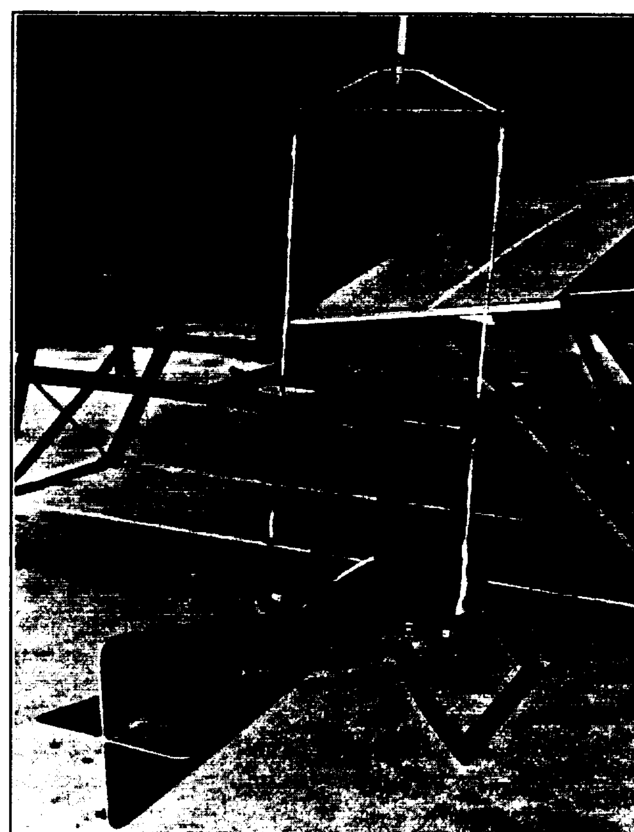


FIGURE 2.—Swivel suspension for flight-path-angle and air-speed recorder

tion of the change in flight-path angle from that at the same air speed with propeller stopped, using a propeller-drag coefficient calculated from the curves given in reference 3.

RESULTS

The lift and drag characteristics of the autogiro are presented in Figures 3 and 4 and in Tables I and II. The area to which the force coefficients are referred is the sum of the swept-disk area and the fixed-wing area, the wing being considered as extending through the fuselage. The use of the swept-disk area is arbitrary, but an arbitrary selection is necessary, inasmuch as the predominating velocity of the rotor blades is not the velocity of flight. The inclusion of the fixed-wing area follows by analogy with a biplane. With this choice of area the coefficients are of the same order of magnitude of those of a normal wing. The angle of attack given in the graphs and tables is the angle between the relative wind and a perpendicular to the rotor axis lying in the plane of symmetry. Drag coefficients, unless otherwise specified, have been calculated from the drag of the aircraft as flown less the drag of the suspended instrument.

The rotor parameter μ is plotted in Figure 3 against angle of attack. This parameter, which determines the state of operation of an autogiro rotor, is defined by the equation

$$\mu = \frac{V \cos \alpha}{\Omega R}$$

where V—true air speed, feet per second.
α—angle of attack, degrees.
Ω—rotor angular velocity, radians per second.

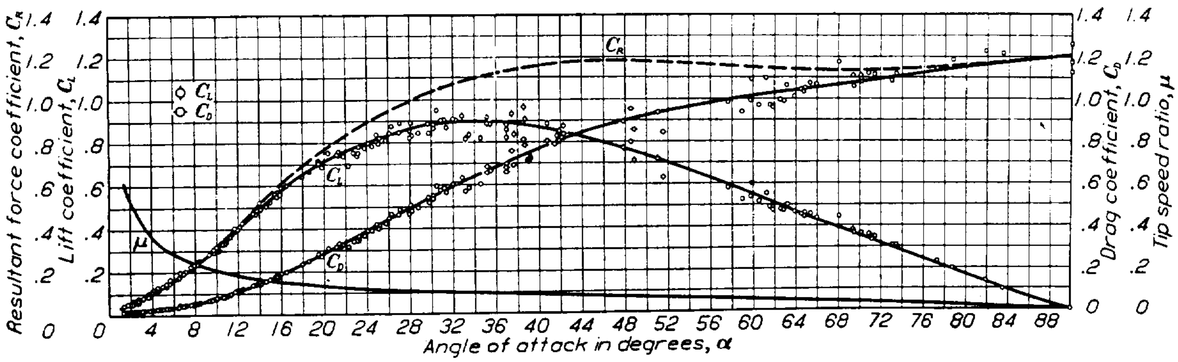


FIGURE 3.—Characteristic curves for *PCA-2* autogiro

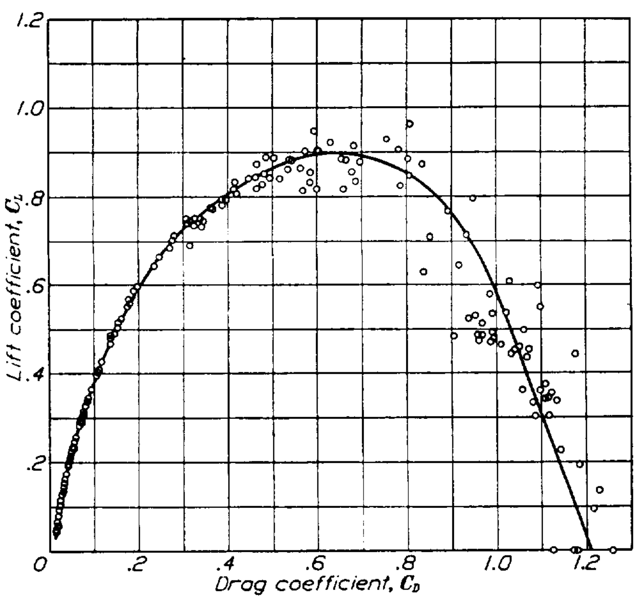


FIGURE 4.—Polar curve for *PCA-2* autogiro

The effect of the calculated propeller drag upon the drag coefficient and the L/D curve against angle of attack is shown in Figure 5. The propeller drag was estimated from the curves in reference 3 and was assumed constant over the range of angles of attack covered by Figure 5.

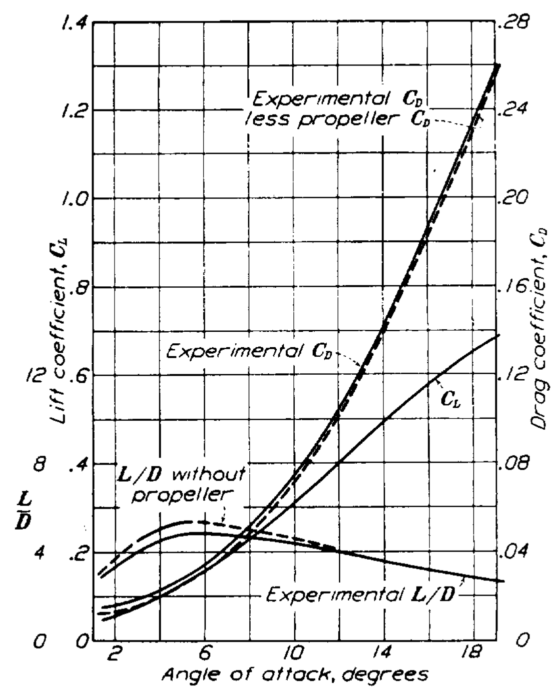


FIGURE 5.—Curves showing effect of propeller on *PCA-2* autogiro characteristic curves. Estimated propeller C_D=0.003, propeller drag=4.93 q. (From reference 3.)

The gliding performance with stopped propeller is shown in Figures 6, 7, and 8. Figure 6 shows the variation in flight-path angle γ and indicated vertical velocity V_v with indicated air speed. Figure 7 shows indicated vertical velocity as a function of flight-path angle. In Figure 8 vertical velocity has been plotted against horizontal velocity, and lines of constant flight-path angle have been shown. The polar distance from the origin, indicated by the circular arcs drawn, represents the air speed along the flight path.

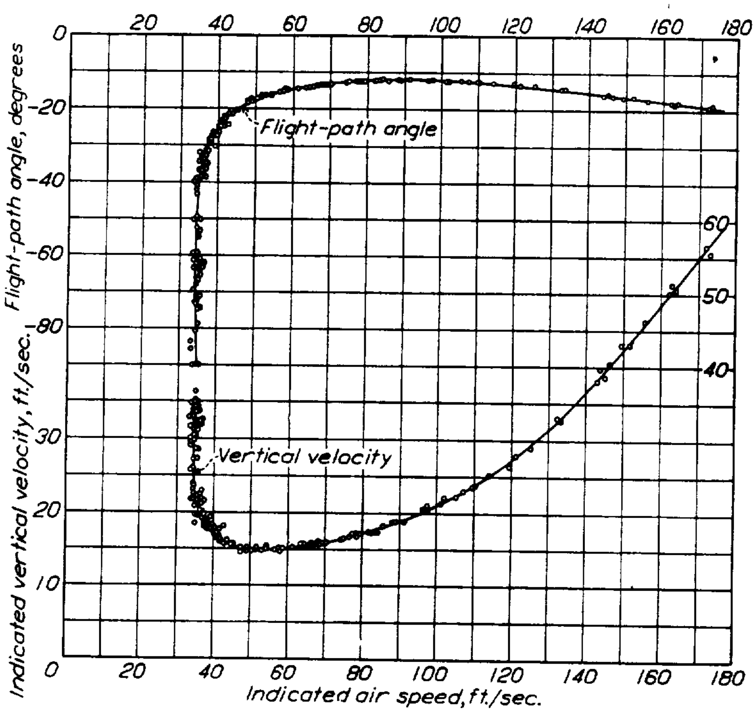


FIGURE 6.—Flight-path angle and vertical velocity as functions of air speed for *PCA-2* autogiro gliding with stopped propeller

Results of the tests with positive thrust are shown in Figure 9, in which the lift coefficients obtained are plotted against angle of attack. The portion of the lift curve obtained with propeller stopped at corresponding angles of attack is shown in the same figure for comparison.

ACCURACY

The effect of accidental errors is reflected in the dispersion of experimental points on the curves. It will be noted that this dispersion increases rapidly above an angle of attack of 16°. This effect is probably a result of the errors introduced by the indirect method of determining flight-path angles at large angles of attack, augmented by the unsteadiness of the aircraft at low air speeds. The number of experimental points obtained is large enough, however, to reduce the resultant accidental errors in faired curves to a small value.

Errors consistent in sign are not indicated by the dispersion of points. The chief source of such errors is the effect of the rotor-induced flow on the magnitude and direction of the resultant air velocity in the vicinity of the suspended flight-path-angle and air-speed recorder. The effect of this flow on the alignment of the suspended instrument, as well as the effect of any inherent misalignment, was eliminated by a determination of the alignment in level flight at various speeds. The alignment thus established is believed precise to within ±0.1°. The effect of the induced flow on the recorded dynamic pressure, however, was not elimiinated. Calculations based on the usual wing theory indicate that the magnitude of the induced velocity at the suspended instrument is approximately $-0.013\ C_R V$ where C_R is the coefficient of resultant force based on disk area. Owing to uncertainty concerning the justification for applying wing theory to this case, no correction to recorded results was applied. It is probable that at high angles of attack the error in dynamic pressure will be from −2 per cent to −3 per cent, whereas at low angles of attack the correction may be safely neglected.

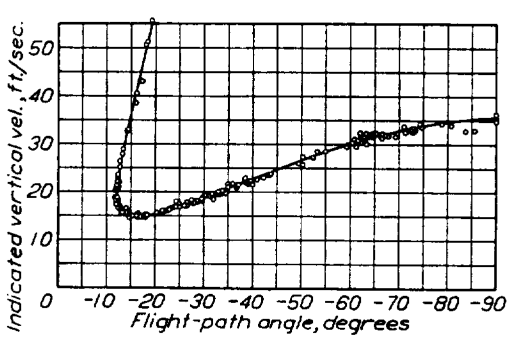


FIGURE 7.—Variation of vertical velocity with flight-path angle for *PCA-2* autogiro gliding with stopped propeller

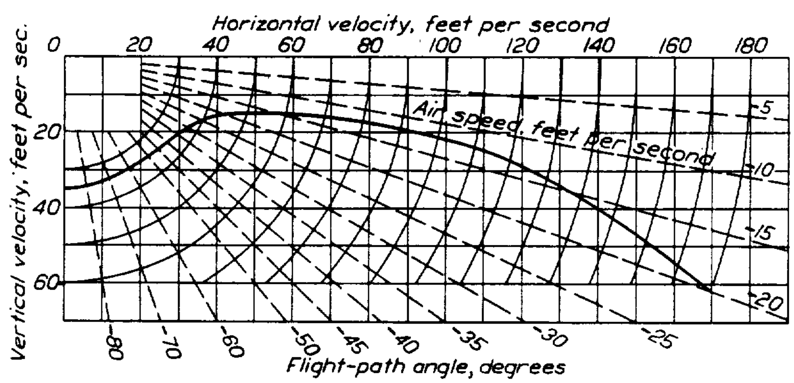


FIGURE 8.—Gliding performance curve of *PCA-2* autogiro, with stopped propeller

Table I presents the data obtained in glides with stopped propeller when the flight-path angle was directly measured, Table II shows the data obtained by indirect measurement of flight-path angle in glides with stopped propeller, and Table III contains the data obtained from glides with rotating propeller.

If the indeterminate effect of rotor-induced velocities on the suspended instrument is disregarded, it is believed that the values of the faired curves may be relied upon within the following limits:

Quantity	Angles of attack from 0° to 16°	Angles of attack from 16° to 90°
C_L	±2 per cent	±3 per cent.
C_D	do.	Do.
α	±0.2°	±4°.
$\mu=\frac{V\cos\alpha}{\Omega R}$	±3 per cent	±4 per cent.
γ—flight-path angle	±0.1°	±4°.
V_v	±2 per cent	±2 per cent.
V	±1 per cent	Do.

DISCUSSION

The curves included in this report show clearly the general aerodynamic characteristics of the autogiro. The curve in Figure 3 illustrates the fact that the resultant force coefficient is almost constant at all angles of attack above that corresponding to maximum lift. The results in Figure 5 show a maximum L/D of 4.8 with propeller stopped, at a lift coefficient of 0.150, corresponding to an air speed of 67 miles per hour. By the subtraction of the estimated propeller drag, a maximum L/D of 5.3 is obtained. The curves of gliding performance (figs. 6, 7, and 8) illustrate the ability of the autogiro to descend steeply at a low air speed; when the vertical velocity is a minimum of 15 feet per second, the air speed is about 53 feet per second (36 miles per hour) and the flight-path angle is −17°. These curves also show the rapid increase in vertical velocity with any small decrease in air speed below 45 feet per second. The data in Figure 9 indicate that the presence of positive thrust has no consistent effect on the lift coefficient.

The large speed range possible for the autogiro is indicated by the ratio between $C_{L_{max}}$ and $C_{D_{min}}$ in Figure 3, the experimental value of $\frac{0.895}{0.015}=60$ being unusually high. Comparable values for a conventional airplane would be $\frac{1.40}{0.050}=28$. Level flight at low speeds proved difficult, however, owing to decreasing control effectiveness as air speed approached its minimum. At air speeds corresponding to the region of $C_{L_{max}}$ the aileron moments were insufficient to overcome the required engine torque. The practical speed range is then less than that indicated by the force coefficients.

The problem of control at the low air speeds and high angles of attack attainable in the autogiro demands attention. During glides at air speeds near the minimum value, corresponding to angles of attack from about 35° to 90°, lateral control was inadequate and the aircraft was unsteady. Elevator control, although sluggish, remained positive at all times, but the ailerons and rudder often proved unable to check or delay a tendency of the autogiro to roll or yaw.

CONCLUSIONS

The tests on the *PCA-2* autogiro as presented in this report lead to the following conclusions:

1. The maximum lift coefficient, based on the sum of wing and swept-disk area, is 0.895, the minimum drag coefficient with propeller stopped is 0.015, the maximum L/D with propeller stopped is 4.8, and the maximum resultant force coefficient is 1.208.
2. The resultant force coefficient is approximately constant for all angles of attack greater than that corresponding to maximum lift.
3. The minimum vertical velocity when gliding with stopped propeller is 15 feet per second, at an air speed of 36 miles per hour, and a flight-path angle of −17°.

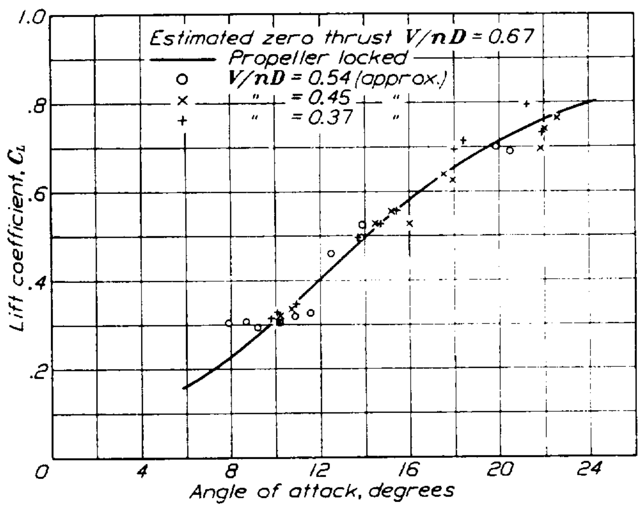


FIGURE 9.—Lift coefficient against angle of attack with varying thrust

4. The vertical velocity in a vertical descent is 35 feet per second.
5. The presence of positive thrust has no consistent influence on lift coefficient.

LANGLEY MEMORIAL AERONAUTICAL LABORATORY,
NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS,
LANGLEY FIELD, VA., *May 2, 1932*.

REFERENCES

1. Coleman, Donald G.: N. A. C. A. Flight-Path-Angle and Air-Speed Recorder. T. N. No. 233, N. A. C. A., 1926.
2. Thompson, F. L., and Keister, P. H.: Lift and Drag Characteristics of a Cabin Monoplane Determined in Flight. T. N. No. 362, N. A. C. A., 1931.
3. Diehl, Walter S.: Engineering Aerodynamics. The Ronald Press Co., New York, 1928.

TABLE I

AUTOGIRO GLIDE TESTS—PROPELLER STOPPED

Flight No.	Run No.	Flight-path angle, γ deg.	Attitude angle, λ deg.	Angle of attack, α deg.	Weight, W lb.	Lift, L lb.	Apparent drag, D_a lb.	Bomb drag, D_b lb.	True drag, D lb.	Dynamic pressure, q lb./ft.²	Lift coefficient, C_L	Drag coefficient, C_D	Rotor speed, Ω rad./sec.	Density, ρ slug/ft.³	True air speed, V ft./sec.	μ $V\cos\alpha/\Omega R$
A-5	1	−15.4	−13.1	2.3	2,904	2,800	771	16	755	25.0	0.067	0.018	----	----	----	----
	2	−16.5	−14.1	2.4	2,868	2,750	815	16	799	27.4	.060	.017	----	----	----	----
	3	−18.0	−15.8	2.2	2,832	2,690	875	16	859	31.9	.050	.016	----	----	----	----
	4	−18.7	−17.3	1.4	2,796	2,650	898	16	882	35.6	.044	.015	----	----	----	----
	5	−16.0	−13.3	2.7	2,899	2,790	800	16	784	24.6	.067	.019	14.3	2.05×10^{-3}	155.0	0.478
	6	−17.3	−15.0	2.3	2,858	2,730	849	16	833	28.9	.056	.017	13.8	2.05	168.0	.538
	7	−18.0	−16.0	2.0	2,817	2,680	871	16	855	31.2	.051	.016	13.5	2.08	173.4	.569
	8	−19.2	−17.7	1.5	2,776	2,620	914	16	898	35.1	.044	.015	13.2	2.08	184.0	.618
A-6	1	−14.5	−11.3	3.2	2,912	2,820	728	15	713	20.8	.081	.020	14.3	2.04	143.0	.440
	2	−16.1	−13.8	2.3	2,884	2,770	799	16	783	25.5	.065	.018	14.3	2.03	158.6	.489
	3	−18.4	−16.7	1.7	2,856	2,710	902	16	886	31.5	.051	.017	13.6	2.05	175.6	.571
	6	−16.8	−14.1	2.7	2,772	2,650	802	16	786	26.4	.060	.018	14.1	2.08	159.7	.500
A-12	1	−12.3	−5.4	6.9	2,904	2,840	619	10	609	8.7	.193	.042	15.6	2.02	93.0	.262
	2	−12.3	−6.5	5.8	2,904	2,840	619	12	607	11.0	.152	.033	15.4	2.09	102.7	.294
	3	−12.2	−7.7	4.5	2,904	2,840	613	13	600	13.1	.128	.027	15.1	2.15	110.8	.324
	4	−12.4	−8.3	4.1	2,868	2,800	617	14	603	14.3	.116	.025	15.4	2.02	119.1	.342
	5	−13.3	−9.5	3.8	2,868	2,790	660	15	645	17.4	.094	.022	14.9	2.12	128.3	.382
	6	−14.2	−11.1	3.1	2,868	2,780	703	15	688	21.1	.077	.019	14.6	2.20	138.8	.419
	7	−12.2	−5.7	6.5	2,832	2,770	598	10	588	9.4	.174	.037	15.3	2.01	96.8	.279
	8	−12.4	−6.8	5.6	2,832	2,770	609	12	597	11.3	.145	.031	15.1	2.10	104.0	.304
	9	−12.4	−7.8	4.6	2,796	2,730	601	13	588	13.6	.119	.026	15.2	2.08	114.6	.333
	10	−12.8	−8.8	4.0	2,796	2,730	618	14	604	15.4	.104	.023	14.9	2.16	119.7	.356
A-13	1	−12.5	−7.2	5.3	2,904	2,830	627	13	614	12.4	.135	.030	15.5	2.02	110.9	.316
	2	−12.4	−8.3	4.1	2,904	2,840	625	14	611	14.5	.116	.025	15.2	2.08	118.0	.343
	3	−12.8	−9.1	3.7	2,868	2,800	634	14	620	17.0	.097	.022	15.2	2.02	129.8	.378
	4	−13.4	−9.7	3.7	2,868	2,790	666	15	651	18.6	.088	.021	15.1	2.10	133.3	.390
	5	−12.2	−6.9	5.3	2,832	2,770	598	12	686	11.3	.145	.031	14.9	2.00	106.3	.316
	6	−13.3	−3.7	9.6	2,832	2,750	651	6	645	5.6	.292	.068	15.0	2.06	73.7	.215
	7	−12.3	−4.7	7.6	2,832	2,770	603	8	595	7.3	.223	.048	----	2.10	83.6	----
	8	−12.0	−5.4	6.6	2,796	2,730	581	9	572	8.3	.198	.041	15.2	2.02	90.5	.262
	9	−12.0	----	----	2,796	2,730	581	10	571	9.3	.175	.037	15.2	2.06	94.8	----
	10	−13.7	−3.7	10.0	2,796	2,710	663	6	657	5.1	.315	.076	15.4	2.10	69.7	.200
A-14	1	−13.1	−3.8	9.3	2,892	2,810	657	7	650	5.9	.283	.066	15.4	1.99	76.8	.218
	2	−12.6	−4.4	8.2	2,892	2,820	630	8	622	6.7	.248	.055	15.2	2.05	80.8	.233
	3	−12.1	----	----	2,892	2,830	607	9	598	8.1	.206	.044	15.1	2.10	88.0	----
	4	−11.9	----	----	2,892	2,830	596	9	587	8.4	.199	.047	15.0	2.15	88.5	----
	5	−12.1	−6.5	5.6	2,850	2,790	599	12	587	11.3	.146	.031	15.3	2.05	105.1	.303
	6	−12.4	−4.7	7.7	2,850	2,780	613	9	604	7.5	.219	.048	15.2	2.12	84.0	.243
	7	−12.4	−4.8	7.6	2,850	2,780	613	8	605	7.3	.224	.049	14.9	2.16	82.4	.243
	8	−12.3	−5.2	7.1	2,808	2,740	598	9	589	8.0	.204	.044	15.2	2.02	88.6	.257
	9	−11.9	−6.2	5.7	2,808	2,750	579	11	568	9.9	.164	.034	15.1	2.07	97.9	.286
	10	−12.2	−7.2	5.0	2,808	2,740	593	12	581	12.2	.133	.028	14.9	2.14	106.6	.316
A-19	1	−14.1	−3.3	10.8	2,886	2,800	705	6	699	4.9	.336	.083	15.5	1.99	70.4	.198
	2	−13.3	−3.7	9.6	2,886	2,810	664	7	657	5.7	.291	.068	15.3	2.02	75.2	.215
	3	−12.8	−4.4	8.4	2,886	2,810	638	8	630	6.6	.254	.057	15.2	2.06	79.8	.230
	4	−12.7	−4.8	7.9	2,886	2,810	635	8	627	7.2	.231	.054	15.0	2.11	82.5	.242
	5	−14.4	−3.1	11.3	2,850	2,760	710	5	705	4.5	.364	.093	15.3	2.00	66.8	.190
	6	−13.5	−3.8	9.7	2,850	2,770	665	6	659	5.4	.305	.072	15.2	2.03	73.0	.210
	7	−12.6	−4.4	8.2	2,850	2,780	621	8	613	7.0	.234	.052	15.0	2.09	81.9	.240
	8	−12.5	−4.8	7.7	2,850	2,780	616	8	608	7.5	.219	.048	14.9	2.14	83.6	.247
	9	−14.0	−3.4	10.6	2,832	2,750	685	6	679	4.9	.330	.081	15.2	2.00	70.2	.201
	10	−13.5	−3.8	9.7	2,832	2,750	660	7	653	5.6	.292	.069	15.0	2.04	73.7	.215
A-20	1	−16.1	−2.7	13.4	2,886	2,770	800	4	796	3.5	.471	.135	15.3	1.99	59.2	.167
	2	−14.3	−3.3	11.0	2,886	2,800	713	6	707	4.8	.345	.087	----	2.03	68.6	----
	3	−13.5	−3.5	10.0	2,886	2,800	673	6	666	5.2	.316	.075	----	2.08	71.0	----
	4	−16.5	−2.5	14.0	2,886	2,770	820	4	816	3.2	.516	.152	----	2.12	54.7	----
	5	−14.1	−3.3	10.8	2,844	2,760	694	6	688	4.8	.342	.085	----	1.99	69.5	----
	6	−13.5	−3.8	9.7	2,844	2,730	711	6	705	5.6	.390	.074	----	2.03	74.0	----
	7	−15.4	−3.0	12.4	2,844	2,740	757	5	752	3.8	.427	.117	----	2.10	60.1	----
	8	−14.0	----	----	2,844	2,760	689	6	683	5.1	.320	.079	----	2.14	68.9	----
	9	−14.7	−3.0	11.7	2,814	2,720	715	5	710	4.0	.402	.105	----	1.96	63.9	----
	10	−13.7	−3.7	10.0	2,814	2,730	667	6	661	5.2	.308	.074	15.4	2.00	72.4	.205
A-21	2	−18.4	−1.9	16.5	2,880	2,730	910	3	907	2.7	.597	.196	----	----	----	----
	4	−18.0	−2.0	16.0	2,832	2,690	875	3	872	2.7	.588	.188	----	----	----	----
	6	−18.0	−2.1	15.9	2,832	2,690	875	3	872	2.9	.556	.178	----	----	----	----
	8	−17.6	−2.0	15.6	2,796	2,660	844	3	841	2.9	.550	.174	----	----	----	----
	10	−17.1	−2.1	15.0	2,796	2,670	821	4	817	3.0	.523	.160	----	----	----	----
A-22	2	−16.5	−2.4	14.1	2,880	2,760	818	4	814	3.5	.490	.145	----	----	----	----
	3	−17.7	−2.1	15.6	2,880	2,740	875	3	872	2.9	.566	.178	----	----	----	----
	4	−16.2	−2.6	13.6	2,880	2,760	804	4	800	3.5	.468	.136	----	----	----	----
	5	−17.6	−2.1	15.5	2,844	2,710	859	3	856	2.9	.560	.177	----	----	----	----
	6	−14.9	−2.9	12.0	2,844	2,750	731	5	726	4.1	.396	.104	----	----	----	----
	7	−16.2	−2.4	13.8	2,844	2,730	794	4	790	3.3	.485	.140	----	----	----	----
	8	−14.8	−2.9	11.9	2,844	2,750	725	5	720	4.1	.396	.103	----	----	----	----
	9	−16.9	−2.3	14.6	2,808	2,700	820	4	816	3.2	.503	.152	----	----	----	----
	10	−15.2	−3.0	12.2	2,808	2,720	739	5	734	4.0	.407	.110	----	----	----	----

TABLE II

AUTOGIRO GLIDE TESTS—PROPELLER STOPPED

Flight No.	Run No.	Vert. velocity V_v ft./sec.	Flight-path angle, γ deg.	Attitude angle, λ deg.	Angle of attack, α deg.	Weight, W lb.	Lift, L lb.	Apparent drag, D_a lb.	Bomb drag, D_b lb.	True drag, D lb.	Dynamic pressure, q lb./ft.^{2}	Lift coefficient, C_L	Drag coefficient, C_D	Rotor speed, Ω rad./sec.	Density, ρ slug/ft.^{3}	True air-speed, V_T ft./sec.	$\mu V \cos \alpha / \Omega R$
A-26	1	19.0	−24.9	−1.8	23.1	2,850	2,580	1,200	2	1,198	2.1	0.734	0.341	--------	2.04x10^{-3}	45.1	--------
	2	20.0	−29.6	−1.6	28.0	2,840	2,470	1,401	2	1,399	1.7	.851	.481	--------	2.08	40.7	--------
A-26A	1	19.5	−27.5	−1.7	25.8	2,886	2,560	1,331	2	1,329	1.9	.808	.420	--------	2.11	42.2	--------
	2	19.6	−29.6	−1.5	28.1	2,868	2,500	1,418	2	1,416	1.7	.887	.503	--------	2.10	39.7	--------
	3	22.9	−39.0	−1.5	37.5	2,850	2,210	1,794	2	1,792	1.4	.929	.754	--------	2.13	36.4	--------
	4	17.4	−22.9	−1.7	21.2	2,832	2,610	1,103	2	1,101	2.1	.741	.313	--------	2.08	44.6	--------
	5	20.9	−32.4	−1.5	30.9	2,814	2,380	1,510	2	1,508	1.6	.901	.572	--------	2.05	39.0	--------
	6	19.5	−28.6	−1.6	27.0	2,796	2,450	1,339	2	1,337	1.7	.844	.461	--------	2.07	40.7	--------
	7	18.6	−25.5	−1.7	23.8	2,778	2,510	1,195	2	1,193	1.9	.771	.366	--------	2.05	43.3	--------
	8	18.3	−24.8	−1.6	23.2	2,760	2,500	1,158	2	1,156	2.0	.747	.346	--------	2.09	43.5	--------
	9	20.4	−30.4	−1.6	28.8	2,742	2,370	1,388	2	1,386	1.7	.841	.493	--------	2.05	40.3	--------
A-27	1	18.9	−28.0	−1.7	26.3	2,868	2,530	1,350	2	1,348	1.7	.872	.464	15.0	2.12	40.2	0.108
	2	17.4	−21.5	−1.7	19.8	2,856	2,650	1,048	2	1,046	2.3	.685	.270	15.2	2.04	47.4	.128
	3	19.3	−28.7	−1.6	27.1	2,844	2,500	1,367	2	1,365	1.7	.888	.484	15.2	2.06	40.2	.109
	4	17.4	−22.9	−1.6	21.3	2,832	2,610	1,102	2	1,100	2.1	.741	.313	15.0	2.09	44.7	.122
	5	19.1	−26.8	−1.6	25.2	2,820	2,520	1,272	2	1,270	1.8	.819	.412	15.0	2.04	42.3	.111
	6	21.7	−33.0	−1.6	31.4	2,808	2,360	1,530	2	1,528	1.6	.865	.561	15.2	2.04	39.8	.098
	7	18.2	−25.0	−1.7	23.3	2,796	2,530	1,180	2	1,178	1.9	.778	.361	14.9	2.06	43.1	.117
	8	18.5	−26.5	−1.6	24.9	2,784	2,490	1,245	2	1,243	1.8	.834	.416	15.0	2.06	41.4	.110
A-28	1	16.9	−20.4	−1.8	18.6	2,860	2,680	998	3	995	2.4	.663	.246	15.4	2.04	48.4	.133
	2	17.8	−23.2	−1.7	21.5	2,843	2,613	1,120	3	1,117	2.1	.745	.318	15.4	2.03	45.2	.121
	3	18.3	−24.3	−1.5	22.8	2,826	2,575	1,164	3	1,161	2.0	.750	.339	15.2	2.06	44.4	.119
	5	18.9	−26.7	−1.6	25.1	2,804	2,508	1,259	2	1,257	1.9	.792	.397	15.1	2.11	42.1	.112
	6	20.4	−29.9	−1.7	28.2	2,787	2,417	1,391	2	1,389	1.7	.829	.478	15.2	2.06	40.9	.108
	7	19.1	−27.8	−1.7	26.1	2,770	2,450	1,294	2	1,292	1.7	.841	.446	15.1	2.06	40.9	.108
A-30	2	20.3	−29.5	−1.5	28.0	2,900	2,520	1,430	2	1,428	1.8	.819	.464	15.0	2.15	41.2	.106
	3	24.2	−38.5	−1.5	37.0	2,890	2,260	1,800	2	1,798	1.6	.817	.659	15.0	2.14	38.8	.092
	4	23.7	−38.4	−1.4	37.0	2,880	2,260	1,790	2	1,788	1.6	.855	.678	14.9	2.14	38.2	.091
	5	23.0	−40.0	−1.4	38.6	2,870	2,200	1,847	2	1,845	1.4	.962	.807	15.1	2.11	35.8	.082
	6	23.4	−38.5	−1.5	37.0	2,860	2,240	1,775	2	1,773	1.5	.873	.695	15.0	2.14	37.6	.089
	7	24.3	−42.3	−1.5	40.8	2,840	2,100	1,910	2	1,908	1.4	.883	.801	14.9	2.15	36.1	.082
	8	20.2	−31.3	−1.6	29.7	2,830	2,410	1,471	2	1,469	1.6	.884	.539	14.9	2.15	38.8	.100
	9	20.3	−31.7	−1.5	30.2	2,820	2,400	1,482	2	1,480	1.6	.880	.543	14.8	2.16	38.6	.100
A-31	1	21.0	−33.8	−1.5	32.3	2,860	2,376	1,590	2	1,588	1.6	.901	.602	14.8	2.18	37.8	.094
	2	20.5	−31.7	−1.5	30.2	2,845	2,420	1,496	2	1,494	1.7	.862	.535	14.8	2.18	39.0	.099
	3	28.6	−50.3	−1.4	48.9	2,830	1,808	2,177	2	2,175	1.5	.709	.852	14.8	2.18	37.2	.071
	4	22.4	−37.0	−1.5	35.5	2,815	2,249	1,695	2	1,693	1.5	.881	.663	14.8	2.18	37.2	.089
	5	22.3	−36.7	−1.5	35.2	2,800	2,245	1,674	2	1,672	1.5	.883	.655	14.8	2.16	37.3	.090
	6	24.7	−43.3	−1.4	41.9	2,785	2,027	1,910	2	1,908	1.4	.847	.803	14.8	2.17	36.0	.079
	7	28.3	−52.4	−1.3	51.1	2,770	1,690	2,194	2	2,192	1.4	.713	.933	14.8	2.20	35.7	.065
	8	19.5	−32.0	−1.5	30.5	2,755	2,336	1,460	2	1,458	1.5	.949	.593	14.8	2.15	36.8	.094
A-32	1	25.0	−43.6	−1.3	42.3	2,870	2,078	1,980	2	1,978	1.4	.872	.833	14.8	2.15	36.2	.079
	2	31.3	−61.2	−1.3	59.9	2,855	1,375	2,501	2	2,499	1.4	.599	1.092	15.1	2.13	35.7	.051
	3	20.6	−32.8	−1.6	31.2	2,840	2,385	1,539	2	1,537	1.6	.904	.583	14.9	2.16	38.0	.095
	4	27.2	−50.2	−1.6	48.6	2,825	1,810	2,170	2	2,168	1.4	.794	.949	14.9	2.15	35.4	.068
	5	22.0	−36.7	−1.5	35.2	2,810	2,253	1,680	2	1,678	1.5	.915	.681	14.9	2.15	36.8	.088
	6	27.5	−49.4	−1.5	47.9	2,795	1,820	2,121	2	2,119	1.4	.767	.891	15.0	2.14	36.2	.070
	7	20.8	−33.5	−1.5	32.0	2,780	2,318	1,535	2	1,533	1.5	.905	.600	14.8	2.13	37.7	.094
	8	22.2	−35.0	−1.5	33.5	2,765	2,264	1,587	2	1,585	1.6	.831	.582	14.8	2.15	38.7	.095
	9	20.8	−34.4	−1.5	32.9	2,750	2,269	1,554	2	1,552	1.5	.921	.630	14.8	2.15	36.8	.091
A-33	1	33.4	−69.4	−1.3	68.1	2,870	1,010	2,686	2	2,684	1.4	.442	1.175	15.2	2.12	35.7	.037
	2	35.7	−74.8	−1.3	73.5	2,855	748	2,750	2	2,748	1.5	.304	1.116	15.1	2.12	37.0	.028
	3	34.1	−63.2	−1.3	61.9	2,840	1,280	2,530	2	2,528	1.6	.485	.958	15.1	2.14	38.2	.051
	4	33.6	−63.6	--------	--------	2,825	1,257	2,530	2	2,528	1.5	.493	.990	15.0	2.14	37.5	.049
	5	34.9	−73.3	--------	--------	2,810	806	2,692	2	2,690	1.4	.338	1.134	15.0	2.13	36.4	.031
	6	34.0	−62.0	--------	--------	2,795	1,310	2,468	2	2,466	1.6	.481	.904	14.9	2.17	38.5	.054
	7	32.7	−60.9	--------	--------	2,780	1,350	2,430	2	2,428	1.5	.530	.951	14.9	2.15	37.4	.054
	8	30.3	−55.0	--------	--------	2,765	1,585	2,260	2	2,258	1.5	.643	.917	14.7	2.13	37.0	.064
	9	32.4	−62.3	--------	--------	2,750	1,278	2,430	2	2,428	1.4	.537	1.022	14.7	2.11	36.6	.051
	10	31.1	−59.4	--------	--------	2,735	1,391	2,350	2	2,348	1.4	.608	1.029	14.9	2.08	36.1	.055
A-34	1	34.4	−62.1	−1.5	60.6	2,895	1,352	2,550	2	2,548	1.6	.512	.967	15.3	2.06	38.9	.056
	2	34.3	−63.3	−1.7	61.6	2,869	1,289	2,560	2	2,558	1.6	.487	.969	15.1	2.12	38.4	.054
	3	34.3	−65.4	−1.5	63.9	2,843	1,180	2,580	2	2,578	1.5	.463	1.010	15.2	2.12	37.7	.048
	4	33.9	−64.2	−1.6	62.6	2,817	1,224	2,530	2	2,528	1.5	.479	.992	15.2	2.12	37.7	.051
	5	22.8	−35.0	−1.8	33.2	2,791	2,290	1,602	2	1,600	1.7	.813	.569	15.0	2.11	39.7	.098
	6	23.0	−36.4	−1.8	34.6	2,765	2,230	1,640	2	1,638	1.6	.817	.600	14.9	2.14	38.8	.095
	7	20.5	−31.6	−1.8	29.8	2,739	2,330	1,435	2	1,433	1.6	.841	.517	14.9	2.14	39.1	.101
	9	30.2	−53.2	−1.6	51.6	2,687	1,608	2,150	2	2,148	1.5	.629	.838	14.7	2.12	37.7	.070
	10	32.0	−60.5	−1.5	59.0	2,661	1,308	2,310	2	2,308	1.5	.524	.937	14.6	2.15	36.8	.057
A-35	1	16.8	−21.5	−2.0	19.5	2,900	2,700	1,063	3	1,060	2.2	.713	.280	14.8	2.15	45.7	.130
	2	18.3	−26.1	−2.0	24.1	2,880	2,580	1,267	2	1,265	1.9	.793	.388	14.5	2.23	41.6	.116
	3	16.6	−22.4	−2.0	20.4	2,860	2,640	1,089	3	1,086	2.1	.750	.309	14.7	2.18	43.6	.124
	4	18.8	−26.4	−1.9	24.5	2,840	2,540	1,282	2	1,280	1.9	.780	.387	14.8	2.16	42.7	.115
	5	16.4	−20.1	−2.1	18.0	2,820	2,650	967	3	964	2.4	.641	.233	14.5	2.15	47.8	.138
	6	18.6	−24.3	−2.0	22.3	2,800	2,550	1,157	3	1,154	2.2	.690	.313	14.5	2.17	45.0	.127
	7	16.6	−21.5	−2.0	19.5	2,780	2,590	1,020	3	1,017	2.2	702	.275	14.7	2.13	45.3	.129
	8	17.6	−23.8	−2.0	21.8	2,760	2,520	1,115	2	1,113	2.0	.734	.325	14.5	2.14	43.5	.123
	9	17.1	−23.4	−2.0	21.4	2,740	2,510	1,087	2	1,085	2.0	.750	.325	14.7	2.13	43.1	.121
A-39	1	33.4	−64.8	−1.6	63.2	2,890	1,226	2,610	2	2,608	1.5	.498	1,060	14.9	2.14	36.9	.050
	2	36.0	−78.8	−1.5	77.3	2,870	557	2,820	2	2,818	1.5	.226	1.142	14.9	2.17	36.7	.024
	3	35.2	−72.4	−1.5	70.9	2,860	863	2,720	2	2,718	1.4	.357	1.121	15.0	2.10	36.9	.036
	4	38.3	−90.0	−1.7	90.0	2,840	0	2,840	2	2,838	1.4	0	1,171	14.9	2.14	36.6	.000
	5	34.8	−72.9	−1.4	71.5	2,820	830	2,700	2	2,698	1.4	.344	1.114	14.7	2.17	36.4	.035
	6	34.4	−71.8	−1.6	70.2	2,800	874	2,660	2	2,658	1.4	.361	1.098	14.7	2.19	36.2	.037
	7	35.1	−72.9	−1.7	71.2	2,780	818	2,660	2	2,658	1.5	.333	1.080	14.7	2.17	36.7	.036
	8	34.7	−72.9	−1.7	71.2	2,770	813	2,640	2	2,638	1.4	.342	1.109	14.7	2.13	36.3	.036
	9	33.7	−66.6	−1.8	64.8	2,750	1,090	2,520	2	2,518	1.5	.443	1.031	14.7	2.17	36.7	.047
	10	33.1	−63.8	−1.9	61.9	2,730	1,202	2,450	2	2,448	1.5	.472	.960	14.7	2.21	36.9	.053

TABLE II—Continued

AUTOGIRO GLIDE TESTS—PROPELLER STOPPED—Continued

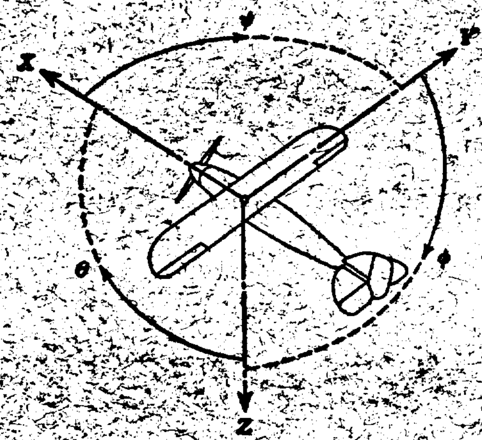
Flight No.	Run No.	Vert. velocity V_v ft./sec.	Flight-path angle, γ deg.	Attitude angle, λ deg.	Angle of attack, α deg.	Weight, W lb.	Lift, L lb.	Apparent drag, D_a lb.	Bomb drag, D_b lb.	True drag, D lb.	Dynamic pressure, q lb./ft.^{2}	Lift coefficient, C_L	Drag coefficient, C_D	Rotor speed, Ω rad./sec.	Density, ρ slug/ft.^{3}	True air-speed, V_T ft./sec.	$\mu V\cos\alpha/\Omega R$
A-40	2	36.0	−74.4	−1.3	73.1	2,880	775	2,770	2	2,768	1.5	.304	1.085	14.9	2.17×10^{-3}	37.4	.032
	3	37.0	−90.0	−1.4	90.0	2,860	0	2,860	2	2,858	1.4	0	1.179	15.0	2.13	36.7	0
	5	35.4	−71.1	−1.6	69.5	2,850	923	2,700	2	2,698	1.5	.362	1.057	14.9	2.17	37.4	.039
	6	33.3	−66.5	−1.6	64.9	2,830	1,128	2,590	2	2,588	1.5	.459	1.050	14.8	2.21	36.3	.047
	8	33.5	−64.6	−1.7	62.9	2,790	1,197	2,520	2	2,518	1.5	.470	.987	14.6	2.20	37.1	.051
	9	32.3	−61.6	−1.8	59.8	2,770	1,318	2,440	2	2,438	1.5	.535	.990	14.7	2.17	36.7	.056
	10	31.3	−59.5	−1.8	57.7	2,760	1,400	2,380	2	2,378	1.4	.579	.982	14.6	2.17	36.3	.059
A-41	2	33.8	−67.1	−1.7	65.4	2,820	1,098	2,600	2	2,598	1.4	.453	1.072	15.1	2.13	36.7	.042
	3	33.9	−71.3	−1.9	69.4	2,790	896	2,640	2	2,638	1.4	.377	1.109	14.9	2.19	35.8	.034
	4	37.0	−90.0	−1.8	90.0	2,770	0	2,770	2	2,768	1.5	0	1.124	14.9	2.15	36.8	0
	5	33.5	−67.8	−1.8	66.0	2,740	1,035	2,540	2	2,538	1.4	.436	1.067	14.9	2.15	36.2	.041
	6	34.1	−83.7	−1.8	81.9	2,720	299	2,700	2	2,698	1.3	.136	1.227	14.6	2.21	34.3	.012
	7	33.2	−66.5	−2.0	64.5	2,690	1,072	2,470	2	2,468	1.4	.452	1.040	14.8	2.14	36.2	.043
A-42	1	36.8	−90.0	−1.9	90.0	2,880	0	2,880	2	2,878	1.4	0	1.258	14.9	2.14	35.5	0
	2	36.1	−80.8	−2.0	78.8	2,860	460	2,820	2	2,818	1.4	.194	1.184	15.2	2.10	36.6	.021
	3	24.2	−41.0	−2.3	38.7	2,830	2,130	1,860	2	1,858	1.4	.906	.781	15.1	2.07	36.9	.085
	4	32.2	−63.4	−2.1	61.3	2,810	1,258	2,510	2	2,508	1.4	.550	1.097	15.0	2.08	36.0	.051
	8	25.2	−43.8	−2.1	41.7	2,710	1,956	1,874	2	1,872	1.4	.824	.787	14.9	2.12	36.4	.081
	9	34.9	−85.6	−2.1	83.5	2,680	210	2,670	2	2,668	1.3	.095	1.214	14.7	2.12	35.0	.012
	10	23.6	−39.6	−1.9	37.7	2,660	2,050	1,697	2	1,695	1.5	.832	.688	14.8	2.13	37.0	.088

TABLE III

AUTOGIRO GLIDE TESTS—PROPELLER ROTATING

Flight No.	Run No.	Vertical velocity, V_v ft./sec	Dynamic pressure, q lb/ft.^{2}	Density, ρ slug/ft.^{3}	True air speed V_T ft./sec.	Flight-path angle, γ_T deg.	Attitude angle deg. λ	Angle of attack, α deg.	Weight, W lb.	Lift, L lb.	Lift coefficient, C_L	Normal flight path angle, γ deg.	Thrust, T lb.	Engine speed, N r. p. m.	V/nD
A-44	1	15.4	5.5	2.16×10^{-3}	71.0	−12.5	−2.3	10.2	2,880	2,810	0.306	−13.4	18	830	0.570
	4	15.6	5.2	2.15	69.1	−13.0	−2.1	10.9	2.840	2.770	319	−13.7	10	820	.562
	6	17.2	2.2	2.17	45.4	−22.3	−1.8	20.5	2,820	2,610	.690	−22.1	−21	500	.605
	7	16.1	4.9	2.16	67.6	−13.8	−2.2	11.6	2,810	2,730	.327	−14.0	−14	830	.543
	9	16.5	2.2	2.16	44.9	−21.5	−1.6	19.9	2,780	2,590	.701	−22.1	19	510	.588
A-45	1	13.6	5.5	2.16	71.0	−11.0	−.9	10.1	2,880	2,830	.307	−13.4	94	1,020	.465
	2	13.7	3.1	2.15	53.9	−14.7	−.2	14.5	2,870	2,780	.527	−16.8	90	810	.444
	3	17.7	2.2	2.18	45.3	−23.0	−1.1	21.9	2,860	2,630	.696	−22.1	−46	610	.496
	4	13.2	4.9	2.16	67.6	−11.2	−.5	10.7	2,840	2,790	.335	−14.0	115	1,010	.447
	5	13.8	2.9	2.15	52.0	−15.3	−.1	15.2	2,830	2,730	.554	−17.5	95	815	.426
	6	17.0	2.1	2.16	43.6	−22.9	−.9	22.0	2,820	2,600	.740	−23.3	10	610	.477
	7	12.9	5.1	2.17	68.5	−10.8	−.6	10.2	2,810	2,760	.321	−13.8	122	1,020	.448
	8	14.8	3.0	2.15	52.9	−16.2	−.2	16.0	2,800	2,690	.527	−17.2	34	815	.433
	9	17.2	2.0	2.15	42.8	−23.7	−1.1	22.6	2,780	2,550	.763	−24.8	43	610	.469
A-46	1	9.6	4.9	2.14	67.5	−8.2	2.7	10.9	2,880	2,850	.345	−14.0	267	1,290	.349
	2	12.3	3.0	2.13	52.8	−13.5	1.9	15.4	2,870	2,790	.557	−17.2	171	1,040	.339
	3	15.7	2.0	2.14	42.9	−21.5	−.3	21.2	2,860	2,660	.795	−24.8	155	760	.377
	4	9.4	5.3	2.13	70.5	−7.6	2.2	9.8	2,840	2,810	.314	−13.6	271	1,280	.368
	5	11.6	3.3	2.14	55.3	−12.1	1.6	13.7	2,830	2,760	.498	−16.3	193	1,020	.362
	6	14.5	2.3	2.14	46.2	−18.2	−.2	18.0	2,820	2,680	.693	−21.1	131	750	.406
	7	9.1	5.0	2.13	68.9	−7.6	2.5	10.1	2,810	2,790	.327	−13.9	284	1,290	.357
	8	12.0	3.0	2.13	53.7	−12.9	1.8	14.7	2,800	2,730	.526	−17.2	195	1,020	.352
	9	14.1	2.2	2.14	45.1	−18.2	.2	18.4	2,780	2,640	.715	−22.1	178	770	.391
A-51	1	15.5	2.6	2.10	49.7	−18.2	−.3	17.9	2,890	2,750	.625	−18.9	22	760	.437
	2	14.4	3.1	2.11	54.4	−15.4	−1.5	13.9	2,870	2,770	.525	−16.8	44	660	.550
	3	13.2	5.5	2.11	71.9	−10.6	−2.7	7.9	2,850	2,800	.303	−13.4	91	815	.589
	4	14.8	2.5	2.12	48.5	−17.8	−.3	17.5	2,830	2,690	.637	−19.5	72	750	.432
	5	14.2	3.2	2.16	54.6	−15.1	−1.3	13.8	2,810	2,710	.497	−16.6	58	670	.544
	6	14.2	5.3	2.11	70.9	−11.5	−2.8	8.7	2,790	2,730	.305	−13.6	76	820	.576
	7	16.4	2.1	2.16	43.9	−21.9	0	21.9	2,770	2,570	.731	−23.3	47	750	.390
	8	13.9	3.4	2.08	57.4	−14.0	−1.5	12.5	2,750	2,670	.460	−16.1	83	660	.580
	9	15.0	5.4	2.06	72.4	−11.9	−2.7	9.2	2,730	2,670	.292	−13.5	46	820	.589

U. S. GOVERNMENT PRINTING OFFICE: 1932



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	Symbol		Designation	Symbol	Positive direction	Designation	Symbol	Linear (component 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

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

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 $C_T=\frac{T}{\rho n^2D^4}$

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

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

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

η, Efficiency.

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

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

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.

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	Symbol		Designation	Symbol	Positive direction	Designation	Symbol	Linear (component along axis)	Angular
Longitudinal	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Lateral	[illegible]	[illegible]	Pitching	M	[illegible]	Pitch	[illegible]	[illegible]	[illegible]
Normal	[illegible]	[illegible]	Yawing	N	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Absolute coefficients of moment

$C_l = \frac{L}{qbS}$ (rolling) $C_m = \frac{M}{qcS}$ (pitching) $C_n = \frac{N}{qbS}$ (yawing)

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

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 $= \sqrt[5]{\frac{\rho V^5}{P n^2}}$

[illegible]

n Revolutions per second, rps

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

NUMERICAL RELATIONS

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

1 metric horsepower = 0.9863 hp

1 mph = 0.4470 mps

1 mps = 2.2369 mph

[illegible]

-12-